CHARTING THE GREEN PATH: EMPIRICAL INSIGHTS INTO EU-UKRAINE ENVIRONMENTAL CONVERGENCE

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Abstract. *The aim* of the study is to conduct an empirical analysis of environmental convergence between the EU and Ukraine. This involves evaluating a set of indicators, identifying clusters of EU and Ukrainian countries to obtain adequate empirical estimates, and directly assessing not only the convergence process but also other patterns of environmental and economic development. *Methodology.* In addition to the classical models of beta, sigma, gamma and delta convergence, the study of environmental convergence should apply methods that focus on the growth process and the increase in the level of economic development of less developed countries, rather than simply on the reduction of development disparities. Such methods should emphasise the importance of efforts and policies aimed at bringing countries closer together and creating favourable conditions for their growth towards higher levels of development. The authors use the concept of upward convergence (divergence). The empirical analysis of environmental convergence between the EU and Ukraine was conducted for the period 2000–2021, divided into two sub-periods: 2000–2013 and 2014–2021, in order to identify trends in the Russian military invasion in 2014 and its impact on environmental and economic convergence during the war. *Results.* Studies of different types of convergence between Ukraine and the EU show different results: some indicators indicate convergence, while others show divergence. In fact, the interaction between Ukraine and the EU is a complex process that manifests itself differently depending on the specific indicators. Some aspects of cooperation are already leading to convergence and similarity between the countries, while others are leading to divergence. This demonstrates the need to implement effective strategies and policies of cooperation between Ukraine and the EU to achieve sustainable development. *Practical implications.* The results obtained can be used to develop environmental policies, commitments, forms of manifestation and main consequences for the ecological and economic system of Ukraine in the context of the Association Agreement and the European Green Deal. The fulfilment of obligations under these initiatives should become the basis for developing effective means of ensuring sustainable development through the implementation of the relevant state environmental and economic policy. *Value/originality.* The advantage of the proposed approach is that it takes into account negative growth, including environmental pollution. The results of the upward convergence assessment serve as a basis for the development of appropriate strategies, mechanisms, policies, effective governance, investment in human capital and infrastructure, and the creation of favourable conditions for entrepreneurship and innovation.

Key words: environmental convergence, green growth, European integration, upward/downward convergence, Association Agreement.

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1. Introduction

The European Union is based on economic, social and territorial unity. It is also based on balanced economic growth and convergence. According to the European Commission's official documents, convergence is the basis for new Member States and thus for countries aspiring to European integration (European Commission, n.d.). The economic growth that underpins this process is accompanied by negative environmental impacts. With the adoption of the European Green Deal (European Commission, 2019), environmental issues have become increasingly important in the development of Member States. This strategy emphasises the need for Member States to take joint action towards sustainable development. This also applies to Ukraine, which has signed the Association Agreement (European Commission, 2016), part of which is dedicated to environmental and economic aspects. This is not only the most important basic instrument for environmental and economic convergence between Ukraine and the EU, but also a strong incentive to reform national environmental and economic policies on a European basis and to ensure their integrated nature. Thus, the research problem is formulated as follows: a methodological toolkit for the assessment of environmental convergence, which, in addition to the classical models of beta, sigma, gamma and delta convergence, includes the use of the method of upward convergence, based on the development of the necessary strategies, mechanisms, policies, effective governance, investment in human capital and infrastructure, and the creation of favourable conditions for entrepreneurship and innovation. The purpose of this paper is to conduct an empirical analysis of environmental convergence between the EU and Ukraine, which involves analysing a set of environmental and economic indicators, identifying clusters of countries to obtain adequate empirical estimates, and directly assessing not only the convergence process but also other patterns of environmental and economic development. The empirical analysis of environmental convergence was carried out for the period 2000–2021, divided into 2 sub-periods: 2000–2013 and 2014–2021, in order to identify trends in the Russia's armed invasion of 2014 and its impact on environmental and economic convergence during the war.

