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Spatial and component structure analysis of the inclusive circular economy: SGICE

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Abstract

Modern statistics and scientific research consider the circular economy rather one-sidedly, essentially as recycling and reuse of resources. The article proposes methodology (concept) of the global inclusive circular economy, which can be considered as a complex multidimensional system, the main components of which are the economic, sociological, ecological and circular aspects of the country's life. To achieve this goal, the GNU regression, econometrics and time-series library was used – an applied software package for econometric modeling, a part of the GNU project. Accordingly, we will define the global inclusive circular economy as the SGICE (Global Inclusive Circular Economy) system, characterized by the vector of functions. For the most exhaustive consideration of the entire range of opportunities of the global inclusive circular economy, the study developed and accordingly analyzed the integrated index of the development of the global inclusive circular economy (IGICE) by ecological, economic, social and circular components with isolated weakly correlated indicators. The ranking of countries was carried out separately by the components of the index, on the basis of which circular cores were distinguished: the social component (Belgium, the Czech Republic, USA, China, France, Greece, Austria, Australia), the ecological component (Japan, Denmark), the economic component (Germany, China), which became the basis for the model of formation of global inclusive circular chains. The conducted cluster analysis based on the component indicators of the index of the global inclusive circular economy confirmed the formation of a large circular gap (gap) in the ecological and circular components. This indicator is introduced for the first time and makes it possible to comprehensively analyze the country and highlight additional effects that arise from the moment of implementation

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of circular business projects and the inclusion of the country (on the basis of firms, corporations) in global circular chains of added value. After all, the main problematic aspects are the illegal trade in waste and growing smuggling, which cause serious negative social consequences and actualize the inclusive component in the justification of the global inclusive circular economy paradigm. Waste reduction combined with wise use of resources has the potential to address the gap resulting from the scarcity of natural resources and a growing global population or consumption. The formation of circular trade will contribute to: the determination of priority materials for trade and the required level of processing capacity, coordination of material quality standards, promoting demand for used goods and secondary raw materials, removing unnecessary regulatory barriers and avoiding environmentally harmful activities such as non-compliance, poor regulation and informal recovery.

Key words: Global Inclusive Circular Economy, circular gap, structural components.

JEL Classification: A20, F02, F23.

1. Introduction

The prerequisites for the formation of a circular economy as a business model are resources and their pricing, the growth of middle-class consumers, «big data», changes in legislation, globalization of management, the transition from «agreement» to «relationships». To ensure the effective functioning of this system, it is necessary to take into account the following methods of effective functioning of circular inclusive economies: inclusiveness in the informal sector, the role of women in society and the economy, the active position of citizens, authorized ecosystem players, political interventions.

The ways of implementing the circular economy are: encouraging innovation, «smart» regulation, promoting goods and services with a shorter life cycle, preventing resource shortages, defining circular policy goals for all economic entities, monitoring the use of land, materials, water, and emissions greenhouse gases. At the same time, measures to introduce industry into the circular process are defined as: fines, cleaning of the territory, coordination of activities between monitoring bodies, liquidation of illegal and unmanaged landfills, environmental monitoring based on the EU methods, alternatives to plastic, inter-sectoral agreements to reduce emissions, investments in circular solutions, cross-border cooperation regarding disposal.

2. Methodology

According to the proposed concept of the global inclusive circular economy, it can be considered as a complex multidimensional system, the main components of which are the economic, sociological, ecological and circular aspects of the country's life. To achieve the goal, the GNU Regression, Econometrics and Time-series Library was used – an applied software package for econometric modeling, part of the GNU project.

Accordingly, we will define the global inclusive circular economy as the S_{GICE} (Global Inclusive Circular Economy) system, characterized by the vector of functions:

$$\overrightarrow{S}_{GICE} = \left(y(\vec{x}_1), y(\vec{x}_2), y(\vec{x}_3), y(\vec{x}_4)\right), \qquad (1)$$

where $\vec{x}_1$– vector of indicators (indicators) describing the economic component, $\vec{x}_2$ – vector of social component indicators, $\vec{x}_3$ – vector of environmental component indicators, $\vec{x}_4$ —vector of circular component system indicators.

Let us consider a set of indicators for each component of the global inclusive circular economy.

Economic component: $\vec{x}_1 = \{x_{1i}\}, i = 1, \dots, 6$

where x_{11} – GDP, million $;

x_{12}– employment, %;

x_{13} – real GDP per capita, $;

x_{14} – GDP growth, %;

x_{15} – taxes related to the environment, % of total tax revenues;

x_{16}.– subsidies for the development of eco-technologies related to the environment, % of total assistance.

Social component: $\vec{x}_2 = \{x_{2i}\}, i = 1, \dots, 5$

where x_{21} – welfare costs from premature death from exposure to lead, equivalent to GDP;

x_{22}– population with access to improved sanitation, % of the total population;

x_{23} – population with access to purified spring drinking water, % of the total population;

x_{24} – population connected to water supply networks, % of the total population;

x_{25} – population connected to water supply networks with preventive disinfection, % of the total population.

Ecological component: $\vec{x}_3 = \{x_{3i}\}, i = 1, \dots, 10$

where x_{31} – greenhouse gas emissions, thousand tons of CO2 equivalent; x_{32}– land use, km^2;

x_{33} – renewable energy, %;

x_{34} – internal consumption of material resources, million tons;

x_{35} – state budget for R&D related to the environment;

x_{36} – ecologically adjusted multifactor productivity growth;

x_{37}– municipal waste is processed or composted, % of processed waste;

x_{38}– productivity of CO2, $/kg;

x_{39} – adjustment to reduce pollution, %;

x_{310} – development of environmental technologies, % of all technologies.

Circulation component:$\vec{x}_4 = x_{4i}, i = 1, \dots, 4$

where x_{41} – percentage of garbage recovery, %;
x_{42}– percentage of recycling garbage, %;
x_{43} – treated household waste, million tons;
x_{44} – recycling garbage, million tons.

To build an integrated indicator of the global inclusive circular economy, we will apply one of the most well-known methods of artificial intelligence - the method of principal component analysis (PCA). The main advantages of this method in our case are the possibility of taking into account a large number of performance indicators of various components of the global inclusive circular economy and bringing them to the main or main component, which will reflect the system as a whole with «maximum» reliability.

The main task of the method of principal components is to replace the original data with some aggregated values in a new space, while solving two tasks - the first of which consists in combining the most important (from the point of view of minimizing the mean square error) values into a smaller number of parameters, but the most informative (reducing the dimensionality of the data space), and the second is to reduce the noise in the data. To solve this problem, PCA looks for a space that best represents the variance of the data. The direction with the largest predicted variance is called the first principal component. The orthogonal direction that captures the second largest predicted variance is called the second principal component, and so on. Note that the direction, maximizing the variance, minimizes the root mean square error.

Finding the main components is reduced to the calculation of eigenvectors and eigenvalues of the covariance matrix of the initial data. Sometimes the method of principal components is called the Karhunen-Loev transformation or the Hotelling transformation.

So, as an indicator, we will use a generalized indicator:

$$P_{GICE} = \frac{1}{N}\sum_{i=1}^{N} \lambda_{y(\vec{x}_i)}, \tag{2}$$

where $\lambda_{y(\vec{x}_i)}$ – s the eigenvalue of the correlation matrix, which characterizes the absolute contribution (significance) of the corresponding main component for the function $y(\vec{x}_i)$to the total variance of the vector of indicators of the system $\vec{x}_i$, N – is the dimension of the vector $\vec{S}$, in our case $N = 4$.

The function $y(\vec{x}_i)$ takes the following form:

$$y(\vec{x}_i) = \sum_{j=1}^{p} w_{kj} \cdot x_{ij}, \tag{3}$$

where w_{kj} – are the elements of the eigenvector of the correlation matrix for the *κ-th* principal component, p – the dimension of the vector $\vec{x}_i$.

For ease of operation and presentation, the integral indicator can be reduced to a scale from 0 to 1. For this, we will use the following formula:

$$Indeks\ (P_{GICE}^{k}) = \frac{P_{GICE}^{k} - \min(P_{GICE})}{\max(P_{GICE}) - \min(P_{GICE})}, \quad (4)$$

where P_{GICE}^{k} – the indicator of the *k*-th country, $\max(P_{GICE})$, $\min(P_{GICE})$ – the maximum and minimum value of the indicator among the studied countries, respectively.

