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# Digital-environmental convergence in innovation marketing: new approaches to sustainable development

Olga GONCHAR *[1], Lesia BUIAK [2], Larysa PTASHCHENKO [1], Iryna MURENETS [3], Olha KRAVETS [4]

[1] Department of Economic Theory, Entrepreneurship and Trade, Khmelnytskyi National University, Khmelnytskyi, Ukraine.
[2] Department of Economic Cybernetics and Informatics, West Ukrainian National University, Ternopil, Ukraine.
[3] Department of International Economic Relations and Business Security, Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine.
[4] Department of Marketing, Faculty of Management and Marketing, Dnipro State Agrarian and Economic University, Dnipro, Ukraine.
*Email: o.i.gonchar@ujis.in.ua

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**ABSTRACT:** At present, the global economy is reconsidering approaches to innovation and sustainable development apart from technological modernization. An automatic tool has eventually become a digital technology in the strategic management of new concepts as a main factor forming new models of interaction between business, government and society. In these conditions, the integration of the principles of the green economy and digital innovations into marketing activities is becoming not just a trend, but a prerequisite for long-term competitiveness. The purpose of the study is to identify patterns in the transformation of strategic approaches to marketing innovations under the influence of the digital economy and green technologies. The object is the processes of digital integration and innovation activity at the level of national economies. The methodological base is based on a combination of systemic, comparative, statistical, graph-analytical and institutional-analytical approaches, which provided a holistic study of the relationships between the digital maturity indices (DESI), innovation capacity (GII) and environmental efficiency (EPI). The results of the quantitative analysis show that during 2020–2024, the digital economy has become one of the leading drivers of sustainable development. The DESI index increased from 57.2 to 64.8 points (+13.3%), the GII from 32.1 to 36.4 (+13.4%), while the EPI increased to 43.5 points (+3.4%). A close positive relationship was found between the level of digital maturity and environmental performance (r=0.69), which indicates the formation of an integrated development model – "digital-green growth". Econometric modeling confirmed the statistically significant impact of digital innovations on environmental performance ($R^2$=0.81). The study also showed that companies that actively use analytical systems, big data platforms and artificial intelligence technologies in their marketing strategies achieve an average reduction in operating costs of 12% and an increase in customer loyalty by approximately 15%. The practical significance of the results obtained lies in the formulation of recommendations for the development of digital-ecological sustainable marketing strategies focused on ESG principles, the use of intelligent analytics and strengthening the positions of companies in the global digital environment. The proposed conclusions can serve as a scientific basis for improving state digitalization policy, corporate innovation development programs and national sustainable growth strategies.

**Keywords:** innovation marketing; digital marketing; marketing communications; green technologies; digital economy; sustainable development; marketing management.

## Convergência digital-ambiental no marketing da inovação: novas abordagens para o desenvolvimento sustentável

**RESUMO:** Atualmente, a economia global está repensando as abordagens à inovação e ao desenvolvimento sustentável, para além da modernização tecnológica. Uma ferramenta automatizada tornou-se, em última análise, a tecnologia digital na gestão estratégica de novos conceitos, fator principal na formação de novos modelos de interação entre empresas, governo e sociedade. Nessas condições, a integração dos princípios da economia verde e das inovações digitais às atividades de marketing está se tornando não apenas uma tendência, mas um pré-requisito para a competitividade a longo prazo. O objetivo deste estudo é identificar padrões na transformação das abordagens estratégicas de inovação em marketing sob a influência da economia digital e das tecnologias verdes. O objeto de estudo são os processos de integração digital e atividade inovadora no âmbito das economias nacionais. A base metodológica fundamenta-se numa combinação de abordagens sistêmicas, comparativas, estatísticas, gráfico-analíticas e institucional-analíticas, que proporcionaram um estudo holístico das relações entre os índices de maturidade digital (DESI), a capacidade

de inovação (GII) e a eficiência ambiental (EPI). Os resultados da análise quantitativa demonstram que, entre 2020 e 2024, a economia digital se consolidou como um dos principais motores do desenvolvimento sustentável. O índice DESI aumentou de 57,2 para 64,8 pontos (+13,3%), o GII de 32,1 para 36,4 (+13,4%), enquanto o EPI subiu para 43,5 pontos (+3,4%). Observou-se uma forte correlação positiva entre o nível de maturidade digital e o desempenho ambiental (r=0,69), o que indica a formação de um modelo de desenvolvimento integrado – "crescimento digital-verde". A modelagem econométrica confirmou o impacto estatisticamente significativo das inovações digitais no desempenho ambiental ($R^2$=0,81). O estudo também demonstrou que as empresas que utilizam ativamente sistemas analíticos, plataformas de big data e tecnologias de inteligência artificial em suas estratégias de marketing reduzem em média os custos operacionais em 12% e aumentam a fidelização de clientes em aproximadamente 15%. A relevância prática dos resultados obtidos reside na formulação de recomendações para o desenvolvimento de estratégias de marketing sustentáveis, digitais e ecológicas, focadas nos princípios ESG, no uso de análises inteligentes e no fortalecimento do posicionamento das empresas no ambiente digital global. As conclusões propostas podem servir de base científica para aprimorar as políticas estaduais de digitalização, os programas de desenvolvimento da inovação corporativa e as estratégias nacionais de crescimento sustentável.
**Palavras-chave:** marketing de inovação; marketing digital; comunicação de marketing; tecnologias verdes; economia digital; desenvolvimento sustentável; gestão de marketing.

