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*Original Research*

# Boosting Regional Sustainability under Digital Economy Environment: Exploring the Moderating Role of Digital Finance in China

**Qun Yang[1]*, Pomi Shahbaz[2]**

[1]Business School, Anyang Normal University, Anyang, Henan 455002, China
[2]Department of Economics, Division of Management and Administrative Science, University of Education Lahore, Pakistan

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## Abstract

Digitalization has a profound impact on the daily lives of individuals and plays a pivotal role in promoting sustainable development. Digital economy has emerged as a prominent driver of sustainable development worldwide. It plays a crucial role in environmental sustainability, economic expansion, and social progress. This study primarily examines the role of the digital economy in facilitating sustainable regional development (SRD). Furthermore, this study examines the moderating effect of digital financial inclusion on the relationship between digitalization and SRD. Panel data from 30 Chinese provinces spanning the period 2011 to 2021 were utilized for this analysis. Digital economy (Digi-E) and SRD were measured using the panel entropy method and principal component analysis. SRD considers three main dimensions of sustainable development: the economic, environmental, and social sustainability of the provinces. The spatial Durbin dynamic model and spatial regression were used to analyze the data. The findings revealed that Digi-E significantly affected SRD, with a marginal effect of 0.297. Similarly, digital financial inclusion significantly and positively moderates the relationship between Digi-E and SRD. The spatial Durbin dynamic model also showed that Digi-E has a significant effect on SRD when both types of weights are considered, such as economic geography and geographic distance. Moreover, it was confirmed that the SRD in the previous year significantly contributed to the SRD in subsequent years, and that the SRD in the local region also significantly contributed to the SRD of the adjacent region. Spatial regression also revealed a significantly positive impact of the interaction terms Digi-E and digital financial inclusion on SRD. Thus, Digi-E can contribute significantly to sustainable regional development both individually and through digital financial inclusion. The new economic growth and development plan requires governments to drive the digital revolution and improve the infrastructure. Governments should increase digital financial services with a focus on rural monitoring.

**Keywords:** sustainable regional development, digital economy, digital financial inclusion, social sustainability, spatial spillover effects

*e-mail: yqbylwzd@163.com

## Introduction

As population increases, concerns such as air and marine pollution, climate change, resource depletion, and biodiversity loss have surfaced and irreversibly harmed human society's evolution, preventing the advancement of sustainable development [1]. One of the key components of sustainable development that prioritizes the advancement of human civilization and nature in harmony is environmental conservation [2]. Digitalization significantly affects people's lives and is crucial for sustainable development. To expedite progress towards Sustainable Development Goals (SDGs), it is essential to utilize the maximum potential of digitalization through active digital collaboration and interactions between researchers and policymakers [3]. Academic discourse revolves around a contentious topic currently under scholarly scrutiny: the means by which development velocity can be upheld while simultaneously demonstrating the utmost reverence for the natural environment, thereby facilitating the attainment of SDGs.

The digital economy (Digi-E) is a prominent economic approach utilized for industrial advancement [4], with the objective of attaining the SDGs. China's Digi-E and technology have experienced significant growth and recently emerged as frontrunners in certain domains [5]. The fundamental concept underlying the Digi-E is enabling the production of goods, provision of services, continuous learning, and innovation through the utilization of advanced technological infrastructure within the context of global market integration and sustainable development [6]. Furthermore, there is a gradual transition in the realm of the Internet from focusing on information to focusing on value. Consequently, the Digi-E is receiving increasing attention. Internet technology offers new opportunities for socioeconomic enterprises and enhances market efficiency and reach [7]. In contrast, the digital economic environment, as a burgeoning force in the realm of the Internet, exhibits comparatively diminished transaction costs when juxtaposed with a tangible economy. The Digi-E exhibits dynamic efficiency as opposed to a static one, resulting in greater benefits compared to the traditional economy and providing a stronger impetus for other avenues of development [8].

Global society is currently undergoing a significant shift towards the digitalization era, characterized by a heavy reliance on advanced digital and computer technology for various aspects of our daily lives. Contemporary innovations have found utility in various domains such as economic, social, ecological, environmentally friendly, and climate-related uses, with the aim of augmenting the productivity and efficiency of specific systems [9, 10]. Digitalization is the process of incorporating technological advances into various aspects of daily existence. The possibility of achieving incorporation can be facilitated by digitizing knowledge. Digitization refers to the process of transforming tangible data and knowledge such as information obtained from sensors or written sources into a format that can be interpreted by computers. The arduous task of converting historical information, such as paintings, images, and video formats, into digital forms has yielded significant benefits facilitated by advancements in information technology.

China's economy has experienced significant advancements in both quality and quantity following the implementation of policy changes and the gradual opening of its markets [11, 12]. Sun et al. [13] and Hao et al. [14] demonstrated a significant improvement in China's economic process. Nevertheless, the prolonged utilization of the conventional vast development framework has resulted in the overconsumption of power, resource scarcity, and a range of adverse environmental challenges, including climate change [15, 16]. Furthermore, the world has reached agreement to foster the advancement of environmentally friendly development [17].

Despite significant progress in high-quality development, China continues to face challenges, such as elevated pollution levels [18, 19]. Hence, the Chinese government has made a deliberate decision to prioritize the establishment of a green and sustainable economy [11, 20]. Recently, there has been notable advancement in the field of digital technology. The Digi-E in China is expanding significantly, with an annual growth rate of 9.7%. Despite the additional challenges posed by the economic recession and global pandemic, this sector contributed 38.6% of the country's GDP in 2020. The process of digitalization has permeated various facets of the countries and contemporary community. Furthermore, digitalization has emerged as a significant catalyst for driving technological advancements and enhancing operational effectiveness, consequently propelling society towards a comprehensive and knowledge-driven transformation. The relationship between economic growth and environmental quality is contingent on technological advancement [21]. Furthermore, digital investments serve as catalysts for promoting environmentally friendly productivity by fostering sustainable production processes. Therefore, it is imperative to ascertain the extent to which digitalization facilitates sustainable regional development (SRD) in China. This study also aims to examine the possible spatial correlation and heterogeneity between digitalization and the growth of an SRD in the country.

The Digi-E has emerged as a novel socioeconomic platform for sustainable development in addition to agriculture and industry worldwide [22]. The ability of the current generation to meet its demands while guaranteeing that future generations will do the same without difficulty is referred to as sustainable development [23]. Sustainable development has become a prominent focal point in the vision, mission, and strategies of research institutions, organizations, and governments worldwide [24]. The concept of

sustainability is commonly defined as the triple bottom line, as proposed by Elkington [25], which entails the harmonization of the three fundamental dimensions of economy, environment, and society.

In light of the growing prominence of the Digi-E, scholars have begun to investigate the economic, environmental, and social ramifications of digitalization. Digitalization has emerged as a significant catalyst for development in the context of a post-epidemic environment and sluggish world economy [26]. This initiative presents an opportunity to address pressing issues of resource depletion and environmental contamination. The existing body of research on the correlation between digital economic environment and sustainable development can be categorized into three distinct groups.

