CIRCULAR ECONOMY: EVALUATION OF THE IMPACT ON THE WELFARE OF EUROPEAN COUNTRIES AND IMPLEMENTATION IN UKRAINE

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CE Circular Economy

HDI Human Development Index

R&D Research and Development

EU European Union

GERD Gross Domestic Expenditure on R&D

GDP Gross Domestic Product

H0 hypothesis 0

H1 hypothesis 1

RE random effect

CHAPTER 1. INRODUCTION

EXECUTIVE SUMMARY

This paper describes the impact of the circular economy on the well-being of European countries and the specifics of its implementation in Ukraine. The circular economy is defined as having the purpose to optimize the use of resources, reduce the level of waste and minimize the negative impact on the environment. The research aims to assess how such approaches can improve economic potential.

Within the framework of the study, several key questions were asked, which describe how the implementation of the circular economy affects the well-being of EU countries, measured by the Human Development Index (HDI) and what policies, similar to European ones, are implemented in Ukraine.

The research methodology includes the use of random effect regression model to analyze the impact of independent variables describing the circular economy on HDI. A part of this article is dedicated to analysis of the current state of circular economy policy implementation in Ukraine based on national national legislation and assessments of relevant research centers.

It is expected that the results of this study will allow a better understanding of the role of the circular economy in increasing the welfare of the population and will contribute to the development of effective strategies for its implementation both in the EU and in Ukraine.

RESEARCH QUESTION AND MOTIVATION

In this study author wants to show how the circular economy which is considered to be a modern strategy and global trend aimed at optimizing the use of resources and improving the environment through technological development: a combination of economic, environmental, and technological factors in Europe, affects the wellbeing of European Union countries and Ukraine. In this research it is considered as such that allows to optimize the use of available resources, with the aim of increasing the economic potential, creating new jobs in the technological sector, and increasing the competitiveness of Ukraine. Based on that, the study examines two key questions in stages:

- Assessment of the impact of the implementation of the circular economy on the well-being of European countries (measured by the Human Development Index).

- Definition of similar policies and assessment of their influence on the well-being of Ukraine.

In the process of consideration of issues the following hypotheses are put forward by the authors in advance:

- Hypothesis № 1.1: Investments in the development of the circular economy (R&D, resource productivity, the level of recycling, etc.) have a positive impact on the well-being of countries;

- Hypothesis № 1.2: Investments in the development of the circular economy have a deferred in-time effect on the country's wellbeing.

- Hypothesis №2.1: The circular economy policy in Ukraine is implemented at a minimal level or not implemented at all.

- Hypothesis № 2.2: The impact of circular economy methods, which are nevertheless introduced in Ukraine, has similar patterns to European countries.

CHAPTER 2. INDUSTRY OVERVIEW AND RELATED STUDIES

Since the circular economy is a relatively new direction, the author begins this chapter with a more general review of sources that will help form a general idea of the key trends of this direction in the European Union and its implementation in Ukraine. And then turns to the description of a more technical source with a methodology close to the one that will be used in the current work.

OVERVIEW:

First, the idea of and current imllementation of circular economy are described.

The active social and economic development of any country always has two sides, or to put it bluntly, it is a zero-sum game: the creation of new enterprises, an increase in production volumes, an increase in the extraction of resources, an increase in trade volumes are necessarily converted into an increase in the economic power and GDP of the country. However, similar actions are always accompanied by negative consequences for the the environment in general, such as the exhaustion of available resources, an increase in the level of waste, an increase in emissions into the environment, and others. The bigger the economy, the bigger the footprint it leaves behind. The negative side of the economic scale prompts the government of countries to seek to minimize the impact of their own actions on the environment.

One of these solutions was the introduction of circular economy methods which main ideas are minimizing waste, making the most of resources and regenerative approach. The circular economy implementation plan in the countries of the European Union was implemented by the European Commission in May 2020 - "A new Circular Economy Action Plan" (European Commision, 2020) . It can be considered the definition of circular economy in the European Union. This plan specifies the key goals and methods of implementing this policy for the coming years. This plan describes the need to use the

circular economy to optimize resource consumption and reduce the impact on the environment and details the very stages of its implementation.

In particular, according to this document, circular economy characterized by:

- The policy of developing sustainable products, introducing the principles of circularity into production processes, and increasing the number of products suitable for sustainable use. Target sectors include electronics, batteries, vehicles, packaging, plastics, textiles, construction and food. This approach should affect the durability, reusability, recyclability of products and reduce the amount of waste.

- In addition to the introduction of sustainable products, separate policies in the field of waste management aimed at their reduction and improvement of waste management systems are also being considered.

- The market of secondary raw materials is also considered separately.

- Next, a reduction in greenhouse gas emissions is expected at the EU and national levels.

- After environmental factors, this document draws attention to the positive impact on population employment related to job creation.

In general, the process of implementing the circular economy is considered complex and systemic for the EU and beyond and will involve the cooperation of parties at different economic levels.

It should be noted that Ukraine is also involved in this plan. Moreover, Ukraine is a participant in the program «EU4Environment» (EU4Environment, 2024). This program is part of an initiative of the European Union aimed at supporting the

Eastern Partnership countries in their efforts to preserve the environment and implement a sustainable economy (EU4Environment, 2024). The active participation of EU4Environment in the implementation of the circular economy in Ukraine is confirmed by its involvement in the development of the National Economic Strategy of Ukraine until 2030 (Cabinet of Ministers of Ukraine, 2021). The described strategy for Ukraine is very close to the general action plan of the European Union. According to National Economic Strategy of Ukraine until 2030 (Cabinet of Ministers of Ukraine, 2021) implementation of the following circular economy principles are envisaged:

- Development of markets for secondary raw materials through improvement and harmonization of Ukrainian legislation with relevant EU legislation with the aim of creation transparent and competitive markets for secondary resources.

- Focusing on waste reduction by encouraging the reduction of waste generation and simplifying procedures for scrap metal operations.

- The importance of effective management of resources and waste like raising awareness of the implementation of resource-saving technologies, getting grants and loans for the implementation of such technologies, and ensuring access to high-quality energy audits is mentioned.

- The implementation of a framework strategy for adapting to climate change until 2030, the creation of a national climate fund and the introduction of "green bonds" to attract investments in eco-modernization and environmental projects are describedAs well as the formation of other circular economy policies and the introduction of a system of extended producer responsibility.