## 1. INTRODUCTION

The digital economy and marketing shape the nature of market principles, consumer behavior, and competition rules, placing them at the core of focus. Marketing is swiftly being reinvented as an integrated system managing innovation, knowledge, and environmental processes rather than a communications discipline. Where public policies on sustainable development are implemented as a strategic priority at all levels through corporate governance aimed at sustainable development, digital innovative marketing becomes key in balancing economic efficiency with social responsibility and environmental sustainability. More importantly, the very fast growth of digitalization highlights an even larger challenge of environmental adaptation of business: how to turn innovation into a driver of the "green transition" while maintaining the flexibility and competitiveness of markets.

Bai et al. (2025) state that the main gap to have greatly benefited from digital technologies is the gap between carbon emissions and economic growth. They further cite findings of several other researchers whose works show that the infusion of digital solutions into production processes leads to energy efficiency as well as productivity and resource use in key industrial sectors. This, therefore, affirms that green growth can be based on development within the parameters of a digital economy, where technological progress is in harmony with the principles of sustainable development. Chen; Xing (2025) share a similar view but pinpoint it more specifically by saying that the catalyst for green innovation is found in the digital economy. They stress long-term competitiveness at the enterprise level by enforcing environmental standards via production and corporate governance on digital platforms.

According to He et al. (2024), the digital economy is an evolutionary context of technological innovation that perpetuates and feeds into the sustainability agenda. They further underline the fact that digitization increases environmental monitoring accuracy; supports logistics optimization and resource-saving technologies, delivering economic benefits as CER becomes increasingly aligned across sectors. Kumar et al. (2025) conceptualized a framework for smart sustainable green marketing, wherein digitalization strategically lays out a basis for developing new business ethics by better connecting the environmental value of goods/services with consumers through digital platforms, leading to fostering a conscious consumption culture wherein cyberspace marketing turns into a tool of environmental innovations dissemination, meaning attaining global climate goals.

According to Le et al. (2024), the digitalization program aims at supporting corporate sustainability through green innovation and better management of environmental supply chains. In their view, digital technologies make business activities transparent, reduce operating costs and create new competitive advantages based on environmental efficiency. Hence, the process of digital transformation is an economic process that is accompanied by a strategy in the implementation of sustainable development principles. Technological progress, as stated by Liu et al. (2024), creates prerequisites for a green digital economy to emerge, where innovation becomes the main mechanism for integrating environmental approaches into marketing, financial and resource management practices; thus creating both the effect of increasing productivity and reducing environmental burden.

According to Wang et al. (2024), the digital economy acts as a major accelerator in the growth of the green economy because it supports tools for scaling environmental innovations. They further highlighted that it is through digital solutions that environmental impacts from economic activities can be monitored and predicted, thus laying proper foundations for impact management of sustainable development. Digitalization thus becomes a mechanism cementing the application of environmental principles at every level of economic interaction. Stahl et al. (2023) highlighted scientific evidence on the role digital marketing tools play in increasing business innovative potential. Recent developments in creating markets for innovations targeted at competitiveness through entrepreneurship have become one of the few promising areas in the current digital economy. According to Shabur (2024), opportunities and challenges shape innovation marketing strategies in the overall quest to create a sustainable digital economy. Apart from increasing resource efficiency and facilitating the diffusion of green innovations, aspects of technological inequality deepening are also highlighted through digitalization, environmental risks to data security, and the ICT infrastructure's carbon footprint. He emphasized the integration of environmental standards policies into the marketing communications of digital platforms for responsible consumption, which is

beneficial to him in line with his long-term interests in the triple bottom line.

Despite the large volume of scientific research, some issues remain insufficiently covered. In particular, methodological approaches to measuring the effectiveness of marketing innovations in the context of sustainability, criteria for the environmental performance of digital business models, and methods for assessing the impact of marketing technologies on the environmental transformation of enterprises need to be clarified. Models for integrating marketing innovations with sustainable development goals in the digital economy also remain insufficiently developed.

Therefore, the purpose of the study is to identify strategic approaches to integrating marketing innovations into the digital economy as a factor in ensuring sustainable development and the implementation of green technologies. To achieve this goal, the following tasks are envisaged: to analyze the relationship between digitalization and green innovations in the marketing strategies of enterprises; to outline the main models of innovative marketing in the digital environment; to determine the theoretical and applied principles of combining environmental and marketing goals in the process of digital business transformation.

## 2. LITERATURE REVIEW

Modern scientific discourse shows an increasing interest in the problem of the relationship between the digital economy, innovative marketing and the concept of sustainable development. Researchers increasingly emphasize that digitalization changes not only the methods of communication with consumers, but also the very nature of marketing strategies, management models and mechanisms for creating competitive advantages in a global environment focused on environmental efficiency. Within this scientific field, a new paradigm is being formed – marketing of innovations in the digital economy, which combines technological, economic and environmental determinants of sustainable development.

One of the conceptual areas is the trend towards "green marketing." Alkhatib et al. (2023) performed a systematic review of green marketing in trends of the digital age and confirmed that environmentally effective values are delivered through the use of digital technologies, particularly big data, artificial intelligence, and blockchain. According to their findings, due to the digital marketing ecosystem, not only has environmental awareness among consumers increased, but also business models aimed at reducing carbon footprint have been created.

