Digital Economy, Environmental Regulation, Sustainable Development in China

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The digital economy and environmental regulation are important drivers of sustainable development, and exploring the coupling of the three is important for promoting the coordinated development of regional economy, society and environment. The development of the digital economy has given rise to a new model of economic growth, but it has also led to the accelerated penetration of digital technology into different areas of China's economic and social development, which has contributed to socio-economic development and environmental protection through the efficient allocation and integration of resources.

digital economy   environmental regulation   sustainable development

1. Introduction

With the advancement of economic globalization, scientific and technological informatization and social knowledge, sustainable development has gradually become a common goal for all countries to strive for [1]. While China's industrialization process is accelerating, the resources and environment are creating rigid constraints on the economy and society in the context of the new normal development. Polluting enterprises with high energy consumption, high pollution and high emissions using coal as the main raw material are causing a certain degree of damage to the environment and economic benefits [2]. How to deal with the relationship between environmental protection and economic growth focuses on the quality of economic development and the efficiency of resource use. Therefore, transforming the mode of economic development, making strategic adjustments to the economic structure and ultimately realizing the establishment of a resource-saving and environmentally friendly society have become important driving forces for the sustainable development of human economy and society [3]. With the current ecological and environmental problems becoming increasingly serious, the digital economy—as the "gas pedal" and "stabilizer" of China's economic growth momentum under the new normal—the use of big data, artificial intelligence and other means to promote the combination of digital technology and the traditional real economy [4], to achieve the "resources-products-pollution emissions" of extensive production into "low-carbon" flexible production and to form "big data + big ecological" integrated development [5], become important internal driving forces to enhance the efficiency of green innovation. In addition, as the basis and condition for enhancing the comprehensive national power of sustainable development, the study of the coupled and coordinated role played by these factors in the process of sustainable development is of great significance in promoting high-quality economic, social and environmental development among other countries and regions.

China's digital economic industry is growing in scale as the infrastructure and development of the digital economy has increased significantly, and its goal of "stabilising growth and promoting transformation" suggests a solution for the replacement of traditional environmentally polluting industries. In addition, sustainable social development cannot be achieved without the support of economic, environmental, social and governance factors. Therefore, through the full release of digital technology, we can provide technical support for precise, scientific and legal pollution control, modernize the ecological environment and ecological governance, improve the living environment and quality of life and achieve sustainable social development. Therefore, the evaluation of the digital economy, environmental regulation and sustainable development plays an important role in the construction of China's overall goal of "ecological priority, conservation and intensive, green and low-carbon development".

2. Digital Economy and Environmental Regulation

Environmental imbalance is an unavoidable problem in China's industrialization process [6], and the digital economy, as an important engine for China's high-quality economic development [7][8], advocates for the construction of a resource-saving and environmentally friendly economic development model [9], putting forward new requirements for the problems of "high pollution, high emissions and low efficiency" that exist in China's traditional industrial structure. Research shows that the digital economy mainly promotes the efficient use of resources in each region through enabling technological innovation and relying on core domain technologies such as the Internet and artificial intelligence [10], and achieves coordinated regional development with real-time, interactive and open characteristics. This requires a strict and standardized combination of environmental policy tools to be formulated by government departments in the process of industrial development at all levels, fully utilizing various digital technologies, promoting the upgrading of regulatory instruments and improving regulatory effectiveness [11]; forming "industry barriers" to existing or upcoming energy-consuming industries; and changing the production method that uses capital, labor and land as traditional industrial factors [12]. In addition, the implementation of strict environmental policies by the government can increase the production costs of enterprises, but when environmental regulations are properly implemented, they can stimulate enterprises to clarify the direction of technological change and thus generate "innovation compensation" to compensate for the short-term increase in production costs, thus achieving the joint improvement of environmental protection, innovation level and economic development [13][14]. Ultimately, a series of environmental regulations will force enterprises to integrate digital resources; reduce the proportion of polluting output; form "digital content, digital intelligence, and digital industry" as the main production factors; and improve the total factor productivity of industry, which will become an important initiative for the development of the digital economy [15].