The first category of prior literature explores the impact of digitalization on economic expansion worldwide. Several scholars have argued that the establishment of communication networks contributes to economic development (ED), highlighting the favorable outcome of digitalization on ED [27]. Jiménez et al. [28] reported that connectivity to the internet contributes to economic advancement. Ren et al. [20] contend that digitalization improves resource efficiency, making it easier to precisely match the supply and demand of consumers, improve managerial performance, and increase the productivity of all factors in a business. Digitalization processes enhance the operational capacity and adaptability of businesses, as digital financial solutions assist enterprises in mitigating challenges related to securing funding [29, 30].

The second category of studies examines the effects of digitalization on environmental sustainability. Nevertheless, no consensus has been reached within the academic community regarding the impact of digitalization on ecological sustainability. The prevailing consensus among scholars is that digitalization has a favorable effect on the ecological environment. The utilization of digitalization enhances the productivity of conventional production systems and diminishes resource depletion by enhancing the effectiveness of supply and demand coordination, improving efficiency through innovative technologies, and reducing the ecological costs of production [31]. Moreover, digitalization plays a crucial role in facilitating the transition towards environmentally sustainable production practices and guiding consumers towards adopting green consumption patterns. This was achieved by establishing an environmental- friendly sharing platform, [32].

The third category examines the influence of digitalization on the different aspects of social dimension of sustainable ED. The digitalization process has been found to have positive influence on different aspects of education only, together with knowledge acquisition, learning capacity, multitasking skills, and student innovation [33-35]. The social growth of a people is contingent on the use of digitalization, as the introduction of technologies leads to improvements in social development indicators. Hence, the results align with prevailing theory and extant scholarly work [36]. Hence, recent research findings have prompted the adoption of digitalization in diverse learning and public institutions [37].

Furthermore, there are many studies that have focused on the role of the digital economy in sustainable development, innovation, economic development, etc. [38-43]. The current study provided some helpful insights; however, there are still some unanswered questions that need to be addressed. Likewise, the prior literature ignored the third dimension of sustainability (the social dimension) and considered only two dimensions of sustainability (economic and environmental) while investigating the impact of digitalization on economic growth and termed it green economic growth. Therefore, this study considers the social dimension along with the economic and environmental dimensions of sustainability while studying the impact of digitalization on growth. Thus, this study uses all three dimensions of sustainability (social, economic, and environmental) to measure SRD, which has not been previously considered by the research community. Moreover, though the study's focus on the digital economy is praiseworthy, it may have benefited from a closer look at how digital finance moderates the connection between the two in order to promote sustainable regional development. Moreover, the moderating role of Digi-F has not been explored in previous studies on digitalization and SRD. The earlier studies may also be missing some of the nuanced dynamics of the digital economy. The results may be improved if the study thoroughly examined sustainability factors, took regional differences and variability into account, and dug further into the mechanisms and causal links. In addition, to make the research more practical, it should explicitly explore policy implications and recommendations and include external factors and contingencies. This will help stakeholders and policymakers. Based on these research gaps, the current study is expected to provide a better understanding of SRD, not just of the green economy, which is not sufficient to describe sustainable development. This study will help policymakers and research communities better understand the importance of digitalization and Digi-F in the digital landscape and foster sustainable regional development.

The primary objective of this study is to analyze the role of the Digi-E in sustainable regional development. For this purpose, we considered three main pillars of sustainable development: economy, environment, and society. Moreover, the moderating role of digital financial inclusion (Digi-F) in the relationship between digitalization and SRD was explored. Within the framework of the Digital Economy (Digi-E), this research significantly contributes to our understanding of sustainable regional development (SRD). By delving deeply into the economic, environmental, and social

aspects of sustainable development, we are able to accomplish our main goal of assessing Digi-E's function in SRD. This research fills a gap in our understanding of the digital economy's impact on regional sustainability by delving into these factors. Furthermore, the study adds to the existing body of knowledge by delving into the moderating effect of Digi-F on the relationship between digitalization and SRD. This sophisticated method acknowledges the complex relationship between easy access to finance and the effect of the digital economy on long-term sustainability. In addition to bolstering our theoretical knowledge, the results have real-world consequences for stakeholders and policymakers. Through the examination of Digi-F's moderating influence, this study offers valuable insights into how digital financial inclusion can be used to achieve more sustainable regional development outcomes in the dynamic digital economy.

The remainder of the study is divided into several sections. The literature and research gaps are reviewed in the next section. The theoretical framework is included in the third section, which entails the impact of digitalization in the economic environment on SRD and also describes the influence of Digi-F on SRD. The fourth section explains the materials and methods used to comply with the objectives of the study. The fifth section presents the results of the study, and the sixth section presents a discussion. The last section presents conclusions and policy implications.

## Materials and Methods

### Theoretical Analysis

The digital economic environment directly and indirectly affects SRD. The influence mechanism of the digital economic environment on SRD is shown in Fig 1.

*The Digital Economic Environment Impact on SRD*

Digitalization is critical to economic change because it promotes inclusive development and increases productivity across all industries. Digital finance and commerce have emerged as key contributors to the transformational process in this context. Recently, there has been increased emphasis on the convergence between digitalization and sustainability. Digitalization plays a significant role in replacing traditional methods of economic growth and competitiveness. Additionally, digitalization has been found to enhance productivity in various economic sectors, such as industry and trade, while contributing to resource conservation and pollution reduction. These findings suggest that digitalization can contribute to sustainable development [44, 45].

Several researchers have conducted research on the environmental implications of Digi-E growth. Their results suggest that, in addition to accelerating economic growth, the rapid expansion of Digi-E, notably via the Internet, significantly improves ecological performance. [46, 47]. The growth of the Digi-E, illustrated by the