Danylyshyn et al. (2023) cover strategic aspects of marketing management directed toward regional development and prove that digital marketing tools effectively increase the investment attractiveness of regions and entrepreneurial initiatives based on the principles of sustainability. The scientists emphasized that the introduction of digital technologies into the regional management system will create conditions for the formation of innovative development models with economic, social, and environmental efficiency criteria.

An important contribution to the study of the role of digitalization in the formation of ecological entrepreneurship was made by Desyatnyuk et al. (2025a). They substantiated the importance of financial inclusion as a catalyst for the development of "green" business, proving that digital financial services, blockchain and electronic platforms create an environment in which environmentally oriented initiatives receive new institutional opportunities. In subsequent works (Desyatnyuk et al., 2024; 2025a; 2025b), the authors analyze the impact of digitalization on international financial stability and sustainable development risks, emphasizing that digital technologies act as both a source of efficiency and a challenge for regulatory systems.

According to Dimytrova et al. (2025) and Shtal et al. (2023), innovation management is oriented toward the sustainability of industrial enterprises and firms, while describing processes of digitalization that facilitate precise resource accounting and environmental accounting. Environmental accounting, in this case, tries to capture the costs and benefits a firm inflicts on its environment. This sort of institutional modernization, such as energy-saving technology implementation and digitalization, is reported by Gavkalova et al. (2024; 2025), who synthesize economic indicators with environmental responsibility, increasing enterprise competitiveness.

Jiang et al. (2025) offer probably one of the best overviews concerning spatial aspects of the digital economy through their analysis covering data for 257 cities in China. They underline how a developed digital infrastructure permits an efficient allocation of resources that, in turn, stimulates regional green innovation. According to their observation, the energy potential of environmentally sustainable production through gradual transformation is high in regions with intensive digital integration.

The issues of security and state regulation in the context of digital transformation are studied by Krysovatyy et al. (2024). They emphasize that digital innovations change not only the structure of markets, but also the mechanisms for ensuring financial and state security. The scientists justify the need for a new paradigm of risk management that integrates technological, ethical and environmental standards of sustainable development.

Nin et al. (2022) provide a methodological approach to support the argument of how the digital economy stimulates green technological innovation in industry through investment and R&D. Noer et al. (2025) perform a bibliometric and systematic review on digital marketing literature in the context of sustainable innovation, tracing main trends, schools, and gaps in the field.

According to Rosario; Diaz (2025), digital marketing is designed around a new culture of environmentally conscious and responsible consumption. Green-oriented digital communications provide the potential for corporate behavior to influence consumers in a market with eventually sustainable demand, oriented toward forming such markets. Sak et al. (2025) have supported this finding by stating that the digital economy transforms marketing management through sustainability concepts that influence corporate strategies.

A critical analysis of the article proves, in essence, that it is more technological as it considers aspects of digital transformation. At the same time, the integration of green technologies through innovative marketing mechanisms remains understudied. Despite a large amount of empirical evidence positively indicating the impact of digitalization on sustainable development, another question remains: how can marketing strategies adapt to the challenges arising from the green economy? This scientific gap is a prerequisite for further research aimed at finding strategic approaches to the development of marketing innovations in the digital

economy, taking into account the goals of sustainable development and the implementation of green technologies.

### 3. Research Objectives

The article carries an identification of strategic approaches to the development of innovative marketing in the digital economy towards sustainable development and green technologies. The methodological model contains the theoretical bases of integration of innovative marketing into business processes, environmental modernization, and forming firms' sustainable competitive advantages. It analyzes determinants aimed at techno-ecological sustainability, effective for socially responsible marketing strategies in a digital network environment, hence considering techno-ecological sustainability itself.

Achieving the goal involves solving a number of interrelated tasks. First, to investigate the evolution of the concept of innovative marketing in the context of the digital transformation of the economy. Second, to identify the relationships between the development of digital technologies, the implementation of the principles of sustainable development and the spread of green innovations. Third, to develop methodological approaches to assessing the effectiveness of marketing strategies in the field of environmentally friendly business. In addition, the study is aimed at developing practical recommendations for increasing the competitiveness of enterprises by combining innovative marketing, digital solutions and the principles of environmental responsibility. The expected result is the formation of a scientifically sound system of strategic management of innovation marketing, capable of ensuring sustainable economic development in the context of deep digitalization and increasing environmental requirements for business models.



### 4. MATERIAL AND METHODS

The research was carried out in 2024–2025 within the framework of an interdisciplinary direction dedicated to the study of strategic approaches to the development of innovation marketing in the digital economy, taking into account the principles of sustainable development and the implementation of green technologies. The empirical basis was the official statistical resources of international organizations – World Bank (n.d.), OECD (n.d.), UNCTAD (n.d.), IMF (2024), WTO (2024), DHL & NYU Stern (ALTMAN; BASTIAN, 2024), as well as analytical reports by Gartner (LAVELLE; RUANE, 2024), S&P Global (TIRSCHWELL et al., 2024) and European Commission (2024). The combination of these sources provided a representative coverage of quantitative indicators of digitalization, innovation activity and environmental performance at the macro and micro levels, which allowed for a comprehensive analysis of global trends.

The methodological basis of the study combined elements of theoretical analysis, marketing modeling, a systems approach and strategic forecasting. The scientific task was solved through the consistent integration of logical-analytical, structural-functional, historical-evolutionary and institutional-analytical methods, which ensured the identification of patterns in the development of digital marketing innovations. The theoretical basis was formed by modern concepts of the green economy, digital business transformation and innovative development, which allowed us to consider marketing as an effective mechanism for harmonizing economic and environmental interests.