The set of indicators of the global inclusive circular economy for the social component will look like this:

$$\vec{x}_2 = \{x_{2i}\}, i = 1, \dots, 5$$

where x_{21} welfare costs from premature death from exposure to lead, equivalent to GDP;

x_{22} — population with access to improved sanitation, % of the total population;
x_{23} – population with access to purified spring drinking water, % of the total population;
x_{24} – population connected to water supply networks, % of the total population;
x_{25} – population connected to water supply networks with preventive disinfection, % of the total population.

To rank countries according to a set of indicators of the social component, we will use a partial case for the integrated indicator *N* =1, accordingly we will get:

$$P_S^i = \lambda_{y(\vec{x}_2^i)}$$

where $\lambda_{y(\vec{x}_2^i)}$ – the eigenvalue of the correlation matrix, which characterizes the absolute contribution (significance) of the corresponding main component for the function $y(\vec{x}_2^i)$ to the total variance of the indicators of the social component system for the *i*-th country.

The regression function $y(\vec{x}_\mathrm{i})$ takes the following general form:

$$y(\vec{x}_2) = \sum_{j=1}^{5} w_{1j} \cdot x_{2j},$$

where w_{1j} – elements of the eigenvector of the correlation matrix for the first principal component. In the course of calculations, some indicators from the set $\vec{x}_2$may turn out to be uncorrelated and not included in the general regression equation.

To rank countries according to a set of indicators of the economic component, we will use the partial case for the integral indicator *N* =1, accordingly we will get:

$$P_E^i = \lambda_{y(\vec{x}_1^i)}$$

where $\lambda_{y(\vec{x}_1^i)}$ – the eigenvalue of the correlation matrix, which characterizes the absolute contribution (significance) of the corresponding main component for the function $y(\vec{x}_1^i)$ to the total variance of the indicators of the economic component system for the *i*-th country.

The function $y(\vec{x}_{\mathrm{i}})$ takes the following form:

$$y(\vec{x}_1) = \sum_{j=1}^{6} w_{1j} \cdot x_{1j},$$

where w_{1j} – the elements of the eigenvector of the correlation matrix for the first principal component. In the course of calculations, some indicators from the set $\vec{x}_1$ may turn out to be uncorrelated and not included in the general regression equation.

3. Empirical results and discussion

According to the proposed concept of the global inclusive circular economy, it can be considered as a complex multidimensional system, the main components of which are the economic, sociological, ecological and circular aspects of the country's life. To fulfill the task, the indicators of the relevant countries and statistics of the Organization for Economic Cooperation and Development for 28 member countries of the organization from 1995 to 2020 were used: Australia, Austria, Belgium, Great Britain, Greece, Denmark, Estonia, Israel, Canada, China, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, Germany, New Zealand, South Africa, South Korea, Poland, USA, Turkey, Hungary, Ukraine, Finland, France, Czech Republic, Japan. The analysis was carried out on the basis of the GNU Regression, Econometrics and Time-series Library (Library for regressions, econometrics and time series) - an applied software package for econometric modeling, part of the GNU project.

Thus, Table 1 shows the results of the economic component of the indicator, in particular, the regression functions and uncorrelated indicators are indicated, respectively, for each country under study. Therefore, on the basis of the analysis carried out for Australia, the proper value of the correlation matrix (i.e. the characteristic number at which a solution can be obtained to describe the global inclusive circular economy), which characterizes the absolute contribution (significance) of the corresponding main component, is equal to λ_y(x ⃗_1) =3,6582 and describes the solution of the given problem for 73% of all processes, which indicates its sufficient adequacy. (see the appendix).

Table 1: Results for the economic component of the indicator

Country	Regression function	% comp.	Weakly correlated indicators
Australia	$y(\vec{x}_1) = 0{,}485 \cdot x_{11} + 0{,}475 \cdot x_{12} + 0{,}5 \cdot x_{13} - 0{,}454 \cdot x_{15} + 0{,}284 \cdot x_{16},$	73%	x_{14}
Austria	$y(\vec{x}_1) = -0{,}5 \cdot x_{11} - 0{,}364 \cdot x_{12} - 0{,}493 \cdot x_{13} - 0{,}494 \cdot x_{15} + 0{,}36 \cdot x_{16},$	76%	
Belgium	$y(\vec{x}_1) = 0{,}483 \cdot x_{11} + 0{,}473 \cdot x_{12} + 0{,}5 \cdot x_{13} + 0{,}362 \cdot x_{14} + 0{,}4 \cdot x_{15},$	76%	x_{16}
Greece	$y(\vec{x}_1) = 0{,}494 \cdot x_{11} + 0{,}483 \cdot x_{12} + 0{,}382 \cdot x_{13} + 0{,}437 \cdot x_{14} + 0{,}431 \cdot x_{15}$	73%	x_{16}

Table 1: Results for the economic component of the indicator (cont.)

Country	Regression function	% comp.	Weakly correlated indicators
Denmark	$y(\vec{x}_1) = 0{,}508 \cdot x_{11} + 0{,}504 \cdot x_{12} + 0{,}499 \cdot x_{13} + 0{,}177 \cdot x_{15} + 0{,}455 \cdot x_{16}$	76%	x_{14}
Great Britain	$y(\vec{x}_1) = 0{,}517 \cdot x_{11} + 0{,}52 \cdot x_{12} + 0{,}521 \cdot x_{13} + 0{,}437 \cdot x_{16}$	89%	x_{14}, x_{15}
Estonia	$y(\vec{x}_1) = 0{,}513 \cdot x_{11} + 0{,}467 \cdot x_{12} + 0{,}514 \cdot x_{13} + 0{,}316 \cdot x_{14} + 0{,}393 \cdot x_{16}$	72%	x_{15}
Israel	$y(\vec{x}_1) = -0{,}587 \cdot x_{11} - 0{,}52 \cdot x_{12} - 0{,}52 \cdot x_{13} - 0{,}276x_{14} + 0{,}339x_{15}$	67%	x_{16}
Canada	$y(\vec{x}_1) = -0{,}538 \cdot x_{11} - 0{,}551 \cdot x_{13} + 0{,}558 \cdot x_{15} + 0{,}307 \cdot x_{16}$	97%	x_{12}, x_{14}
China	$y(\vec{x}_1) = -0{,}452 \cdot x_{11} + 0{,}443 \cdot x_{12} - 0{,}462 \cdot x_{13} + 0{,}455 \cdot x_{14} + 0{,}423 \cdot x_{15}$	92%	x_{16}
Latvia	$y(\vec{x}_1) = 0{,}482 \cdot x_{11} + 0{,}482 \cdot x_{12} + 0{,}483 \cdot x_{13} + 0{,}16 \cdot x_{14} + 0{,}327 \cdot x_{15} + 0{,}411 \cdot x_{16},$	66%	
Lithuania	$y(\vec{x}_1) = -0{,}516 \cdot x_{11} + 0{,}514 \cdot x_{12} + 0{,}520 \cdot x_{13} - 0{,}428 \cdot x_{15} + 0{,}122 \cdot x_{16},$	72%	x_{14}
Luxembourg	$y(\vec{x}_1) = -0{,}476 \cdot x_{11} - 0{,}4 \cdot x_{12} - 0{,}477 \cdot x_{13} - 0{,}054 \cdot x_{14} + 0{,}459 \cdot x_{15} + 0{,}416 \cdot x_{16}$	72%	
Mexico	$y(\vec{x}_1) = 0{,}493 \cdot x_{11} + 0{,}461 \cdot x_{12} + 0{,}499 \cdot x_{13} + 0{,}483 \cdot x_{15} + 0{,}248 \cdot x_{16},$	77%	x_{14}
Netherlands	$y(\vec{x}_1) = 0{,}435 \cdot x_{11} + 0{,}444 \cdot x_{12} + 0{,}432 \cdot x_{13} + 0{,}467 \cdot x_{14} + 0{,}457 \cdot x_{15},$	88%	x_{16}
Germany	$y(\vec{x}_1) = -0{,}446 \cdot x_{11} - 0{,}423 \cdot x_{12} - 0{,}442 \cdot x_{13} - 0{,}299 \cdot x_{14} + 0{,}344 \cdot x_{15} + 0{,}38 \cdot x_{16},$	83%	
New Zealand	$y(\vec{x}_1) = -0{,}462 \cdot x_{11} - 0{,}499 \cdot x_{12} - 0{,}425 \cdot x_{13} - -0{,}427 \cdot x_{15} + 0{,}417 \cdot x_{16},$	75%	x_{14}
South Africa	$y(\vec{x}_1) = -0{,}556 \cdot x_{11} + 0{,}132 \cdot x_{13} + 0{,}576 \cdot x_{14} + 0{,}585 \cdot x_{15}$	67%	x_{12}, x_{16}
South Korea	$y(\vec{x}_1) = 0{,}516 \cdot x_{11} + 0{,}524 \cdot x_{12} + 0{,}521 \cdot x_{13} + 0{,}433 \cdot x_{15},$	87%	x_{14}, x_{16}
Poland	$y(\vec{x}_1) = 0{,}453 \cdot x_{11} + 0{,}455 \cdot x_{12} + 0{,}451 \cdot x_{13} + 0{,}435 \cdot x_{14} - 0{,}438 \cdot x_{15},$	79%	x_{16}
Turkey	$y(\vec{x}_1) = -0{,}536 \cdot x_{11} - 0{,}529 \cdot x_{12} - 0{,}531 \cdot x_{13} + 0{,}389 \cdot x_{15},$	85%	x_{14}, x_{16}
Hungary	$y(\vec{x}_1) = -0{,}468 \cdot x_{11} - 0{,}474 \cdot x_{12} - 0{,}466 \cdot x_{13} - 0{,}474 \cdot x_{14} + 0{,}34 \cdot x_{15}$	76%	x_{16}
Finland	$y(\vec{x}_1) = 0{,}536 \cdot x_{11} + 0{,}492 \cdot x_{13} + 0{,}478 \cdot x_1 + 0{,}379 \cdot x_{15} + 0{,}315 \cdot x_{16},$	62%	x_{12}
France	$y(\vec{x}_1) = -0{,}522 \cdot x_{11} + 0{,}112 \cdot x_{12} - 0{,}514 \cdot x_{13} - 0{,}497 \cdot x_{14} - 0{,}014 \cdot x_{15} + 0{,}451 \cdot x_{16}$	79%	
Czech Republic	$y(\vec{x}_1) = -0{,}433 \cdot x_{11} - 0{,}435 \cdot x_{12} - 0{,}436 \cdot x_{13} - 0{,}364 \cdot x_{14} + 0{,}436 \cdot x_{15} + 0{,}334 \cdot x_{16}$	80%	
Japan	$y(\vec{x}_1) = -0{,}489 \cdot x_{11} - 0{,}503 \cdot x_{12} - 0{,}476 \cdot x_{13} + 0{,}205 \cdot x_{14} + 0{,}49 \cdot x_{15}$	76%	x_{16}

