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Environmental Convergence in the Context of Integration between Ukraine and the EU: Empirical Evidence and Policy Implications

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Abstract: The European Green Deal will play a key role in the development of the environmental policies of the EU and its neighbouring countries (i.e. Ukraine). Accordingly, the implementation of environmental policies will contribute to the development of national economies on a convergent basis of Ukraine and the EU. The aim of this study is to analyse environmental convergence between the EU and Ukraine, taking into account the complex specificities of combining economic growth and reducing environmental impacts. In addition to the classical models of beta, sigma, gamma and delta convergence, we use methods to study environmental convergence that are based on increasing the level of economic development of less developed countries rather than reducing the unevenness of their development and include club convergence and distributional dynamics approaches. Such methodologies emphasise the importance of efforts and policies aimed at bringing countries closer together and creating favourable conditions for them to achieve higher levels of development. The result of the empirical analysis of the environmental convergence of economies using different methodologies shows that the Ecological Footprint is characterised by different results. In this context, a narrowing of the Ecological Footprint gap between countries is shown, indicating common development trends and that countries with lower levels of development are on a faster growth path to catch up with countries with higher levels of development. Another finding is that Russia's armed invasion has affected Ukraine's convergence with the EU and will continue to have a negative impact on the country's economic development and influence on convergence processes.

Keywords: environmental convergence; green growth; Ukraine-EU integration; catch-up.

JEL classification: O44; O57; C02.

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1. INTRODUCTION

The European Union is based on economic, social and territorial unity, balanced economic growth and convergence. As noted by Eurofound (2018), “convergence trends between member states have been achieved in recent decades in both economic and social dimensions”. With the adoption of the European Green Deal by the European Commission, significant attention has been paid to environmental issues in the development of member states. This approach confirms the importance of joint action by Member States towards sustainable development (Fetting, 2020). On the other hand, according to the official documents of the European Commission, convergence is the basis for new member states and therefore for countries whose goal is European integration (European Commission, 2023), which Ukraine is.

In connection with the European integration vector of Ukraine’s development, we emphasize that Ukraine has chosen the path of European integration by signing the Association Agreement between Ukraine and the EU in 2014 and has embarked on the path of implementing ambitious and complex reforms, the overall goal of which is to achieve economic growth. The model of European integration is based on the process of convergence, and the economic growth on which this process is based is accompanied by a negative impact on the environment. Therefore, the Association Agreement, one of the parts of which is devoted to environmental and economic aspects, is not only a fundamental tool for socio-economic convergence of Ukraine and the EU, but also a strong incentive for reforming environmental and economic policy on a European basis and ensuring its integrated character.

Numerous empirical studies on this topic by researchers from all over the world now form a strong basis for the development of relevant regional economic policies by the governments of countries. The period since the 1980s has been characterized by an increased interest of researchers in the processes of convergence of regions and countries, since such processes have important positive consequences for the well-being of the population, economic growth and are the basis for the development of effective regional polices. At the same time, the impetus for such an increase in the interest of economists in this topic was undoubtedly related to the development of powerful statistical data sets created by Maddison (1980), Summers and Heston (1988), which activated precisely the empirical research on convergence processes. It should be noted that the idea of convergence and the emergence of its basic hypothesis, as well as the first empirical studies, appeared in the academic literature much earlier. Kuznets (1973), Abramovitz (1986) and Raup (1963) were the first to study the theoretical and methodological foundations of regional socio-economic convergence.

A review of the classical economic literature on convergence shows that this concept covers a wide range of processes, including environmental ones. Since the 1972 United Nations Conference on the Environment in Stockholm, where the concept of sustainable development was first discussed, numerous events have been held and international agreements have been adopted to address environmental issues, notably the Kyoto Protocol (United Nations, 1997), the Sustainable Development Goals (United Nations, 2016) and the Paris Agreement (Centre for International Law, 2015). However, despite the existence of a large number of environmental policies and initiatives, the processes of environmental and economic convergence, their contents, signs, characteristics and functions have only been partially studied.

This article is devoted to the comprehensive analysis of the nature and content of the convergence processes between the EU and Ukraine, taking into account the environmental component. The environmental modernization and post-war reconstruction of Ukraine in the context of its integration into the EU is particularly complex, as it involves deep institutional transformations in various spheres, which is primarily related to the process of achieving compliance with European regulations and legislation, standards and requirements for environmental protection, energy efficiency and sustainable development.

Drawing an analogy with socio-economic convergence, we note that environmental convergence is possible when countries with low per capita emissions of pollutants increase their emissions, and a country with high per capita emissions reduces them.

The research is divided into five sections: Section 2 presents detailed literature review. Section 3 represents methodology and Section 4 the data. Section 5 shows the empirical results. Section 6 concludes the study.

2. LITERATURE REVIEW

There are numerous empirical studies in the scientific literature on environmental convergence, which is considered as a key goal of emission reduction efforts in different countries. Environmental convergence is the basis of many scientific schools of climate change research (Barassi *et al.*, 2018). In addition, converging countries can jointly address environmental threats and coordinate their emission reduction commitments.

The analysis of Scopus and WoS sources on the term "environmental convergence" allowed us to conclude that the subject of numerous empirical studies based on the methodology of the theory of economic growth is the convergence of CO2 emissions (Table no. 1).

Table no. 1 – Research on environmental convergence: analysis of Scopus and WoS

Source	Countries/period	Indicator	Type	Result
(Strazicich and List, 2003)	100 countries/1960-1997	CO2 emissions	β, stochastic convergence	Stochastic convergence
(Nguyen Van, 2005)	100 countries/1966-1996	CO2 emissions	β, distributional dynamics	Exists in 26 developed countries
(Rui *et al.*, 2019)	Provinces of China/1995-2015	CO2 emissions	σ, β - convergence	Exists
(Panopoulou and Pantelidis, 2009)	128 countries/1960-2003	CO2 emissions	Club convergence	There are 2 clubs
(Herrerias, 2013)	Developed countries/1980-2009	CO2 emissions	Distributional dynamics	Exists
(Ordás Criado *et al.*, 2011)	25 EU countries	SOx and NOx emissions	Non-parametric method	Convergence exists
(Camarero *et al.*, 2013)	22 OECD countries/1980-2008	CO2 emissions	Club convergence	There are 2 clubs
(Solarin, 2014)	African countries	CO2 emissions	β - convergence	Exists
(Zhao *et al.*, 2015)	30 provinces of China/1995-2011	CO2 emissions	β - convergence	Exists
(Acaravci and Erdogan, 2016)	South Asia, East Asia, EU, Latin America, Middle East, North America, Sub-Saharan Africa /1960-2011	CO2 emissions	Stochastic convergence	Exists
(Runar *et al.*, 2017)	124 countries/1885-2010	CO2 emissions	β - convergence	Exists

Source	Countries/period	Indicator	Type	Result
(Apergis and Payne, 2017)	50 US states	CO2 emissions	β - and σ-convergence	Both types exist
(Barassi *et al.*, 2018)	28 OECD countries/1950-2013	CO2 emissions	Stochastic convergence	Poor results
(Rios and Gianmoena, 2018)	141 countries/1970-2014	CO2 emissions	β - convergence	Mixed
(Yu *et al.*, 2019)	74 cities of China/2005-2015	CO2 emissions	β - and σ - stochastic convergence	Exist, except stochastic
(Fernández-Amador *et al.*, 2019)	66 countries/1997-2014	CO2 emissions	β - convergence	Exists (weak)
(Apergis *et al.*, 2020)	6 countries of Central America	CO2 emissions, energy use	Club convergence	Exists

