Methodological approach to the assessment of the level of intellectualization of the green economy in terms of sustainable development

Ju Orlovska, K Dryhola and A Khlivitskaya

Prydniprovska State Academy of Civil Engineering and Architecture, 24a Chernyshevsky Street, Dnipro 49600, Ukraine

E-mail: drygola.kristina@pgasa.dp.ua

Abstract. As part of the global course for sustainable development and the green economy, socio-economic processes are acquiring intellectual content. The purpose of this study is to form a methodology for assessing the level of intellectualization of the green economy. The author's index GIEI has been formed in this research on the basis of selected indicators that reflect green policy, green intellectual capital and goals of the green economy. Within the index, there are three subindices, which are assigned weight coefficients, which were calculated based on the results of expert analysis. The results showed that the green policy has the greatest weight coefficient. The obtained index can be used to assess the level of intellectualization of the green economy of world countries and to provide a basis for further research on key elements of the world's green policies to identify effective tools that can be used in the green development strategies of states.

1. Introduction

Scientific progress and the achievements of technological revolution have led to a change in the role of human in modern socio-economic processes. Historically, people have actively participated in production cycles and, above all, used their physical abilities. With the development of material and technical base of all industries and the emergence of new technologies, which was a consequence of changes in technological paradigms, people go beyond production processes.

Thus, instead of active physical participation in production cycles, which is compensated by mechanized and automated production processes and the emergence of artificial intelligence, a person begins to perform organizational and control functions. That is, over the last century, the role of human and the importance of human capital in the economic system have changed dramatically.

Given the modern course of humanity for sustainable development and green economy, this process can be considered as green intellectualization. The change in the direction of innovations and technologies from economically expansionary to ecological and environmental protective characterizes the transition to an intellectual economy, which can be considered as a type of economic system based on knowledge of the laws of material nature and society, which should be aimed at human development and ensure the economic and social well-being of mankind while minimizing the destruction of planetary ecosystems due to man-made transformations and in the long run improving the level and quality of life.
Thus, the intellectual economy is the foundation of green growth, which highlights the role of information, knowledge and skills of people as the main economic resource, and information and intellectual products as the main end product, which should operate in the direction of achieving global sustainable development goals. The intellectualization of production processes at all stages of the product cycle is the main content of green growth. In these conditions, it is necessary to explore the essence and estimate the green intellectual capital, which is the driver of modern intellectualization of green economy.

2. Literature review

The intellectual aspect of industrial and economic relations began to be considered by scientists in the late nineteenth century. Thus, A. Marshall in his work "Principles of Economics" [1] in 1890 noted that knowledge is the main catalyst for production processes and is the foundation of production. Later, these ideas were reflected in the scientific works of J. Schumpeter [2], who emphasized the importance of a specific combination of knowledge for the development of innovation in production processes. That is, scientists began to understand the transformation from industrial to postindustrial type of development, characterized by increasing the role of human intellectual abilities, special knowledge, skills, competencies that form the basis of both tangible and intangible sectors of the economy.

Modern intellectualization of scientific economic theories was characterized by the emergence of a new direction of scientific research, namely the theory of knowledge economy, the foundations of which were laid in the works of Drucker P [3], Makhlup F [4], and were developed in the works of Chartland H [5], Brinkley J [6], Tapscott D [7], White D, Gunasekaran A, Ariguzo J [8], Shazrazad H [9]. The main emphasis of these theories was that knowledge and information were considered not only a necessary and important resource in production processes, but also acted as the end product of this type of economic system in the form of innovation, information and intellectual products. That is, knowledge becomes both a resource and the end product of the system.

Given the current course for sustainable development and green economy, this process of intellectualization acquires a "green" specificity. Thus, the intellectual economy can be considered as the foundation of green growth, which puts the role of information, knowledge and skills of people in the main economic resource, and information and intellectual products in the main end product. In these conditions, it is necessary to explore the essence of intellectual capital, which is the engine of modern economic processes, and in terms of the course of the green economy is transformed into green intellectual capital (GIC).

