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Impact of the COVID-19 pandemic on environmental degradation. Theoretical considerations based on the environmental Kuznets curve

Wpływ pandemii COVID-19 na degradację środowiska. Rozważania teoretyczne oparte na środowiskowej krzywej Kuznetsa

Introduction

The pandemic caused by the COVID-19 virus results in the fact that the outlook for economic growth in most countries remains highly uncertain. It is expected that the annual global GDP growth is going to fall to 2,4% in 2020 from the already weak 2,9% in 2019. At the same time, the growth may even be negative in the first quarter of 2020. Unfortunately, even more negative scenarios are possible in the form of a global recession involving many countries. The most powerful negative impact, mainly on financial markets, tourism and the international supply chain, will be visible in the countries closely connected with China, namely: Japan, South Korea and Australia, among others (OECD, 2020). Detailed research predicting the negative impact of the pandemic on the international supply chain has been published by A. G. Herrero along with T. Nguyen and J. Tan (2020), Asian Financial Think Tank experts.

Similar research concerning the influence of COVID-19 on international trade, electricity consumption and air transport has been published by Estrada et al. (2020). It should be pointed out that those declines have not been insignificant for the environment. First studies tackling the impact of the COVID-19 pandemic on environmental degradation and the economy started to appear at the beginning of 2020[1]. As examples may serve articles by D. T. Molintasa (2020) where the

[1] At this point it is worth referring to a study by J. Lee and W. J. McKibbin from 2003 entitled "Globalization and Disease: The Case of SARS" concerning the impact of SARS on

author briefly presents the influence of the pandemic on trade, the economy and, particularly, on reducing CO_2 emissions and limiting global warming in China as well as research carried out by L. Myllyvirta (2020). In the present article the authors want to present, applying the concept of the Kuznets environmental curve, how temporary economic instability, caused by the COVID-19 pandemic, may affect environmental degradation.

Thus, the main research objective we set out is to show the impact of the sudden recession, in the presented analysis caused by the COVID-19 pandemic, on environmental degradation. This phenomenon is explained by means of deterministic dynamic models, which describe the level of environmental degradation with the immediate biodegradation of toxins and with the biodegradation of toxins spread over time. At the same time, it is assumed that the emission volume is the function of GDP per capita and therefore it is connected to the production volume described by dependencies such as Cobb-Douglas function where, apart from labour resources and the capital, function arguments are energy consumption and openness in foreign trade. The presented models can be applied to estimate the total volume of contamination and its maximum level according to the rate of economic changes measured with GDP per capita.

1. The concept of environmental Kuznets curve

It is worth noting that for nearly three decades the Environmental Kuznets Curve (hereinafter referred to as EKC) has been a key notion describing relations between the level of environmental degradation and economic growth measured in GDP per capita. The first study devoted to this concept was the article by G. M. Grossman and A. B. Krueger (1991) in which the authors referred to the Kuznets Curve reflecting the relations between the economic development and social inequalities. Grossman and Krueger's ideas were popularised by the World Bank, which in 1992 issued a report entitled "Development and the Environment". Then the subject of EKC was tackled by Shafik and Bandyopadhay (1992), Selden and Song (1994), Holtz-Eakin and Selden (1995) and later became widespread, multithreaded scientific research.

The abundance of articles concerning the Kuznets curve triggered the attempt to classify and typify different ways of the application of this notion, methods of its theoretical justification and the models being subject to theoretical verifica-

the global economy. Obviously, the scale of the SARS impact on the economy in relation to COVID-19 is incomparable.

tion. Most of the considered theoretical models constitute deterministic models, however, a part of them refers to stochastic justifications (the first such model was presented by Pindyck (2000). Another significant classification divides models into static and dynamic (Gruszecki & Jóźwiak, 2019). The first ones mainly refer to the function of utility following the lead of McConell (1997) as well as Andreoni and Levinson (2001), and to the macroeconomic production function (the trend was initiated by Lopez, 1994). Dynamic models take into consideration the allocation of resources variable in time, tax policy and the impact of new technologies (e.g. Stokey, 1998; Egli & Steger, 2007).