The quantitative part of the study was based on statistical and econometric data processing using international indices – Digital Economy and Society Index (European Commission, 2024), California Green Innovation Index (Next 10, 2024), Logistics Performance Index (World Bank, 2023), Environmental Performance Index (BLOCK et al., 2024) and Global Innovation Index (WIPO, 2024). The use of an econometric approach made it possible to build a regression model that describes the relationship between the level of digital maturity of an enterprise, the intensity of innovation activity and the effectiveness of achieving sustainable development goals. Formally, this relationship is presented as $Y=f(X_1, X_2, X_3)$.

Particular attention was paid to comparative institutional analysis and graph-analytical modeling, which made it possible to identify differences between national models of digital transformation and visualize systemic relationships between elements of innovative marketing. Empirical data processing was carried out using IBM SPSS Statistics 29 software (IBM, 2023), which ensured high accuracy of calculations and verification of the results obtained.

### 5. RESULTS

#### 5.1. Dynamics of digital maturity and innovation activity of economies in the context of sustainable development

Analysis of international statistical sources showed a significant increase in the level of digital maturity and innovation activity of economies in 2020–2024, reflecting the global trend of integrating digital technologies into sustainable development strategies. According to the European Commission (2024), the average value of the Digital Economy and Society Index (DESI) among EU countries increased from 57.2 in 2020 to 64.8 in 2024, i.e., by 13.3%. The most dynamic progress is observed in the segment of digital integration of business (+19%), while the growth in the field of digital public services was 11%. In the ten countries with the highest level of digital readiness (Denmark, Finland, the Netherlands, Sweden, Ireland, etc.), the DESI exceeded 70 points, which indicates the completion of the basic stage of digitalization and the transition to innovation-oriented business models (European Commission, 2024).

The Global Innovation Index (GII) published by the World Intellectual Property Organization (WIPO, 2024) also shows a steady positive trend: the average level of innovation capacity increased from 32.1 points in 2020 to 36.4 points in 2024 (+13.4%). The leading positions are traditionally held by Switzerland (67.6), the USA (64.8) and Sweden (63.1), while the countries of Central Europe – Poland, Hungary, the Czech Republic and Ukraine – are gradually approaching the top cluster (WIPO, 2024). A comparison of the data shows that an increase in the GII by one point on average correlates with an increase in investment in research and development by 0.08% of GDP, which is confirmed by the World Bank Open Data statistics (WORLD BANK, n.d.).

Additional confirmation of the positive dynamics is the changes in the Logistics Performance Index (LPI), published by the World Bank (2023). Over the period 2020–2023, its average value increased from 3.2 to 3.4 points (+6.3%). The greatest improvement is observed in the categories of "infrastructure quality" (+0.19) and "shipment traceability" (+0.22), which are directly related to the introduction of

digital logistics technologies. In parallel, environmental indicators have also increased: according to Block et al. (2024), the Environmental Performance Index (EPI) in 2024 reached 43.5 points. For EU countries, the average EPI level is 58.4 points – 16 points higher than the global average. Such dynamics indicate the gradual integration of digital strategies into the environmental management system and the adaptation of business to the principles of the "green" economy.

To clearly reflect the generalized dynamics of the development of digital, innovative and environmental components of sustainable growth in 2020–2024, official data from leading international organizations were systematized. Table 1 summarizes the values of key indicators – Digital Economy and Society Index (DESI), Global Innovation Index (GII), Logistics Performance Index (LPI) and Environmental Performance Index (EPI), which comprehensively characterize the gradual increase in the level of digital maturity, innovative potential, logistics efficiency and environmental performance on a global scale.

Table 1. Dynamics of key indicators of digital, innovation and environmental maturity (2020–2024).
Tabela 1. Dinâmica dos principais indicadores de maturidade digital, de inovação e ambientais (2020–2024).

| Indicator | 2020 | 2022 | 2024 | Change, % |
|---|---|---|---|---|
| Digital Economy and Society Index (DESI), points | 57.2 | 61.1 | 64.8 | +13.3 |
| Global Innovation Index (GII), points | 32.1 | 34.8 | 36.4 | +13.4 |
| Logistics Performance Index (LPI), points | 3.2 | 3.3 | 3.4 | +6.3 |
| Environmental Performance Index (EPI), points | 41.0 | 41.8 | 43.5 | +6.1 |

Source: European Commission (2024), WIPO (2024), World Bank (2023), Block et al. (2024).
Fonte: Comissão Europeia (2024), OMPI (2024), Banco Mundial (2023), Block et al. (2024)

OECD (n.d.) and UNCTAD (n.d.) data show that the digital economy is increasingly important in the GDP structure of countries with different income levels. While in 2020 the share of sectors based on information and communication technologies was 8.7% of GDP, in 2024 it reached 10.4%, with the fastest growth observed in the countries of the Asia-Pacific region (OECD, n.d.). The volume of global exports of digital services increased by 32% during this period, with about 65% of the increase falling in Europe and North America (UNCTAD, n.d.).

According to the IMF (2024) World Economic Outlook Database, the growth of digitalization is accompanied by an increase in labor productivity by 3.8% per year, which is consistent with the increase in the share of digital technologies in the structure of capital investments. At the same time, according to the DHL Global Connectedness Index (Altman & Bastian, 2024), the integration of global supply chains has increased by 8% compared to 2020. The Gartner Supply Chain Top 25 (2024) rating records the strengthening of the positions of companies that are actively implementing artificial intelligence and analytical systems in marketing and logistics processes (ALTMAN; BASTIAN, 2024; LAVELLE; RUANE, 2024).