GIC is considered as a major factor of green growth, which is stated in the studies of Yusliza M [10], Zaid A [11], Yusoff Y [12], Yong J [13], Yadiati W [14], Wang J [15], Kalenyuk I [16], Shah S [17], Astuti P [18]. Its main components are green human capital (GHC, knowledge, specific skills, creativity, experience), green organizational capital (GOC, management systems, organizational solutions, corporate culture, green products, patents, licenses, trademarks) and green relational capital (GRC, relations in society, norms of culture, law, socio-economic relations, business communications).

But still there is no single vision for the method of assessing the level of intellectualization of the green economy and the degree of development of green intellectual capital [20,21,22]. That is why the purpose of this study is to form a methodology for assessing the level of intellectualization of the green economy.

3. Methodology

The research method is expert analysis for choosing indicators for assessment of the level of intellectualization of the green economy as well as the interpretation of given results. Indicators should be standardized to the single measurement system and transformed under the author's methodology to the form of Green Intellectual Economy Index (GIEI).
The formation of the index is based on the peculiarities of intellectualization of the green economy, which should take into account modern transformations characterized by informatization, digitalization, robotics, greening of production processes, creation of global green value chains, development of highly skilled services, achievements of "Industry 4.0" and "Industry 5.0" and intellectual component of both production cycles and social connections. The relationship of these scientific concepts can be represented in the form of a scheme of intellectual content of green growth, which is the basis for the development of green economy (Fig. 1).

![Figure 1. Scheme of intellectual content of green growth.](image)

The basis of green growth should be green education, which contributes to the acquisition of specific knowledge, skills, competencies on the laws of development of material nature and society and the rules of their harmonious combination on the path to growth, resulting in the formation of green intellectual capital, the consequence of the use of which in socio-economic processes is economic growth and social welfare with a simultaneous reduction of environmental degradation and depletion of resource potential. Hence, the effect of decoupling is formed between economic growth and environmental impact. It is this diversity of influence that is the basis of green growth, which in the long run makes it possible to achieve the global goals of sustainable development.

It should be noted that the basis of green growth is the development of green sectors of the economy, which in the context of globalization is manifested in the formation of global green value chains, which are based on green innovations in Industry 4.0 and Industry 5.0. These conditions create the foundation for green jobs based on social inclusion and gender equality, which in the long run leads to increased socio-economic well-being and higher living standards.

Based on the above the GIEI should cover indicators of green policy, which is the basis of the course for a green economy; indicators of the development of the green economic sector, namely in the context of intellectualization and the components of green intellectual capital as well as indicators of the goals of the green economy.
Thus, it is suggested to evaluate three groups of indicators – green policy, green intellectual capital and the goals of the green economy. Selected indicators and indices for each group are given in Table 1.

### Table 1. Selected indicators for the Green Intellectual Economy Index.

| Indicator                          | Unit                                 |
|-----------------------------------|--------------------------------------|
| Green policy                      | Development of environment-related technologies % all technologies |
|                                   | Development of environment-related technologies inventions per capita |
|                                   | Petrol end-user price USD per litre |
|                                   | Electricity support % total fossil fuel support |
|                                   | Terrestrial protected area % land area |
|                                   | The ease of doing business index (DB) index |
| Green Intellectual Capital GHC    | Human Development Index (HDI) index |
| GOC Network Readiness Index (NRI) | index                                |
| GRC Information and Communication Technologies Index (ICT) | index |
| Green Economy Goals Sustainable Development Goals Index (SDGI) | index |

All selected indicators should be standardized and transformed to a single measurement system, in the range from 0 to 1, which is suggested to be carried out using the maximum and minimum values according to the following formula:

$$I_{ij} = \frac{x_{ij} - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}}$$  \hspace{0.5cm} (1)

where $I_{ij}$ – standardized i-th indicator of the j-th country;
$x_{ij}$ – the actual value of the i-th indicator of the j-th country;
$x_{\text{min}}$ – the minimum value of the indicator;
$x_{\text{max}}$ – the maximum value of the indicator.