The analysis of these two documents shows similar trends in the policy of implementing the circular economy in Ukraine and the European Union, which allows Ukraine to be included in further descriptive and regression analyzes on par with other European countries.

RELATED STUDY:

The next step after reviewing the principles of the circular economy in this article is to describe relevant research on the topic. Due to the fact that the direction of the circular economy is relatively new, and the databases for analysis are quite small, currently not so many studies are devoted to modeling the impact of the circular economy on the well-being or GDP of countries.

On of the articles addressing relevant issues is "Circular Economy Innovation and Environmental Sustainability Impact on Economic Growth: An Integrated Model for Sustainable Development" (Eglantina Hysa, 2020) . This article is used as an example of modeling the impact of the implementation of the circular economy on the GDP of countries.

The article examines the relationship between selected indicators of the circular economy, including the main components of environmental and economic growth. The paper describes the principles of the selection of indicators, in particular, based on a literature review and relying on the availability of data. And also evaluates the influence of these variables on the economic growth of the countries of the European Union.

The methodology used by the authors is a panel data analysis with fixed effects with aim of identifying the impact of the circular economy on the economic growth of European countries. The generalized method of moments (GMM) is also used for dynamic panel data analysis to support the results of the regression analysis. The authors generate a model that includes five independent variables:

- Environmental Tax Revenues.
- The level of recycling of municipal waste (Recycling Rate of Municipal Waste).
- Private investment, jobs and gross value added related to the circular economy (Private Investment, Jobs, Gross Value Added related to CE).
- Patents related to Recycling.
- Trade-in Recyclable Raw Materials.

and evaluates their impact on dependent - GDP per capita.

The result of the study shows that circular economy indicators have a positive effect on economic growth. (Eglantina Hysa, 2020)

This article is relevant because it also assesses the impact of the circular economy on a variable that characterizes the well-being of a country - GDP, and also applies panel data analysis.

Another noteworthy study on the topic of the circular economy is monograph "Circular economy in Ukraine – a chance for transformation in industry and services" (Antoniuk, Bochko, & Kulczycka, 2024). This study examines in detail the approaches and mechanisms of circular economy (CE) implementation in Ukraine at the state, business, and individual levels, as well as clearly outlines a number of critical issues related to it.

At the beginning the authors outline the concept of a circular economy in Ukraine as one that allows preserving natural resources due to the reuse of materials, waste processing and the integration of the principles of sustainable development at various levels. An important player is the state, which is responsible for the implementation of "green" public procurement, environmental standards, and the adaptation of legislation to the

European one. The authors rely on the above-described National Waste Management Strategy until 2030. In addition to the state, the role of business is also considered. Circular economy for enterprises involves increasing productivity through, for example, reducing the cost of raw materials (repurchase of used materials, recovery and recycling of products), as well as a general reduction of the impact on the environment. The last link in the analysis is individual consumers, for whom the circular economy consists of responsible choice, reuse of products, etc.

In addition to the general description of the concepts, the work considers a number of cases related to the implementation of the circular economy in Ukraine. The authors raise the issue of illegal landfills in the Transcarpathian region. The reason for their appearance is insufficient coverage of solid household waste collection (often formed in coastal areas, where during floods, garbage is carried downstream). The influence of military operations on the water resources of Ukraine is described separately. Attacks on infrastructure cause the destruction of hydrotechnical structures and the leakage of dangerous substances into reservoirs, which causes significant damage to ecosystems. Separately, the authors describe the investment attractiveness of the circular economy in Ukraine. Eco-industrial clusters that contribute to sustainable development, economic security and investment attraction are described. The advantages of such clusters are access to the latest technologies, knowledge and markets, as well as opportunities to increase the technological level of products and the depth of processing. Involvement of companies in global value added chains allows them to increase their competitive advantages and gain access to foreign investments.

CHAPTER 3. METHODOLOGY

This study is carried out with the aim of testing four hypotheses about the impact of the circular economy on the well-being of the population.

The first hypothesis predicts that investments in the development of the circular economy, in particular spending on research and development (R&D) in the field of environmental protection, the level of waste recycling, resource productivity, etc., have a positive effect on the country's human development index (HDI) because first this is how investments contribute to economic growth by creating new jobs and stimulating innovation. Second, it reduce the level of environmental pollution, which should reduce the negative effect on the health component. And finally it also allow to optimize the production and use of materials, which allows in the long term to continue to provide the following generations with all the necessary goods.

The next hypothesis assumes that the positive impact of investments in the circular economy on the well-being of countries is not manifested immediately, but after a certain time. This means that the effect of the investment may be delayed. The implementation of relevant changes connected with development of waste processing infrastructure or the introduction of new technologies takes time to implement and start functioning effectively. It also takes time to adapt such changes in the context of existing social patterns of behavior and consumption.

According to the third hypothesis, the policy of the cyclical economy in Ukraine is implemented at a very low level or not at all. It could be because of low funding or the absence of an appropriate centralized policy on the part of the governing agencies.

The fourth hypothesis suggests that circular economy methods, which are being implemented in Ukraine, have a similar impact on the economy and the well-being of the population, as in the countries of the European Union. Considering that basic principles

of the circular economy are similar for all countries they should have a similar impact in countries with a similar level of economic development.

To verify these hypotheses various methods of data analysis are used. First, to assess the impact of the implementation of the circular economy on the well-being of the population and test first and second hypotheses a Random Effects Panel Regression is used. Such a model is appropriate because it involves working with panel data, taking into account the specifics of each object. This analysis accounts for the influence of random effects (certain historical, cultural or economic differences) between observations, which is important because the analysis is carried out for a large number of different countries. Such differences are assigned a random character and it is considered that they do not affect the relationship between the independent variables and the dependent variable. In addition, within-group (within one country) and between-group (over the entire data set) analysis is provided, which is another advantage for an analysis of panel data.