It should be noted that the CO2 emissions indicator reflects only part of the cumulative impact of extensive energy use. In addition to CO2 emissions, the use of resources such as forests, soils, oil, gas and mining reserves also has a significant impact on the environment. For example, in developed countries, the number of specific pollutants per unit of output has decreased as a result of technological progress and the implementation of strict environmental legislation, bur wastewater pollution has simply shifted from nitrogen oxides and sulphur to solid waste, so that total waste remains high and per capita waste may even remain constant (Stern, 2004). This point means that the theoretical basis of environmental convergence lies in the concept of the Kuznets curve, which operates when the most developed countries (and also the biggest polluters) reduce their emissions. While this situation is observed, the process of economic growth in the poorer and developing countries will bring their per capita emissions closer to the level of the developed economies. This concept, first introduced by Grossman and Krueger (1991), describes an inverted U-shaped relationship between pollutants and GDP per capita, the idea being that in the early stages of economic growth, the state of the environment deteriorates, but after a certain level of income (tipping point) is reached, per capita pollution starts to decline.

The evidence for the interdependence of the Kuznets curve is rather weak and, as Stern (2004) notes, most of the estimates in the available empirical studies are not statistically significant. Another study (Prebisch, 1950), on the other hand, argues that the concept of the Kuznets curve is of theoretical importance, but that technological progress and the effects of globalization make the curve more equal across developing countries.

The relationship between pollution, per capita income and the catching-up process is explained by three theses (Panayotou, 1993; Stern, 2017). First, the composition of manufactured products determines the environmental impact of economic activity, i.e. countries that specialize more in agricultural production or tertiary activities pollute less than countries that mainly produce other types of products. It follows that the concept of the Kuznets curve is closely linked to the transition from a manufacturing to a service-based economy, since the tertiary sector leads to changes in the structure of production costs that are less harmful to the environment. Second, technological progress can promote the diffusion of the changes in the structure of production costs between countries, as well as the diffusion of less polluting production technologies, thereby promoting energy efficiency. Third, changes in individual preferences, together with appropriate government policies, increase the demand and supply for environmentally friendly goods and services.

On the basis of such interpretations, the following limitations to the use of the Kuznets curve concept in the development of environmental policy can be highlighted:

1) the assessment of pollution commonly used in Kuznets curve analysis is based on a limited set of pollutants; studies have found negative empirical assessments of the Kuznets curve based on the ecological footprint, which is a comprehensive indicator of the impact of human activity on the environment. Studies of CO2 emissions, for which the impact is global, show a tendency to increase with rising per capita income, even in developed countries;

2) statistical estimates of the concept vary considerably depending on the method and indicators chosen;

3) the existence of hysteresis may reduce the relevance of the Kuznets curve concept for environmental policies, as the costs of repairing damage and improving environmental quality after a tipping point has been reached may be significantly higher than the costs of preventing pollution.

In addition, several mechanisms create environmental convergence when it comes to emissions, such as CO2. First, while international agreements (such as the Kyoto Protocol) aim to reduce emissions in high-income countries, there are no commitments for developing countries. Second, as noted by Requate (2005); Vine and Hamrin (2008), economic instruments such as emission taxes and environmental legislation contribute to emission reductions only in developed countries. In addition to these two mechanisms, the development of the tertiary sector of the economy and technological progress slow down pollution in high-income countries and contribute to the growth of CO2 emissions in low-income countries (Payne, 2020).

In the context of the theoretical study of environmental convergence, it is important to carry out a detailed literature analysis of the catching-up process in the green economy, similar to its "traditional" counterpart. For example, Baumol (1986), in a well-known publication, demonstrated a significant effect of socio-economic convergence in the process of regional catching-up. The analysis of convergence as a process of achieving well-being, based on indicators with different initial conditions, is the subject of research by a wide range of economists in the field of economic growth theory. Today, there is a large number of studies on different states of convergence, whose theoretical and methodological basis is σ-convergence, which is a measure of the level of economic "reserves", and β-convergence, which is a measure of the growth rate of the economy. These two concepts allow an empirical assessment of the catching-up process achieved by combining the relevant economic indicators. However, such convergence is usually considered as conditional and territorial, due to the different possibilities of resource allocation in each country/region. In fact, this condition directly affects the convergence coefficient through the influence of the independent variables on the coefficients of the production function (Barro and Sala-i-Martin, 1992).

Some studies prove the existence of club convergence, where economic growth occurs in a group of countries/regions with similar development conditions; countries converge to a territorial steady state, thus receiving a significant impact of territorial distribution and different convergence conditions (Quah, 1996). In addition, the role of technological efficiency in the formation of long-term convergence, based on the leapfrogging effect in less developed regions, has been studied in the literature. The catching-up process triggered by technological backwardness and regional innovation capacity has been integrated into a single conceptual framework in order to identify more ways of accelerating the convergence of key economic drivers (Fagerberg, 1994). Further acceleration of technological catching-up in less developed countries may depend to a large extent on the emergence of new technological innovations, involving technological demonstration, imitation and diffusion.

In the projection of the environmental economics, the object becomes “green” well-being and not the efficiency of the economy. There are numerous studies in the scientific literature that have carried out convergence analysis and found that the catch-up problem is not only economic but also environmental. The relationship between convergence analysis and sustainable development in different fields (sustainable lifestyles, sustainable agriculture, sustainable energy, etc.) has been explored by several scholars (Pugliese, 2001; Markandya *et al.*, 2006; Farges, 2015). To address the problem of ensuring sustainable economic growth in less developed countries, as well as their efforts to catch up with more developed countries with lower levels of pollution, factors of the green economics have been added to the convergence analysis paradigm (Brown *et al.*, 2009). Thus, environmental convergence reflects resource-dependent economic convergence with negative environmental impacts.

3. METHODOLOGY

The analysis of environmental (and other types) convergence between Ukraine and EU countries has a significant problem, which is that classical convergence studies consider homogeneous systems of countries/regions (US states, Chinese provinces, EU countries, etc.), which cannot be said about Ukraine and 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. One of the methods used to overcome such bottlenecks can be the selection of countries based on characteristics such as geographical proximity (e.g. Poland, Slovakia, Hungary, Romania and Bulgaria), similarity of economic characteristics (e.g. Bulgaria, Romania, Latvia and Lithuania), institutional proximity (e.g. Bulgaria, Romania, Croatia), the formation of a representative sample (e.g. Germany, France, Spain, Italy and Poland) or the use of an approach consisting in the evaluation of club convergence, the theoretical foundations of which were developed by Baumol (1986).

Indeed, it is in this case that club convergence has the greatest theoretical and practical value and can be used in this study. According to this concept, countries with the same level of income or economic development tend to form an “economic club” in which the economic indicators and policies of these countries converge. Club convergence occurs as a result of the influence of two factors. The first factor is that high-income countries become more economically similar to each other, which may be due to similar market conditions, technological innovation or the spread of best practices. The second factor is that countries with a lower levels of income or economic development will try to catch up with countries with a higher levels and move closer to their economic indicators. This can be done by implementing relevant reforms, attracting foreign investment, transferring technology or other mechanisms that contribute to economic growth.