2. Ecological Convergence: Concept Definition

Conceptual theoretical studies of regional economic growth are based on two broad but opposing theoretical approaches to regional convergence. According to the first approach, the neoclassical theory of regional growth, market forces eventually lead to a general convergence of per capita incomes in integrated economic systems. The assumptions of this approach are based on the well-known model of economic growth outlined in the seminal works of Solow (1956) and Swan (1956). Based on a general equilibrium system, these models assume that there are no, or at least stable, disparities in per capita income between regions, thus creating a model of convergence to a single level of per capita income. Representatives of the second approach (Myrdal, 1957; Perroux, 1950; Kaldor, 1972), known as the "post-Keynesian" approach, postulate the argument that regional disparities in per capita income are constant and that divergence in per capita income is therefore the most likely outcome. The theoretical study of convergence processes is based on the first approach because, on the one hand, the neoclassical model provides both a theoretical justification and the possibility of convergence of per capita income across regions and, on the other hand, the neoclassical model is fully supported by the empirical literature.

According to the above approaches to convergence, there are a number of countries (regions) that are members of the so-called "convergence club", i.e., these countries (regions) are in the process of converging in socio-economic development with more developed countries (regions).

By shifting the focus from the above to the projection of a green economy, the issue is one of green welfare rather than economic efficiency. The scientific literature contains numerous studies that analyse convergence and show that the problem of catching up is not only related to the economy, but also to the environment. The relationship between convergence analysis and sustainable development has been studied by several scholars from different disciplines (Pugliese, 2001; Markandya et al., 2006; Farges, 2015). On this basis, green economy factors have been added to the convergence analysis paradigm to address the problem of sustainable economic growth in less developed countries and their catching up with more developed countries with lower pollution levels (Brown et al., 2009; Pretty, 2013; Li, 2015).

Thus, environmental convergence reflects economic convergence, which is resource-dependent and has a negative impact on the environment. The overall paradigm of catching up in the green economy can be represented by the following logical relationship (Zhu, 2020): "growth targets > growth dynamics > growth path". Compared to socio-economic catch-up models, their environmental counterparts focus on improving the environment in less developed countries. At the same time, growth dynamics for less developed countries often depend on catching up in green technologies, the key indicator of which is environmental total factor productivity.

Since the European integration model is based on the process of convergence, Ukraine's integration into the EU should be beneficial for environmental protection in Ukraine, in particular through the development of new legislation, policies and practices of the European model. Accordingly, Ukraine has to fulfil a number of environmental obligations within the framework of multilateral European integration cooperation, which raises the issue of empirical research on environmental and economic convergence between the EU and Ukraine.

3. Upward (Downward) Convergence and the Environment

The majority of economists utilise the widely recognised concepts of sigma and beta convergence as a methodological foundation for examining processes of convergence/divergence. These concepts find their roots in the neoclassical theory of economic growth as prescribed by Solow (1956), Ramsey (1928), and Cass (1965). It should be emphasised that in neoclassical models of economic growth, the process of convergence describes the tendency of per capita incomes to converge between "economies", i.e., countries, regions, provinces, states, etc. As noted by Quah (1990), income is a generic concept in these models and is used as an indicator of convergence: GDP or GRP per capita, return on capital, inflation, wages per worker, and even political sentiment.

The main idea of classical economic growth studies (Swan, 1956) is that regions with lower levels of economic development grow faster than regions with higher levels of economic development. In neoclassical growth models, the convergence effect is enhanced by the movement of capital and technology from rich to poor regions, as well as labour from poor to rich regions.

Heichel et al. (2005), analysing the above-mentioned areas of convergence research, identify four main methods by which convergence is conceptualised: β – convergence (a country with a lower level of a certain indicator "catches up" with the leading country); σ – convergence (aimed at reducing the variability of relevant indicators); γ – convergence (examines changes in the ranking of countries with respect to a particular indicator or policy goal) and δ – convergence (includes analysis of the country's "distance" from the reference model). However, beta convergence refers to the speed with which less developed countries catch up with more developed countries in terms of economic performance (GDP per capita), while sigma convergence refers to the variance or inequality of economic performance between countries over time. At the same time, the focus of environmental

convergence is shifting towards indicators of sustainable development rather than economic indicators. Thus, the methodologies used to analyse environmental convergence should take into account the complexities of combining economic growth and reducing environmental impact. It is also clear that it is not enough to assess the level of convergence alone.