Particularly important in the precise description of the environmental Kuznets curve is the issue concerning the possibility of contaminants accumulation. Therefore, when defining the curve of this type, it should be considered whether studying contaminants level only current emissions are taken into account, assuming at the same time their immediate biodegrability, or the accumulated toxic impact from the past is taken into consideration as well. This issue is tackled by a few researchers (e.g. Lopez, 1994; McConell, 1997).

In its standard version the EKC concept assumes that the graph of the curve is shaped into the U letter turned upside down, which is linked to the fact that in the pre-industrial and early industrial periods, along with the economic development, an initially slow and then rapid increase in the environmental pollution takes place (referred to as *P*). Then, when the income per capita (hereinafter referred to as *y*) exceeds a certain amount, characteristic of a particular economy and defined as *turning point* (referred to as *TP*), the increase in the income per capita is accompanied by the decrease in the level of contaminants (Figure 1).

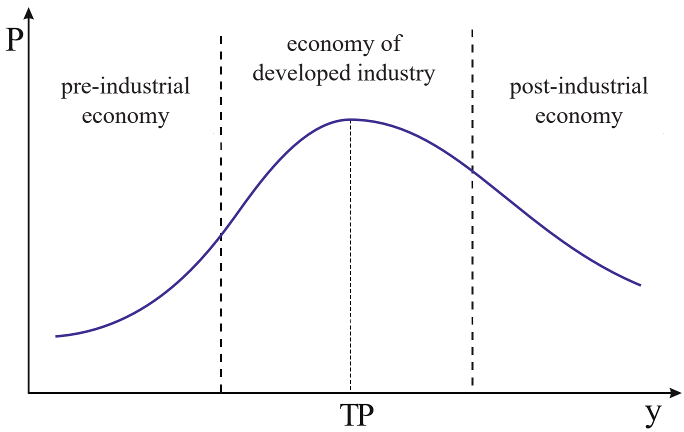

Figure 1. The Environmental Kuznets Curve

Source: A. R. Gill, K. K. Viswanathan and S. Hassan (2018, p. 1636).

Thereby, the course of EKC shall be examined in the context of three consecutive periods in history, each of which is characterised by particular tendencies of macroeconomic nature and each correspods to a certain range of variability of GDP per capita. In each of the mentioned periods, to a different extent and in varying proportion, three key factors are revealed: 1) the scale effect which results in the fact that the environmental pollution rises as production increases, 2) the technological effect which causes the reduction of degradation level through the implementation of new environmentally friendly technologies and management methods, 3) the composition effect contributing to an increase in the GDP-share of those economic sectors which do not degradate or degradate the environment to a lesser extent. In our considerations one more effect is added – 4) the effect which is connected to the supply and demand shock resulting from sudden disturbances in the economy, such as the COVID-19 pandemic. The theoretical principles of such an economic model has been presented by L. Fornano and M. Wolf (2020). It is interesting that the conduct of the governments of states affected by the COVID-19 pandemic is in compliance with the recommendations for the economic policy resulting from the model described by the authors. In general, they depend on expansionary monetary and fiscal policies. In our model, described in the following parts of the article, we suggest additional solutions which consist in stimulating economy through environmentally friendly technological innovations.

2. Basic concepts of the model

In the present article the following two types of curves depicting the level of environmental degradation are taken into consideration: type I: curves representing toxic emissions of substances characterised by immediate biodegrability; type II: curves depicting the processes in which the emissions from the previous period still affect the condition of the environment, however, their impact decreases exponentially over time. Both curves of type I and type II are vulnerable to the phenomenon of the supply and demand shock caused, for example, by the COVID-19 pandemic, which is implied in a more detailed analysis of both models and concepts constitutive for them: emissions and GDP per capita presented below.