It follows from the above that the assessment of the clusters of the EU countries and Ukraine for the purpose of their convergence analysis is of particular importance. For this purpose, the approach of Phillips and Sul (2007) was used, which includes the following steps:

1) for panel data, the corresponding indicator for the most recent observation period is sorted in descending order;

2) the formation of the main cluster, which involves the estimation of logistic regression for the first *k* countries $(2<k<N)$ with maximization *k* with condition that *t*-statistics $t>1,65$; i.e. the size of the main cluster k^* is defined as $k^*=\arg\max_k\{t_k\}$ if $\min\{t_k\}>-1,65$; if this condition is not met for $k=2$ (the first two countries), then the first country is discarded and the iteration is repeated; if condition $\min\{t_k\}>-1,65$ is not met for any of the values, then there is a divergence characteristic of all countries.;

3) the logistic regression is re-estimated with the gradual addition of the country not included in the main cluster; if t_k greater than the critical value c^*, then this country is included in the convergence club; countries included in the main cluster k^* and added in this step form the first convergence club;

4) if the condition is not met in the previous step, i.e. $t_k<c^*$, then these countries are then placed in a separate group and a further logistic regression analysis is carried out to check the condition. $\min\{t_k\}>-1,65$; if the condition is met, a second club is formed and steps 1-3 are repeated to identify other clubs.

The range of convergence methods and models is quite broad, depending on the type of convergence being studied and on the field of research: social policy, fiscal policy, environmental policy, trade, banking regulation, telecommunications, health care, monetary policy, migration policy, infrastructure, competition, justice and data protection policy, agricultural policy, education policy, foreign policy (Heichel *et al.*, 2005).

The vast majority of economists use two well-known concepts of σ- and β- convergence, based on the neoclassical theory of economic growth by Solow (1956), Ramsey (1928) and Cass (1965), as a methodological basis for studying convergence/ divergence processes. In neoclassical models of economic growth, the process of convergence describes trends in per capita income equalization between economies, i.e. countries, regions, provinces, states, etc. As noted by Quah (1990), income is a generalized concept in these models and is used, for example, as an indicator of convergence: GDP or GRP per capita, return on assets, inflation rate, wage per employee, pollutants and even political sentiment.

The concept of convergence is that economies with low levels of per capita income (relative to their steady-state levels) tend to grow faster in key per capita indicators. This dynamic is often confused with another meaning of convergence, which is that the dispersion of real income per capita for a given group of regions decreases over time. All measures of income inequality (Gini, Theil, Atkinson, etc.) are distributional statistics that give some indication of variance. And one of them is the standard deviation of the logarithm of income $\sigma_t=\sigma(\ln y_t)$, where income at a given time *t* is a direct characteristic of the distribution, which has been called σ-convergence. This is possible if the inequality $\sigma_{t+T}<\sigma_t$ holds for some time interval *T*. At the same time, β-convergence provides a direct assessment of the economic hypothesis that countries with lower income levels will develop faster than countries with higher income levels (Barro and Sala-i-Martin, 1992).

A condition for σ-convergence is the presence of β-convergence, so the analysis should begin with the evaluation of the last (Barro and Sala-i-Martin, 2004). Thus, the beta-convergence equation, which, as mentioned above, is based on neoclassical models of economic growth, the purpose of which is to formalise and substantiate the factors of uneven development of regions (countries, provinces), as well as to find the reasons that lead to the convergence of income levels per capita of the region over time. The main thesis of classical studies of economic growth (Ramsey, 1928; Solow, 1956; Cass, 1965) is that regions with a lower level of economic development grow faster than regions with a higher level of economic development. In neoclassical growth models, the convergence effect is enhanced by the movement of capital and technology from economically rich to poor regions, and of labour from poor to rich regions.

The analysis of β-convergence has a strong applied value in studies that examine the processes of differentiation in the socio-economic and environmental development of countries/regions. Today, a large number of scientists from all over the world publish research results every year, which are based on the use of β-convergence and its modifications. Empirical studies use a statistical analogue of the neoclassical Solow-Swan growth model. To account for these modifications, we write the unconditional β-convergence equation in the form:

$$\gamma_i = \alpha + \beta y_{i,o} + \varepsilon_i \tag{1}$$

where $\gamma_i = t^{-1}\left(\log y_{i,t} - \log_{y_i,0}\right)$ - per capita income growth rate (or other indicator), and unconditional convergence occurs if $\beta < 0$, $i = \overline{1,n}$ - region (country), ε - error.

The conducted detailed critical analysis of the β-convergence methodology leads us to the conclusion that the corresponding empirical analysis of the unevenness of the development of countries should be carried out in a complex manner with other methods, which are used to conceptualize the quantitative assessment of convergence (Heichel *et al.*, 2005).

Thus, the second most common method is σ-convergence, which reflects a reduction in the differences in the corresponding statistical indicator between the countries concerned. Obviously, the quantitative measures of this type of convergence are the coefficients of standard deviation and variation. The latter is considered to be the most appropriate for assessing homogeneity, as it allows the trends of variability between the different indicators studied to be examined (Boyle and McCarthy, 1999). Accordingly, if the coefficient of variation decreases over time, this reflects the σ-convergence process. The main advantage of using this type of convergence is that it basically corresponds to the conceptual understanding of convergence, i.e., the degree of homogeneity achieved by countries. At the same time, the main disadvantage of using the coefficient of variation in this case is that its decrease may be caused by an increase in the average value of the indicator being studied, and not by a decrease in the standard deviation. Therefore, if comparing indicators is not the goal of the study, it is desirable to calculate σ-convergence using a “pure” measure of variability, such as standard deviation.

It is worth noting that the analysis of β-convergence is covered exclusively in academic literature, but σ-convergence is widely used in practice at the state level for the development of relevant policies (European Commission, 2016).

Another concept, called γ-convergence, consists in studying the “movements” of countries and was developed as a variant of β-convergence, which, as we have already seen, does not reflect the dynamics between countries (Holzinger *et al.*, 2014). The γ-convergence analysis compares country ratings at different points in time to assess the "mobility" of countries. If there is a catching-up process between countries with higher rankings, then convergence will be observed. The change in the level of the resulting indicators can therefore be measured by a simple association measure, such as the Kendall's rank consistency index, which measures the degree of consistency or similarity between two rankings or ratings of the same set of objects:

$$KI_t = \frac{Var\left\lfloor \sum_{t=0}^{T} raiting\left(Y\right)_{i,t} \right\rfloor}{\left(T+1\right)^2 Var\left(raiting\left(Y_{i,0}\right)\right)}, \tag{1}$$

where KI_t - the Kendall index at a given time *t*, $-1 \leq KI_t \leq 1$, Var - dispersion, $raiting\left(Y\right)_{i,t}$ - current rating of the country *i* at the time *t*, $raiting\left(Y\right)_{i,0}$ - current rating of the country *i* at the initial moment of time, *T* - number of periods.

A corresponding positive value of the index (2) indicates agreement between the ratings, while a negative value indicates the exact opposite or inverse agreement between the ratings. A value of 0 indicates no statistical agreement between the rankings. The Kendall index is calculated by comparing a pair of ranks for each item in the two rankings. If the order of the rank pairs is the same in both rankings, they are considered consistent, and if the order of the rank pairs is opposite, they are considered inconsistent.