Based on the above, in addition to the classical models of beta, sigma, gamma and delta convergence, the study of environmental convergence should use methods that focus on the growth process and the increase in the level of economic development of less developed countries, rather than simply on the reduction of development disparities. Such methodologies should emphasise the importance of efforts and policies aimed at bringing countries closer together and creating favourable conditions for their growth towards higher levels of development. They should also take into account that growth can also be viewed in a negative light (e.g., pollution). One such methodological approach is the concept of upward convergence (divergence), which was used by the European Foundation for the Improvement of Living and Working Conditions (Mascherini et al., 2018) in a study of the convergence of market, labour, living conditions and general socio-economic indicators in EU countries.

The analysis of upward convergence involves the assessment of both productivity growth and convergence. Therefore, the use of the statistical convergence methods described above is not sufficient to assess upward convergence, as it is multidimensional. Upward convergence implies a simultaneous reduction in regional disparities, increased socioeconomic equality and a more equitable distribution of resources. It should be emphasised that upward convergence is not an "automatic" process, as there are many factors that influence its achievement. Upward convergence requires appropriate strategies, mechanisms and policies, good governance, investment in human capital and infrastructure, and the creation of a favourable environment for entrepreneurship and innovation.

4. Methodology and Data Description

Consider the methodological approaches to the analysis of upward convergence in more detail according to (Mascherini et al., 2018). Denote by $j = \overline{1,n}$ number of observations, $t = \overline{1,k}$ – period, $X(t,j)$ – continuous random variable, $g(X)$ – monotonic increasing variance function, and $\mu(X(t))$ – average value of X in moment t. Then a weak upward convergence exists between t and i if:

$$\begin{cases} g(X_t) < g(X_{t-1}) \\ \mu(X(t)) \geq \mu(X(t-1)) \end{cases}. \qquad (1)$$

A corresponding strict upward convergence exists between t and i if:

$$\begin{cases} g(X_t) < g(X_{t-1}) \\ X(t) \ge X(t-1), \forall j = \overline{1,n} \end{cases}. \qquad (2)$$

In their study of upward convergence for EU countries, Mascherini et al. (2018) conclude that conditions (1) and (2) are not always met. For example, there may be a situation when the productivity of countries increases and disparities between them increase, or, conversely, when overall efficiency decreases, countries become less heterogeneous. In this case, there are obviously three other cases: upward divergence, downward divergence and downward convergence.

Upward divergence occurs when productivity grows and disparities between countries increase. In this case, upward divergence in the weak and strict sense is formalised as (3) and (4), respectively:

$$\begin{cases} g(X_t) \ge g(X_{t-1}) \\ \mu(X(t)) \ge \mu(X(t-1)) \end{cases}. \qquad (3)$$

$$\begin{cases} g(X_t) \ge g(X_{t-1}) \\ X(t) \ge X(t-1), \forall j = \overline{1,n} \end{cases}. \qquad (4)$$

Downward divergence occurs when productivity falls and disparities between countries decrease. In this case, upward divergence in the weak and strict sense is formalised as (5) and (6), respectively:

$$\begin{cases} g(X_t) \ge g(X_{t-1}) \\ \mu(X(t)) < \mu(X(t-1)) \end{cases}. \qquad (5)$$

$$\begin{cases} g(X_t) \ge g(X_{t-1}) \\ X(t) < X(t-1), \forall j = \overline{1,n} \end{cases}. \qquad (6)$$

Similarly, descending convergence in the weak and strict sense is formalised as (7) and (8), respectively:

$$\begin{cases} g(X_t) < g(X_{t-1}) \\ \mu(X(t)) < \mu(X(t-1)) \end{cases}. \qquad (7)$$

$$\begin{cases} g(X_t) < g(X_{t-1}) \\ X(t) < X(t-1), \forall j = \overline{1,n} \end{cases}. \qquad (8)$$

There are several advantages to using this approach to analysing environmental convergence:
1) Conceptual framework. The approach is based on the methods of empirical analysis of upward convergence in EU countries with different "patterns" (upward/downward convergence/divergence). These patterns can also be transferred to environmental convergence: for example, in the case of GDP per capita convergence, it is positive to increase GDP per capita while reducing disparities between countries, but in the case of environmental indicators, it is of interest to observe a situation where, for example, pollution levels decrease while disparities decrease.
2) Methods and indicators. The approach uses a variety of methods and indicators used to measure upward convergence; these can be adapted and applied to environmental convergence analysis, allowing for the assessment of trends in environmental convergence between countries or regions.
3) Examples and recommendations. The approach provides examples and recommendations on upward convergence in the EU. These examples can be used to identify similar processes in the environment and economy, and to develop strategies and policies aimed at achieving environmental and economic convergence.

