

**Ministry of Education and Science of Ukraine
Sumy State University
Kaunas University of Technology, School of Economics and
Business
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International Centre for Enterprise and Sustainable**



"ECONOMICS FOR ECOLOGY"

*("EU practices of education for sustainable
development")*

*Materials
International scientific-practical conference
(Ukraine, Sumy, May14–17, 2024)*

*Sumy
Sumy State University
2024*

УДК: 330.15:502/504

Авторський знак: S70

The conference is held within the Jean Monnet Modules “Fostering EU Practices of Education for Sustainable Development through the Brand Language: Interdisciplinary Studies” (101085708-ESDbrandEU-ERASMUS-JMO-2022-HEI-TCH-RSCH), Jean Monnet Module “Youth and Business: EU Practices for Cooperation” (101126538 — YouthBEU — ERASMUS-JMO-2023-HEI-TCH-RSCH) (2023-2026) and “Disruptive technologies for sustainable development in conditions of Industries 4.0 and 5.0: the EU Experience (101083435 — DTSDI — ERASMUS-JMO-2022-HEI-TCH-RSCH)”



Co-funded by
the European Union

Editor-in-Chief Prof., Dr. Oleksandra Karitseva, head of the economics, entrepreneurship and business administration, Sumy State University

Approved by the Academic Council of SSI BIEM of Sumy State University
(protocol №2, 5 September 2024)

Economics for Ecology : Proceedings of the International Scientific and Practical Conference, Sumy, May 14–17, 2024 / edited by Karitseva Oleksandra and Kubatko Oleksandr . – Sumy : Sumy State University, 2024 – 103 p. (*electronic edition*)

For scientists, scientists, students, graduate students, representatives of business and public organizations and higher education institutions and a wide range of readers.

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THE IMPACT OF THE DIGITAL ECONOMY ON CARBON REDUCTION POTENTIAL

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Since the Industrial Revolution, Massive energy consumption have led to a large amount of carbon dioxide (CO₂) emission, which resulted in many environmental problems such as global warming, extreme weather, etc. In 2023, China's carbon dioxide emissions increased by 565 million tons, accounting for 35% of global carbon dioxide emissions [1], which is 2.6 times the peak carbon emissions of the European Union (4.85billion tons) and 2.1 times the peak carbon emissions of the United States (6.00 billion tons). However, in terms of GDP, excluding exchange rate fluctuations, China is only about 70% of the United States. In 2020, China exceeded the national emission reduction targets promised at the 2009 Copenhagen Climate Summit and clearly set goals for peaking carbon emissions before 2030 and achieving carbon neutrality before 2060. At the same time, the rapid development of information technology provided an environment for the growth of digital economy, which is gradually becoming the engine of economic growth and carbon reduction in China. In 2025, China will update its emission reduction targets and submit a national independent contribution towards 2035. Carbon reduction targets are urgent and the task is heavy. How the digital economy affects the carbon reduction potential is worth studying.

The digital economy is a more advanced and sustainable form of economy [1]. The digital economy has accelerated the penetration and integration of digital technology and digital elements into deeper and broader fields through continuously upgrading network infrastructure and information tools such as smartphones, promoting the transformation of economic forms from industrial economy to smart economy, and thus bringing about a transformation of the entire economic operation mode [2]. The integration of the digital economy and various industries has shown significant positive externalities, such as inclusive economic growth [3], high-quality development [4-7], regional innovation [8], industrial structure upgrading [9, 10], etc., and has also shown positive effects on total factor productivity [11], enterprise management [12], and corporate governance [13] at the micro level. Furthermore, the development of the digital economy will provide support for carbon reduction through the use of digital technology, the mutual promotion of digital elements and digital technology, and cross disciplinary technological complementarity. Firstly, research has shown that technological progress can drive carbon dioxide reduction [14]. The digital technology has the characteristic of sustainable improvement [15], which is a typical manifestation of technological progress. The effective application of continuously developing digital technology in various aspects of carbon reduction can improve the efficiency of emission reduction work and increase the potential for carbon