The γ-convergence methodology described makes it possible to obtain additional quantitative characteristics of the convergence of countries over time. Although the use of this type of convergence is not widespread in the academic literature, it can be effective in the development of relevant policies, as it allows countries and governing bodies to gain insight into trends in the equalisation of economic indicators and the effectiveness of policies aimed at ensuring more equal development. Thus, the corresponding application of γ-convergence has been carried out by Holzinger *et al.* (2014), where the authors study the convergence of national environmental policies of OECD member countries.

Finally, the concept of δ-convergence has been proposed by Heichel *et al.* (2005) to quantify the distance of a country from an exemplary model, in particular countries with the highest level of development. δ-convergence can be calculated as the sum of the distances between the maximum and the minimum values of a given indicator for countries:

$$\delta_t = \sum_{i=1}^{N} \left(MAX\left(x_{i,t}\right) - x_{i,t}\right), \tag{3}$$

where $x_{i,t}$ - the value of the corresponding indicator for the country *i* at time *t*.

Accordingly, the closing of the gap between a given country and the leading country over time represents convergence (3). δ-convergence is a measure of the extent to which countries are becoming similar to countries at a higher level of development. Although the calculations in (3) may be imprecise due to the presence of outliers, delta convergence is an effective quantifier of convergence towards a given policy objective. The first studies

(Heichel *et al.*, 2005) of delta convergence were concerned with examining changes in costs in a small group of countries, which became the basis for developing appropriate mechanisms for improving policies over time.

In the context of the study of methodological approaches to the analysis of environmental convergence, it is worth adding that, based on the interpretations of the neoclassical theory of economic growth, the dynamics of development depends on one or more structural characteristics of the economy of each country, regardless of the initial conditions. Contrary to approaches based on endogenous models of economic growth (the formation of convergence clubs), such dynamics may be the result of differences in the initial conditions of different economies with similar structural characteristics. In other words, β-convergence does not allow us to identify the true factors that determine the environmental growth of a given country, since it is well known that a positive coefficient β in ratio (1) is a necessary but not sufficient condition for reducing interregional dispersion (Barro and Sala-i-Martin, 1991). Barro and Sala-i-Martin (1992) emphasize that the study of β-convergence must necessarily be complemented by the assessment of σ-convergence. On the other hand, the analysis of σ-convergence uses only one indicator, which is a major drawback in the study of environmental convergence as a set of indicators and therefore provides insufficient information on convergence dynamics. It is not able to detect cases of cluster convergence, which can be accompanied by both an increase and a decrease in unevenness. It is therefore more informative to examine the form of the distribution of the values of the relevant indicators over time (Magrini, 2007). The method of analysing the dynamics of income distribution over time, first proposed by Quah (1993), makes it possible to detect interregional asymmetries based on the mathematical evaluation of a stochastic kernel (e.g. Gaussian). Such a technique is appropriate for assessing the environmental and economic convergence of the EU countries and Ukraine, as it allows specific effects for each country to be taken into account. Accordingly, denote by $y_i(t)$ the level of the corresponding indicator in the country *i* at time *t*, and by $\bar{y}(t)$ - the average level of this indicator for all countries; then we consider its normalized value in the form of: $x_i(t) \equiv y_i(t)/\bar{y}(t)$; by $F_{x(t)}$ denote the density of the distribution $x(t)$, by $f_{x(t)}$ - a probability measure associated with $F_{x(t)}$.

Let us consider the dynamics of the distribution of the indicator y in the following form (Magrini, 2007):

$$f_{x(t+s)}(A) = \int_{-\infty}^{\infty} M_{t,s}(x, A)\, f_{x(t)} dx \qquad (4)$$

where $M_{t,s}$ - the stochastic kernel, on which you must focus your attention when analyzing the dynamics of the distribution of the corresponding indicator, the period between *t* and $t+s$; estimation of $M_{t,s}$ will provide information on the shift of countries from one part of the distribution to another.

In this study, the stochastic kernel was estimated by dividing the estimate of the joint distribution function $f_{x(t),(t+s)}$ by the estimate of the partial (separate) distribution function:

$$p_{t,s} = f_{x(t+s)|x(t)} = \frac{f_{x(t),x(t+s)}}{f_{x(t)}} \tag{5}$$

The stochastic kernel estimate shows where different parts of the original distribution are headed over time. The line $x_{t+s} = x_t$ is a mobility line, peaks (local maxima) along which indicate the presence of convergence clusters.

Assuming that for all $t \geq 0$ stochastic process $x(t)$ is Markov, and the matrix of transition probabilities is $P_{t,s}$ does not depend on time, model (5) can be considered as a finite state Markov chain. Therefore, the stochastic kernel can be interpreted as a transition matrix, and the distribution densities in equation (4) can be estimated by kernel density estimation.

Convergence in this case is analysed on the basis of the appearance (geographical shape) of the three-dimensional graph of the stochastic kernel or the corresponding contour plot. Conclusions are drawn from the placement of data relative to the main diagonal in such graphs. The conclusion of convergence therefore follows from the concentration of most of the graph around the value 1 on the time axis $t+s$ in parallel to the time axis *t*. On the other hand, if the formation of two or more modes (peaks) is observed, we can speak of polarization. The bimodal distribution of indicators in countries indicates polarization, similar to the result of income convergence among poor countries and convergence among rich countries. The presence of two or more modes in the distribution density can indicate the polarization of countries by indicator, and their formation in a time sequence $F_{x(t)}$ about cluster convergence.

Based on this, the monomodal or multimodal ergodic distribution can be used to conclude that there is environmental convergence between the EU countries and Ukraine.

Thus, as a counterpart to the classical beta, sigma, gamma and delta convergence models, this study includes alternative methodologies that focus on enhancing the economic development of less developed countries rather than merely reducing disparities. These approaches emphasise policy efforts, institutional changes and economic mechanisms that create favourable conditions for sustainable growth.

One key approach is club convergence, which considers groups of countries with similar economic structures and levels of development, allowing for differentiated convergence trends rather than assuming uniformity across countries. This method provides insights into how countries progress towards environmental and economic convergence based on their specific conditions.

Another important methodology is the distributional dynamics approach, which goes beyond traditional convergence measures by analysing the evolution of the entire distribution of environmental and economic indicators over time. Unlike classical models, this approach allows the identification of patterns within sub-groups, helping to assess whether less developed countries are gradually catching up with wealthier nations or whether divergence persists. By applying stochastic kernel estimation, this technique provides a more detailed perspective on the structural changes that influence environmental and economic convergence across regions.

These methods provide a more distinct understanding of convergence by taking into account country heterogeneity, structural change and the role of policy interventions in shaping economic and environmental trajectories.

4. DATA

When analysing the convergence of environmental development in Ukraine and EU countries, it is important to choose appropriate indicators. For example, the Kyoto Protocol defines six indicators for assessing harmful emissions: CO2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (United Nations, 1997). The Kyoto Protocol requires countries to reduce their emissions of these gases, of which CO2 emissions account for the largest proportion (70%) of greenhouse gas emissions. In addition, these emissions have been identified as the largest man-made environmental pollutant (United Nations, 1997).