The key role in formal and mathematical definitions of function of both types is played by the emission function: $y \longmapsto em(y)$, where y refers to GDP per capita. The image of this function and the shape of its graph in the form of the reversed U letter is a result of microeconomic considerations with the application of, for example, the function of utility and preference, (see e.g. Andreoni & Levinson, 2001 and Lopez, 1994). Further, the correlation $y \longmapsto em(y)$, will be treated as the value known. Due to the dynamic character of the model it shall be assumed that $y = y(t)$. Thus, type I curves are defined as

$$(1)\ EKC^{(0)}\big(y(t)\big) = em(y(t))$$

For type II curves such an equation is used:

$$(2)\ EKC^{(b)}\big(y(t)\big) = em\big(y(t)\big) + \int_0^t em(y(u))e^{-b(t-u)}du,$$

where $b > 0$ is the parameter that reflects the rate of biodegrability.

Thus, it can be seen that in type I, $EKC^{(0)}$ is, in fact, the same as *em* function. In type II, the right side of the equation (2) is the sum of the component defining $EKC^{(0)}(y(t))$ and the residual component reflecting the influence of accumulated past contaminants on the current state. The $EKC^{(0)}(y(t))$ component is, in fact, a point on the Kuznets curve which corresponds to the moment of time *t* and, on the other hand, the correlation $t \longmapsto EKC^{(0)}(y(t))$ is the time line of Kuznets curve reflecting a certain time interval.

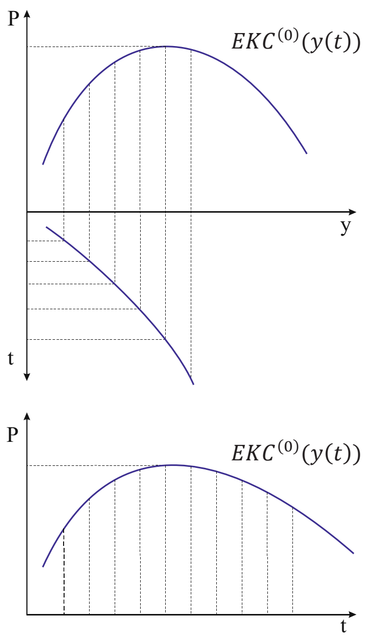

Figure 2. $EKC^{(0)}$ curves and income per capita (on the left) and $EKC^{(0)} \circ y$ (on the right)

Source: own study.

It shall be noticed that if in the equation (1) dependencies on time *t* are omitted, $EKC^{(0)}$ equals $em(y)$, and this creates a dependency typical of the environmental Kuznets curve. Such a dependency for curves (2) generally does not occur. However, when GDP income per capita increases, $EKC^{(b)}$ is expressed by the equation:

$$(3)\ EKC^{(b)}(y) = em(y) + \int_0^{inc^{-1}(y)} em(y(u)) \cdot e^{-b(t-u)} du,$$

where $y \longmapsto inc^{-1}(y)$ is the function inverse to *y(t)*.

Since the assumption of a constant increase of GDP per capita is excessively restrictive, the dependency (3) may be treated merely as an approximation used for identifying the level of contaminants, when *y(t)* is treated as the function of the rising trend.

Thus, it shall be noted that

$$\lim_{t \to +\infty} e^{-bt} \int_0^t em\big(y(u)\big) \cdot e^{bu} du = \frac{1}{b} \lim_{t \longrightarrow +\infty} em(y(t)),$$

so assuming that, along with the economic growth, emissions are decreasing and, with the additional assumption that the biodegradation occurs fast (i.e. *b* is high), it can be seen that for high values of *t* the second component of the equation (2) is relatively small.

In formulae (1)-(3) the component describing the amount of emissions of toxic substances is directly sensitive to the economic crisis which results in the reduction of industrial production, like, for example, during a pandemic such as the COVID-19. Also, the correction of functions describing the change of GDP per capita over time which consists in a slowdown of economic growth or negative growth is reflected in the above mentioned formulae.