reduction. Secondly, digital technology can fully tap into the potential value of carbon emission related big data such as energy data and carbon footprint, driving the comprehensive penetration of digital elements in the field of carbon reduction [16]. At the same time, the continuous accumulation and mining of carbon emission related big data promote the deep use and continuous progress of digital technology, increasing emission reduction capabilities. Finally, the digital economy can quickly compile and imitate complex advanced knowledge available in other regions or industries, triggering complementarity between existing technologies in different fields of use [2], providing richer technological and knowledge support for carbon reduction. However, digital technology and its digital industry itself are high energy consuming industries [16], and the operation of data centers requires a large amount of energy. Previous studies have shown that data centers and cloud servers are key sources of carbon footprint [17], which can lead to significant carbon emissions. However, this portion of carbon emissions is necessary for maintaining the operation of digital economy facilities such as data centers, and is difficult to eliminate through self-development. It belongs to typical non emission reducing new carbon emissions and does not have room for emission reduction. When the digital economy develops to a higher level, digital facilities such as data centers and cloud servers operate at full capacity, which will increase a large amount of non emission reducing carbon emissions, thereby reducing the potential for urban carbon reduction.

Green innovation plays an important role in carbon reduction, and various industries can produce green innovation results [18]. Green innovation efficiency refers to the degree of greenization of regional innovation efficiency, which measures the quality of innovation development after considering environmental pollution and energy consumption comprehensively. It is the green index of innovation quality [19]. Green innovation efficiency is a part of innovation efficiency, closely related to technological progress, and green innovation will promote energy structure and efficiency improvement through new energy technology and low-carbon technology, thereby promoting carbon reduction. Miao Lunjun and Chen Jing (2022) found that the development of the digital economy can have an indirect impact on carbon emissions through innovation efficiency [20]. The digital economy can promote carbon reduction through two paths: expanding social and economic scale and enhancing green technology innovation capabilities [21]. Some studies have also studied the mechanism of green technology innovation that affects carbon emissions from the perspective of the absolute and average amount of green innovation [22], but few studies have explored the impact of the digital economy on urban carbon reduction potential from the perspective of the mechanism of green innovation efficiency.

In the theoretical mechanism and research hypothesis section, firstly, we discussed the concept of carbon reduction potential and digital economy, and conducted a theoretical analysis of the relationship between carbon reduction potential and digital economy. Secondly, we sorted out and discussed the role of

green innovation efficiency in the impact of digital economy on carbon reduction potential, and proposed our research hypothesis. In the section of calculating the carbon emission reduction potential index, we sorted out the research and calculation methods of three types of carbon emission reduction potential. Based on the panel data of 281 cities in China from 2011 to 2020, we construct the carbon reduction potential index which include the shadow prices of CO₂ from the perspective of fairness and efficiency to evaluate the carbon reduction potential based on the in-depth analysis of the rest space of carbon reduction and the efficiency of carbon reduction. In the study design section, the dependent variable, explanatory variable, mediating variable and controlled variable were introduced. At the same time, We take green innovation efficiency as a mediating variable and constructs two-way fixed effects regression model and mediating effect model based on analyzing the relationship between digital economy, green innovation efficiency, and carbon reduction potential and their influencing mechanism. The results show that the digital economy presents an inverted “U”-shaped impact on carbon reduction potential, and the development of digital economy can improve the carbon reduction potential in most city at present. Further research shows that the green innovation efficiency presents an obvious mediating effect. But for some reasons, the digital economy has an inhibitory effect on green innovation efficiency which delays the time it takes for carbon reduction potential to reach it maximum value. At the same time, the impact of digital economy on carbon reduction potential has obvious heterogeneity on regional, urban scale and policy, that is, the impact in eastern China, the large urban scale, which is divided from GDP and population, as well as pilot cities of policy such as new energy cities, low-carbon cities, smart cities and broadband China, is significantly stronger than that in other area. Finally, this paper provides some relevant suggestions.

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