The general equation of the model looks like

$$HDI_{it} = \beta_0 + \beta_1 * Recycling\ Rate_{it} + \beta_2 * Resource\ Productivity\ _{it} + \beta_3 * GERD_{it} + \beta_4 * Renewable\ energy_{it} + \beta_5 * Gas\ emission_{it} + \beta_6 * Government\ Effectiveness_{it} + \beta_7 * Educational\ Attainmene_{it} + v_{it} + \epsilon_{it}$$

Were

- HDI_{it}- The Human Development Index for country i in period t
- $Recycling\ Rate_{it}$ - Recycling Rate of Municipal Waste Revenues for country i in period t

- $Resource\ Productivity_{\ it}$ Resource Productivity per unit of resources used for country i in period t
- $GERD_{it}$ - Gross Domestic Expenditure on R&D for country i in period t
- $Renewable\ energy_{it}$ the percentage of use of renewable energy relative to the whole for country i in period t
- $Gas\ emission_{it}$ - greenhouse gas emissions per capita for country i in period t
- $Government\ Effectiveness_{it}$ - estimated quality of public services for country i in period t
- $Educational\ Attainmene_{it}$ - the percentage of the educated population relative to the entire population of the corresponding age group for country i in period t
- υ_{it} - individual random effects for country i in period t
- ϵ_{it} residual terms not explained by the model for country i in period t

Data preparation. The first stage of building a model is preparatory - data collection and formatting. Annual data on independent and dependent variables were collected for the countries of the European Union. A method of mean values is used to fill in some missing values in the data. The next step is to evaluate the relationship between the variables using the Pearson correlation coefficient and check for multicollinearity of the variables using the Variance Inflation Factor (VIF). The last stage of data preparation is the visualization of the distribution of values for each variable and a visual assessment of normality. In addition, log transformation is performed and the distribution of initial and Log-transformed valuesvalues is compared to select he optimal one.

Model construction. To confirm the relevance of using a model with random effects, two models are built: a model with a fixed effect and a model with a random effect. Their explanatory power and coefficients of independent variables are compared. The optimal model is selected using the Hausman test, where

- H0: there are no evidence to reject random effect model;
- H1: there are evidence to reject random effect model.

After creating the model, its correctness is checked using the Durbin-Watson test. This test check data for autocorrelation in the residuals of the regression model. To compensate for the effect of autocorrelation on statistical inferences, Newey-West standard errors are applied, which adjust the standard errors to more accurately assess the significance of the variables.

Based on the results of the mode evaluation, the hypothesis about the positive impact of the implementation of circular economy methods on the well-being of the population in the European Union countries are confirmed or denied.

The next step is to check whether investments in the development of the circular economy have a time-delayed effect on the welfare of the country. To evaluate this hypothesis, based on the initial models, three additional models were created by introducing time lags of 1, 2, and 3 years for the independent variables. The general equations of these models are:

- **A random-effects model with lag 1:**

$$HDI_{it} = \beta_0 + \beta_1 * Recycling\ Rate_{it+1} + \beta_2 * Resource\ Productivity\ _{it+1} + \beta_3 * GERD_{it+1} + \beta_4 * Renewable\ energy_{it+1} + \beta_5 * Gas\ emission_{it+1} + \beta_6 * Government\ Effectiveness_{it+1} + \beta_7 * Educational\ Attainmene_{it+1} + +\upsilon_{it+1} + \epsilon_{it+1}$$

- **A random-effects model with lag 2:**

$$HDI_{it} = \beta_0 + \beta_1 * Recycling\ Rate_{it+2} + \beta_2 * Resource\ Productivity\ _{it+2} + \beta_3 * GERD_{it+1} + \beta_4 * Renewable\ energy_{it+2} + \beta_5 * Gas\ emission_{it+2} + \beta_6 * Government\ Effectiveness_{it+2} + \beta_7 * Educational\ Attainmene_{it+2} + +\upsilon_{it+2} + \epsilon_{it+2}$$

- **A random-effects model with lag 3:**

$$HDI_{it} = \beta_0 + \beta_1 * Tax_{it+3} + \beta_2 * Recycling\ Rate_{it+3} + \beta_3 * Resource\ Productivity\ _{it+3} + \beta_4 * GERD_{it+3} + \beta_5 * Renewable\ energy_{it+3} + \beta_6 * Gas\ emission_{it+3} + +\beta_7 * Government\ Effectiveness_{it+3} + \beta_8 * Educational\ Attainmene_{it+3} + \upsilon_{it+3} + \epsilon_{it+3}$$

Based on the comparison of the impact and significance of the variables in each of the four models, the hypothesis described above will either be confirmed or denied. Additionally, each model will be checked for correctness using the same methods applied to the main model without time lags.

After that, the research examines the third and fourth hypotheses about the current state of implementation of the cyclical economy policy in Ukraine. This stage involves the analysis of legislative norms and strategies related to the implementation of the circular economy in Ukraine. Search for companies working in this industry. As well as the collection and assessment of available quantitative indicators. It is worth noting that due to the lack of a sufficient amount of data, it is currently not possible for Ukraine to conduct a regression analysis similar to the one proposed for European countries.

CHAPTER 4. DATA AND DESCRIPTIVE ANALYSIS

For this study, historical data on the well-being of the population and indicators that characterize investments in the circular economy are used. All data are collected for the period 2000-2022.

DATA DESCRIPTION:

HDI (UNDP, 2024) is used to assess the welfare of the population. According to metadata "The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living… The health dimension is assessed by life expectancy at birth, the education dimension is measured by mean of years of schooling for adults aged 25 years and more and expected years of schooling for children of school entering age. The standard of living dimension is measured by gross national income per capita. The HDI uses the logarithm of income, to reflect the diminishing importance of income with increasing GNI. The scores for the three HDI dimension indices are then aggregated into a composite index using geometric mean. Refer to Technical notes for more details." (UNDP, 2024).

To understand the level of well-being of different groups of countries, it is suggested to consider the dendrogram of the HDI for the active countries of the European Union and Ukraine for 2022 present in Figure 3.1. Also, the numerical value of the index and the cluster to which the country belongs are presented in Appendix 1.

The dendrogram consists of 4 clusters according to the HDI level.