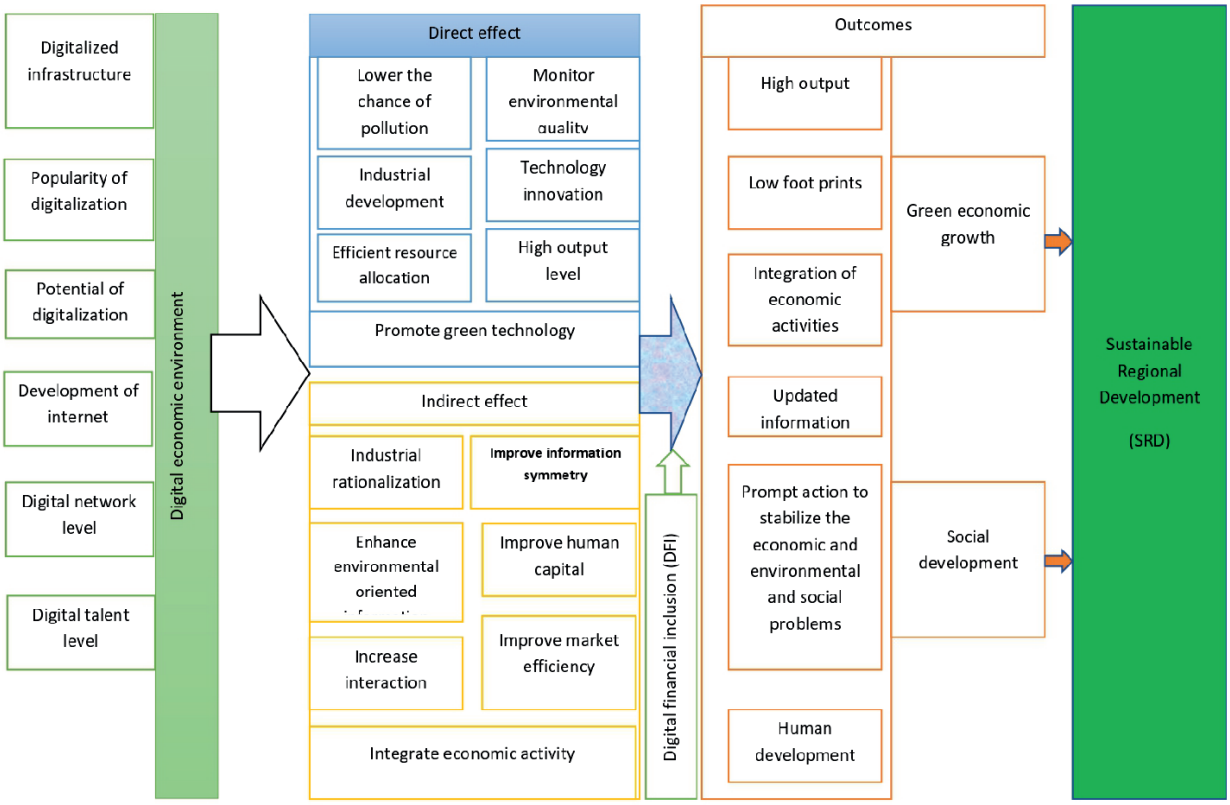


Fig. 1. Mechanism analysis between digital economic environment and sustainable regional development.

Internet, significantly improves ecological performance. [46, 47]. The growth of the Digi-E, illustrated by the Internet, has yielded significant economic advancements and notable enhancements in environmental sustainability. The emergence of the Digi-E has had a significant influence on greenhouse gas emissions such as CO2, serving as a prominent indicator of transformation within the context of climate change. Advancements in the Digi-E have led to an increase in the level of digital technology. Digitalization compels enterprises that exhibit high levels of pollution and emissions to allocate greater resources to research and development. The objective is to attain efficient resource utilization and promote SRD through environmentally friendly practices [48]. However, the advent of the internet has resulted in significant transformations in connectivity and communication. It expedited the pace at which information is transmitted, enhanced accessibility to a wide range of information, and facilitated greater opportunities for knowledge dissemination, utilization, and innovation. This has enabled conventional industries to leverage the widespread adoption and adaptation of digital technology for industrial advancement, thereby fostering technological catch-up and economic integration. Additionally, the Internet has played a pivotal role in the growth of ecologically sustainable industries [49], while simultaneously mitigating harmful emissions [50]. The digitization process promotes SRD by increasing the efficiency and effectiveness of industrial structures. Digitalization can improve conventional industries by allowing for more efficient resource utilization and allocation, and promoting the harmonious expansion of multiple sectors [51, 52]. It also improves the movement of innovative components because of their low cost, environmental friendliness, greater efficacy, ease of reproduction, and broad accessibility. Furthermore, digital elements solve the inherent limitations of traditional component manufacturing. Furthermore, the digitization process boosts market rivalry and increases the rate of return on numerous factors. Furthermore, it promotes information-sharing, integration, and coordinated growth between the upstream and downstream sectors of the industrial chain. The adoption of environmentally friendly industrial practices makes it easier to achieve both resource preservation and ED [53].

China has transitioned from a rapid development phase to a phase of slower economic growth, corresponding to the expansion and increased use of the Digi-E [54]. Nonetheless, China's rapid economic growth can be described as a simplified development model. ED has slowed owing to a variety of issues, including an inefficient industrial framework, declining demographic advantages and a drop in total factor productivity. As a result, technical innovation and demand stimulation have emerged as key drivers of future sustainable ED [55, 56]. Digitalization is the driving force behind the formation of fresh forms of dynamic energy, enabling sustainable development and distinguishing the Digi-E.

*Digitalization Spatial Impact Analysis on SRD*

In comparison to the conventional economy, the digitalization process exhibits numerous characteristics of information-network collaboration. This phenomenon lowers temporal and spatial barriers, thereby broadening and intensifying economic interactions between diverse geographical regions. Digitalization plays a vital part in stimulating the pervasive adoption of sustainable technology and digital knowledge across a variety of regions. This expedites the dissemination process by accelerating the establishment of a regional green innovation system and circumventing spatial constraints. In addition, it significantly improves the efficient allocation of resources and overall structure of the industry. On the other hand, the participation of users on various platforms improves their comprehension and practice of sustainable development. The incorporation of digital platforms permits diverse areas to observe ecological quality and resource efficiency actively, thereby promoting the collective development of green technology. There is evidence that the digitalization process has a spatial spillover effect, resulting in economic growth improvements in adjacent cities [57]. Consequently, the digitalization process has a spatial spillover effect on SRD.

*Digital Financial Inclusion (Digi-F) Impact on SRD*

The use of cost-effective digital techniques to expand formal financial services to people who are presently excluded from or have limited access to the financial system is referred to as Digi-F. These services are targeted at these people's unique requirements and are supplied responsibly, guaranteeing affordability for clients and sustainability for service providers [58]. The use of digital money has proven beneficial in reducing environmental inequality. Its adoption has a greater effect on lowering industrial pollution emissions in areas with high pollution levels than in those with low pollution levels. Consequently, digital banking has the ability to close pollution gaps in various places. According to Li et al. [59], digital financial development can reduce regional economic gaps and facilitate sustainable regional development (SRD). Digi-F is critical for providing widespread access to digital financial services and, as a result, encouraging long-term economic growth. Tay et al. [60] emphasize the need to align and facilitate Digi-F activities and endeavors to successfully contribute to the attainment of the SDGs by 2030. According to the findings of this study, emerging countries, especially those in Asia, are aggressively pursuing and improving Digi-F as a method of reducing economic disparity among their people. Digi-F has the potential to open new opportunities for low-income people and businesses, as well as small-scale businesses, who now have little or no access to traditional financial services. Digi-F is critical for increasing a country's financial inclusion and achieving long-term development [61].