Thus, convergence is observed when the distance between two trends decreases over time, and divergence is observed when the distance between the trends increases. However, when it comes to using (1)-(8) to analyse convergence/divergence between the EU and Ukraine, it is necessary to take into account the dynamics of changes in the relevant indicators over time, as the overall reduction in disparities between the EU and Ukraine may hide various unobserved factors. For example, heterogeneity between countries may be reduced if a lower-developed country moves towards a policy goal faster than other countries; at the same time, heterogeneity may also be reduced if leading countries slow their growth while other countries remain unchanged. In fact, both cases point to a reduction in development heterogeneity, which is the essence of convergence. On this basis, the different types of convergence (1)-(8) are further analysed using 19 models in Mascherini et al. (2018).

5. Data Description

The Kyoto Protocol defines six indicators used to assess harmful emissions: carbon dioxide (CO_2), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. The Kyoto Protocol requires countries to reduce emissions of these gases, of which CO_2 emissions account for the largest share (70%) of greenhouse gas emissions. In addition, these emissions have been identified as the largest environmental pollutant associated with human activity (Strazicich, 2005).

However, many studies, such as (UNEP, 2009), state that the most appropriate method for assessing the impact of human activities on global sustainability should be the footprint method. There are many types of footprints, such as carbon footprint, water footprint, emissions footprint, energy footprint, nitrogen footprint, biodiversity footprint, phosphorus footprint, waste footprint, social footprint, financial footprint, economic footprint,

exergy footprint, chemical footprint and ecological footprint (Cucek et al., 2012).

Since environmental convergence is a system of complex interrelationships between environmental and economic processes, several indicators were used: GDP per capita, the current US figure (World Bank, 2023), ecological footprint (Global Footprint Network, 2021) and CO_2 emissions (Climate watch, 2021). The empirical analysis of environmental convergence between Ukraine and the EU was conducted for the period 2000–2021, divided into two sub-periods: 2000–2013 and 2014–2021 to identify trends in the Russia's military invasion in 2014 and its impact on environmental and economic convergence in wartime.

6. Findings

The analysis of the environmental and economic development of Ukraine and the EU countries has a major problem, which is that classical convergence studies consider homogeneous systems of countries/ regions (US states, Chinese provinces, EU countries, etc.), which is not the case for Ukraine and the EU countries. In addition, there are other bottlenecks related to different methodologies and standards of statistical reporting, political and social challenges, cultural and historical differences. Based on the above, it is useful to assess the clusters of countries in order to carry out a convergence analysis. For this purpose, the approach of Philips and Sul (2007) was used, according to which a convergent club was identified, consisting of countries such as Ukraine, Romania, Bulgaria, Greece, Poland, Croatia, Hungary and the Baltic States. Despite the low statistical significance of the calculations, the Baltic states are included in the qualitative analysis because the experience of these countries can be useful for Ukraine, as all three Baltic states are now successful economies and prosperous states that have integrated into the North Atlantic Alliance and the European Union. Ukraine has a similar historical experience, but has not been able to follow the same path.

Section 3 presents the methodology of upward convergence, which allows to emphasise the importance of efforts and policies aimed at bringing countries closer together and creating favourable conditions for their growth to higher levels of development. The relevant patterns are shown in Table 1.