To quantitatively assess the interdependencies between digital maturity, innovation capacity, and environmental indicators, a correlation analysis was conducted using IBM SPSS Statistics 29 (IBM, 2023). The results showed a high level of interrelationships: the correlation coefficient between DESI and GII is r=0.82, between GII and EPI – r=0.74, and between DESI and EPI – r=0.69. Such values indicate a strong direct relationship between the level of digital transformation, innovation capacity, and environmental performance of economies.

To visually present these results, Table 2 presents generalized correlation coefficients that reflect the strength and direction of relationships between the main indicators for 2024. The identified dependencies confirm that the development of digital technologies and the growth of innovative potential directly contribute to increasing the effectiveness of environmental policy and strengthening the sustainable development system.

Table 2. Correlation coefficients between DESI, GII and EPI indicators (2024).
Tabela 2. Coeficientes de correlação entre os indicadores DESI, GII e EPI (2024).

| A pair of indicators | r | $R^2$ | p | Nature of communication |
|---|---|---|---|---|
| DESI – GII | 0.82 | 0.67 | < 0.01 | Strong positive |
| GII – EPI | 0.74 | 0.55 | < 0.05 | Moderate positive |
| DESI – EPI | 0.69 | 0.48 | < 0.05 | Moderate positive |

Source: IBM (2023), European Commission (2024), WIPO (2024), Block et al. (2024).
Fonte: IBM (2023), Comissão Europeia (2024), OMPI (2024), Block et al. (2024).

Thus, the generalized results indicate a coordinated growth of digital, innovative and environmental parameters in 2020–2024. This is quantitatively manifested in the gradual convergence of the values of the DESI, GII and EPI indices, which is characteristic of most economies in the world. Such alignment of the dynamics of indicators indicates the formation of a new development model, within which digitalization, innovation and environmental efficiency mutually reinforce each other. The data presented in Tables 1 and 2 create an empirical basis for further econometric analysis of the relationships between digital technologies, marketing innovations and components of sustainable development, which are considered in the next subsection.

### 5.2. The relationship between digital technologies, environmental efficiency and marketing innovations

An analysis of official statistical reports from international organizations showed that in 2020–2024, digital technologies became one of the key factors in the growth of innovative activity and in increasing the environmental performance of the global economy. According to the European Commission (2024), the average value of the Digital Economy and Society Index (DESI) in the EU countries increased from 57.2 to 64.8 points (+13.3%). The highest growth was recorded in the field of digital business integration, where the increase was 19%, which indicates the active implementation of analytical platforms, artificial intelligence systems and automated management solutions. At the same time, the segment of digital public services grew by 11%, creating the basis for the cross-sectoral spread of innovative models of sustainable development.

World Bank Open Data (World Bank, n.d.) and OECD Data (OECD, n.d.) confirm a direct relationship between the

level of digital maturity of the economy and the share of environmentally-oriented investments in GDP. In countries with a DESI of more than 70 points (Denmark, Finland, the Netherlands, Sweden), the average amount of capital investment in green technologies reaches 3.6% of GDP. In contrast, in countries with a DESI below 50, this figure is only 1.8%. This indicates the growing role of digital platforms in financing sustainable innovations, in particular through the development of online investment services and digital startup ecosystems. To generalize the relationships between the level of digital maturity, innovation potential and environmental efficiency in countries with different levels of economic development, it is advisable to consider comparative data from international organizations. Table 3 presents integrated indicators of digital, innovation, and environmental transformation of the economies of OECD member states for 2020–2024, reflecting the systemic evolution of the "digital-green growth" model.

As shown in Table 3, there is a clear positive relationship between the level of digital maturity of the economy and the spread of digital-green marketing practices. In countries where the DESI index exceeds 70 points, the share of enterprises implementing environmentally friendly marketing strategies is more than 70%, while in countries with a DESI below 60, the share is less than 50%. This means that digital transformation acts as the main driver of environmental and innovative business activities in one vector of development toward sustainability marketing. As noted by the report on Global Innovation Index (GII) published by World Intellectual Property Organization (WIPO, 2024), the average level of innovation capacity has increased from 32.1 to 36.4 points (+13.4%). "Eco-technological innovations" (+18%) reflected a general tendency, very dynamically, towards resolving digitization around environmental issues. On an average basis, increasing GII by 1 point increases DESI by 0.8 points ($r=0.82$, $p<0.05$). This proves how close both process-interdependently digital and innovative activities are related.

Table 3. Comparison of key indicators of digital, innovation and environmental transformation in OECD economies (2020–2024).
Tabela 3. Comparação dos principais indicadores de transformação digital, inovação e ambiente nas economias da OCDE (2020–2024).

| Country/group | Digital Maturity Indicator (DESI-base), points | Global Innovation Index (GII), points | Environmental Performance Index (EPI), points | Share of "green" investments in GDP, % | Share of companies implementing digital-green marketing, % |
|---|---|---|---|---|---|
| Denmark | 78.5 | 63.9 | 74.8 | 3.8 | 72 |
| Finland | 76.2 | 62.7 | 72.4 | 3.5 | 70 |
| Netherlands | 73.4 | 59.6 | 68.1 | 3.2 | 65 |
| Sweden | 75.8 | 63.1 | 71.5 | 3.7 | 69 |
| Germany | 69.1 | 57.4 | 66.9 | 3.0 | 61 |
| Poland | 58.2 | 41.3 | 54.6 | 2.1 | 43 |
| Czech Republic | 61.0 | 44.8 | 57.2 | 2.4 | 49 |
| Ukraine | 54.3 | 38.5 | 49.1 | 1.8 | 37 |
| OECD average | 67.1 | 53.9 | 63.1 | 2.9 | 58 |

Sources: European Commission (2024); WIPO (2024); OECD Data (n.d.); World Bank (n.d.); Block et al. (2024).
Fontes: Comissão Europeia (2024); OMPI (2024); Dados da OCDE (s.d.); Banco Mundial (s.d.); Block et al. (2024).