## Variables' Description

### *Sustainable Regional Development (SRD)*

To measure SRD, we have considered three main pillars of sustainable development: economic, environmental, and social sustainability [62]. Consequently, regional development should be economically viable, environmentally friendly, and socially acceptable. Measuring SRD is not an easy task, but the practice of selecting suitable variables to measure SRD is widely adopted around the world. These variables are known as "Indicators" [63]. The current study selected the prominent variables that would be able to describe the suitability for measuring SRD in provinces in China. Table 1 describes those variables and their units. The SRD of the provinces is an ED model that not only considers the regional product and inputs such as fixed capital and labor but also focuses on environmental sustainability and efficient utilization of resources. For environmental sustainability, we have considered three indicators, including the energy consumption of provinces. Industrial water discharged, and carbon footprints. Each type of energy source consumed was considered, like coal, gas, electricity, LPG, petrol, etc. Moreover, the human development index of each province was also incorporated for social sustainability. HDI is providing a more comprehensive picture of human development (social sustainability) in the region by considering the three main factors, such as education, life expectancy, and income [64]. Thus, the current SRD model describes the synchronized advancement of economic expansion, environmental preservation, and social development.

The current study has adopted principal component analysis to measure the SRD index (henceforth SRDI) based on the above indicators. Moreover, following ul-Haq and Boz [62], the composite SRDI values fall between 0 and 1. In this measuring procedure, the variables were first normalized by using the mini-maxi formula. The purpose of this activity was to make the indicators unitless. After that, the indicators were used in PCA for calculating the weights to combine all indicators into one index form. The value close to 1 describes the high level of SRD in the $i^{th}$ province.

### *Digi-E Index*

Digitalization is a widely used concept that is measured by considering different indicators. However, there is an absence of an inclusive understanding of the Digi-E concept, resulting in certain shortcomings in the academic and logical construction of the measurement system. Consequently, the study findings may also exhibit a biased perspective. This paper aims to develop a Digi-E index across six dimensions. Table 2 describes these dimensions and the correlating indicators that have been used to calculate the Digi-E index. The digital infrastructure provides valuable frameworks for understanding the growing interconnections within information system communities in the modern age. It plays a crucial role in facilitating the provision of information services in various functional domains, including health, transportation, and business. They achieve this by establishing a socio-technical framework that enables partnership governance, resource sharing, and system integration [65]. The acceptance of digital innovations is reflected in the popularity of the Digi-E among residents. It also contributes to sustainable development in economically productive sectors. Moreover, the potential of digitalization describes the growing acceptance of digitalization and how it contributes to the economies of the regions by absorbing the labor force and growing the IT market. The internet's development has become a basic necessity of society, which assists the government and public to perform

Table 1. Dimensions and indicators of SRD.

| Outcome | | Dimensions | Indicators | Definition | units |
|---|---|---|---|---|---|
| Sustainable regional development (SRD) | Green Economy | Economics | GDP | Gross regional product of provinces | Million Yuan |
| | | | Capital Stock | Fixed asset investment of provinces | Million yuan |
| | | | Labor | Employed persons in three major sectors of provinces | Numbers |
| | | Environment | Energy Consumption | Renewable and non-renewable energy consumption | Different units |
| | | | Industrial Waste water | Industrial Waste water discharged | Tonn |
| | | | $CO_2$ emission | | Million ton (MT) |
| | Human Development | Social | Education | Human Development index (HDI) of provinces | --- |
| | | | Life Expectancy | | |
| | | | Income | | |

official and civil activities [66]. The extent and variety of digital services expand as digital literacy increases, resulting in the rapid evolution and advancement of digitalization. Therefore, the enhancement of digitalization capability is subsequently accompanied by environmental, economic, and social well-being [67]. Following the entropy weight method [68], the current study measured the composite Digi-E index quantitatively in an objective manner.

*Moderating Variables*

The limited availability of formal services has negative implications for the wellbeing of the citizens and their social cohesion and protection. This, in turn, hampers the overall sustainable ED of nations [69]. Therefore, Digi-F is essential for the poor to avail financial services for sustaining their livelihoods and for businessmen to stabilize their business operations, which ultimately contribute to the economic growth of the economy [60]. It presents novel perspectives for socio-economically disadvantageous people and small enterprises with restricted or non-existent entry to the traditional financial system. Moreover, it plays a crucial role in enhancing a nation's financial inclusion, contributing to the realization of SDGs, and facilitating greater economic growth [61]. Ozili [70] described that Digi-F provides a platform for businesses to perform secure investment, saving, and capital formation and it facilitates economies in accomplishing their SDGs by 2030 [71]. The current study is expected to show that Digi-F inclusion can play an important moderating role between the digitalization economy and the regional sustainable development. The provincial Digi-F index of China (developed by Peking University China) was utilized in current study..

*Control Variables*

The demographic factors among the provinces are different, which may induce regional sustainable development and the digitalization of the economy differently. We have included some control variables in the empirical analysis that may also influence SRD. This activity assists us in controlling the omitted variable bias. The provincial government intervenes in economic activity to control market inefficiencies and also control provincial resource allocation. Thus, we used government intervention (GovI) as a control variable in the current study. For this, we used the ratio of government expenditure in science and technology to GDP as a proxy variable for the GovI [72]. Second, the trade openness among the provinces inhibits the efficiency of sustainable development in the region. Thus, we have considered the natural log of total value of imports and exports (destination and cargo) as a proxy variable for trade openness (ToP). The natural log of population in terms of the resident population

Table 2. Indicators of Digi-E index.

| | Indicators | Definitions | Units |
|---|---|---|---|
| Digital economy index | Digital Infrastructure | Broadband ports of internet per capita | Numbers |
| | | Cell phones per capita | Numbers |
| | | Computer used per 100 persons | Numbers |
| | | Business Volume of Telecommunication Services | Million Yuan |
| | Digital Popularization | Popularization Rate of Mobile Telephone | Set/100 person |
| | Potential of Digitalization | Employed Persons in Urban Units, Scientific Research and Technical | Numbers |
| | | Income from IT Service | Yuan |
| | | Total Value of Technical Market | Yuan |
| | Internet Development | Length of Optical Cable Lines | Km |
| | | Broad Band Subscribers of Internet | Number |
| | | Capacity of Mobile Telephone Exchanges | Numbers lines |
| | Digital network level | Mobile phone subscribers | Number |
| | | Users of Digital TV | Numbers |
| | | Mobile internet subscribers | Numbers |
| | Digital talent level | Educational Funds | Yuan |
| | | Inventions Patents granted | Numbers |
| | | Students enrolled in higher education institutes | Numbers |

at the year-end of each province was used because the population of a region puts pressure on the utilization of natural resources and limits long-term economic growth and development [73]. At last, we have also considered urbanization, and residences in urban entities at year end were used as a natural log of urban population as a proxy variable for urbanization.