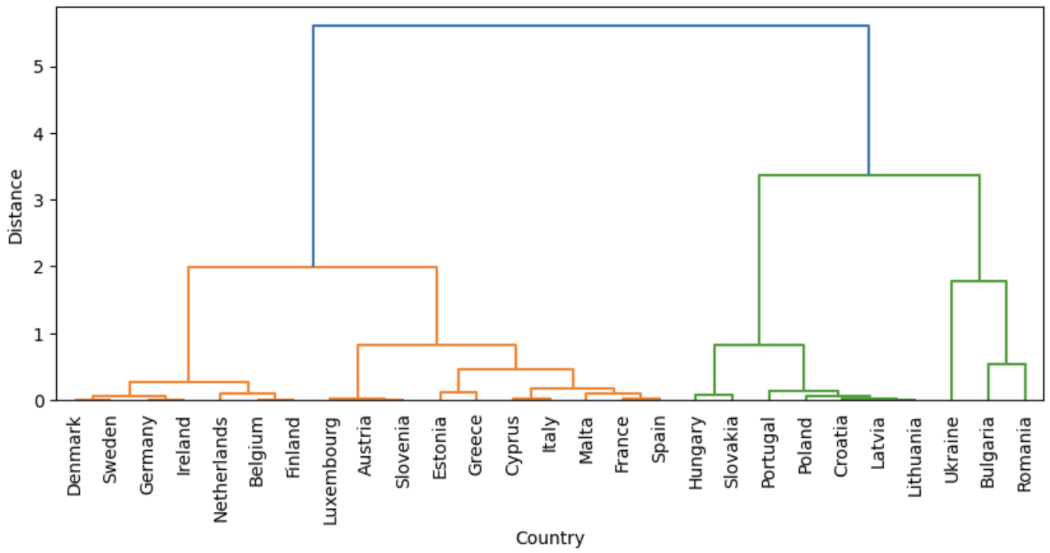

Figure 3.1 Dendrogram of European Countries and Ukraine based on HDI 2022

Such countries as Sweden, the Netherlands, Denmark, Finland, Germany, Ireland, United Kingdom, Belgium have a high HDI and form the first cluster. This class of countries is characterized by a high standard of living, developed economy, high quality of education and medical care. The economies of these countries are usually highly developed with a strong emphasis on innovation and high levels of per capita income.

Countries with an average HDI fell into the next cluster: Spain, Italy, Slovenia, Cyprus, Estonia, Austria, Malta, France. They have developed economies, but perhaps with less high levels of income compared to the countries of the first cluster. They also invest in education and healthcare, but may have some economic challenges.

A separate branch is created by the third and fourth clusters, which represent countries with HDI below the average and low levels. Croatia, Latvia, Poland, Portugal have a lower average HDI level. Their economies may be at a stage of development. The last cluster is the countries with a low HDI level, which includes Ukraine, Bulgaria and Romania.

The economies of such countries are considered potentially less developed, with problems in the sphere of health care, education and income of the population. Such countries often need international aid and support to overcome economic challenges and improve living conditions.

HDI is a dependent variable that is potentially influenced by independent variables that describe the circular economy: Recycling Rate of Municipal Waste (Eurostat, 2024), Resource Productivity (Eurostat, 2024), GERD (Eurostat, 2024), Renewable energy, Greenhouse Gas Emissions per Capita, Government Effectiveness, Tertiary educational attainment.

Recycling Rate of Municipal Waste - "The indicator is part of the Circular Economy indicator set. It is used to monitor progress towards a circular economy on the thematic area of 'waste management'. Recycling rate of municipal waste gives an indication of how waste from final consumers is used as a resource in the circular economy. Municipal waste reflects mainly waste generated by the final consumers as it includes waste from households and waste from other sources that is similar in nature and composition to household waste." (Eurostat metadata, 2024) Over the past 22 years, this indicator shows a constant growing trend from the value of 20.7% in 2000 to 48.6% in 2022 (Eurostat, 2024).

Resource Productivity - according to metadata this "indicator is part of the Circular Economy indicator set. It is used to monitor progress towards a circular economy on the thematic area of 'Production and consumption'. Improvements in material productivity – the efficiency of material use – helps to reduce environmental pressure and impacts, but has grown much more slowly than labor and energy productivity." (Eurostat metadata, 2024).

GERD (Gross Domestic Expenditure on R&D) by Sector of Performance. "The indicator measures gross domestic expenditure on R&D (GERD) as a percentage of the

gross domestic product (GDP) — also called R&D intensity." (Eurostat metadata, 2024). A comparison of GERD percentages by country (Figure 3.2) of the European Union and their HDI shows that in most cases the countries with a higher percentage of GERD are in clusters with a high level of the HDI. That is, a positive correlation between variables can be observed.

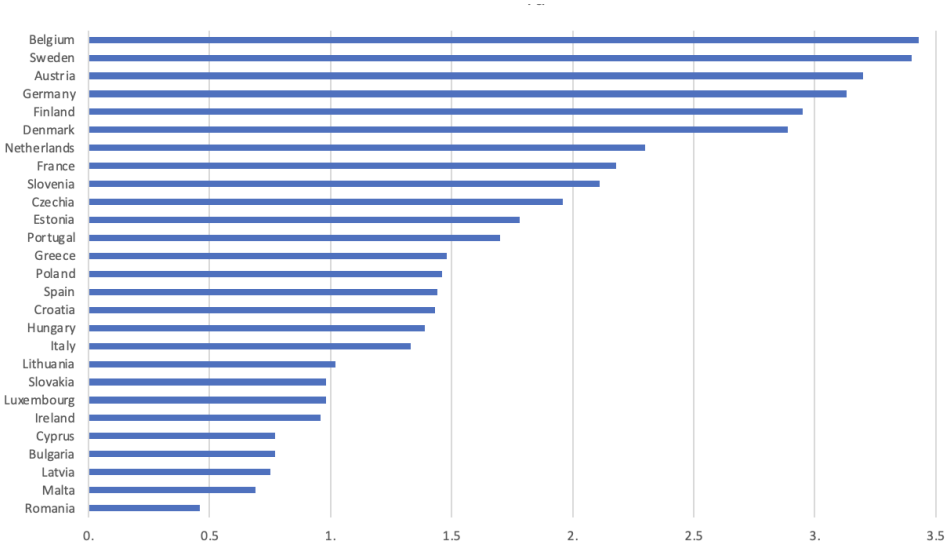

Figure 3.2 of GERD percentages by country

Renewable energy "is defined as the contribution of renewables to total primary energy supply (TPES)." (OECD, 2024). This indicator describes what share of the total energy consumed by a certain country comes from renewable energy sources. And, accordingly, it can be used to describe the efficiency and scale of distribution of alternative energy sources (the implementation of which is part of the circular economy policy).