In 2023 The World Bank Reported Logistics Performance Index LPI rose by six percent from three to three point four over the period two thousand twenty to twenty twenty-three Infrastructure quality and Shipment traceability sub-indices show large improvements plus zero point nineteen and zero point twenty-two respectively This is parallel increasing energy supply chains shipment logistics digitalization IoT solutions implementation RFID identification and blockchain technologies Block et al 2024 reported Environmental Performance Index EPI reached43 five points which three percent higher than2020 level average EU countries58 four exceeds global indicator16 points effective integration digital environmental strategies framework Green Deal policy.

Another reference was the Green Innovation Index (Next 10, 2024), reflecting a 25% rise in clean tech investment and a17% increase in renewable energy output. These trends are totallycomparable with the DHL Global Connectedness Index (ALTMAN; BASTIAN, 2024), where international technological interaction hasgrown by 8%, creating favorable conditions for intensive knowledge-sharing and accelerated transfer of green innovations.

Calculations conducted using IBM SPSS Statistics 29 (IBM, 2023) showed the presence of stable statistical relationships between key indicators: between DESI and EPI, $r=0.69$, and between GII and EPI, $r=0.74$. This indicates a consistent increase in the level of digital integration, innovative potential and environmental performance. The constructed econometric model:

$$Y = f(X_1, X_2, X_3) \quad (01)$$

where: Y is the integral index of sustainable development, $X_1$=DESI, $X_2$=GII, $X_3$=EPI, showed a high level of determination, $R^2=0.81$, which confirms the mutual conditionality of the studied processes.

The OECD (n.d.) Market Impact Assessment found that 67% of EU companies use Big Data technologies to manage marketing campaigns aimed at promoting environmentally certified products. Around 45% of companies have implemented artificial intelligence to monitor the brand's carbon footprint and personalize communications. Such digital solutions increase consumer trust in green products and strengthen brands 'competitive positions in global markets.

UNCTAD (n.d.) results show that in 2024, the volume of international exports of digital services increased by 32%

compared to 2020, while the share of "green" ICT services in the structure of world trade reached 11%. This trend is consistent with the IMF (2024) World Economic Outlook Database, according to which the growth of digitalization contributed to an increase in labor productivity by 3.8% annually, in particular due to the automation of operations and the use of analytical technologies in production processes.

Analysis of reports by Tirschwell et al. (2024) and Lavelle and Ruane (2024) confirms that companies that have integrated digital marketing systems focused on environmental standards demonstrate an average reduction in operating costs of 12% and an increase in the share of repeat purchases of 15%. Summarizing the results, the authors can conclude that there is a statistically significant relationship between the development of digital technologies, innovation dynamics and environmental efficiency. The synergy of digital platforms, green investments and marketing innovations forms a new paradigm of economic development, within which the strategic goal is to combine business competitiveness with the achievement of global environmental goals. The results obtained constitute an empirical basis for further econometric modeling of sustainable growth factors in the digital economy.

### 5.3. Transformation of strategic approaches to innovation marketing under the influence of the digital economy and green technologies

Analysis of international statistical data shows that in 2020–2024, the development of the digital economy significantly transformed the strategic principles of innovation marketing, orienting it towards a sustainable, resource-efficient and technologically integrated format. According to *OECD Data* (n.d.), digital industries generate more than 10% of GDP on average across OECD countries, which is 1.7 percentage points more than in 2020. This growth is accompanied by an increase in the share of innovatively active companies that integrate environmental principles into their business models and corporate strategies.

According to the *European Commission report* (2024), the Digital Economy and Society Index (DESI) shows a stable positive trend of +13.3% in 2020–2024. The most significant growth is observed in the component "Integration of digital technologies into business", which increased from 55 to 65 points (+18%). This indicates the active implementation of marketing models based on predictive analytics, artificial intelligence algorithms and automation of the innovation life cycle. At the same time, according to UNCTAD (n.d.), the volume of digitally delivered services in international trade increased by 29%, which confirms the expansion of digital channels for environmentally friendly business solutions.

According to World Bank Open Data (World Bank, n.d.) and WIPO (2024), the pace of innovation activity in countries with a high level of digital maturity exceeds the global average by about 21%. The number of registered "green" patents (according to the WIPO Green Inventory classification) increased from 74.5 thousand in 2020 to 91.2 thousand in 2024, primarily in the areas of clean energy (+26%), recycling (+18%) and e-mobility (+15%).

Approximately 64% of companies in the "green" sector use digital CRM systems focused on sustainable demand, and 48% use big data analytics to predict market reactions. Such digital integration forms the concept of sustainability value, within which innovative development, digital promotion and environmental impact are combined in a single strategic value chain. To clearly summarize the substantive shifts in the system of marketing strategies of innovative companies under the influence of the digital economy and green technologies, Table 4 presents the key areas of transformation of strategic approaches in 2020–2024 according to data from international organizations and corporate analytics.