Source: constructed by author.

x_{11} – GDP, million \$;

x_{12} – employment, %;

x_{13} – real GDP per capita, \$;

x_{14} – GDP growth, %;
x_{15} – taxes related to the environment, % of total tax revenues;
x_{16}.– subsidies for the development of eco-technologies related to the environ ment, % of total assistance.

Similarly, research was conducted for all proposed countries (Table 1).

Weakly correlated indicators for the economic component turned out to be the following:

- *GDP growth, %:*
  Australia, Denmark, Great Britain, Canada, Lithuania, Mexico, New Zealand, South Korea and Turkey.
- *taxes related to the environment, % of total tax revenues:*
  Great Britain, Estonia.
- *subsidies for the development of eco-technologies related to the environment, % of total assistance:*
  Belgium, Greece, Israel, China, Netherlands, South Africa, South Korea, Poland, Turkey, Hungary, Japan.
- *employment, %:*
  Canada, Finland.

The decrease in the influence of the economic component in the overall integrated indicator of the global inclusive circular economy in the following countries is caused by the growth of the following indicators.

This means that an increase in the weight of the displayed indicators affects the main component among the set of indicators of the economic component, which generally frees up space for other components in the integrated indicators of the global inclusive circular economy, for example, for circular, ecological or social (or inclusive).

Table 2: Indicators that lead to a decrease in the economic component of GICE

Countries	Indicators
Australia	taxes related to the environment, % of total tax revenues
Austria	GDP, million $; employment, %; taxes related to the environment, % of total tax revenues
Israel	GDP, million $; employment, %; GDP growth, %.
Canada	GDP, million $; real GDP per capita, $.
China	GDP, million $;

Table 2: Indicators that lead to a decrease in the economic component of GICE (cont.)

Countries	Indicators
Lithuania	GDP, million $; taxes related to the environment, % of total tax revenues
Luxembourg	GDP, million $; employment, %; real GDP per capita, $.
Germany	GDP, million $; employment, %;
New Zealand	GDP, million $; employment, %;
	taxes related to the environment, % of total tax revenues
Turkey	GDP, million $; employment, %;
Hungary	GDP, million $; employment, %; GDP growth, %;
France	real GDP per capita, $; taxes related to the environment, % of total tax revenues
Czech Republic	GDP, million $; employment, %; real GDP per capita, $.
Japan	GDP, million $; employment, %; real GDP per capita, $

Source: constructed by author.

The table shows the rating of the countries of the world for which research was conducted, according to the economic component of the global inclusive circular economy.

Table 3: Rating of the countries of the world according to the economic component of the global inclusive circular economy

Attitude	Country	Indicator, $\lambda_{y(\vec{x}_1)}$	Normalized index
1	Belgium	4.8185	**1**
2	Czech Republic	4.76	**0.9807**
3	USA	4.7321	**0.9714**
4	China	4.6212	**0.9348**
5	France	4.6083	**0.9305**
6	Greece	4.5131	**0.8991**

Table 3: Rating of the countries of the world according to the economic component of the global inclusive circular economy (cont.)

Attitude	Country	Indicator, $\lambda_{y(\vec{x}_1)}$	Normalized index
7	Austria	4.4996	**0.8946**
8	Australia	4.38	**0.8551**
9	Lithuania	3.9858	0.7248
10	South Korea	3.9389	0.7093
11	Israel	3.9173	0.7022
12	Mexico	3.8922	0.6939
13	Estonia	3.8876	0.6924
14	United Kingdom	3.8749	0.6882
15	Poland	3.8676	0.6857
16	Luxembourg	3.8424	0.6774
17	Latvia	3.7489	0.6465
18	Hungary	3.7426	0.6444
19	Netherlands	3.6259	0.6059
20	Denmark	3.5104	0.5677
21	Japan	3.4447	0.5460
22	Canada	3.319	0.5044
23	Germany	3.2441	0.4797
24	Finland	3.1894	0.4616
25	Ukraine	**3.137**	**0.4443**
26	New Zealand	3.002	0.3997
27	Turkey	2.2761	0.1598
28	South Africa	1.7926	0

Source: constructed by author.

Germany and China are the absolute leaders in the group of the economic component of the indicator, according to the analysis of these countries, GDP and employment in Germany and GDP in China determine this component (Germany is the strongest economically in Europe, and one of the leading in the world, and China – the leader in world exports and imports). The lion's share of production and, accordingly, employment is occupied by fossil fuels and, accordingly, global supply chains.

The transformation of supply chains into global multi-stage production networks has occurred in a benign environment of falling trade barriers and an implicit willingness to accept growing interdependence and associated risks. But over the last decade, we have had a number of events caused by «black swans». Although such cases should be quite rare, there have been several in the world over the past decade: China's introduction of export quotas for critical resources in 2010; earthquake and tsunami in 2011; the flood in Thailand later that year; the US-China trade war. After the 2011 episodes, some companies made adjustments and created alternative sources, particularly for semiconductors coming from Japan's Naka region. Even in the wake of the recent trade war, many companies have reverted to quota status, believing it will be nearly impossible to replace their key suppliers in China.

Relying on suppliers with unique capabilities causes serious problems, consider semiconductors as an example. Taiwan represents about 22% of the world's semiconductor integrated circuit manufacturing capacity and more than half of its foundry capacity. One company, Taiwan Semiconductor Manufacturing Company (TSMC), accounts for about 67% of Taiwan's capacity and by far the largest share of the global market for the most advanced chip manufacturing processes. Companies like Apple and Qualcomm are completely dependent on this company for their most advanced chips. Accordingly, TSMC has geographically diversified its capacity across three science parks on the island, but the company as a whole still depends on a single Dutch supplier for its advanced lithography systems. This supplier, ASML, in turn depends on a single plant in Germany for its optical engine. Developing an alternative source of supply goes beyond chip design companies. Addressing this critical dependency is actually one of the pillars of the Chinese government's Made in China 2025 initiative (underscoring the scale of the challenge).