Factors such as population, urbanization, trade openness (ToP), and government intervention (GovI) are crucial in determining the nature of sustainable regional development. By directing policies that foster ecological preservation, social justice, and economic expansion, when properly executed, government intervention can spur sustainable development [74, 75]. Incentives for green activities, investments in infrastructure, and legislation that supports them can all add up to a more sustainable region. According to Sheikh et al. [76], trade openness influences sustainable development's economic component. Economic growth, innovation, and job prospects can all be enhanced by gaining access to global markets. To minimize unintended social and environmental impacts, it is important to carefully analyze the type of trade activities when assessing the effect of trade openness on sustainable development [77]. The sustainability equation's most important variables are the dynamics of population and urbanization. The stress on resources and infrastructure caused by a rapidly expanding human population has the ability to exacerbate existing social and environmental disparities [78]. Conversely, there are advantages and disadvantages to urbanization. Urban development that is well-planned can increase productivity, service accessibility, and economic activity, while uncontrolled urbanization can lead to pollution, social inequalities, and congestion [79].

## Data Sources

The current study used the data of 30 provinces from 2011 to 2021 for analyzing the impact of Digi-E on SRD, while we have considered the data from 2011 to 2018 for analyzing the synergistic impact of Digi-E and Digi-F on SRD due to the data availability regarding Digi-FI. It is highly probable that the chosen provinces encompass a significant amount of China's economic activity. By focusing on 30 provinces, the research may look at how the rise of digital finance and the digital economy has affected long-term regional planning in places that are crucial to the national economy. Both local initiatives and central government policies have an impact on the growth of China's regions. Researchers can learn more about the effects of the digital economy and digital finance on sustainable development by looking at a variety of provinces and their policies and initiatives. Important policy suggestions can be derived from this. Using panel data from all 30 provinces in China yields a complete and consistent dataset that stands the test of time. Because of this, we can look at how sustainable development indicators have changed over time, how widespread the use of the digital economy has been, and how digital finance has moderated this tendency. When data is consistent across provinces, it makes the study more reliable and valid. To do a comparison analysis, it is necessary to examine more than one province. The study can take into account variances in economic structures, geographical features, and regulatory contexts to evaluate variations in the influence of digital finance and the digital economy on sustainable regional development. This comparative study improves understanding of regional dynamics by making them more complex. Overall, this study's focus on 30 provinces in China is warranted since it has the ability to offer policymakers in the region information that is reflective of the diversity of the country. The selected method permits an exhaustive investigation into the interconnected webs of digital finance, sustainable development, and the digital economy in various Chinese regional settings. The data was collected from the National Bureau of Statistics of China, the China Statistical Year Book, the Global Data Lab, and carbon emission Accounts and Data sets. The average growth rate method was used to impute the missing values in the sample.

## Model Specifications

### *Benchmark Regression Model*

For conducting the empirical analysis, we have constructed the econometric model through a series of steps. In order to explore the impact of Digi-E on SRD, the benchmark regression model is utilized to explore the linear relationship between Digi-E and SRD. At first, we investigated the relationship between the Digi-E and SRD without considering the control variables, and model A has been constructed. Further, the linear relationship has been confirmed by incorporating the control variables, and Model B has been formulated. Where $\mu_{it}$ represents the individual fixed effect, and $\delta_{it}$ describes the random error term.

$$SRD_{it} = \beta_o + \beta_1 Digi - E_{it} + \mu_{it} + \delta_{it} \quad \text{Model A}$$

$$SRD_{it} = \beta_o + \beta_1 Digi - E_{it} + \beta_2 GovI_{it} + \beta_3 ToP_{it} + \beta_4 Pop_{it} + \beta_5 Urban_{it} + \mu_{it} + \delta_{it} \quad \text{Model B}$$

Before analyzing the moderating role of digital financing (Digi-F), we constructed Model C for exploring the individual impact of Digi-F on SRD without control variables and then with control variables (Model D).

$$SRD_{it} = \beta_o + \beta_1 Digi - F_{it} + \mu_{it} + \delta_{it} \quad \text{Model C}$$

$$SRD_{it} = \beta_o + \beta_1 Digi - F_{it} + \beta_2 GovI_{it} + B_3 ToP_{it} + \beta_4 Pop_{it} + \beta_5 Urban_{it}\, \mu_{it} + \delta_{it}$$

Model D

At last, the interaction term of Digi-F with the Digi-E index was incorporated to analyze the moderating role of Digi-F between digitalization in the region and SRD. For this purpose, first Model E was constructed without control variables and then Model F with control variables.

$$SRD_{it} = \beta_o + \beta_1 Digi - E_{it} + \beta_2 Digi - F_{it} + \beta_3 Digi_{it} * Digi - F_{it} + \mu_{it} + \delta_{it}$$

Model E

$$SRD_{it} = \beta_o + \beta_1 Digi - E_{it} + \beta_2 Digi - F_{it} + \beta_3 Digi_{it} * Digi - F_{it} + \beta_4 GovI_{it} + B_5 ToP_{it} + \beta_6 Pop_{it} + \beta_7 Urban_{it} + \mu_{it} + \delta_{it}$$

Model F

It is necessary to notice that the digitalization in the region exhibits a distinct characteristic of "spatial effect" on SRD. The development of digitalization in a particular region extends beyond local economic activities and lowers carbon emissions. It also affects living and economic activities in other regions through the transformation of information and the movement of economic resources [80]. In the provinces of China, the regional (provincial-level) development of digitalization may also have spatial features that influence regional sustainable development. It could be described based on the spatial and spill over impact of the internet on economic activities and SRD [81, 82].

Therefore, we have focused on the spatial effect characteristic of the Digi-E on the SRD. We explored the impact of Digi-E on SRD in a spatial context. The Spatial Durbin model was employed in this study, which is famous in the context of its practical applicability [83, 84]. This model is an amalgamation of the spatial lag (SL) Model and the spatial error (SE) model. The SLM considers the spatial correlation among the dependent variables, and the SEM concerns the spatial influences of the random disturbance error term. This study determines the spatial effects of Digi-E on SRD, both within and across different regions. The expression of the Spatial Durbin model is as follows:

Spatial Durbin model for Digi-E and SRD

$$SRD_{it} = \partial_o + \rho W SRD_{it} + \partial_1 WDigi - E_{it} + \partial_1 Digi - E_{it} + \partial_2 WGovI_{it} + \partial_2 GovI_{it} + \partial_3 WToP_{it} + \partial_3 ToP_{it} + \partial_4 WPop_{it} + \partial_4 Pop_{it} + \partial_5 WUrban_{it} + \partial_5 Urban_{it} + \mu_{it} + \delta_{it}$$

Spatial Durbin model for Digi-F and SRD:

$$SRD_{it} = \partial_o + \rho W SRD_{it} + \partial_1 WDigi - F_{it} + \partial_1 Digi - F_{it} + \partial_2 WGovI_{it} + \partial_2 GovI_{it} + \partial_3 WToP_{it} + \partial_3 ToP_{it} + \partial_4 WPop_{it} + \partial_4 Pop_{it} + \partial_5 WUrban_{it} + \partial_5 Urban_{it} + \mu_{it} + \delta_{it}$$