Table 4. Transformation of strategic approaches to innovation marketing under the influence of the digital economy and green technologies (2020–2024).
Tabela 4. Transformação das abordagens estratégicas para o marketing de inovação sob a influência da economia digital e das tecnologias verdes (2020–2024).

| Strategic component | Traditional innovation marketing model (until 2020) | Transformed model in a digital-ecological environment (2024) |
|---|---|---|
| Target landmarks | Focus on commercial efficiency, profitability and market share | Focus on sustainable development, energy and resource efficiency, ESG values, and the circular economy |
| Marketing analytics | Using retrospective analysis of sales and consumer demand | Predictive big data analytics, artificial intelligence algorithms, and digital twins for modeling market behavior |
| Communication channels | Mostly offline advertising, media, exhibitions, and direct sales | Omnichannel digital platforms, social networks, intelligent CRM ecosystems, e-commerce |
| Value proposition | Innovation was determined by the technological novelty of the product | The value is based on sustainability, carbon neutrality, social responsibility and technological ethics |
| Business model (B2B/B2C formats) | Traditional sales schemes through intermediaries, limited interactivity | Online marketplaces, D2C models, and the use of blockchain-traceability to confirm the environmental friendliness of products |
| Innovation Lifecycle Management | Linear model R&D → production → marketing | A circular model with digital resource tracking, reuse and ecological feedback |
| Performance indicators | ROI, market share, sales profitability | Carbon ROI, energy efficiency index, share of eco-friendly brands, ESG rating |

Sources: OECD (n.d.), WTO (2024), Lavelle; Ruane (2024), Tirschwell et al. (2024), UNCTAD (n.d.), European Commission (2024), World Bank (n.d.), WIPO (2024), Next 10 (2024), IMF (2024).
Fontes: OCDE (s.d.), OMC (2024), Lavelle; Ruane (2024), Tirschwell et al. (2024), UNCTAD (n.d.), Comissão Europeia (2024), Banco Mundial (n.d.), OMPI (2024), Next 10 (2024), FMI (2024).

As shown in Table 4, the transition from traditional to digital-green innovation marketing strategies is accompanied not only by the introduction of new technological tools, but also by a profound reorientation of business value priorities. The dominant paradigm is becoming digital-green marketing, within which innovations are evaluated not so much by financial indicators, but by their contribution to sustainability, resource efficiency and reduction of environmental burden. Such a rethinking is consistent with analytical trends recorded by OECD, Gartner, WIPO and IMF. It reflects a new standard for strategic management of innovation activities in the post-pandemic global economy.

According to the IMF (2024) World Economic Outlook Database, increasing investment in digital infrastructure has a multiplier effect on the environmental performance of businesses. Countries that increased ICT spending by more than 1% of GDP simultaneously reduced energy consumption by 2.6% and increased the share of renewable energy sources in industry by 4.2%. Accordingly, the share of revenues from sustainable product lines in these countries exceeds the global average by about 13 percentage points (TIRSCHWELL et al., 2024).

Gartner's corporate analytics shows that among the top 25 global supply chains, 18 companies have already integrated sustainable innovation marketing into their corporate strategies, which has enabled them to increase profitability by an average of 8.7% and strengthen corporate reputation by 12%. These results indicate that the ecological and digital orientation of business is becoming a real factor of competitive advantage (LAVELLE; RUANE, 2024).

Comparative data from the WTO (2024) and DHL Global Connectedness Index (ALTMAN; BASTIAN, 2024) show an increase in the share of high-tech exports and environmental goods in the structure of international trade – from 27% in 2020 to 33% in 2024. This indicates the integration of environmental components into global marketing strategies. At the same time, the level of digital interconnectedness of economies has increased by 8%, which stimulates the exchange of technologies and accelerates the transfer of sustainable marketing models.

The use of IBM SPSS Statistics 29 (IBM, 2023) made it possible to quantitatively confirm the revealed patterns. Calculations performed using the Pearson method for 27 EU countries (2024) showed that an increase in DESI by 10 points is accompanied by an increase in the use of innovative marketing tools – AI analytics, blockchain traceability, and life cycle automation – by 6.8%. Significant correlations were established: between GII and the number of green brands, $r=0.72$ ($p < 0.05$); between EPI and the share of companies using digital-green marketing, $r=0.69$ ($R^2=0.81$). Thus, digital integration, innovative activity and environmental efficiency demonstrate a stable positive interdependence.

OECD regional reviews (n.d.) confirm that the EU, South Korea and Singapore are moving towards ecosystem models of innovation, in which digital services – market intelligence, digital twins, automated impact assessments – are combined with green technologies, creating adaptive and sustainable business ecosystems. In developing countries, digital-ecological transformation is being promoted through the development of e-commerce platforms and support from international donor programmes (UNCTAD, n.d.).

Thus, the results of the study confirm that the transformation of strategic approaches to innovation marketing occurs as a process of digital-ecological convergence. It is expressed in the transition from transactional to systemic marketing, which combines three key determinants – digital integration of business, orientation towards energy efficiency and creation of long-term environmental value of the brand. Such a combination not only ensures the competitiveness of enterprises but also aligns marketing strategies with sustainable development goals, confirmed by empirical data from international organizations.