The decentralized, informal economy makes up a significant portion of the global economy, employing an estimated 61% of all workers. In fact, including agriculture, the informal sector accounts for more than 90% of total employment in a number of African and Asian countries. Despite the low cost of labor characteristic of the informal sector, they can cope with highly efficient sorting and reverse logistics techniques at the «last mile» or the last point of the value chain, involve poor working conditions, insufficient income, and as a result problems of related to health. However, this decentralized, distributed nature of the informal economy modifies the economic structure into a very organic and flexible organism. Therefore, the driver of social justice is the requirement to improve the qualifications and organization of informal workers, ensuring that their working conditions will improve. Education is also a necessary element to facilitate some processes and tasks in the informal economy, which are a kind of tools that will help to implement and prolong the concept of circularity and inclusiveness. Education is an absolutely essential element for young entrepreneurs, designers and engineers on the technical characteristics of circularity and employment (i.e. job vacancies) among the informal sector and communities in recycling waste into new products. In this way, we are talking about filling newly created niches in the labor market, creating and providing circular workplaces of the future.

This is especially true for those entrepreneurs who solve visible environmental problems and provide jobs for as many people as possible. Such interests are important for continuous growth in the areas of social and sustainable entrepreneurship. Coupled with this, digital technologies across the informal economy can also help secure supply and redefine business models by promoting consumer confidence. Digital access and engagement can not only stimulate markets for new products, but also services that do not use assets, secondary materials and human capital.

Therefore, the cooperation of local authorities and the provision of adequate institutional representation of the informal sector in the development of local and national policies through associations, chambers of commerce and unions are key development paths to achieve this, as well as improving working conditions, which are key aspects in the formation of the social and inclusive component of the GICE indicator.

The set of global inclusive circular economy indicators for the environmental component will look like this: $\vec{x}_3 = \{x_{3i}\}, i = 1, \dots, 10$

where x_{31} – greenhouse gas emissions, thousand tons of CO2 equivalent;
x_{32}– land use, km²;
x_{33} – renewable energy, %;
x_{34} – internal consumption of material resources, million tons;
x_{35} – state budget for R&D related to the environment;
x_{36} – ecologically adjusted multifactor productivity growth;
x_{37}– household waste is processed or composted, % of processed waste;
x_{38}– productivity of CO2, \$/kg;
x_{39} – adjustment to reduce pollution, %;
x_{310} – development of environmental technologies, % of all technologies.

To rank countries according to the set of indicators of the environmental component, we will have a partial case for the integrated indicator *N* =1:

$$P_S^i = \lambda_{y(\vec{x}_3^i)} \quad (5)$$

where $\lambda_{y(\vec{x}_3^i)}$– the eigenvalue of the correlation matrix, which characterizes the absolute contribution (significance) of the corresponding main component for the function$y(\vec{x}_3^i)$ to the total variance of the indicators of the ecological component system for the *i*-th country.

The regression function $y(\vec{x}_\text{i})$ takes the following general form:

$$y(\vec{x}_3) = \sum_{j=1}^{10} w_{1j} \cdot x_{3j}, \quad (6)$$

where w_{1j} – the elements of the eigenvector of the correlation matrix for the first principal component. In the course of calculations, some indicators from the set $\vec{x}_3$ may turn out to be uncorrelated and not included in the general regression equation.

Table 4: The results of the study on the ecological component of the indicator

Country	Regression function	% comp.	Weakly correlated indicators
Australia	$y(\vec{x}_3) = -0{,}322 \cdot x_{31} - 0{,}392 \cdot x_{33} - 0{,}408 \cdot x_{34} + 0{,}42 \cdot x_{37} - -0{,}391 \cdot x_{38} + 0{,}277 \cdot x_{39} + 0{,}413 \cdot x_{310},$	78%	$x_{32}x_{35}x_{36}$
Austria	$y(\vec{x}_3) = -0{,}317 \cdot x_{34} + 0{,}411 \cdot x_{35} + 0{,}43 \cdot x_{36} + +0{,}393 \cdot x_{37} - 0{,}433 \cdot x_{38} + 0{,}433 \cdot x_{310},$	84%	$x_{31}x_{32}x_{33}$
Belgium	$y(\vec{x}_3) = -0{,}453 \cdot x_{31} + 0{,}406 \cdot x_{33} - 0{,}441 \cdot x_{35} + 0{,}378 \cdot x_{36} - -0{,}339 \cdot x_{37} + 0{,}421 \cdot x_{38},$	70%	$x_{32}x_{34}x_{39}x_{310}$
Greece	$y(\vec{x}_3) = 0{,}427 \cdot x_{31} - 0{,}386 \cdot x_{33} + 0{,}422 \cdot x_{34} - 0{,}414 \cdot x_{38} + +0{,}39 \cdot x_{39} + 0{,}409 \cdot x_{310},$	86%	$x_{32}x_{35}x_{36}x_{37}$
Denmark	$y(\vec{x}_3) = 0{,}358 \cdot x_{31} + 0{,}317 \cdot x_{32} - 0{,}36 \cdot x_{33} + 0{,}385 \cdot x_{36} - -0{,}376 \cdot x_{37} - 0{,}368 \cdot x_{38} + 0{,}334 \cdot x_{39} + 0{,}37 \cdot x_{310},$	85%	$x_{34}x_{35}$
Great Britain	$y(\vec{x}_3) = 0{,}425 \cdot x_{31} - 0{,}42 \cdot x_{33} + 0{,}353 \cdot x_{35} - 0{,}371 \cdot x_{37} - -0{,}41 \cdot x_{38} + 0{,}293 \cdot x_{39} + 0{,}356 \cdot x_{310},$	77%	$x_{32}x_{34}x_{36}$
Estonia	$y(\vec{x}_3) = -0{,}372 \cdot x_{31} + 0{,}378 \cdot x_{32} + 0{,}498 \cdot x_{33} - 0{,}438 \cdot x_{36} + +0{,}209 \cdot x_{37} + 0{,}485 \cdot x_{38},$	86%	$x_{34}x_{35}x_{39}x_{310}$
Israel	$y(\vec{x}_3) = 0{,}36 \cdot x_{31} - 0{,}447 \cdot x_{33} - 0{,}305 \cdot x_{37} - 0{,}454 \cdot x_{38} - -0{,}417 \cdot x_{39} + 0{,}444 \cdot x_{310},$	79%	$x_{32}x_{34}x_{35}x_{36}$
Canada	$y(\vec{x}_3) = 0{,}234 \cdot x_{33} - 0{,}324 \cdot x_{34} - 0{,}019 \cdot x_{35} + 0{,}425 \cdot x_{36} - -0{,}426 \cdot x_{37} - 0{,}457 \cdot x_{38} - 0{,}234 \cdot x_{39} + 0{,}463 \cdot x_{310},$	83%	$x_{31}x_{32}$
China	$y(\vec{x}_3) = -0{,}425 \cdot x_{33} - 0{,}407 \cdot x_{34} + 0{,}432 \cdot x_{35} + 0{,}393 \cdot x_{36} - -0{,}426 \cdot x_{38} + 0{,}363 \cdot x_{310},$	89%	$x_{31}x_{32}$
Latvia	$y(\vec{x}_3) = -0{,}124 \cdot x_{31} + 0{,}091 \cdot x_{34} + 0{,}404 \cdot x_{35} + 0{,}444 \cdot x_{36} + +0{,}467 \cdot x_{37} + 0{,}488 \cdot x_{38} + 0{,}401 \cdot x_{310},$	79%	x_{37}
Lithuania	$y(\vec{x}_3) = -0{,}415 \cdot x_{32} + 0{,}39 \cdot x_{33} \mp 0{,}379 \cdot x_{34} - 0{,}426 \cdot x_{35} + +0{,}421 \cdot x_{37} + 0{,}416 \cdot x_{38},$	88%	$x_{31}x_{36}x_{310}$
Luxembourg	$y(\vec{x}_3) = -0{,}385 \cdot x_{31} + 0{,}403 \cdot x_{33} + 0{,}408 \cdot x_{34} + 0{,}342 \cdot x_{36} + +0{,}361 \cdot x_{37} + 0{,}392 \cdot x_{38} + 0{,}349 \cdot x_{39},$	82%	$x_{32}x_{35}x_{310}$

Table 4: The results of the study on the ecological component of the indicator (cont.)