3. Digital Economy and Sustainable Development

The concept of sustainable development was first proposed by the United Nations in 1987 [16], which mainly calls for the development of all aspects of society to meet the needs of the present while not endangering the normal needs of future generations, and makes a clear plan for the way forward for human social development. More studies have taken the refinement of the concept of sustainable development as a starting point [17][18], and

gradually expanded to the analysis of its mechanism of action and exploration of its influencing factors in social, economic and ecological dimensions [19][20]. Currently, China is facing a critical period of transformation from industrial civilization to ecological civilization [21], and in the context of sustainable development, the digital economy realizes social governance through market transformation, financial quality and efficiency improvement, and value reconstruction, which provides the direction of future changes to the quality of social development, market operation mechanism and industrial structure adjustment [22][23]. However, there are still problems such as the "digital divide" between regions, network information security and imperfect regulatory laws, which to a certain extent reveal that digital governance lags behind the development of society in terms of system and theory [24][25]. In addition, in terms of sustainable economic development, the digital economy mainly empowers traditional labor methods to be digitalized, intelligent and networked; reduces energy consumption in production; and promotes the integration of Internet technologies with economic systems to efficiently invest limited resources in production activities and form economies of scale, mainly by improving the efficiency of matching supply and demand in the free flow of factors [26][27]. Finally, digital transformation, relying on information technology and changes in the internal and external environment [28], can accurately identify ecological and environmental problems, promote the construction of a dynamic system for monitoring ecological and environmental data, continuously improve green innovation capacity, and promote the synergistic development of the green economy and the digital economy [29][30][31].

4. Environmental Regulation and Sustainable Development

Environmental regulation is a policy system consisting of four dimensions: command and control, market incentives, social participation and voluntary action [32]. According to Pigou's theory of welfare economics, environmental taxation can promote the internalization of external uneconomical environmental pollution by enterprises and promote more "environmentally friendly" production decisions, thus achieving a win-win situation for both market defects and social welfare [33]. In the current context of increasing pressure on economic, social and ecological development, only by taking the path of sustainable development and making the rate of human demand for resources lower than the rate of regeneration of the resources themselves and their substitutes can we realize the construction of an ecological civilization with the aim of harmonious coexistence between human beings and themselves, human beings and nature and human beings and society [34], and then finally realize the goal of sustainable development—the balance of economy, society and ecology [35]. In addition, the impact of environmental regulation on sustainable development is not limited to the macro-level effects on industrial restructuring [36], reduction of pollution emissions [37] and resource utilization enhancement in the traditional sense [38], but more micro-specific levels such as labor employment [25][39], urban–rural income gaps [40], high and low commodity prices [41] and public health and safety [42], which generate corresponding mechanisms of action.

A review of the literature shows that there is a wealth of previous research on the two causal relationships between the digital economy, environmental regulation and sustainable development, exploring the unidirectional influence or coupling of a single subsystem on another subsystem, which is of strong reference value for this study. However, as the digital economy, environmental regulation and sustainable development are important building

blocks of China's "new development pattern", few studies have integrated the three subsystems into the same framework and explored their coupling and coordination. Therefore, this research takes 30 provinces (autonomous regions and municipalities directly under the central government) in China as the research object (Tibet, Hong Kong, Macao and Taiwan are not included in the scope of this study due to serious data deficiencies), selects the data from 2011 to 2020 when the development level of the three subsystems was improving rapidly and constructs an evaluation index system for the three subsystems based on the coupling mechanism of digital economy, environmental regulation and sustainable development. The spatial and temporal distribution of the coupling and coordination relationship is explored, with a view to providing a reference for decision making to promote the coupling and coordination degree of digital economy, environmental regulation and sustainable development.

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