In the scientific literature, CO2 emissions are used to study the convergence of indicators of negative environmental impact (Table no. 1). Since the publication of the first study (Strazicich and List, 2003), in which the authors used the unit root criterion to confirm the convergence of 22 industrialized countries for the period 1960-1997, the discussion on the convergence of CO2 emissions has been extensively explored in the scientific literature on energy and environmental economics. Recent studies on environmental convergence have addressed different types and characteristics of convergence, as well as numerous econometric methods (in particular unit root tests, clustering algorithms, cross-sectional and distributional analysis). Due to the use of different econometric approaches and data sets, the results of these studies are ambiguous, with some authors finding convergence in per capita CO2 emissions and others finding divergence. An analysis of the publications shows (Table no. 1) that the authors of most of them focus on the national convergence of emissions between countries, with limited research at the sectoral and regional levels. With regard to the latter, due to the availability of qualitative statistical information, the main focus of research is on the regions of China and the states of the USA.

The environmental catching-up hypothesis assumes that poorer countries are more polluted than rich countries, and that pollution diverges between rich and poor countries over time. The reason for this differentiation is the capital level of countries at the initial point in time. As developing countries begin to adopt environmental technologies and their income levels rise, the gap between the quality of the environment in rich and poor countries will narrow and their pollution indicators will converge. Although economic growth initially causes environmental damage, it eventually leads to an improvement in environmental quality over time. According to the study by Stern (2004), the convergence hypothesis shows that pollution decreases faster in countries with a high level of pollution than in countries with a low level of pollution. If rich countries start with a high level of pollution, while poor countries start with a low level of pollution, the result will be similar to the Kuznets curve hypothesis. However, unlike this hypothesis, which has been extensively explored in many studies, the literature on pollution convergence is quite limited. This means that it is a major disadvantage if countries focus only on reducing CO2 emissions and ignore other sources of pollution (Lin *et al.*, 2018). Therefore, the relevant indicators of negative environmental impact, including CO2 emissions, should be complemented by complex cumulative indicators. For example, the study (Ozcan *et al.*, 2019) highlights the following key indicators for analysing the impact on sustainable development: analysis of energy consumption, analysis of electricity consumption (i.e. the amount of energy used directly in direct and indirect transformations for the production of goods or services), environmental input-output tables, ecological footprint, carbon footprint, environmental pricing, Life Cycle Assessment (i.e. the assessment of the environmental impacts associated with all stages of the life cycle of a commercial product, good or service).

However, in many studies, in particular in (UNEP/SETAC, 2009), it is noted that the most appropriate method for assessing the impact of human activity on global sustainability is the footprint itself. At its core, the Ecological Footprint reflects human demand on natural resources and has six components: fields, pastures, forests, fisheries, built-up areas and carbon footprint. The use of the Ecological Footprint in the study of environmental convergence is not so common and is present in several papers (Table no. 2).

Table no. 2 – The use of the Ecological Footprint in the study of environmental convergence

Source	Period	Countries	Main result
(Ulucak and Apergis, 2018)	1961-2013	EU	The empirical results confirm the existence of certain convergent clubs. The empirical results show differences in the quality of the environment as well as in the strategy of each EU member according to the assigned club.
(Bilgili *et al.*, 2019)	1961-2014	All	Ecological and economic convergence is observed in 15 countries from each continent. The results showed the presence of ecological footprint convergence for African, American and European countries, while the null hypothesis of convergence was rejected for Asian countries.
(Solarin *et al.*, 2019)	1961-2014	92	The results showed the existence of 10 clubs of convergence. At the same time, there are five clubs for the level of CO2 emissions, seven for the footprint of cultivated areas and two for the footprint of fisheries. It was concluded that the environmental protection policy should take into account the unique ways of convergence of each of the countries of the cluster according to the indicator of ecological footprint, as well as its components.
(Yilanci and Korkut Pata, 2020)	1961-2016	ASEAN	It was found that the Ecological Footprint is non-linear, with divergence in the second regime and absolute in the first. The second regime represents about 80% of the sample. It was concluded that there is an absolute convergence of the Ecological Footprint in the region studied.
(Erdogan and Okumus, 2021)	1961-2016	All	Main conclusions: a) dependency exists for all income groups; b) the methods used show clear convergence; c) there are several convergence clubs. The existence of club convergence implies that the environmental policy of each country studied should be developed according to its membership in a particular club.

As environmental convergence is a system of complex interactions between environmental and economic processes, we have used the Ecological Footprint (Global Footprint Network, 2022) for its empirical analysis, which allows a more complete assessment of the interrelationship between these processes. Using indicators separately leads to a one-sided assessment, distorts the real situation and does not take into account other factors that may affect environmental and economic convergence.

Based on the above, an empirical analysis of the environmental convergence of the national economies of the EU countries and Ukraine was conducted for the period from 2000 to 2022, divided into two sub-periods: 2000-2013 and from 2014 onwards, in order to identify the trends of the Russian armed invasion from 2014 and its impact on environmental convergence in the conditions of war. This can allow appropriate forecasting and strategic planning of policy implications for the period after 2022 and, in particular, after the war.

5. EMPIRICAL RESULTS

The assessment of club convergence using the methodology of Phillips and Sul (2007) did not reveal any club convergence and the following results were obtained: the negative β coefficient of -0.4889 indicates that the economies in this group are diverging over time and the magnitude of the beta suggests a moderate degree of divergence; the small standard error and the high absolute *t*-value indicate that the estimate of divergence is accurate and statistically significant, so that a *p*-value of 0 confirms that the evidence for divergence is robust. These results indicate that the group of economies under consideration is experiencing significant divergence. The strong statistical significance of the negative beta coefficient suggests that the divergence is not due to random variation but reflects a real and substantial divergence trend among these economies. Taking into account the results obtained, as well as qualitative features such as geographical proximity and similarity of economic characteristics, we formed a convergence club consisting of such countries as Ukraine, Romania, Bulgaria, Greece, Poland, Croatia, Hungary and the Baltic States. Despite the low statistical significance of the calculations, the Baltic countries are included on the basis of the results of the qualitative analysis, because the experience of these countries can also be useful for Ukraine, as all three Baltic states are now successful economies and nations that have integrated into the European Union. Ukraine went through a similar historical experience, but could not follow the same path.

The next step was to assess β-, σ-, δ- та γ-convergences. β-convergence calculations were carried out according to relationship (1), which indicates that the higher β parameter, the faster the level of average growth responds to the difference between $\log\left(\hat{y}^*\right)$ and $\log\left[\hat{y}(0)\right]$, and therefore there is a higher rate of convergence to the steady state. The graph of β-convergence (Figure no. 1) helps to visualize the degree of convergence of the economic indicators of the countries studied.

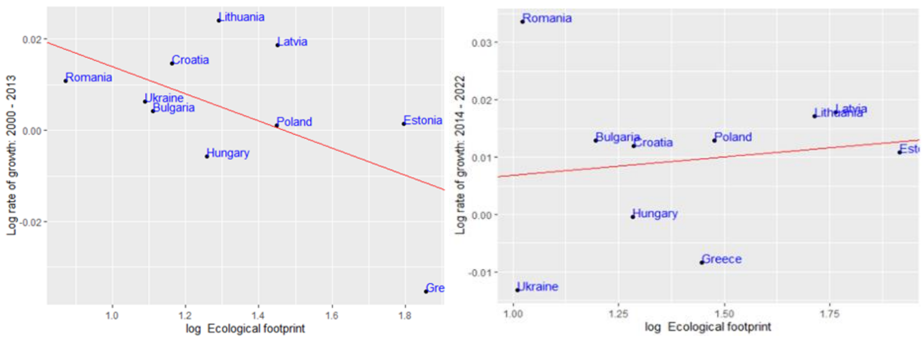

Figure no. 1 – β-convergence: subperiods 2000-2013 and 2014-2022

The downward trend (Figure no. 1) for the 2000-2013 sub-period indicates the presence of beta convergence for the club of countries studied, and therefore they have a faster pace of Ecological Footprint, although the gap between them tends to decrease over time. This proves the theoretical thesis that countries with a lower level of development have the potential for faster growth and catching up with countries with a higher level of development; for the subperiod 2014-2022 there is an upward trend and therefore a divergence. Detailed quantitative estimates are presented in Table no. 3.