Country	Regression function	% comp.	Weakly correlated indicators
Mexico	$y(\vec{x}_3) = -0{,}408 \cdot x_{31} + 0{,}324 \cdot x_{32} - 0{,}411 \cdot x_{33} - 0{,}357 \cdot x_{34} + +0{,}274 \cdot x_{35} - 0{,}433 \cdot x_{38} + 0{,}409 \cdot x_{310},$	74%	$x_{36}x_{37}x_{39}$
Netherlands	$y(\vec{x}_3) = -0{,}469 \cdot x_{33} + 0{,}338 \cdot x_{35} - 0{,}173 \cdot x_{36} - 0{,}461 \cdot x_{37} - -0{,}432 \cdot x_{38} - 0{,}111 \cdot x_{39} + 0{,}475 \cdot x_{310},$	83%	$x_{31}x_{32}x_{34}$
Germany	$y(\vec{x}_3) = 0{,}337 \cdot x_{31} - 0{,}419 \cdot x_{32} - 0{,}421 \cdot x_{33} - 0{,}417 \cdot x_{37} - -0{,}364 \cdot x_{38} + 0{,}271 \cdot x_{39} + 0{,}392 \cdot x_{310},$	83%	$x_{34}x_{35}x_{36}$
New Zealand	$y(\vec{x}_3) = -0{,}431 \cdot x_{33} - 0{,}414 \cdot x_{34} + 0{,}313 \cdot x_{35} - 0{,}315 \cdot x_{36} - -0{,}418 \cdot x_{37} - 0{,}387 \cdot x_{38} + 0{,}347 \cdot x_{310},$	76%	$x_{31}x_{32}x_{39}$
South Africa	$y(\vec{x}_3) = -0{,}378 \cdot x_{31} - 0{,}522 \cdot x_{35} + 0{,}238 \cdot x_{36} - 0{,}512 \cdot x_{39} + 0{,}516 \cdot x_{310},$	72%	$x_{32}x_{33}x_{34}x_{37}x_{38}$
South Korea	$y(\vec{x}_3) = -0{,}371 \cdot x_{31} - 0{,}421 \cdot x_{33} - 0{,}426 \cdot x_{35} - 0{,}373 \cdot x_{37} - - 0{,}426 \cdot x_{38} + 0{,}428 \cdot x_{310}$	90%	$x_{32}x_{34}x_{36}x_{39}$
Poland	$y(\vec{x}_3) = -0{,}353 \cdot x_{33} + 0{,}491 \cdot x_{34} + 0{,}462 \cdot x_{35} - -0{,}208 \cdot x_{36} + 0{,}422 \cdot x_{37} + 0{,}446 \cdot x_{38},$	76%	$x_{31}x_{32}x_{39}x_{310}$
Turkey	$y(\vec{x}_3) = 0{,}442 \cdot x_{31} + 0{,}391 \cdot x_{33} + 0{,}449 \cdot x_{34} + 0{,}222 \cdot x_{36} + +0{,}355 \cdot x_{37} + 0{,}363 \cdot x_{38} + 0{,}378 \cdot x_{310},$	69%	$x_{32}x_{35}x_{39}$
Hungary	$y(\vec{x}_3) = 0{,}369 \cdot x_{31} - 0{,}348 \cdot x_{34} - 0{,}411 \cdot x_{35} + 0{,}482 \cdot x_{37} - -0{,}489 \cdot x_{38} + 0{,}319 \cdot x_{310}$	93%	$x_{32}x_{33}x_{36}x_{39}$
Finland	$y(\vec{x}_3) = 0{,}419 \cdot x_{31} - 0{,}387 \cdot x_{32} - 0{,}424 \cdot x_{33} - 0{,}38 \cdot x_{35} - -0{,}407 \cdot x_{37} + 0{,}430 \cdot x_{310},$	84%	$x_{34}x_{36}x_{38}x_{39}$
France	$y(\vec{x}_3) = 0{,}447 \cdot x_{31} - 0{,}173 \cdot x_{34} + 0{,}216 \cdot x_{35} - 0{,}451 \cdot x_{37} - -0{,}441 \cdot x_{38} + 0{,}359 \cdot x_{39} + 0{,}443 \cdot x_{310}$	83%	$x_{32}x_{33}x_{36}$
Czech Republic	$y(\vec{x}_3) = 0{,}339 \cdot x_{31} - 0{,}414 \cdot x_{33} - 0{,}405 \cdot x_{34} - 0{,}319 \cdot x_{35} + +0{,}224 \cdot x_{36} - 0{,}402 \cdot x_{37} - 0{,}397 \cdot x_{38} + 0{,}28 \cdot x_{310}$	72%	$x_{32}x_{39}$
Japan	$y(\vec{x}_3) = 0{,}342 \cdot x_{31} - 0{,}368 \cdot x_{32} - 0{,}362 \cdot x_{33} + 0{,}371 \cdot x_{34} 0{,}261 \cdot x_{35} - 0{,}374 \cdot x_{37} - 0{,}365 \cdot x_{38} + 0{,}372 \cdot x_{310}$	86%	$x_{36}x_{39}$

Source: constructed by author.

Leader countries in the economic and social component of the GICE indicator have a strong influence on the global economic arena. They produce 66% of GDP, with only 20% of the world's population, plus their material consumption per capita is 10 times that of developing countries. The material influence of such countries lies in the high share of employed services, which provide 71% of the EU's GDP and 80% of the USA's. In contrast, agriculture provides only 4% of employment in developed countries – compared to 25% in countries such as Pakistan and 18% in India. Imports and export volumes account for 68% of world trade, illustrating the extent to which countries that will initiate change in the implementation of a global inclusive circular economy are at the stage.

Per capita waste production is close to low enough to indicate effective waste avoidance and management in advanced GICE countries (according to the constituents studied) and compensates for the disproportionately large amount of incoming materials. The leading countries of GICE are faced with a difficult choice, which in some cases obliges them to make a costly «correction» of the current situation. In the energy transition, for example, such countries are faced with accumulated assets, demanding to get rid of dependence on coal or nuclear power plants. Trade restrictions imposed by developing countries have prompted some countries to change, in particular, to take control of their own waste that needs processing. China actually imports with restrictions on certain types of waste, prompting other countries to take similar measures (to impose trade restrictions on other countries and regions), accelerating the development of a national circular direction, such as the economic program in Australia and other measures at the local, regional and national levels.

In a world with limited resources, «heavyweights» - consumers are a problem both for themselves and for others. It is precisely such developed countries, which are already in the spotlight regarding their climate responsibilities and post-industrial status, that are under special pressure and under the influence of the development of Industry 4.0. in the direction of their digitization and building a smart society.

Based on the above, it is possible to distinguish the following methods of consumption in the «heavyweight» countries:

- firstly, to reduce the consumption of goods due to the extension of their service life;
- secondly, to increase the efficiency of the use of materials with the help of new technologies and circular design;
- thirdly, to reduce the total number and volume of necessary goods, through the promotion and adoption of business models of joint use (proliferation of sharing platforms).

Since such countries consume a disproportionate amount of global resources, they bear the entire burden of bringing packaging to a circular design. Such a circular design in the future will allow stockpiling towards renewable resources during construction or production, optimizing utility during the use phase (perhaps in combination with approaches reoriented to circular business models) and, for as long as possible, maintaining and preserving what is already a consequence of reuse, recycling and extension of their service life.

Table 5: Indicators that lead to a decrease in the ecological component

Countries	Indicators
1	**2**
Australia	• emissions of greenhouse gases, thousand tons of CO2 equivalent; • renewable energy, %; • internal consumption of material resources, million tons; • productivity of CO2, $/kg;
Austria	• internal consumption of material resources, million tons; • productivity of CO2, $/kg;
Belgium	• emissions of greenhouse gases, thousand tons of CO2 equivalent; • the state budget for R&D related to the environment; • municipal waste is processed or composted, % of processed waste;
Greece	• renewable energy, %; • x_38– productivity of CO2, $/kg
Denmark	• renewable energy, % • municipal waste is processed or composted, % of processed waste; • productivity of CO2, $/kg
Great Britain	• renewable energy, % • productivity of CO2, $/kg
Estonia	• emissions of greenhouse gases, thousand tons of CO2 equivalent; • environmentally adjusted multifactor productivity growth;
Israel	• renewable energy, %; • municipal waste is processed or composted, % of processed waste; • regulation to reduce pollution, %;
Canada	• internal consumption of material resources, million tons; • the state budget for R&D related to the environment; • municipal waste is processed or composted, % of processed waste; • productivity of CO2, $/kg; • regulation to reduce pollution, %;
China	• renewable energy, %; • internal consumption of material resources, million tons; • productivity of CO2, $/kg;
Latvia	• greenhouse gas emissions, thousand tons of CO2 equivalent

Table 5: Indicators that lead to a decrease in the ecological component (cont.)