Greenhouse Gas Emissions per Capita "are measured in tonnes per person of carbon dioxide-equivalents" (al., 2024) Based on the goals and steps of the implementation of the circular economy in the countries of the European Union, the dynamics of reducing greenhouse gas emissions is one of the important indicators showing its implementation.

Government Effectiveness – "capturing perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies" (Kaufmann, 2010). This indicator (World Bank, 2024) shows how quickly and qualitatively the government implements various policies, including those aimed at implementing a circular economy.

Tertiary educational attainment - "share of the population aged 25-34 who have successfully completed tertiary studies (e.g. university, higher technical institution, etc.)" (Eurostat, 2024). The level of education of the population affects the level of skills required for new research, as well as the general level of awareness of the population related to the circular economy.

DATA DISTRIBUTION:

To verify and better understand the data, an analysis of the distribution of variables was performed (Appendix 2).

HDI - shows an average high level of human development with a normal distribution with a noticeable peak around 0.85–0.9

Recycling Rate is asymmetrically distributed, with a shift to the right. Most values are within 20-60%.

Resource Productivity - indicators are distributed with a large shift to low values (50-150), which may mean low resource productivity.

GERD indicates 1-2% of investments between countries

GHG Emissions shows that wicks are concentrated between 10-15 units, with a slight decline after that value.

Government Effectiveness has unimodal distribution and show different level of government effectiveness across the countries in range between 0 and 2.

Tertiary educational attainment distribution is also unimodal, and ranges from 10% to 60%.

CHAPTER 5. RESULTS

The initial stage of this study was the assessment of interdependencies between variables using the construction of a correlation matrix (Figure 5.1).

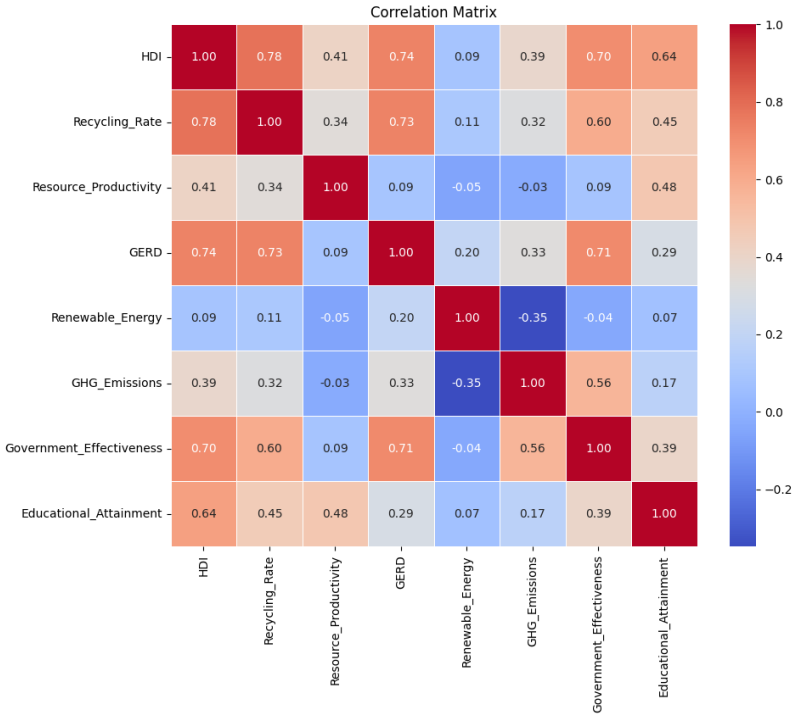

Figure 5.1 Correlation Matrix

The matrix indicates a strong positive correlation – 0. 78 between recycling rate and HDI. This may be due to the fact that waste recycling is a component of sustainable development policy plan of the government that seeks to address the quality of life of the people. There is also a presence of close correlation between GERD, or Gross Enrollment in Research and Innovation and HDI = 0. 73. GERD often results to the creation of new products and innovations, that increase personal efficiency and the quality of life. Recycling Rate and GERD are positively correlated not only with the HDI, but also with each other - 0.73 correlation. Based on this, it can be assumed that countries actively invest in innovation and research in the areas of ecology and waste minimization. The matrix also shows that countries with high government efficiency have a higher HDI

value (correlation - 0.70). Such dependence is expected, since government activities are aimed at improving the welfare of the population. The presence of a positive relationship between the HDI and the attainment of education (0.64) is due to the fact that education is one of the factors that actually determines the general well-being of the population. There is weak or almost no correlation between other pairs of variables. This may indicate that they do not have a direct effect on well-being.

RANDOM EFFECTS PANEL REGRESSION

The next step is to evaluate the model itself. First, the Hausman test was performed to assess the correctness of the choice of the model with the Random effect. The Hausman Test Statistic: 2.144 with P-value: 0.976 shows that there is no reason to reject the random effect model and it can be preferred over the fixed effect model. It could be supposed that time-invariant characteristics at the entity level do not affect dependent variable. So based on Hausman Test during the research was created Random Effects Panel Regression with Newey-West standard errors (Table 5.1, Table 5.2)

Table 5.1 Random Effects Estimation Summary

Dep. Variable:	HDI	R-squared:	0.7984
Estimator:	RandomEffects	R-squared (Between):	0.6698
No. Observations:	621	R-squared (Within):	0.8046
		R-squared (Overall):	0.7092
		Log-likelihood:	1877.5
Cov. Estimator:	Driscoll-Kraay	F-statistic:	346.83
Entities:	27	P-value:	0

Table 5.2 Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value
const	0.7427	0.0313	23.706	0

Recycling Rate	0.0004	8.75E-05	4.0346	0.0001
GERD	0.009	0.0028	3.1666	0.0016
Resource Productivity	7.64E-05	1.66E-05	4.5943	0
Renewable Energy	0.0004	0.0002	2.3928	0.017
GHG Emissions	0.0011	0.0007	1.4457	0.1488
Government Effectiveness	0.0031	0.0033	0.9218	0.357
Educational Attainment	0.0022	0.0002	10.989	0

Recycling rate (0. 0004) has positive and significance relationship with HDI. As the level of waste recycling increases by one unit the HDI also increases by 0. 0004. It helps to lessen pollution and waste in the environment and in this regard enhances the quality of life and health of the people.