Spatial Durbin model for synergistic impact of Digi-E and Digi-F on SRD:

$$SRD_{it} = \partial_o + \rho W SRD_{it} + \partial_1 WDigi - E_{it} + \partial_1 Digi - E_{it} + \partial_1 WDigi - F_{it} + \partial_1 Digi - F_{it} + \partial_1 W(Digi - E_{it} \times Digi - F_{it}) + \partial_1 (Digi - E_{it} \times Digi - F_{it}) + \partial_2 WGovI_{it} + \partial_2 GovI_{it} + \partial_3 WToP_{it} + \partial_3 ToP_{it} + \partial_4 WPop_{it} + \partial_4 Pop_{it} + \partial_5 WUrban_{it} + \partial_5 Urban_{it} + \mu_{it} + \delta_{it}$$

Here, i depicts the provinces of China, and t describes the time (years). The SRD is the sustainable regional development index; Digi-E describes the economy/ regional digitalization index. The Govl denotes the government interventions, ToP shows trade openness of provinces, Pop is population size, Urban is urbanization. $\rho$ denotes the spatial spillover effect coefficient or spatial autoregressive coefficient of SRD, $\partial$ describes the coefficient of each variable, and W depicts the spatial weights matrix. This econometric method is well suited for the current study. Because it takes spatial dependence into account, acknowledging that surrounding regions impact each other's development, the Spatial Durbin Model is crucial for investigating the Digi-E and SRD links. It keeps track of spatial autoregressive effects that help us understand how regions change over time by looking into how Digi-E affects the SRD of both the affected areas and areas close by. By taking into account the fact that digital economic activity and SRD indicators occur simultaneously, the model is able to address endogeneity concerns and guarantee reliable results. Recognizing that the relationship between Digi-E and SRD differs between locations, it accounts for spatial heterogeneity, which is crucial for developing region-specific policies. Incorporating spatial links allows the model to shed light on the effects of policies across regions, which is useful for developing coordinated strategies. For better policymaking, improved predictions of Digi-E's effect on SRD are essential, and enhanced predictive accuracy makes this possible. With the model's help, we may overcome problems with spatial autocorrelation and get more reliable parameter estimations by accurately representing spatial structures.

## Results

Descriptive analysis describes the mean, standard deviation, minimum, and maximum values of the variables in Table 3. The mean value of SRD (0.582) is closer to the maximum than its minimum value. It describes how SRD is good in the provinces. The Digi-E index mean value is far away from its maximum (0.903), which depicts that the overall digitalization level in the provinces is not at its highest level over the period analyzed. The Digi-F mean value seems closer to its maximum value than its minimum, which implies that the digital financial level is largely penetrated in the provincial economy. Concerning the control variables, the mean value of GovI is 0.0046, which describes that the local government's expenditure on science and

Table 3. Descriptive analysis of variables.

| Variables | Obs. | Mean | SD | Mini. | Maxi. |
|---|---|---|---|---|---|
| SRDI | 360 | 0.582 | 0.185 | 0.109 | 0.827 |
| Digi-EI | 360 | 0.369 | 0.126 | 0.043 | 0.903 |
| Digi-FI | 240 | 188.19 | 84.98 | 18.33 | 377.73 |
| GovI | 360 | 0.0046 | 0.0026 | 0.0016 | 0.0129 |
| ToP | 360 | 17.64 | 1.62 | 12.65 | 21.11 |
| Pop | 360 | 8.20 | 0.74 | 6.33 | 9.45 |
| Urban | 360 | 0.59 | 0.12 | 0.34 | 0.90 |

technology is only 0.46% of the regional gross product. It is far from its maximum and closer to its minimum value, which implies that the local government's expenditure is much lower as compared to its regional gross product. The mean of Top (trade openness level) of 17.64 is much closer to the maximum than its minimum, which discloses that the provinces have a high degree of openness to the outside economy. The population and urbanization means are far from their minimum, which implies an increasing population and urbanization level in the province over the analyzed period.

To overcome the problem of multicollinearity among the variables, we first analyzed the correlation scores among all variables. In this regard, the outcome of the correlation matrix depicts that the variables are not highly correlated. The highest correlation value between Digi-E and Digi-F is 0.671. After that, the Digi-FI and SRDI have a correlated value of 0.573, while the correlated value between the Digi-E and SRD is 0.543. All the other variables have correlated values with each other of not more than 0.54. The mean value of VIF 3.78 less than 10 describes a negligible multicollinearity

Table 4. Correlation and VIF analysis.

| | SRDI | Digi-EI | Digi-FI | GovI | ToP | Pop | Urban | VIF-value |
|---|---|---|---|---|---|---|---|---|
| SRDI | 1 | | | | | | | 4.62 |
| Digi-EI | 0.543 | 1 | | | | | | 3.71 |
| Digi-FI | 0.573 | 0.671 | 1 | | | | | 3.09 |
| GovI | 0.432 | 0.482 | 0.512 | 1 | | | | 2.74 |
| ToP | 0.273 | 0.432 | 0.473 | 0.374 | 1 | | | 2.48 |
| Pop | 0.432 | 0.527 | 0.289 | 0.276 | 0.472 | 1 | | 3.77 |
| Urban | 0.503 | 0.472 | 0.382 | 0.381 | 0.388 | 0.409 | 1 | 6.09 |

Table 5. Basic regression results of impact of Digi-Ei on SRD.

| Variables | Model A | Model B | Model C | Model D | Model E | Model F |
|---|---|---|---|---|---|---|
| Digi-EI | 0.324*<br>(0.098) | 0.297*<br>(0.085) | | | 0.329*<br>(0.076) | 0.237*<br>(0.018) |
| Digi-FI | | | 0.208**<br>(0.109) | 0.195*<br>(0.053) | 0.255**<br>(0.150) | 0.173**<br>(0.083) |
| Digi-EI × Digi-FI | | | | | 0.472*<br>(0.055) | 0.543*<br>(0.083) |
| βo | 2.453*<br>(0.754) | 2.332*<br>(0.893) | 4.29*<br>(1.15) | 5.09*<br>(1.42) | 3.82*<br>(1.07) | 4.18*<br>(1.32) |
| Control variables | No | Yes | No | Yes | No | Yes |
| Fixed effects | Control | Control | Control | Control | Control | Control |
| R2 | 0.618 | 0.722 | 0.562 | 0.691 | 0.682 | 0.747 |

Values in parenthesis describe standard errors. *, and ** shows significance level at 1% and 5% respectively.

effect between variables (Table 4). Thus, this implies that the data can be used for empirical analysis.