Countries	Indicators
1	**2**
Luxembourg	• greenhouse gas emissions, thousand tons of CO2 equivalent
Mexico	• greenhouse gas emissions, thousand tons of CO2 equivalent • renewable energy, %; • internal consumption of material resources, million tons • productivity of CO2, $/kg
Germany	• land use, km^2 • municipal waste is processed or composted, % of processed waste • productivity of CO2, $/kg • renewable energy, %;
South Africa	• emissions of greenhouse gases, thousand tons of CO2 equivalent; • the state budget for R&D related to the environment • regulation to reduce pollution, %;
Poland	• renewable energy, %; • environmentally adjusted multifactor productivity growth
Finland	• land use, km^2; • renewable energy, %; • the state budget for R&D related to the environment; • municipal waste is processed or composted, % of processed waste
France	• internal consumption of material resources, million tons • municipal waste is processed or composted, % of processed waste • productivity of CO2, $/kg
Czech Republic	• renewable energy, %; • internal consumption of material resources, million tons; • the state budget for R&D related to the environment • municipal waste is processed or composted, % of processed waste; • productivity of CO2, $/kg
Japan	• land use, km^2; • renewable energy, %; • the state budget for R&D related to the environment • municipal waste is processed or composted, % of processed waste; • productivity of CO2, $/kg

Source: constructed by author.

The table shows the rating of the countries of the world for which research was conducted, according to the environmental component of the global inclusive circular economy.

Table 6: Rating of the countries of the world according to the ecological component of the global inclusive circular economy

Position	**Country**	**Indicator, $\lambda_{y(\vec{x}_3)}$**	**Normalized index**
1	Japan	6.9147	**1**
2	Denmark	6.7992	**0.9682**
3	Germany	5.9637	*0.7379*
4	Czech Republic	5.7241	*0.6718*
5	Luxembourg	5.7176	*0.6701*
6	Australia	5.4443	0.5947
7	United Kingdom	5.4076	0.5846
8	South Korea	5.3953	0.5812
9	China	5.3548	0.5701
10	Lithuania	5.3035	0.5559
11	Mexico	5.1803	0.5220
12	Greece	5.1587	0.5160
13	USA	5.0768	0.4934
14	Finland	5.0639	0.4899
15	Austria	5.0472	0.4853
16	Turkey	4.8309	0.4257
17	Israel	4.7633	0.4070
18	New Zealand	4.6616	0.3790
19	Netherlands	4.2680	0.2705
20	Canada	4.1352	0.2339
21	Belgium	4.1084	0.2265
22	Poland	3.9752	0.1898
23	France	3.9200	0.1746
24	Latvia	3.9133	0.1728
25	Hungary	3.8993	0.1689
26	South Africa	3.5843	0.0821
27	Estonia	3.4134	0.0350
28	Ukraine	**3.2865**	**0**

Source: constructed by author.

So, the rating of the countries of the world according to the ecological component of the global inclusive circular economy with the derived normative index shows the highest rating in Japan and Denmark. The group of countries with an indicator from 0 to 0.2 includes Ukraine and Estonia, South Africa, Hungary, Latvia, France, Poland. Unlike the social component, the ecological component is not represented by countries with high data, which would allow the indicator to be brought to a higher level.

Modern statistics and scientific research consider the circular economy rather one-sidedly, essentially as recycling and reuse of resources. The article proposed methodology (concept) of the global inclusive circular economy. It can be considered as a complex multidimensional system, the main components of which are the economic, sociological, ecological and circular aspects of the country's life. To achieve the goal, the GNU Regression, Econometrics and Time-series Library was used - an applied software package for econometric modeling, part of the GNU project. Accordingly, we will define the global inclusive circular economy as the SGICE (Global Inclusive Circular Economy) system, characterized by the vector of functions. For the most exhaustive consideration of the entire range of opportunities of the global inclusive circular economy, the work developed and accordingly analyzed the integrated index of the development of the global inclusive circular economy (Igice) by ecological, economic, social and circular components with isolated weakly correlated indicators, and the ranking of countries was carried out separately by the components of the index, on the basis of which circular cores are distinguished: social component (Belgium, Czech Republic, USA, China, France, Greece, Austria, Australia); ecological component (Japan, Denmark); economic component (Germany, China), which became the basis for the model of formation of global inclusive circular chains. The conducted cluster analysis based on the component indicators of the index of the global inclusive circular economy confirmed the formation of a large circular gap (gap) in the ecological and circular components. This indicator is introduced for the first time and makes it possible to comprehensively analyze the country and highlight additional effects that arise from the moment of implementation of circular business projects and the inclusion of the country (on the basis of firms, corporations) in global circular chains of added value. After all, the main problematic aspects are the illegal trade in waste and growing smuggling, which cause serious negative social consequences and actualize the inclusive component in the justification of the global inclusive circular economy paradigm. Waste reduction combined with resource wise use has the potential to address the gap resulting from the scarcity of natural resources and a growing global population or consumption. The formation of circular trade will contribute to: determination of priority materials for trade and the required level of processing capacity; coordination of material quality standards; promoting demand for used goods and secondary raw materials; removing unnecessary regulatory barriers and avoiding environmentally harmful activities such as non-compliance, poor regulation and informal recovery.

The next step is the ranking of countries according to the circular component. Accordingly, the set of indicators of the global inclusive circular economy for the circular component will look like this:

$$\vec{x}_4 = x_{4i}, i = 1, \dots, 4$$

where x_{41} – percentage of garbage recovery, %;
x_{42} – percentage of recycling garbage, %;
x_{43} – treated household waste, million tons;
x_{44} – recycling garbage, million, tons.

To rank countries according to a set of indicators of the circular component, we will use the partial case for the integrated indicator N =1, accordingly we will get:

$$P_{\mathrm{C}}^{i} = \lambda_{y(\vec{x}_4^i)} \quad (7)$$

where $\lambda_{y(\vec{x}_4^i)}$– eigenvalue of the correlation matrix, which characterizes the absolute contribution (significance) of the corresponding main component for the function $y(\vec{x}_4^i)$ to the total variance of the indicators of the circular component system for the ith country.

The function $y(\vec{x}_{\mathrm{i}})$ takes the following form:

$$y(\vec{x}_4) = \sum_{j=1}^{6} w_{1j} \cdot x_{4j}, \quad (8)$$

where w_{1j} – elements of the eigenvector of the correlation matrix for the first principal component. In the course of calculations, some indicators from the set $\vec{x}_4$may turn out to be uncorrelated and not included in the general regression equation.

Countries are of absolute importance in shaping the circular economy. However, we are talking about a world that is only 8.6% circular, which indicates the corrosive effects and negative trends of the tradition of accepting waste.

Table 7: Results of analysis by circular component

Country	Regression function	% comp.	Weakly corre-lated indica-tors
Australia	$y(\vec{x}_4) = -0{,}506 \cdot x_{41} + 0{,}66 \cdot x_{43} + 0{,}556 \cdot x_{44},$	76%	x_{42}
Austria	$y(\vec{x}_4) = 0{,}536 \cdot x_{41} + 0{,}463 \cdot x_{42} + 0{,}477 \cdot x_{43} + 0{,}52 \cdot x_{44}.$	86%	
Belgium	$y(\vec{x}_4) = 0{,}543 \cdot x_{41} - 0{,}691 \cdot x_{43} + 0{,}476 \cdot x_{44}$	76%	x_{42}
Greece	$y(\vec{x}_4) = 0{,}568 \cdot x_{41} + 0{,}581 \cdot x_{43} + 0{,}582 \cdot x_{44}$	96%	x_{42}
Denmark	$y(\vec{x}_4) = 0{,}499 \cdot x_{41} + 0{,}5 \cdot x_{42} + 0{,}494 \cdot x_{43} + 0{,}506 \cdot x_{44}.$	96%	
Great Britain	$y(\vec{x}_4) = 0{,}474 \cdot x_{41} + 0{,}463 \cdot x_{42} + 0{,}481 \cdot x_{43} + 0{,}575 \cdot x_{44}.$	72%	

Table 7: Results of analysis by circular component (cont.)