All standardized indicators should be transformed to subindices: $I_{gpc}$ – subindex of green policy, $I_{gic}$ – subindex of green intellectual capital, $I_{gic}c$ – subindex of green economy goals. The first two subindices consist of several indicators and indices, and therefore should be transformed to one indicator by the arithmetic mean. The green economy goals subindex is suggested to be equated to the Sustainable Development Goals Index (SDGI), as SDGI are the ultimate goals of the green economy, which can be achieved under conditions of green growth. These three subindices should be combined
into a single formula of the Green Intellectual Economy Index using the weights coefficients obtained during the expert analysis which was carried out according to the method, that has already been successfully used by the authors in the formation of the index for the assessment of the bioeconomy [19].

For evaluation 10 groups of experts were formed on the basis of Prydniprovska State Academy of Civil Engineering and Architecture. Each group consisted of 10 scientists in different branches of science. The analysis was conducted by the method of questionnaires, in which scientists evaluated each indicator on a 5-point scale for weight in assessing the degree of intellectualization of the green economy. On the basis of the results weight coefficients for every subindex were calculated using the Fishburn formula:

\[ a_i = 2 \cdot \frac{n - r_i + 1}{n(n+1)} \]  

where \( a_i \) – weight coefficient for the i-th subindex
n – number of evaluation criteria;
\( r_i \) – expert points.

The obtained weight coefficients formed the basis of the author's approach to the methodology of the GIEI.

4. Results and discussions
The obtained results of the expert analysis allowed to calculate the weights for the indicators of the evaluation of the level of intellectualization of the green economy. The results are presented in Table 2.

| Total points | Deviation | Deviation square | Range | Weight coefficients |
|--------------|-----------|-----------------|-------|---------------------|
| Development of environment-related technologies (%) | 47 | 7.1 | 50.41 | 3 | 0.145 |
| Development of environment-related technologies (per capita) | 46 | 6.1 | 37.21 | 4 | 0.127 |
| Petrol end-user price | 29 | -10.9 | 118.81 | 9 | 0.036 |
| Electricity support | 35 | -4.9 | 24.01 | 8 | 0.055 |
| Terrestrial protected area | 28 | -11.9 | 141.61 | 10 | 0.018 |
| DB | 40 | 0.1 | 0.01 | 5 | 0.109 |
| HDI | 50 | 10.1 | 102.01 | 1 | 0.182 |
| NRI | 36 | -3.9 | 15.21 | 7 | 0.073 |
| ICT | 39 | -0.9 | 0.81 | 6 | 0.091 |
| SDGI | 48 | 8.1 | 65.61 | 2 | 0.164 |

Since indicators must be grouped into three subindices, their weight coefficients must also be grouped to three weights. To do this, the coefficients for the indicators within one subindex were summed. According to the obtained results, the weights were distributed as follows – \( I_{gp} \) = 0.491, \( I_{gic} \) = 0.345, \( I_{gex} \) = 0.164.

The three subindices should be combined into a single formula of the Green Intellectual Economy Index using the weights obtained during the expert analysis, according to the following formula:

\[
GIEI = 0.491 \cdot I_{gp} + 0.345 \cdot I_{gic} + 0.164 \cdot I_{gex}
\]  

(3)
where GIEI – Green Intellectual Economy Index; 
$I_{gp}$ – green policy subindex; 
$I_{gic}$ – green intellectual capital subindex; 
$I_{geg}$ – green economy goals subindex.

The obtained formula can be used to assess the level of intellectualization of the green economy of countries and form a basis for further research in this area.

5. Conclusion
At the present stage of human development, the green economy acquires an intellectual context, which is characterized by an increasing role of intellectual capital. When assessing the level of intellectualization of the green economy, it is necessary to take into account the green policy, which is the basis of green growth, the degree of development of the components of green intellectual capital and the goals of the green economy. The author's method of assessment using the Green Intellectual Economy Index provides an opportunity to evaluate each component, taking into account its role in the process of intellectualization. According to the results, the greatest role is played by the green policy of the state, which is the basis for green growth and creates a favorable environment for the development of green intellectual capital. That is why an important task of future research is to analyze the key elements of green policy in different countries in order to identify effective tools that can be used in green development strategies.

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