The empirical analysis of upward convergence models (Table 1) allows to identify the factors and policies that contribute to positive trends in upward convergence, as well as the reasons that lead to slower development, which in turn allows to understand what policies and measures should be taken to support convergence. In addition, pattern analysis allows to determine which indicators and measures should be taken into account when assessing the convergence process. Studies of different types of convergence between Ukraine and the EU show different results (Table 1): some indicators indicate convergence, i.e., the alignment of Ukraine and the EU, while others show divergence. Indeed, the interaction between Ukraine and the EU is a complex process that manifests itself in different ways depending on specific indicators. Some aspects of cooperation have already led to rapprochement and similarities between the countries, while others have led to divergences. This demonstrates the need to implement effective strategies and policies for EU-Ukraine cooperation in order to achieve sustainable development. For example, if there is a discrepancy in an economic group of indicators, the state may implement measures such as:
– Attracting foreign investment by improving the business climate, protecting property rights, reducing bureaucratic obstacles and simplifying business registration procedures;
– developing strategic plans and programmes for the development of priority economic activities;
– promoting innovation and science in the retail sector;
– developing transport, energy and information and communication infrastructure;

Table 1

Convergence patterns

Country	GDP per capita, current USD		Ecological footprint, gha		CO₂ emissions, metric tons per capita	
	2000/2014	2014/2021	2000/2014	2014/2021	2000/2014	2014/2021
Bulgaria	Slower pace	Catching up	Slower pace	Slower pace	Crossing	Diving
Croatia	Flattening	Crossing	Catching up	Slower pace	Outrunning	Inversion
Greece	Flattening	Inversion	Outrunning	Outrunning	Diving	Catching up
Estonia	Crossing reversed	Outrunning	Crossing	Slower pace	Catching up	Crossing reversed
Hungary	Flattening	Outrunning	Slower pace	Slower pace	Outrunning	Inversion
Latvia	Crossing reversed	Outrunning	Outrunning	Outrunning	Inversion	Inversion
Lithuania	Crossing reversed	Outrunning	Crossing reversed	Outrunning	Inversion	Inversion
Poland	Outrunning	Flattening	Flattening	Outrunning	Catching up	Diving
Romania	Slower pace	Catching up	Catching up	Catching up	Outrunning	Inversion
Ukraine	Slower pace	Slower pace	Diving	Diving	Crossing reversed	Outrunning

– stimulating regional development;
– public-private partnership;
– investments in education and training, etc.

On the other hand, if there is a discrepancy in the environmental group of indicators, the state may take the following measures:
– Legislative regulation of environmental norms and standards;
– encouraging environmental protection activities through the mechanisms of benefits, subsidies, taxes, and so forth;
– development of renewable energy sources;
– reduction of emissions and pollution;
– energy efficiency and saving;
– protection of natural resources and biodiversity;
– environmental education and consumer awareness.

Thus, the calculated patterns can become the basis for the development of a comprehensive state policy aimed at achieving specific goals to reduce environmental impact and promote sustainable development.

Another conclusion is that convergence patterns have changed since 2014, so the Russian military invasion in 2014 has an impact on environmental and economic convergence in wartime. This requires the adoption of appropriate policies and strategies for the period after 2022.

7. Conclusions

An empirical analysis of environmental convergence between the EU and Ukraine is carried out. The convergence club is defined, which includes such countries as Ukraine, Romania, Bulgaria, Greece, Poland, Croatia, Hungary and the Baltic States. Despite the low statistical significance of the calculations, the Baltic States are included in the qualitative analysis, as their experience may be useful for Ukraine. Studies of different types of rapprochement between Ukraine and the EU show mixed results: convergence, i.e., rapprochement, is observed in some indicators, while divergence is observed in others. Indeed, the interaction between Ukraine and the EU is a complex process that manifests itself differently depending on the specific indicators. Some aspects of cooperation are already leading to rapprochement and similarities between the two countries, while others are leading to divergences. This demonstrates the need to implement effective strategies and policies of cooperation between Ukraine and the EU to achieve sustainable development and convergence.

The upward convergence approach focuses on the growth process and on increasing the level of economic development rather than on reducing development disparities. The advantage of the proposed approach is that it takes into account negative growth, including environmental degradation. The results of the upward convergence assessment can provide a basis for the development of appropriate strategies, mechanisms, policies, good governance, investment in human capital and infrastructure, and the creation of favourable conditions for entrepreneurship and innovation.

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