Country	Regression function	% comp.	Weakly corre-lated indica-tors
Estonia	$y(\vec{x}_4) = 0{,}54 \cdot x_{41} + 0{,}603 \cdot x_{43} + 0{,}589 \cdot x_{44},$	86%	x_{42}
Israel	$y(\vec{x}_4) = 0{,}553 \cdot x_{41} - 0{,}383 \cdot x_{42} + 0{,}56 \cdot x_{43} + 0{,}484 \cdot x_{44}.$	79%	
Canada	$y(\vec{x}_4) = 0{,}494 \cdot x_{41} + 0{,}5 \cdot x_{42} + 0{,}504 \cdot x_{43} + 0{,}502 \cdot x_{44}.$	98%	
China	$y(\vec{x}_4) = -0{,}531 \cdot x_{41} + 0{,}625 \cdot x_{43} + 0{,}572 \cdot x_{44}$	78%	x_{42}
Latvia	$y(\vec{x}_4) = 527 \cdot x_{41} + 0{,}661 \cdot x_{43} + 0{,}534 \cdot x_{44}$	74%	x_{42}
Lithuania	$y(\vec{x}_4) = 0{,}557 \cdot x_{41} + 0{,}561 \cdot x_{42} - 0{,}289 \cdot x_{43} + 0{,}54 \cdot x_{44}.$	78%	
Luxembourg	$y(\vec{x}_4) = 0{,}56 \cdot x_{41} - 0{,}229 \cdot x_{42} + 0{,}591 \cdot x_{43} + 0{,}533 \cdot x_{44}.$	72%	
Mexico	$y(\vec{x}_4) = 0{,}571 \cdot x_{41} + 0{,}619 \cdot x_{43} + 0{,}54 \cdot x_{44}$	74%	x_{42}
Netherlands	$y(\vec{x}_4) = 0{,}525 \cdot x_{41} + 0{,}555 \cdot x_{42} - 0{,}446 \cdot x_{43} + 0{,}466 \cdot x_{44}$	77%	
Germany	$y(\vec{x}_4) = 0{,}486 \cdot x_{41} + 0{,}504 \cdot x_{42} + 0{,}494 \cdot x_{43} + 0{,}516 \cdot x_{44}$	93%	
New Zealand	$y(\vec{x}_4) = 0{,}585 \cdot x_{41} + 0{,}561 \cdot x_{43} + 0{,}586 \cdot x_{44},$	91%	x_{42}
South Africa	$y(\vec{x}_4) = 0{,}585 \cdot x_{41} + 0{,}561 \cdot x_{43} + 0{,}586 \cdot x_{44}$	91%	x_{42}
South Korea	$y(\vec{x}_4) = 0{,}46 \cdot x_{41} + 0{,}465 \cdot x_{42} + 0{,}539 \cdot x_{43} + 0{,}531 \cdot x_{44}.$	83%	
Poland	$y(\vec{x}_4) = 0{,}575 \cdot x_{41} + 0{,}582 \cdot x_{43} + 0{,}575 \cdot x_{44}$	98%	x_{42}
Turkey	$y(\vec{x}_4) = 0{,}425 \cdot x_{41} + 0{,}523 \cdot x_{42} + 0{,}52 \cdot x_{43} + 0{,}524 \cdot x_{44}$	80%	
Hungary	$y(\vec{x}_4) = 0{,}51 \cdot x_{41} + 0{,}539 \cdot x_{42} - 0{,}416 \cdot x_{43} + 0{,}525 \cdot x_{44}$	84%	
Finland	$y(\vec{x}_4) = 0{,}461 \cdot x_{41} + 0{,}526 \cdot x_{42} + 0{,}487 \cdot x_{43} + 0{,}523 \cdot x_{44}$	87%	
France	$y(\vec{x}_4) = 0{,}576 \cdot x_{41} + 0{,}578 \cdot x_{43} + 0{,}578 \cdot x_{44}$	99%	x_{42}
Czech Republic	$y(\vec{x}_4) = 0{,}476 \cdot x_{41} + 0{,}515 \cdot x_{42} + 0{,}494 \cdot x_{43} + 0{,}515 \cdot x_{44}$	92%	
Japan	$y(\vec{x}_4) = -0{,}527 \cdot x_{41} + 0{,}443 \cdot x_{42} + 0{,}498 \cdot x_{43} + 0{,}535 \cdot x_{44}.$	82%	

Source: constructed by author.

The linear economy and its legacy are embedded deep within our society. These problems are highlighted by a widening circular gap. It is driven by entrepreneurs, businesses and communities coming together. So, sensing this acute urgency and parallel emerging opportunity, a growing number of countries and national governments are now beginning to shape their strategies to support investment in a sustainable and specific circular economy agenda. In addition to facilitating national and local action, national governments are also key agents and organizers of the global coordination or global coalition that together effectively establish new circular rules. In turn, the dynamics of this world trade is reflected correctly through national, regional and local markets. This can be seen in global supply chains that often cross continents - leaving footprints wherever they go in terms of resource and material extraction, processing, production, consumption and waste management. Until such joint governance systems exist, countries will remain tempted to regulate the quality of imports and exports by acting unilaterally, shirking their environmental and social responsibilities.

Table 8: Weakly correlated indicators of the circular component

Country	Indicator
Australia	• debris recovery percentage
Belgium	• processed household waste
Israel	• percentage of recycling waste, %
China	• debris recovery percentage
Lithuania	• processed household waste
Luxembourg	• percentage of recycling waste, %
Netherlands	• processed household waste, million, tons
Hungary	• processed household waste, million, tons
Japan	• debris recovery percentage, %

Source: constructed by author.

The table shows the rating of the countries of the world for which research was conducted according to the *circular component* of the global inclusive circular economy.

Table 9: Ranking of the countries of the world by the circular component of the global inclusive circular economy

Position	Country	Indicator, $\lambda_{y(\vec{x}_1)}$	Normalized index
1	**Canada**	**3.9411**	**1**
2	**Denmark**	**3.8456**	**0.9497**
3	**Germany**	**3.7145**	**0.8806**
4	**Czech Republic**	**3.71**	**0.8782**
5	*Finland*	3.4847	0.7595
6	*Austria*	3.4446	0.7384
7	*Hungary*	3.3892	0.7092
8	*Japan*	3.2734	0.6482

Table 9: Ranking of the countries of the world by the circular component of the global inclusive circular economy (cont.)

Position	**Country**	**Indicator, $\lambda_{y(\vec{x}_1)}$**	**Normalized index**
9	*Israel*	3.1874	0.6029
10	*Lithuania*	3.1303	0.5728
11	*Netherlands*	3.0689	0.5405
12	France	2.9826	0.4950
13	Poland	2.9334	0.4691
14	Greece	2.899	0.4510
15	United Kingdom	2.8922	0.4474
16	Belgium	2.7625	0.3791
17	New Zealand	2.743	0.3688
18	USA	2.743	0.3688
19	South Africa	2.743	0.3688
20	Luxembourg	2.6456	0.3175
21	Estonia	2.5277	0.2554
22	China	2.35	0.1617
23	South Korea	2.3458	0.1595
24	Australia	2.2956	0.1331
25	Mexico	2.2375	0.1025
26	Latvia	2.2219	0.0943
27	Turkey	2.218	0.0922
28	Ukraine	2.043	0

Source: constructed by author.

According to the ranking of the countries of the world according to the circular component of the global inclusive circular economy, the leaders are Canada, Denmark, Germany and the Czech Republic. The group of countries with a normalized index (0–0.2) consists of China, South Korea, Australia, Mexico, Latvia, Turkey and Ukraine. Based on the obtained indicators in the ratings by components, an integral index of the global inclusive circular economy was determined for the countries under study. The results of calculations are given in Table 10.

Table 10: A generalized indicator of the global inclusive circular economy

Position	Country	Ecological	Economic	Social	Circular	iGICE
1	Germany	0.7379	1.0000	0.4797	0.8806	0.7745
2	Czech Republic	0.6718	0.4718	0.9807	0.8782	0.7506
3	Denmark	0.9682	0.4815	0.5677	0.9497	0.7418
4	Japan	1.0000	0.4781	0.5460	0.6482	0.6681
5	Austria	0.4853	0.4968	0.8946	0.7384	0.6538
6	USA	0.4934	0.7230	0.9714	0.3688	0.6392
7	China	0.5701	0.8350	0.9348	0.1617	0.6254
8	Luxembourg	0.6701	0.6893	0.6774	0.3175	0.5886
9	Greece	0.5160	0.4178	0.8991	0.4510	0.5710
10	Canada	0.2339	0.5310	0.5044	1.0000	0.5673
11	Lithuania	0.5559	0.3936	0.7248	0.5728	0.5618
12	Netherlands	0.2705	0.7479	0.6059	0.5405	0.5412
13	Belgium	0.2265	0.5202	1.0000	0.3791	0.5314
14	United Kingdom	0.5846	0.3853	0.6882	0.4474	0.5264
15	Hungary	0.1689	0.4899	0.6444	0.7092	0.5031
16	Australia	0.5947	0.4185	0.8551	0.1331	0.5003
17	Israel	0.4070	0.2738	0.7022	0.6029	0.4965
18	France	0.1746	0.3735	0.9305	0.4950	0.4934
19	Finland	0.4899	0.1794	0.4616	0.7595	0.4726
20	Mexico	0.5220	0.5121	0.6939	0.1025	0.4576
21	South Korea	0.5812	0.3518	0.7093	0.1595	0.4505
22	Poland	0.1898	0.3667	0.6857	0.4691	0.4278
23	New Zealand	0.3790	0.4676	0.3997	0.3688	0.4038
24	Latvia	0.1728	0.5323	0.6465	0.0943	0.3615
25	Estonia	0.0350	0.3947	0.6924	0.2554	0.3443
26	Turkey	0.4257	0.3054	0.1598	0.0922	0.2458
27	Ukraine	0.0000	0.0836	0.4443	0.0001	0.1320
28	South Africa	0.0821	0.0001	0.0001	0.3688	0.1127

Source: constructed by author.