GERD (0. 009) - from the above table it could be conclude that there also is the relationship between GERD and HDI in that GERD has a positive relationship with HDI. An increase in investment in research and development by 1 unit leads to improvement of the HDI by 0. 009. Technological advancements increase efficiency and create new job as well as enhance the living standards since it introduces improvements in technology and improvement in the productivity of the population.

Resource productivity (7.64E-05) has a positive and significant effect on HDI. This shows that the welfare of a country is higher if it uses its natural resources efficiently. Optimum use of available resources usually leads to measures to reduce costs, increase production and, therefore, to economic development and an increase in living standards. However, it has very small coefficient value.

Renewable Energy (0. 0004) there is positive relationship between share of renewable energy and HDI, an increase in the share of renewable energy by 1 unit increases the HDI by 0.0004. The application of renewable resources helps to minimize the level of pollution, ensures the diversification of energy supply and opens new opportunities for further growth of economy, which contributing to the HDI.

GHG Emissions (0. 0011) - due to p -value the results of the estimation show an insignificant impact of greenhouse gases emissions for HDI.

Government Effectiveness (0.0031) is one more statistically insignificant variable in the model. So improvements in government effectiveness has no visible impact on HDI. Hewever it remains an important factor of circular economy implementation.

Educational Attainment (0.0022) – has a strong positive relationship with HDI. A one-unit increase in educational attainment leads to a 0.0022 improvement in HDI.

According to the coefficient of determination (R-squared), the model explains about 80% of the variation of the dependent variable (HDI) with the help of the independent variables. This is quite a high indicator for this model. Good explanatory power is also indicated by the F-statistic. The high value of the F-statistic (346.83) and the corresponding p-value = 0.0000 indicate that the model overall is statistically significant and also rejects the null hypothesis that all coefficients of the model are equal to zero.

Durbin-Watson test value = 0.513, which indicates that the residuals of the model have autocorrelation. However, the use of Newey-West standard errors allows us to compensate for the effect of autocorrelation on statistical inferences.

Also, table of Variance Inflation Factor values indicates low to moderate multicollinearity for independent variables that should not affect model quality (Table 5.3).

Table 5.3 Variance Inflation Factor

Variable	VIF
const	28.744189
Recycling Rate	2.780319
Resource Productivity	1.510032
GERD	3.309041
Renewable Energy	1.355981

GHG Emissions	1.78544
Government Effectiveness	2.934149
Educational Attainment	1.643747

A random-effects model results and assumptions conclude that investment in research and innovation, recycling waste, utilizing fresh power sources and resource proficiency, educational attainment impact HDI of the population in countries.

After creating the model, the next step was to investigate whether investments in the development of the circular economy have a time-delayed effect on the welfare of the country. So, a comparison of four models was performed: without a lag (the model described above) and three models where a lag of 1, 2 and 3 years is applied to the independent variables (Appendix 3).

1. **The basic model without lag (No Lag) has**

- R-squared (Overall) = 0.7984, F-statistic = 346.83 (p-value = 0.0000)

This model has the highest explanatory power. Most independent variables (except GHG Emissions and Government Effectiveness) are statistically significant, and most of the coefficients have the expected signs (positive for resource productivity, recycling level, and investment in innovation).

The model with lags has a worse explanatory power and fewer significant variables:

2. **Lag in 1 year:**

- R-squared (Overall) = 0.3902, F-statistic = 55.94 (p-value = 0.0000)

Recycling Rate, Renewable Energy, and Educational Attainment are statistically significant, but the overall effect is weaker.

3. **Lag in 2 years:**

- R-squared (Overall) = 0.1911, F-statistic = 20.619 (p-value = 0.0000)

Recycling Rate is still statistically significant, but the overall effect on HDI is decreasing.

4. **Lag in 3 years:**

- R-squared (Overall) = 0.1113, F-statistic = 10.909 (p-value = 0.0000)

Recycling Rate and Educational Attainment are significant, but their impact on HDI is weaker.

Based on these data, it can be seen that the explanatory power of the model decreases every year. And the best is the basic model without lag. Most of its variables are statistically significant, and their impact on the HDI is the strongest. It can also be assumed that investments in the development of the circular economy do not have a significant delayed effect on the welfare of the country (HDI). That is, the main impact of investments is manifested directly or in the short term (during the current year).

CIRCULAR ECONOMY IMPLEMENTATION IN UKRAINE

In Ukraine, the active implementation of circular economy methods began against the background of changes in national policy regarding European standards in the field of environmental sustainability, waste management, resource efficiency, and renewable energy after the signing of the Association Agreement with the European Union in 2014. The primary stage of this process was the introduction of new or changes to existing legislation and the development of relevant strategies. The impact of such legislation and strategies is currently quite difficult to assess using regression analysis methods due to the absence necessary volume of statistical. Eurostat does not provide information on the value of circular economy indicators for Ukraine. Some of the data can be found on

local statistical sites such as Derzhstat, but mostly the data is incomplete. For example, data about waste is provided only starting from 2019 (Waste, 2021)

However, an overview of the laws and strategies themselves, as well as the activities of enterprises in this field, is offered below.

Speaking of legislation, the main one is the Law of Ukraine "On Waste" (1998, amended in 2024) (Verkhovna Rada of Ukraine, 2024) , it describes the key approaches to waste management, recycling and reuse of materials. Later, the Law "On Alternative Energy Sources" (2003) (Verkhovna Rada of Ukraine, 2003) was adopted, which introduced the concept of "green tariff" and described measures to support renewable energy sources with the aim of developing green energy. These laws should be adopted in order to stimulate enterprises and investors to introduce environmentally friendly technologies and recycling. The most recent and extensive is the National Waste Management Strategy until 2030 (Cabinet of Ministers of Ukraine, 2021). It provides for the reduction of waste in landfills and the development of infrastructure for their processing, which contributes to the circular economy.

In addition to the implementation of relevant strategies and legislation, an important point is their realization within the framework of private enterprises working in the field of renewable energy and waste processing.