Table no. 3 – Summary of beta convergence results

Period	Coefficient	Estimate	Std. Error	t-statistic	p-value	Adj. R-squared	Result
2000-2013	Intercept	0.04380	0.0211	2.08	0.0715	0.23271	Convergence
	Initial income (indic)	-0.02982	0.0154	-1.93	0.0896		
2014-2022	Intercept	0.00053	0.0222	0.0237	0.982	-0.10143	Divergence
	Initial income (indic)	0.00636	0.0154	0.414	0.690		

The comparison in Table no. 3 shows a remarkable change in the patterns of environmental convergence before and after 2014. The earlier period (2000-2013) showed weak signs of convergence, while the latter period (2014-2022) suggests a shift towards divergence, although not statistically significant. This shift could be attributed to the geopolitical and economic impact of the Russian invasion of Ukraine, which may have disrupted the convergence process among the economies analysed. Further analysis with additional variables and robustness checks would be beneficial to fully understand the underlying factors driving these changes. However, it is important to note that the beta convergence analysis gives a general idea of the trends, but does not take into account all the possible factors affecting the green growth of countries.

Another important feature is sigma convergence, which shows how similar countries are becoming to each other on a given indicator. To assess sigma convergence, we calculated the coefficients of standard deviation and variation. Recall that beta convergence is a necessary but not sufficient condition for sigma convergence. As an example, let's visualise sigma convergence graphically (Figure no. 2). The results of sigma convergence show the main disadvantage of using this type of convergence: the reduction in the coefficient of variation is caused by an increase in the mean instead of a reduction in the standard deviation. In such a case, it is desirable to use a "pure measure of variability", in particular the standard deviation, to compare indicators.

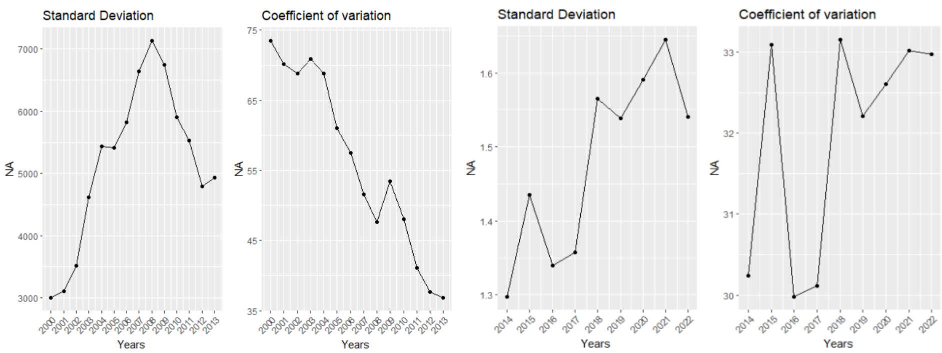

Figure no. 2 – σ -convergence: subperiods 2000-2013 and 2014-2022

For the period 2000-2013, there is a slight decrease in the standard deviation and the coefficient of variation of the Ecological Footprint, suggesting a small sigma convergence. This indicates that the dispersion of the Ecological Footprint across regions has slightly decreased over this period. While there were some years (e.g., 2003 and 2007) where dispersion increased, the overall trend is towards decreasing inequality in environmental impact. For the period 2014-2022, the increasing trend in both the standard deviation and the coefficient of variation indicates sigma divergence, meaning that the dispersion of the Ecological Footprint across regions increased. This suggests that environmental inequality between regions has risen over this period. The results show that regional disparities have increased in post-2014, which may be partially attributable to the invasion of Ukraine by Russia and its subsequent economic and geopolitical ramifications. This divergence suggests that the invasion may have exacerbated regional environmental inequalities, possibly due to economic disruptions, shifts in trade patterns, political instability, and differing regional responses to these challenges. Overall, the findings highlight that while there was some movement towards environmental convergence before 2014, the period following the invasion saw a reversal of this trend, with growing disparities in ecological footprints across regions.

The next type of γ -convergence uses country rankings to compare their "mobility" and measures the degree of convergence based on changes in rankings over time. If countries with higher rankings gradually move closer to countries with lower rankings, this indicates a process of convergence. At the same time, the analysis of gamma convergence was carried out according to the relationship (2), where a positive value of the Kendall index indicates consistency between ratings and a negative value indicates the complete opposite or reverse consistency between ratings. A value of 0 indicates no statistical consistency between the rankings. The results of the Kendall's index analysis are shown in Figure no. 3.

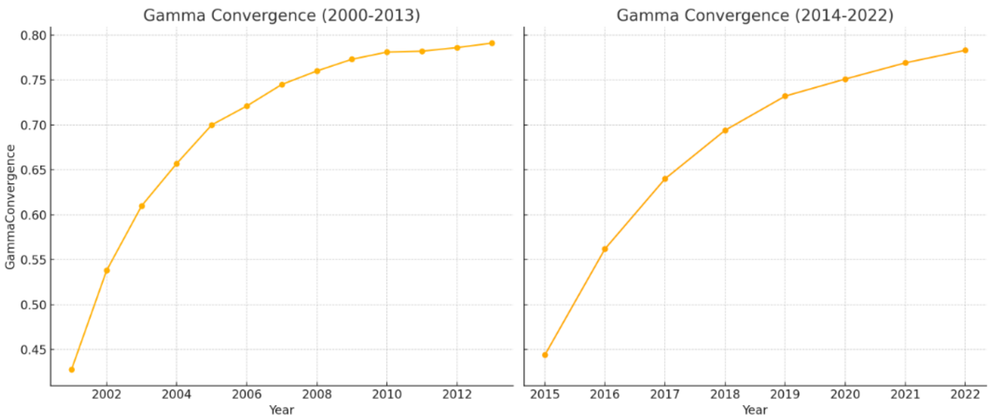

Figure no. 3 – γ -convergence: subperiods 2000-2013 and 2014-2022

The continued upward trend in gamma values (Figure no. 3) indicates even less mobility between countries in their Ecological Footprint rankings than in the previous period. This suggests that the rankings of countries have become more entrenched, with less movement between higher and lower rankings. The very high and increasing gamma values suggest a strong process of environmental convergence. The rankings of countries in terms of their ecological footprint became even more stable and consistent, reinforcing the trend observed in the earlier period. This suggests that countries with initially higher Ecological Footprints may have continued to move closer to countries with lower Footprints, albeit at a slower pace due to the increasing stability. In 2000-2013, there was a trend of environmental convergence, with increasing consistency in country rankings and decreasing mobility, indicating that countries were moving towards similar ecological footprints. In 2014-2022, the trend towards environmental convergence continued, with even higher consistency in rankings and further reduced mobility, suggesting entrenched positions and potentially greater stability in ecological footprints. The geopolitical instability since 2014, in particular the Russian invasion of Ukraine, may have contributed to this trend by increasing regional disparities and reducing the movement towards convergence.