## Individual and Synergistic Impact of Digi-E and Digi-F on SRD

Table 5 presents the results of basic regression. These results imply that the individual impact of Digi-E on SRD with and without the incorporation of the control variables is significant at $p<0.01$. Without considering the control variables, the coefficient of Digi-E, ($\beta$=) 0.324, is slightly greater than ($\beta$=) 0.297 when all control variables were incorporated in the regression, but still, the coefficient was significant at $p<0.01$. This implies that the more economies are digitalized, the more SRD will be in the provinces of China. Similarly, the coefficients of Digi-F with ($\beta$ = 0.195) and without ($\beta$ = 0.208) control variables are also significant at $p<0.01$ and $p<0.05$, respectively. In terms of Digi-F's role

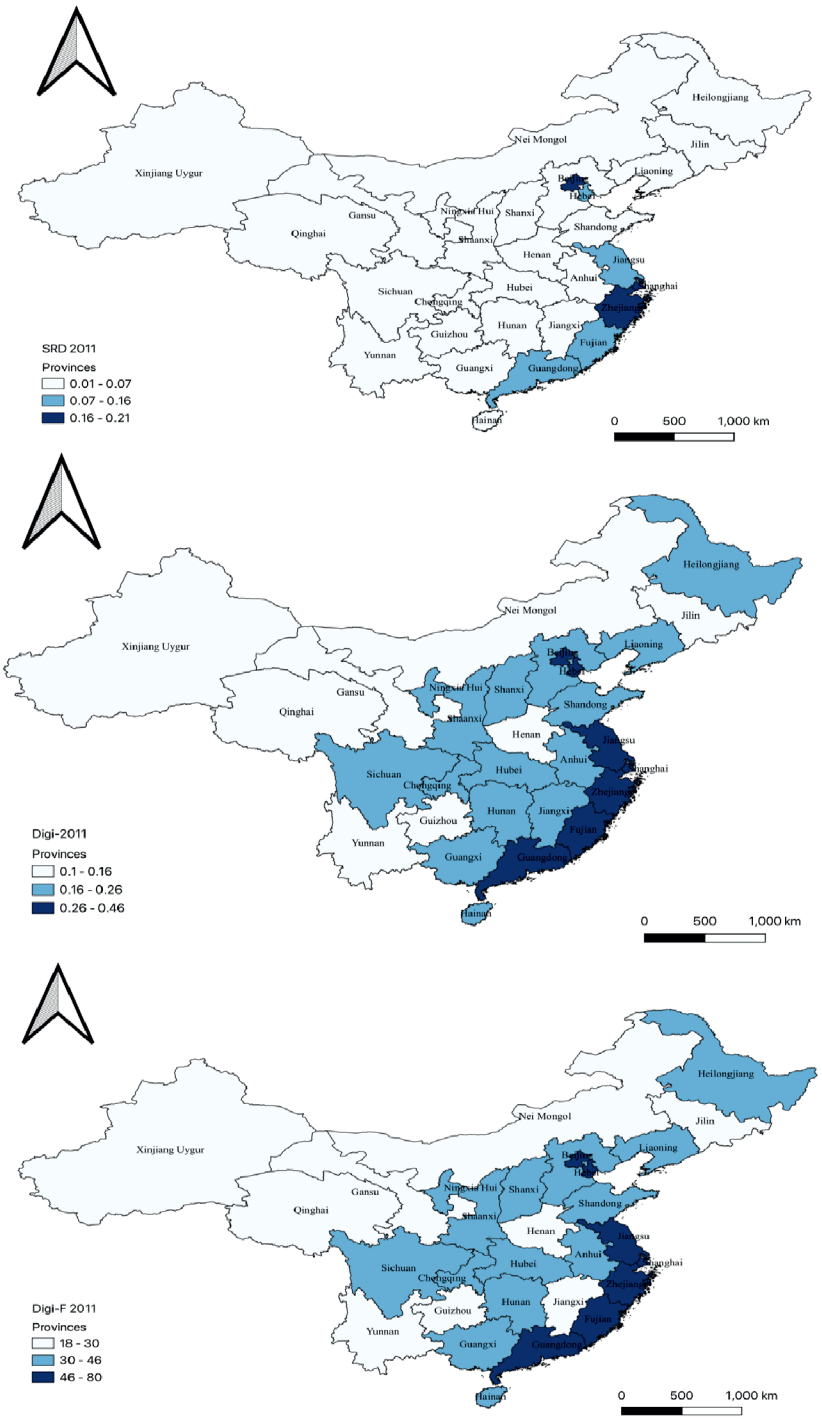


Fig. 2. Spatial-temporal evolution trend of SRD, Digi-E and Digi-F in 2011.