According to the results of calculations, the integral index was normalized according to formula (4), which is shown in Table 10. The table shows that Germany has the best indicator of global inclusive circular economy from the given list of countries $P^1_{GICE} = 4{,}612$, which took, accordingly, the first position in the rating. Among the specified countries, Ukraine occupies the last position in terms of the value of the integrated indicator $P^5_{GICE} = 2{,}013$.

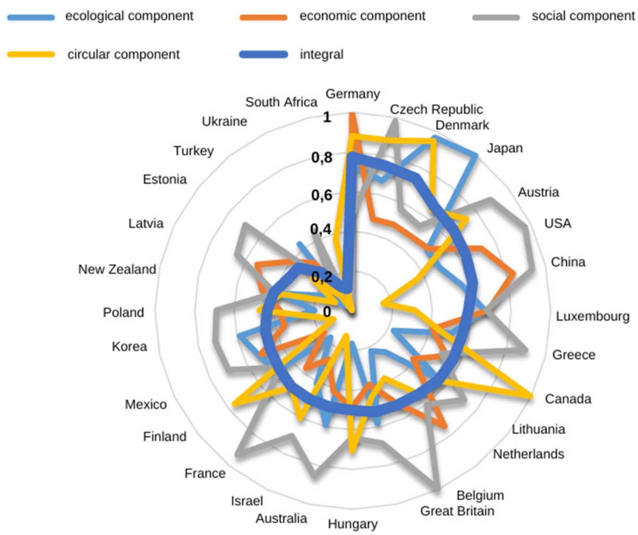

Figure 1: Integral index of the global inclusive circular economy

Source: constructed by author.

So, for the leading countries of Germany, the Czech Republic, and Denmark, in which iGICE is within 0.74-0.77, the highest values are shown by the circular component (0.94-0.88). In addition, it is important to note that Denmark has a high ecological component of the indicator (0.97). Thus, in the potential formation of global circular chains of added value, these countries will play the role of circular cores. In addition, the cluster analysis (Fig. 3.14) based on the component indicators of the global inclusive circular economy index revealed a huge circular gap (gap-circularity) between this core and other countries (1).

Thus, Figures 1 and 2 make it possible to formulate separate clusters, on the basis of which the cores of the global inclusive circular economy with isolated gaps (gap-circularity) between them are distinguished.

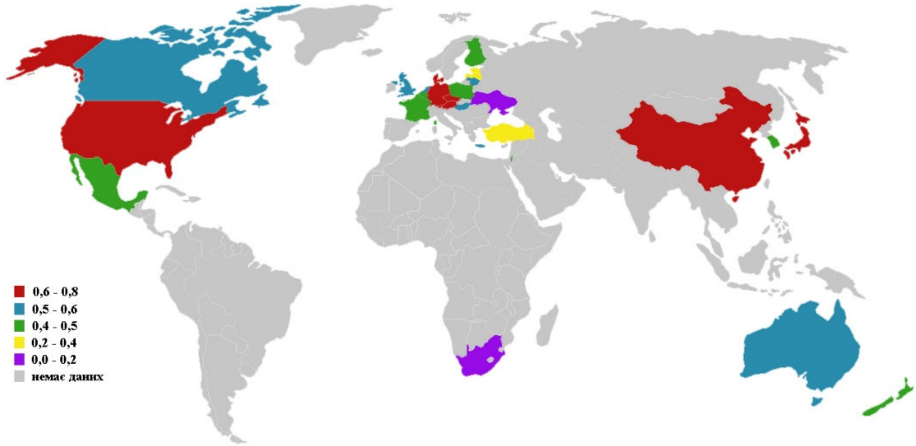

Figure 2: Mapping the integral index of the global inclusive circular economy

Source: constructed by the author.

The second group with iGICE 0.62-0.67 consists of the following countries: Japan, Austria, USA, China. This group is special in that it includes the leading countries in international trade and the international economy in general - these are the USA and China. Accordingly, for them, the most important component of the index is social and economic. In addition, based on the sectoral analysis of international trade in waste and scrap for 2016, the USA, China, Germany and Canada are the leaders in export and import, which confirms their place in the first group according to the index. The third group is the most numerous (9 out of 28 studied countries) iGICE within 0.5: Luxembourg, Greece, Canada, Lithuania, the Netherlands, Belgium, Great Britain, Hungary, Australia. The most important component is the social one, along with the average level of the circular component. In addition, the social vector is the core that unites all the studied countries. This confirms the socially inclusive vector, which is actively implemented in all countries and reflects the inseparability in the positioning of the global inclusive circular economy, where inclusiveness is at the priority level. The fourth group of countries (0.40-0.49) consists of seven countries with the highest index of the social component, with the exception of Finland, where the maximum is the circular. A low level of iGICE (0.24-0.36) is noted in Latvia, Estonia and Turkey.

4. Conclusion

The work analyzed the integral index of the development of the global inclusive circular economy indicator (Igice) according to environmental, economic, social and circular components with isolated weakly correlated indicators and ranked countries separately according to the components of the index, on the basis of which the circular cores were isolated: social component (Belgium, Czech Republic, USA, China, France, Greece, Austria, Australia); ecological component (Japan, Denmark); economic component (Germany, China), which became the basis for the model of formation of global inclusive circular chains. Leader countries in the economic and social component of the GICE indicator have strong influence on the global economic arena. They produce 66% of GDP, having only 20% of the world's population, plus their material consumption per capita the population is 10 times larger than in developing countries. Material the influence of such countries lies in the high share of employed services, providing 71% GDP of the EU and 80% of the US. In contrast, agriculture provides only 4% employment in developed countries, while in countries like Pakistan this figure is 25%, and in India - 18%. The import and export amounts are 68% of world trade, illustrating the degree to which countries are which will initiate changes in the implementation of the global inclusive circular economy.

The production of waste per capita is close enough which indicates effective waste avoidance and management in leading GICE countries (according to the studied components) and compensates for the disproportionately large amount of incoming materials. The leading countries of GICE are facing a difficult task of a choice that in some cases obliges them to make a costly "adjustment" to the current situation. In the energy transition, for example, such countries face each other with accumulated assets, demanding to get rid of dependence on coal or nuclear power plants. Trade restrictions imposed by countries that developing countries encouraged some to change, in particular, to take control of their own waste that needs processing. China actually imports with restrictions on certain types of waste, encouraging other countries to take similar measures (introduce trade restrictions by other countries and regions), accelerating development in national circular direction, such as the economic program in Australia and other events at local, regional and national levels.

In a world with limited resources, "heavyweights" - consumers are a problem for themselves and for others. It is such developed countries, which are already in the center of attention regarding their climatic responsibilities and post-industrial situation, that are under special pressure and under the influence of the development of Industry 4.0. in their direction digitization and building a smart society.

Based on the above, the following methods of consumption can be identified in "heavyweight" countries: first, to reduce the consumption of goods due to the extension of their term exploitation; secondly, to increase the efficiency of the use of materials with the help of new technologies and circular design; thirdly, to reduce the total number and volume of necessary goods, through promotion and adoption of sharing business models (proliferation of sharing platforms).

Because such countries consume disproportionately global resources, they bear the entire burden of bringing packaging to circularity design. Such a circular design will allow for stacking in the future stocks towards renewable resources during construction or production, optimizing utility during the use phase (perhaps in combination with approaches that are reoriented into circular business models) and, as long as possible, to maintain and preserve what is already a consequence of the repeated use, processing and extension of their service life. The conducted cluster analysis based on the component indicators of the index of the global inclusive circular economy confirmed the formation of a large circular gap (gap) in the ecological and circular components. Graphical visualization of the data clearly showed the circular circle that the index forms.

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