In the study of γ -convergence, the ratings can be used to determine the change in the level of the indicators and to observe the process of convergence or divergence of countries. In general, a higher rating indicates more "mobile" or more developed countries. A lower rating indicates less mobility or a lower level of development. In other words, the general idea of the γ -convergence ratings is to compare the level of the indicators between countries at different points in time. The corresponding ratings are shown in Table no. 4.

Table no. 4 – γ- convergence: the average ranking of countries from the convergence club

Period	Average rank									
	Bulgaria	**Croatia**	**Estonia**	**Greece**	**Hungary**	**Latvia**	**Lithuania**	**Poland**	**Romania**	**Ukraine**
2000-2013	2	5	10	6	4	9	8	7	1	3
2014-2022	2	4	10	6	3	9	8	7	5	1

The results of the γ -convergence analysis between Ukraine and the EU (Tables no. 3 and no. 4) show that Ukraine is characterized by a high level of "mobility" or growth compared to EU countries. This indicates that Ukraine has achieved positive changes in relevant environmental, which is the result of effective economic reforms, environmental policies and other factors contributing to environmental and economic growth.

Accordingly, the δ -convergence provides a quantitative assessment of the distance of the country from an exemplary model, in particular the country with the highest level of development. Delta convergence has been estimated according to relationship (3). First, the dynamics of change in the Ecological Footprint are presented for the whole period under consideration (Figure no. 4).

According to Figure no. 4, convergence is visualised in the period 2000-2009; the period 2009-2016 is characterised by the presence of delta divergence, caused by the 2008 crisis. In addition, we see an increase in the level of divergence after 2014, which also logically explains the impact of Russia's military invasion on Ukraine's economic development. Finally, the period 2016-2022 is characterised by an increase in the level of environmental growth, which led to the convergence of the club of countries studied.

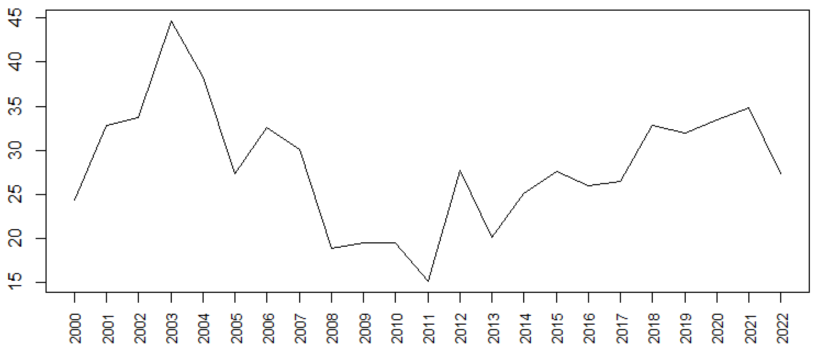

Figure no. 4 – δ -convergence of the ecological footprint for the convergence club

When analysing delta convergence, it is also important to assess how much a particular country's indicator differs from the average of a group of countries. For example, let's consider the sum of the increase and decrease in the Ecological Footprint compared to the average for the club of countries (Figure no. 5).

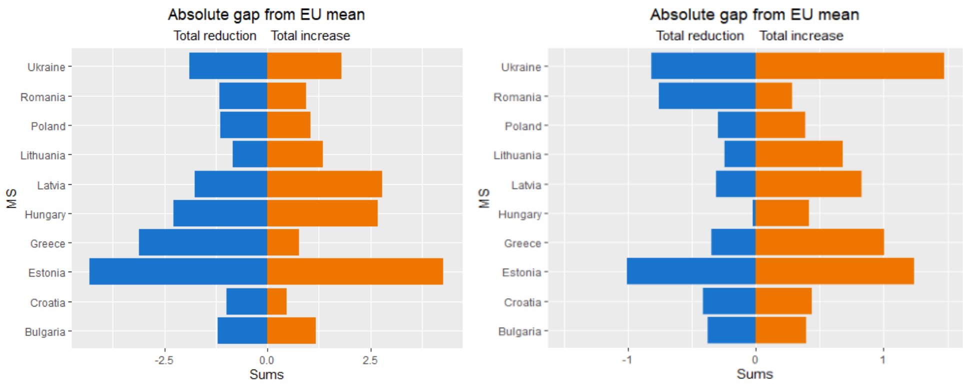

Figure no. 5 – Cumulative change in Ecological Footprint from the average of the club of countries: subperiods 2000-2013 (left) and 2014-2022 (right)

The graphical visualisation (Figure no. 5) provides an opportunity to observe the approach or distance of the respective indicator to/from the reference country (benchmark). In particular, in the period 2000-2013 we can speak about a high degree of divergence between Ukraine and the studied countries, which slightly decreased in the second subperiod. A more detailed analysis of the delta convergence is presented in Table no. 5.

Let's move on to the analysis of the form of income distribution over time according to the method (4-5), which allows us to analyse changes in the distribution of indicators. This approach considers not only the average values of the indicators, but also their distribution, taking into account the differences in development between countries. It also makes it possible to determine whether inequality in the distribution of indicators is increasing or decreasing over time and to identify which groups of countries are performing better or worse.

Table no. 5 – Cumulative change in indicators from the average for the club of countries: delta-convergence

Period	Convergence (k) / divergence (d)									
	Bulgaria	**Croatia**	**Estonia**	**Greece**	**Hungary**	**Latvia**	**Lithuania**	**Poland**	**Romania**	**Ukraine**
2000-2013	k	k	k	k	d	d	d	k	k	k
2014-2022	d	d	d	d	d	d	d	d	k	d

In order to detect the biomodality (the distribution of a random variable has two distinct peaks) of the distribution of the Ecological Footprint, we will construct appropriate graphs: a three-dimensional graph of the stochastic kernel and the corresponding contour plot (Figures no. 6 and no. 7).

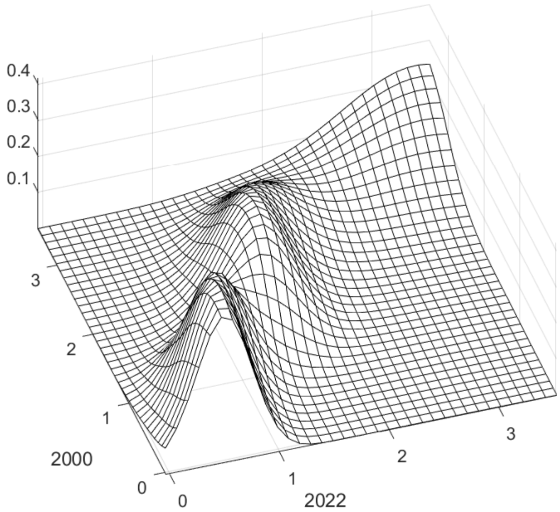

Figure no. 6 – Stochastic core: distribution of footprint relative to the 2000-2022 mean

The graphical form of the plane in Figure no. 6 allows us to draw additional conclusions compared to the previous analysis. Thus, two local maxima are clearly visible in both the poor and rich parts of the distribution of the density of the Ecological Footprint of Ukraine and the EU countries; in addition, a bulge in the centre of the graph is clearly visible, i.e. the density of the distribution of the average values of the indicator studied. The density clustering around the maxima is sharper and around the averages - softer, i.e. regions with average income levels are not distinguished. Looking at the 3-dimensional diagram allows us to draw a preliminary conclusion about the biomodality of the distribution and the presence of cluster convergence.