DTEK is worth noting among such enterprises. Currently, DTEK Renewables is considered the largest producer of renewable energy in Ukraine (DTEK, 2024). The key direction in renewable energy is investment in solar and wind power plants. In addition to DTEK in the southern regions, the company UDP Renewables (UDPR, 2024) specializes in the construction of solar and wind stations. Eco-Optima (ecooptima, 2024) which develops projects in the field of green energy, are smaller in terms of production volume, but also significant. As for the field of processing, Ukraine presents a unique

technology of processing fallen leaves into paper. The company Re-leaf is engaged in it (Releaf, 2024).

If we still evaluate the level of implementation of the circular economy in Ukraine by the available quantitative indicators, then according to the Razumkov Centre, the capacity of renewable energy sources (RES) in Ukraine as of 2021 has reached 12.8 TWh, which provides about 8% of the total electricity production in the country (Konechenkov, 2022). The situation with waste as of 2020 is worse, only 3-6% of waste in Ukraine was recycled, while most of the waste went to landfills (Gordiychuk, 2021). The dynamics of expenditure on scientific research and innovation (GERD) is also negative, from 0.71% of GDP in 2010 to 0.41% of GDP in 2020 (State Statistics Service of Ukraine, 2021), which is significantly lower than the average in EU countries (1.8% in 2020). Despite the fact that the circular economy is still in the early stages of its implementation in Ukraine, it can be assumed that the circular economy methods implemented in Ukraine have similar patterns to European countries. The main aspect of this is that implementation takes place by adapting Ukrainian legislation to EU standards. Therefore, the main principles, such as reducing waste, switching to renewable energy, increasing resource efficiency, and introducing producer responsibility for the life cycle of products, are common to both Ukraine and EU countries. At the same time, it is worth noting that the pace of implementation of these methods in Ukraine is lagging behind due to a number of economic challenges.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

RECOMMENDATIONS FOR IMPLEMENTATION IN UKRAINE

Based on the conducted research, a number of recommendations can be made regarding the spread of the circular economy in Ukraine

In particular, it is worth continuing efforts to create a circular economy as an investment priority, as this is a key success factor. Research shows that investment in scientific research (GERD), development of processing infrastructure and use of renewable energy sources have a positive impact on the Human Development Index (HDI). Therefore, it is important to spread state programs to support investments in waste processing projects, the development of renewable energy, and the introduction of environmental innovations.

It is also worth attracting private investment through preferential conditions for enterprises operating in the circular economy, for example, through tax breaks or preferential lending for environmentally friendly projects. And also involve international donor organizations and programs to support environmental projects. For example, projects related to renewable energy can receive funding through international programs.

An important point is the improvement of the legislative framework. The current legislative framework in Ukraine is insufficient to support the full development of the circular economy. According to the analysis, the level of implementation of laws remains low, and their impact on the economy and ecology does not reach European standards. For this, it is necessary to finally harmonize the legislation with European standards. It is necessary to continue the adaptation of legislative acts in accordance with EU directives in the field of waste processing, environmental taxation and energy efficiency. A mandatory step is to improve the mechanisms of monitoring and control over the

implementation of laws. A system of incentives for enterprises can also be effective in this case.

Perhaps the most critical is improving the infrastructure for waste processing. In Ukraine, the infrastructure for waste processing is poorly developed, which slows down their effective disposal. It is necessary to expand the network of waste processing plants and create conditions for the construction of new enterprises engaged in the processing of various types of waste.

So, summing up, two directions are critical for Ukraine now - the first is legislative. Ukraine needs to finalize the harmonization of legislation in accordance with European standards, which will provide an opportunity to adopt more useful practices. And the second is more practical - focus on waste processing. The issue of infrastructure development for waste processing is currently acute for Ukraine, which is confirmed by its coverage in the previously mentioned studies. This direction is not just important, but really has the greatest potential potential for reducing the negative impact on the environment and creating new jobs.

RECOMMENDATIONS FOR IMPROVING RESEARCH

To improve the results, it is possible to expand the data sample, since one of the limitations of the study was the use of data only for the countries of the European Union and Ukraine. Data on other countries with different levels of circular economy development can be added. This will allow to obtain more variable data and provide better statistical accuracy of the results.

Also, the result of the study can be checked using alternative methods of analysis (the study used a random effect to build models). Model with generalized moments (GMM) can be used, which will allow to take into account dynamic changes over time and possible reciprocal effects between indicators.

One of the possible options for improving the study is to expand the number of indicators - the study focused on such variables as the level of recycling, the use of renewable energy sources and environmental taxes. However, it is possible to add variables describing innovation processes in industry (for example, the number of "green" patents, the level of digitalization of the economy, etc.), since innovation plays a key role in the development of a circular economy.

GENERAL CONCLUSIONS

The study analysed all the aspects of CE approach and its importance for the welfare of the European Union member countries and the feasibility of its application in Ukraine. The scores also provided evidence that circular economy is a useful instrument for sustainable development to maximize resource utilization and minimize adverse environment impact. This shows the need to increase the implementation and development of such policies. Evaluating the hypotheses put forward at the beginning of the research, the following conclusions can be drawn.

The hypothesis about the impact of investments in the development of the circular economy on the welfare of countries (HDI) is confirmed. Investments in waste recycling, resource efficiency and renewable energy use increase the Human Development Index (HDI), because they reduce the impact on people's health, improve living standards and create new jobs.

The hypothesis about a delayed in time impact was not confirmed. The analysis showed that the effects of investments in the circular economy are the highest in the short term. Models with lags of 1, 2, and 3 years indicate a lower explanatory level, which means that the effects of investment are most visible in the current year.

The analysis of hypotheses about Ukraine, the one that the policy of the circular economy in Ukraine is at best implemented to a very low degree or almost does not exist, partially confirmed this statement. The development of the circular economy in Ukraine is still in

its early stages. At the same time, the level of implementation remains very weak, for example regarding waste recycling or the introduction of alternative sources. Thus, despite the fact that the country has some legislative acts, such as the Law "On Waste" and "On Alternative Energy Sources", the real degree of compliance with such norms is still rather low. For instance only 3 to 6% of overall waste produced in Ukraine undergo recycling while much more waste is recycled in countries of the European Union. But it is worth noting that in Ukraine there are successful cases of the implementation of the circular economy among enterprises, for example, the growth of capacities of renewable energy sources.