The income per capita *y* obviously depends on GDP, further indicated as Y, and the population N, i.e. $y = Y/N$. At the same time, according to various models Y is the function of capital K, labour L and other parameters such as an openness in foreign trade TR or energy or technology used in the process of production. In literature, for example, the following function is used (see Kyophilavong & Shahbaz, 2015):

$$(4)\ y(t) = \frac{\phi}{N} E(t)^{\alpha_1} \cdot TR^{\alpha_2} \cdot K(t)^{\beta} \cdot L(t)^{1-\beta}, \alpha_1, \alpha_2 > 0, 0 < \beta < 1.$$

Thus, the dependency of the above type should be taken into consideration describing the dynamics of environmental degradation with the use of formulae which define curves of type I and type II. It should be noted, though, that the above dependency expresses a tendency of macroeconomic character in the economy while, as it has already been mentioned, the microeconomic approach is defined through the function $y \longmapsto em(y)$.

It should be pointed out that it is just the openness in international trade TR, measured as the relation of the sum of exports and imports to GDP, that can be significantly changed in the event of the COVID-19 pandemic. Preliminary research results and the approximate forecasts of consequences of the disruption in the international supply chain in the countries of the Asia-Pacific region have been presented by the above mentioned A. G. Herrero T. Nguyen and J. Tan (2020). From other studies we know that the trade openness considerably affects the environmental degradation in the way which is reflected by the environmental Kuznets curve. It is also confirmed in studies by: Al-Mulali and Ozturk (2016), Dogan and Seker (2016), Dogan and Turkekul (2016), Ertugrul et al. (2016), Jebli et al. (2016), Li et al. (2016), Sinha and Sen (2016), Ozatac et al. (2017), Sapkota and Bastola (2017), or Zhang et al. (2017). For these reasons it can be expected that, at the time of the COVID-19 pandemic, the disruption of the global supply chain and the introduction of restrictions limiting economic activities will result in the economic slowdown and, as a consequence, the slowdown in the pace of environmental degradation. The consequences of this phenomenon for the environment may be differentiated in the long term. As it has been mentioned above, we are going to present a certain, environmentally friendly, concept of preventing the economy from slowing down in the following part.

3. The issue of time course of Kuznets curve: the tunelling effect as a consequence of COVID-19

In this part of the article we are going to tackle certain non-standard environmental Kuznets curves and their time courses. On the basis of the environmental Kuznets curve a number of questions concerning the impact of the dynamics of economic changes on the environmental degradation in the future can be answered. Thus, based on models taking into consideration both sudden declines in supply and demand and accelerated changes of paradigms of economic and social development which lead to the growth of economy that is faster and safer for ecosystems, various options of changes in the level of contaminants depending on GDP per capita can be presented. The scenarios of a sudden collapse, which is followed by “a bounceback” using new technologies and matched by the corrected and more environmentally “friendly” EKC, are depicted in Figure 3.

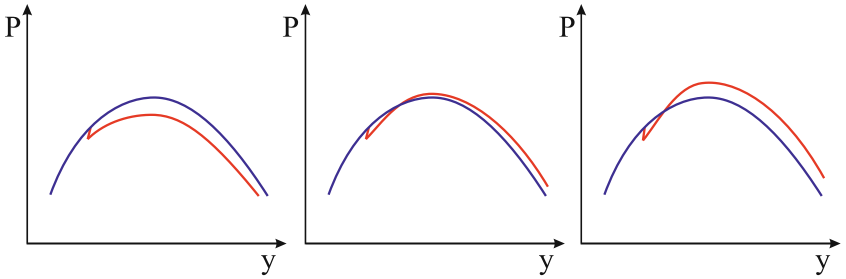

Figure 3. Three possible trajectories of a new EKC (in red) as a reaction to the COVID-19 crisis

Source: own study.

In the case a) emerging from the crisis is the most optimal for the environment; the case b) should be considered as more realistic, new technological and organisational solutions are effective, but not before the more advanced phase of the development; the case c) describes the situation of the development (after the crisis) which does not refer to new solutions.

The emerging possibility of the decrease in the maximum level of contaminants linked to the change in the shape of Kuznets curve is directly connected to the so-called tunnelling effect, which was pointed out by M. Munasinghe (1999). This effect manifests itself in the flattening of the environmental Kuznets curve. In his article Munasihghe emphasises the issues concerning political economy and its potentially positive impact on limiting market imperfections, institutional limitations and the stability of economic processes. Thus, the issue of tunnelling, from the point of view of the author of the article, is the problem of choosing the optimal economic and social policy. The phenomenon oftunnelling is depicted in Figure 4.