This conclusion is confirmed by the analysis of the percentage contour plot in Figure no. 7: Two peaks of the density of the distribution of high and low levels of the indicator are traced, and the density of the distribution of regions with an average level of Ecological Footprint is not traced.

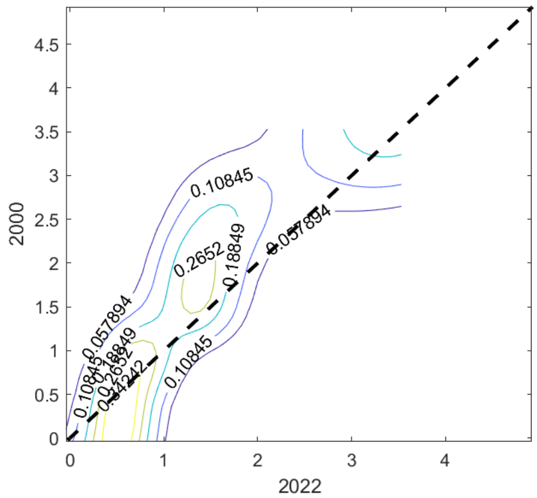

Figure no. 7 – Percentage contour plot of Ecological Footprint distributions: 2000-2022, Ukraine - EU

Figure no. 7 allows us to draw a conclusion: the peaks of the density of the distribution of high levels of the ecological footprint are below the 45-degree diagonal in comparison with similar peaks of low levels, which indicates a decrease of their difference in the years 2000-2022, i.e. there is a convergence of Ukraine and EU countries. The assessment of the distribution itself (Figure no. 8) allows us to conclude that we do not reject the hypothesis of divergence, since the studied distribution is moving in time to unimodal (the random variable has only one pronounced peak point or maximum): ergodic (statistical properties of the system in time or space are preserved when the mean values or other characteristics can be calculated as averages over all possible paths or realisations of the system).

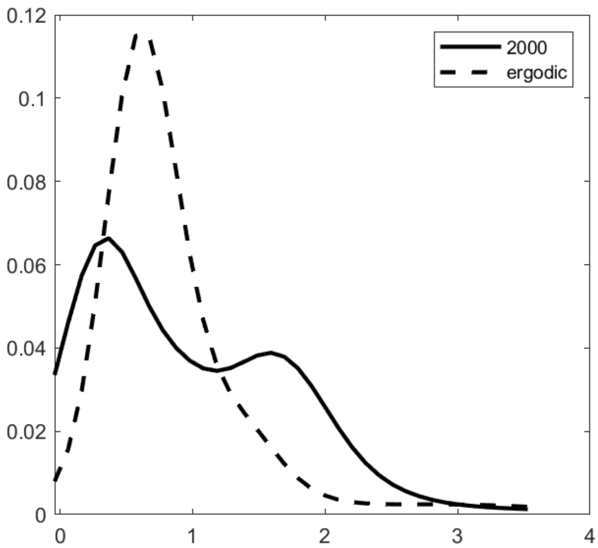

Figure no. 8 – Ergodic distribution of the Ecological Footprint: 2000-2022, Ukraine – EU

Despite the complexity of the practical application of such a technique, it will be useful for the analysis of environmental and economic convergence because it will allow the effectiveness of policies, programmes and reforms aimed at reducing the gaps between countries to be assessed. It makes it possible to visualise in more detail the distribution of development outcomes and to determine whether it is possible to achieve greater uniformity in the achievement of convergence objectives.

In order to improve clarity and to track the contribution of each output to the final objective, the following Table no. 6 provides a centralised summary of the main empirical findings:

Table no. 6 – Summary of Ecological Footprint convergence results and their implications

Period	Beta Convergence	Sigma Convergence	Gamma Convergence	Delta Convergence	Interpretation
2000-2013	Weak Convergence	Declining Variability	Moderate Mobility	Some Convergence	Initial signs of catching up due to economic and policy alignment
2014-2022	Divergence	Increasing Dispersion	Limited Mobility	Widening Gaps	Geopolitical instability and economic shocks reversed previous convergence trends

The table above provides a structured overview of convergence patterns specifically for the Ecological Footprint, helping to understand how different time periods have influenced environmental convergence trends.

Furthermore, the analysis of the distributional form of the Ecological Footprint provides additional insights into convergence over the whole period (2000-2022). Traditional models struggle to detect cluster convergence, which can involve both increasing and decreasing inequalities. The use of stochastic kernel estimation allows an in-depth examination of interregional asymmetries over time. The results indicate that while some initial convergence was observed, the distribution has widened over time and shows signs of increasing divergence in recent years. These findings support the conclusion that geopolitical instability has negatively affected environmental convergence trends in Ukraine and its peer group.

The results of this study have significant implications for Ukraine's environmental and economic policies. Given the observed divergence in the ecological footprint between Ukraine and the EU, the increasing differences in environmental indicators call for a structured approach to policy adaptation. In order to achieve environmental convergence, Ukraine should focus on the following strategies:

- legislative adaptation and policy alignment. Ukraine must continue to align its environmental policies with EU standards, particularly in the areas of emissions control, green energy development and biodiversity conservation. Strengthening environmental governance and enforcement will be key to achieving sustainable convergence;

- investment in green technologies and infrastructure, as the divergence observed after 2014 highlights the need for significant investment in renewable energy, waste management and sustainable transport. International cooperation and foreign direct investment can play a crucial role in financing these initiatives;

- post-war economic recovery and environmental sustainability because the war has severely disrupted Ukraine's economic activities and environmental policies. Reconstruction efforts should integrate green development strategies to ensure that post-war recovery supports long-term sustainability and resilience;
- reducing regional disparities, as disparities in environmental convergence across Ukraine's regions suggest the need for targeted interventions. Strengthening local governance, improving environmental monitoring and increasing resource allocation to underdeveloped areas will contribute to more balanced growth;
- leveraging EU integration for sustainable development: Ukraine's European integration process provides an opportunity to accelerate environmental convergence through access to EU funding, knowledge-sharing initiatives and collaborative research projects on sustainability.

6. CONCLUSIONS

This study has shown that environmental convergence follows similar principles to socio-economic convergence. Countries with lower per capita emissions can increase their emissions while high emitting countries reduce their emissions, leading to a balanced environmental trajectory. However, approaches to analysing environmental convergence must take into account the complexities of combining economic growth with reducing environmental impacts. In addition to classical beta, sigma, gamma and delta convergence models, distributional dynamics and stochastic kernel estimation provide a more comprehensive perspective by identifying structural shifts and regional asymmetries.

Our empirical findings show mixed results in terms of environmental convergence between Ukraine and the EU. While some methodologies point to convergence, others highlight divergence, suggesting that Ukraine's integration into the EU environmental framework is a complex and multifaceted process. Some dimensions of cooperation promote convergence, while others increase divergence.

Geopolitical instability has played an important role in shaping convergence trends. The Russian armed invasion in 2014 altered Ukraine's trajectory towards EU alignment, negatively impacting economic stability, environmental policies and institutional development. The full-scale invasion in 2022 further exacerbated these challenges, disrupting key policies that could have facilitated convergence.

To reduce divergences and improve environmental integration with the EU, Ukraine needs to adopt a multi-pronged approach, including regulatory reforms, investments in sustainable technologies and adjustments to regional policies. A continued focus on cooperation with EU countries, drawing on international expertise and funding opportunities, will be essential to strengthen Ukraine's environmental and economic resilience in the long term.

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