The hypothesis about similar patterns of implementation of the circular economy policy in Ukraine and the countries of the European Union was also partially confirmed. The main aspects of the circular economy in Ukraine correspond to the European ones, but the implementation of the process is much slower due to certain economic and social factors.

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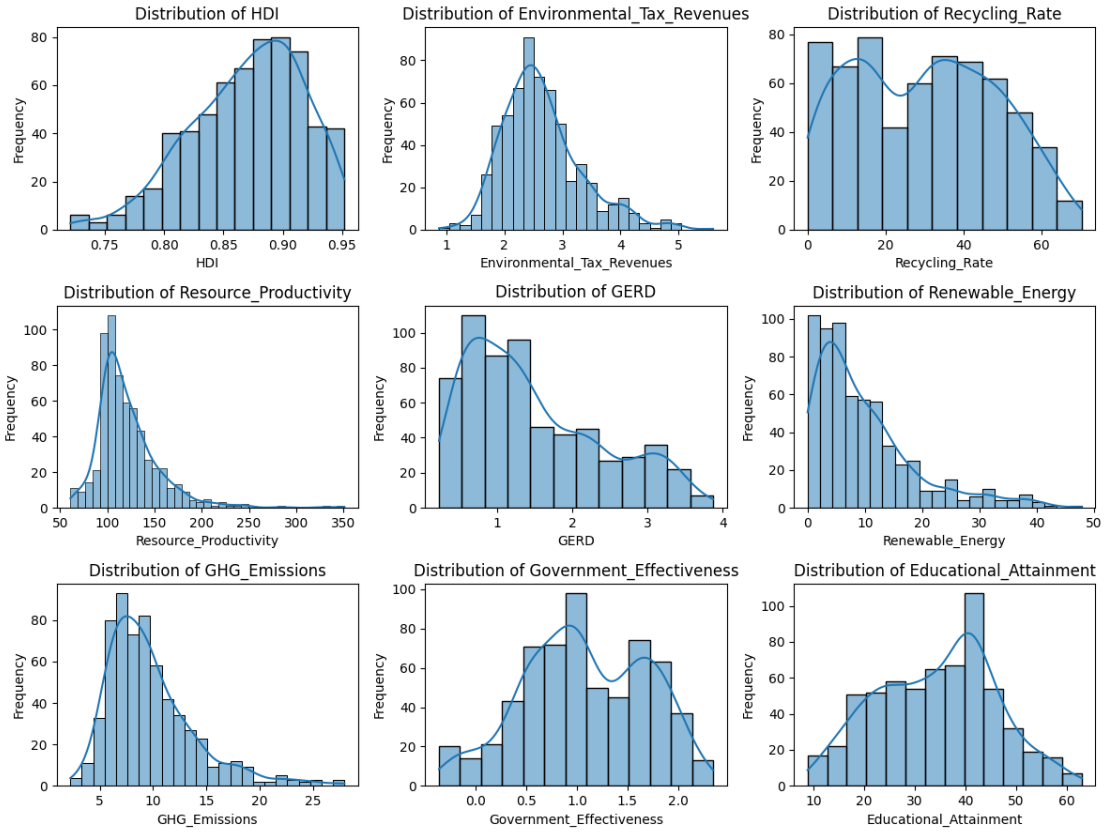
APPENDIX 1

THE HDI FOR THE ACTIVE COUNTRIES OT EU AND UKRAINE FOR 2022

Country	**HDI 2022**	**Cluster**
Belgium	0.942	1
Sweden	0.952	1
Denmark	0.952	1
Netherlands	0.946	1
Finland	0.942	1
Germany	0.95	1
Ireland	0.95	1
Spain	0.911	2
Slovenia	0.926	2
Malta	0.915	2
Luxembourg	0.927	2
Austria	0.926	2
Greece	0.893	2
France	0.91	2
Estonia	0.899	2
Cyprus	0.907	2
Italy	0.906	2
Latvia	0.879	3
Lithuania	0.879	3
Poland	0.881	3
Portugal	0.874	3
Slovakia	0.855	3
Croatia	0.878	3
Hungary	0.851	3
Ukraine	0.734	4
Romania	0.827	4
Bulgaria	0.799	4

APPENDIX 2

VARIABLE DISTRIBUTIONS



APPENDIX 3

MODEL COMPARISON

	No Lag	**Lag 1 Year**	**Lag 2 Years**	**Lag 3 Years**
Dep. Variable	HDI	HDI	HDI	HDI
Estimator	RE	RE	RE	RE
No. Observations	621	620	619	618
Cov. Estimator	Driscoll-Kraay	Driscoll-Kraay	Driscoll-Kraay	Driscoll-Kraay
R-Squared (Within)	0.8046	0.3061	0.113	-0.2005
R-Squared (Between)	0.6698	0.5554	0.4666	0.408
R-Squared (Overall)	0.7092	0.3902	0.1911	0.1113
F-statistic	346.83	55.94	20.619	10.909
P-value (F-stat)	0	0	0	0
const	0.7427	0.7869	0.8075	0.8251
	(23.706)	(36.995)	(37.572)	(37.912)
Recycling_Rate	0.0004	0.0003	6.734e-05	-7.228e-05
	(4.0346)	(1.9125)	(0.2597)	(-0.2473)
GERD	0.0090	0.0686	0.0045	0.0025
	(3.1666)	(1.6397)	(0.8453)	(0.4995)
Resource_Productivity	7.637e-05	1.784e-05	3.5e-05	5.153e-05
	(4.5943)	(0.3357)	(0.8493)	(1.2664)
Renewable_Energy	0.0004	0.0004	0.0004	0.0001
	(2.3928)	(2.8047)	(2.4240)	(0.0001)
GHG_Emissions	0.0011	0.0009	0.0008	-0.0004
	(1.4457)	(1.2502)	(1.1883)	(-0.3329)
Government_Effectiveness	0.0031	-0.0006	0.0055	0.0080
	(0.9218)	(-0.2908)	(1.2288)	(1.2138)
Educational_Attainment	0.0022	0.0015	0.0009	0.0006
	(10.989)	(4.6851)	(1.8773)	(1.0375)

T-stats reported in parentheses