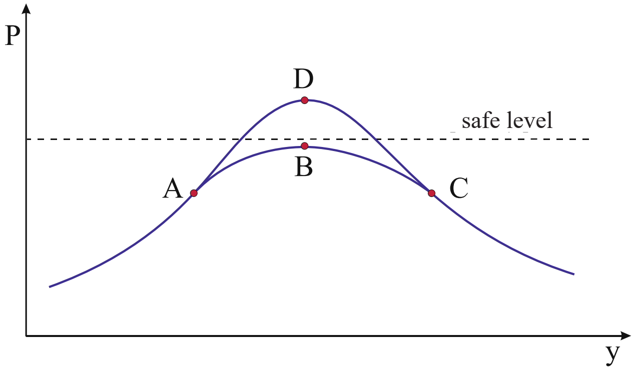

Figure 4. Two graphs of EKC curves referring to various economic and social policies

Source: based on Munasinghe (1999).

In Figure 4 point A refers to the decision on the choice of economic and social policies. At this point the bifurcation of EKC occurs, ADC branch reflects the sub-optimal economic policy and the ABC arc refers to the optimal, or close to optimal, policy (it should be taken into account that point A can give origin to more branches corresponding to various political decisions). ABC arc can be called "a tunnel" in relation to all less optimal courses of the environmental Kuznets curve, and the phenomenon itself can be defined as "tunnelling".

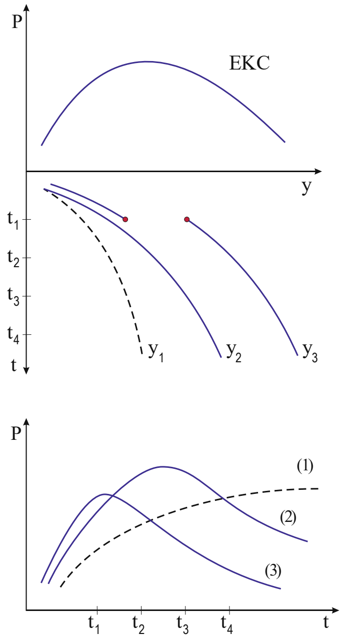

Figure 5. Three different time lines corresponding to the same EKC

Source: own study.

We are going to attempt to describe the tunnelling effect in a somewhat different way. Let us assume that some EKC curve is given.

Having analysed Figure 5, it can be figured out that, firstly, in the case of the dependency of a continuous type $t \longmapsto y(t)$ the maximum level of contaminants is the same, however, in the case of GDP per capita increasing slower (over the whole period of time) this maximum is more extended over time. Secondly, when GDP per capita grows by leaps and bounds and if this growth is high, the decrease in the maximum level of contaminants is possible. Thirdly, the entire volumes of contaminants (represented by the surface restricted from the above by the graphs of EKC time lines and from below by the time axis) are lower in the case of faster economic growth.

It shall be noted that also for EKC curves, verified by the COVID-19 crisis and "the bounceback", a relevant time line can be presented. For the case a) Figure 3 its illustration is Figure 6.

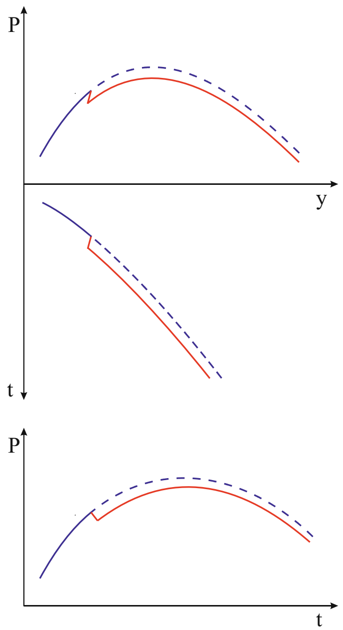

Figure 6. EKC time line verified by COVID-19 crisis and "the bounceback"

Source: own study.