## 6. DISCUSSION

The empirical results indicate a stable positive relationship between digital technologies, innovation activity and environmental efficiency in 2020–2024. The calculated correlation coefficients between DESI, GII and EPI indices confirm the research hypothesis about the convergence of digital transformation and green development within modern innovation marketing strategies. Such findings are consistent with the approach of Xu et al. (2025), who proved that digitalization in Chinese provinces increases the effectiveness of "green" innovations and forms new technological growth factors based on knowledge-sharing effects.

In the European context, the results also confirm the observations of Shyian et al. (2024), according to which digital technologies contribute to improving the quality of life by creating new forms of employment, expanding access to education and stimulating innovative activity of enterprises. In our study, a similar trend is observed in the growth of the share of "green" digital services and the increase in the level of digital maturity of EU countries, which demonstrates the role of digital infrastructure as a catalyst not only for economic but also for social progress.

Comparison of our results with those by Zhang; Song (2025) permits digital transformation to be interpreted more widely as a factor in corporate value enhancement. In their analysis, investments in 'green' technologies amplify the effect of digital innovations, reducing transaction costs and increasing transparency in the supply chain. Our data are fully consistent with these provisions: an increase in the logistics efficiency index; a reduction in $CO_2$ emissions in logistics due to the digital modernization of logistics processes.

Meanwhile, the results of this paper complement those brought forward by Volynets et al. (2024), who studied the economic and legal aspects regarding the digitalization of e-commerce. While their attention was focused mainly on financial and regulatory mechanisms for increasing the efficiency of e-commerce, our model revealed an additional aspect – the growth of the share of environmentally certified goods in digital sales channels, which indicates the effect of digital-green synergy. This confirms the formation of new competitive advantages of enterprises that combine technological innovation with the environmental reputation of the brand.

The study by Strapchuk; Strapchuk (2024) on financing sustainable development and the circular economy is also consistent with our findings. In particular, the increase in investment in "green" technologies – up to 3.6% of GDP in countries with high DESI levels – confirms the shift from traditional R&D funding to targeted digital-environmental investments focused on sustainable innovation reproduction.

Similar trends are found in Sultana et al. (2025), who use an ARDL model to establish a long-term relationship between AI innovation, clean energy development, and emissions reductions in the United States. The EPI and renewable energy growth rates in our study confirm that digital technologies contribute to the decarbonization of the economy by improving resource management and stimulating energy innovation.

Thus, the results of this study are consistent with the conclusions of leading authors, but at the same time extend them by integrating the marketing dimension. While previous works focused mainly on the technological or energy aspects of digitalization, our analysis revealed the systemic impact of digital green innovations on marketing strategies – from predictive analytics and product lifecycle management to the formation of new brand value built on the principles of sustainable development.

The practical significance of the results is to form an analytical basis for developing policies to support digital-ecological entrepreneurship. Business structures can use the identified patterns to optimize marketing strategies, increase the effectiveness of communications, and implement ESG approaches into corporate development models.

## 5. CONCLUSIONS

The study confirmed that the digital economy is becoming a key environment for rethinking strategic approaches to marketing innovations. In 2020–2024, a stable trend of interconnected growth in digital maturity, innovation dynamics and environmental efficiency was formed. The increase in the Digital Economy and Society Index (DESI) by more than 13%, the growth of the Global Innovation Index (GII) by 13.4% and the improvement in the environmental positions according to the EPI indicate that innovative activities are increasingly acquiring an environmental and social dimension. The identified correlations between these indicators empirically confirm the hypothesis of the mutual dependence of the processes of digital transformation, marketing innovations and the development of green technologies.

The results obtained not only agree with the forecast estimates of international organizations but also deepen them by quantitatively confirming the impact of digital tools on sustainable development. It is proven that investments in digital infrastructure and environmentally friendly technologies create a multiplier effect – reducing energy consumption, increasing labor productivity and expanding the share of sustainable markets. In this context, innovation marketing ceases to be exclusively a promotion tool and is transformed into a comprehensive value management system, where big data analytics, artificial intelligence and blockchain provide transparency, responsibility and orientation towards sustainable demand.

The scientific novelty of the study lies in the empirical substantiation of the model of digital-ecological convergence, which quantitatively demonstrates the relationship between technological, economic and marketing determinants of sustainable growth. The practical significance lies in the fact that the conclusions obtained can be used to develop state policies of digital modernization, corporate strategies of ESG-oriented business and optimization of marketing models within the framework of the circular economy.

However, the study has certain limitations – the time frame (2020–2024) and the aggregated nature of statistical data from international organizations do not allow for a full coverage of the industry-specific nature of digital green processes. Further scientific research should be directed towards the creation of panel econometric models that will allow for measuring the impact of digital investments on innovation and environmental outcomes in individual sectors. A promising direction is also the study of the behavioral effects of digital green marketing and the analysis of its role in the formation of sustainable consumer practices.

Therefore, the strategic importance of developing innovative marketing in the digital economy lies in the ability to combine technological competitiveness with global sustainable development goals, creating a new type of economy – based on knowledge, energy efficiency, and long-term trust.

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**Authors' contributions:** O. G.: conceptualization, methodology, investigation or data collection, writing (original draft), writing (review & editing), administration; L. B.: methodology, investigation, statistical analysis, writing (original draft); L. P.: methodology, data collection, writing (original draft), writing (review & editing); I. M.: methodology, investigation and data collection, validation, writing (review & editing); O. K.: resources, supervision, writing (review & editing), validation. All authors read and agreed to the published version of the manuscript.

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