Figure 6 depicts how the appropriate use of new technologies and, perhaps, also new legal and organisational solutions affects the new course of EKC curve in the optimal situation – case a) Figure 3. Two trajectories of the environmental Kuznets curve were indicated in the Figure. The dotted line represents predicted levels of contaminants in the event of a pandemic. The solid line depicts the new trajectory which is the result of a reaction to the production drop caused by

COVID-19 and "the bounceback" with the use of new environmentally friendly technologies and procedures. In such a case the new trajectory of the curve goes below the old trajectory, which means that at a given GDP per capita the level of environmental degradation should be lower.

A summary and conclusions

In the present article we consider the situation in which we deal with a crisis caused by the COVID-19 pandemic. It shall be assumed that, as a result of the pandemic, restrictions limiting the economic activity are introduced and the disruption of the global supply chain occurs. Consequently, we show how such a temporary economic instability caused by the COVID-19 pandemic affects environmental degradation. For this purpose we use the concept of the environmental Kuznets curve.

Since the economic growth diminishes as a result of the COVID-19 pandemic, it should be pointed out that in the circumstances of the decrease in foreign trade, exports especially, in a developing economy (i.e. represented by the rising EKC arc) a drop in the level of contamination may occur over a short period of time, however, the volume of contaminants in longer time intervals will be increased. Therefore, the following recommendations for the economic policy can be made: the long-term stagnation for the income per capita approximating TP, which is dangerous for the environment, should be avoided; on the basis of the forecast EKC curve for a given area the economy should be stimulated especially in the situation when GDP per capita is similar to the value of turning point (TP), whereas the optimal economic stimulation could take place through the support of environmentally friendly investments and legal and organisational solutions.

The above mentioned recommendations require to be supported by empirical research; the form of *em* function should be verified considering its changes as a result of the COVID-19 pandemic, as this function is of key importance for both models, the model describing immediate biodegradation and the one with postponed biodegradation; thus, the TP value of the modified environmental Kuznets curve, the shape of which is a result of COVID-19 pandemic, can be estimated. The forecast concerning the form of $EKC^{(b)}, b \geq 0$ for various economic areas shall enable the verification of the hypothesis regarding the causal link between the pace of growth of GDP per capita (for the values similar to TP) and the maximum level of contaminants and the level of aggregated contamination in relevant time intervals, as well. It should be kept in mind that the drop and then the increase in GDP per capita also depend, due to the presented model, on the volume of trade openness (TR), which, in turn, is heavily influenced by the development of the COVID-19 pandemic.

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Abstract

This paper investigates how the economic crisis caused by the COVID-19 pandemic affects environmental degradation. We assume that the pandemic results in restrictions in economic activity and disruption of the global supply chain. The methodological approach taken in this study is based on the Kuznets environmental curve. We are using deterministic dynamic models to explain environment degradation and economic destabilization. Our findings suggest several courses of action for economic policy. For example, that optimal stimulation of the economy in the current crisis could take place through the support of environmentally friendly investments and legal and organizational solutions.

Keywords: environment pollution, environmental Kuznets curve, COVID-19, coronavirus

Streszczenie

W artykule został rozważony problem kryzysu spowodowanego wystąpieniem pandemii COVID-19. Założono, że w wyniku pandemii następuje wprowadzenie restrykcji ograniczających aktywność gospodarczą oraz zakłócenie globalnego łańcucha dostaw. Zbadano również w jaki sposób destabilizacja gospodarki wywołana pandemią COVID-19 wpływa na degradację środowiska. Wykorzystano w tym celu koncepcję środowiskowej krzywej Kuznesta. Destabilizacja i degradacja środowiska zostały objaśnione za pomocą deterministycznych modeli dynamicznych. Na podstawie analizy tych modeli sformułowano zalecenia dla polityki gospodarczej, sugerując m.in., że optymalna stymulacja gospodarki w kryzysie mogłaby odbywać się przez wsparcie inwestycjami oraz przez przyjaznymi środowisku rozwiązania prawno-organizacyjne.

Słowa kluczowe: zanieczyszczenie środowiska, środowiskowa krzywa Kuznetsa, COVID-19, koronawirus.

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