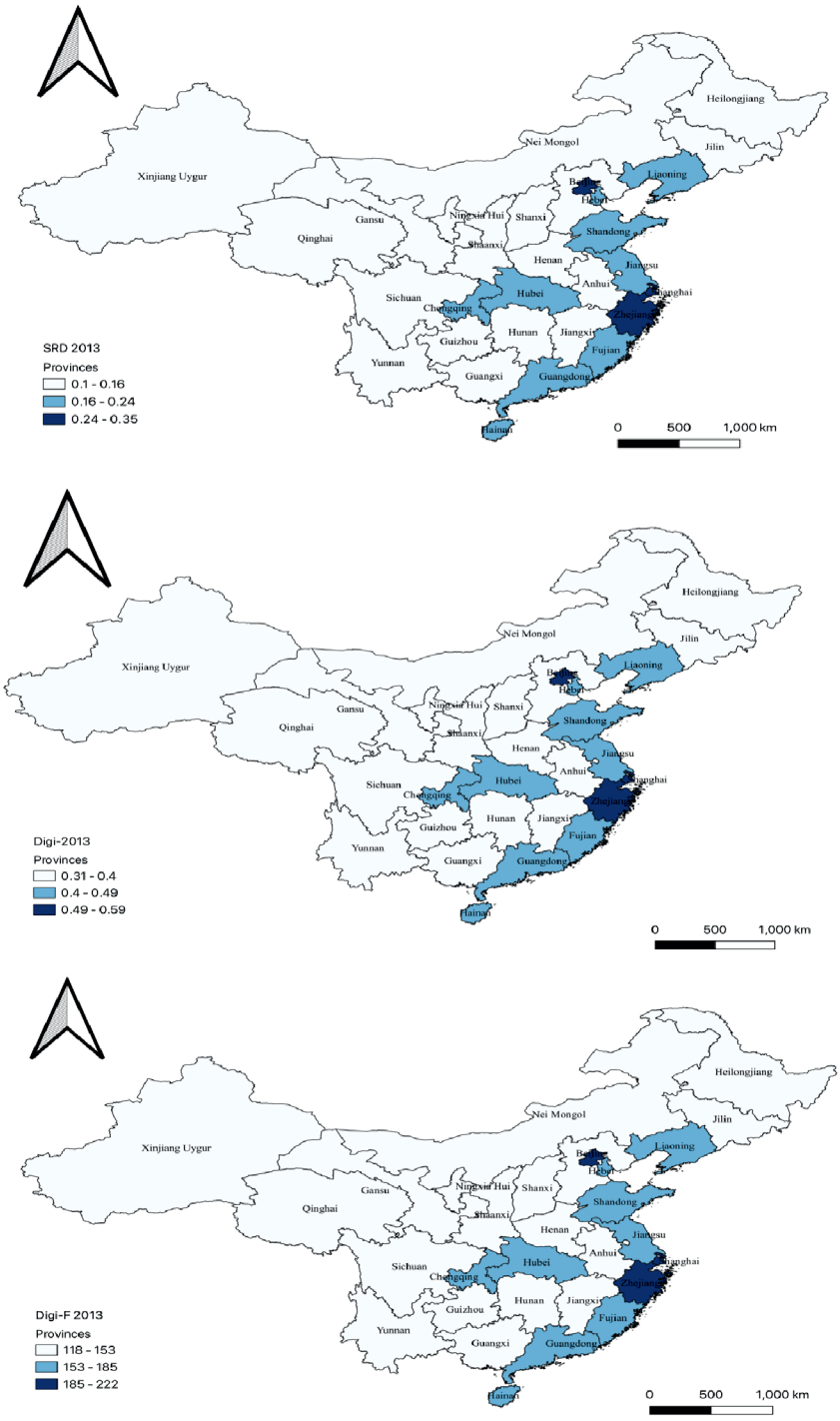


Fig. 3. Spatial-temporal evolution trend of SRD, Digi-E and Digi-F in 2013.

as a moderator between Digi-E and SRD, the effect of the Digi-E and Digi-F interaction term (Digi-EI×Digi-FI) on SRD is significant and positive at $p<0.01$. This implies that increasing Digi-F enhances the effect of the Digi-E on SRD. Therefore, when Digi-F increases, it assists the poorest economic agents in timely accessing financial resources, which may contribute to the sustainable economic, environmental, and social development of the regions.

## Spatial Distribution Trend of Digi-E, Digi-F and SRD

We incorporated the spatial distribution trend map of Digi-E, Digi-F, and SRD in 2011, 2013, 2015, and 2018, respectively. First, we applied Jenks natural breakdown method to classify SRD, Digi-E, and Digi-F into low, medium, and high levels. Observing Fig. 2 to 5, it is concluded that the provinces have achieved high levels of SRD in 2018 compared to 2011. Fig. 2 shows that all provinces have low or medium levels of SRD,

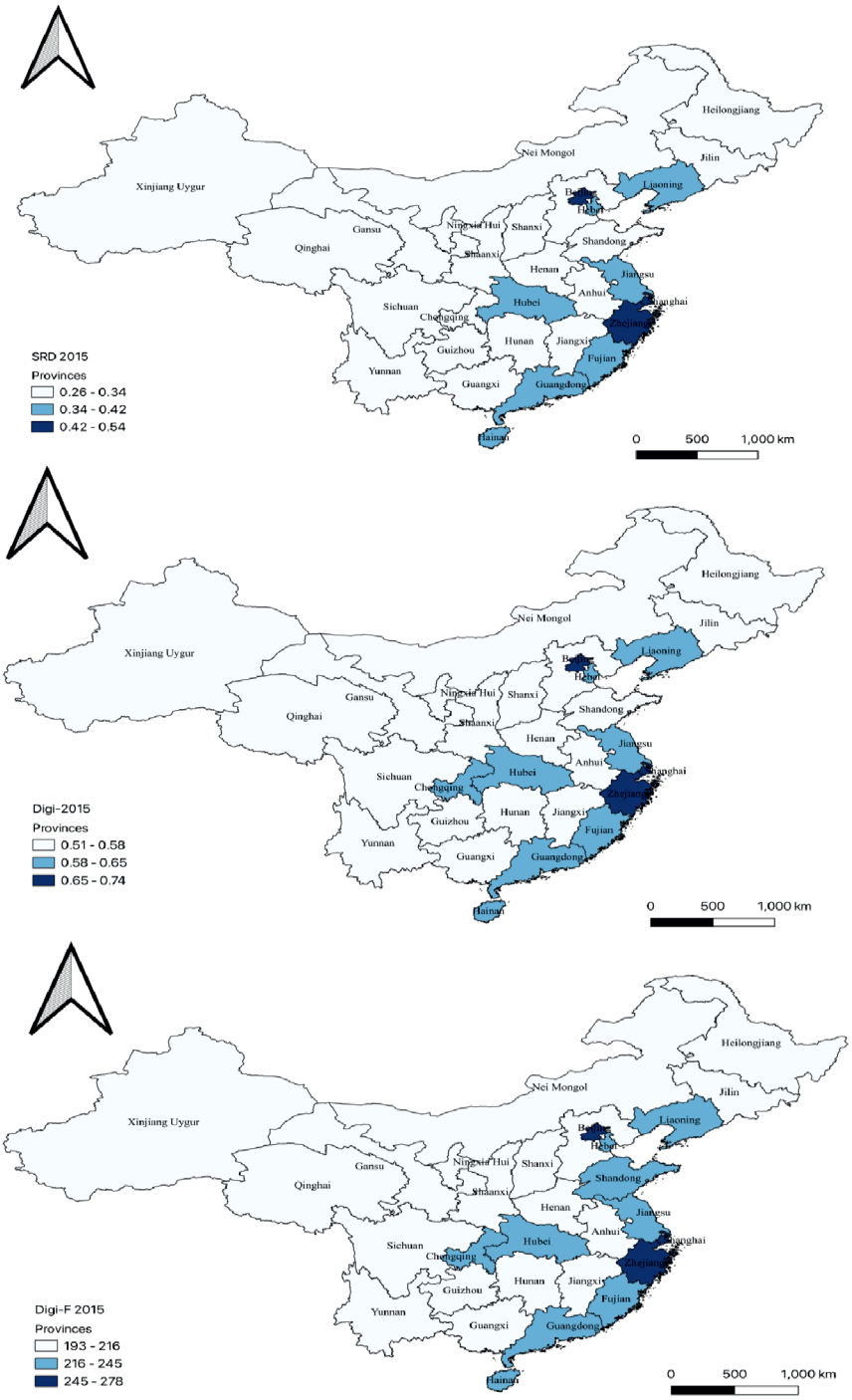


Fig. 4. Spatial-temporal evolution trend of SRD, Digi-E and Digi-F in 2015.

Digi-E level, and Digi-F, except for two provinces, Beijing and Zhejiang. In Fig 3, almost 09 provinces, including Liaoning, Hebei, Shandong, Jiangsu, Guangdong, Fujian, Hainan, Hubei and Chongqing, have approached the medium level of digitalization and 02 province including Beijing and Zhejiang also approached high level of digitalization in 2013, and Digi-F has approached its medium level in all these provinces, while all remaining provinces also improved their financial inclusion as compared to that in 2011. Concerning the SRD of provinces in 2013, all provinces have experienced improvements in their regional development, only two provinces, Beijing and Zhejiang, achieved a high level of sustainable development, and more five provinces also have achieved a medium level of sustainable development. Those five provinces have only a medium level of digitalization and Digi-F.

Fig. 4 describes that most of the provinces have started to achieve their good level of digitalization and Digi-F, but only a few of them have approached a high level of SRD in 2015. During the time period of 2013 to 2015, it was observed that all provinces have improved

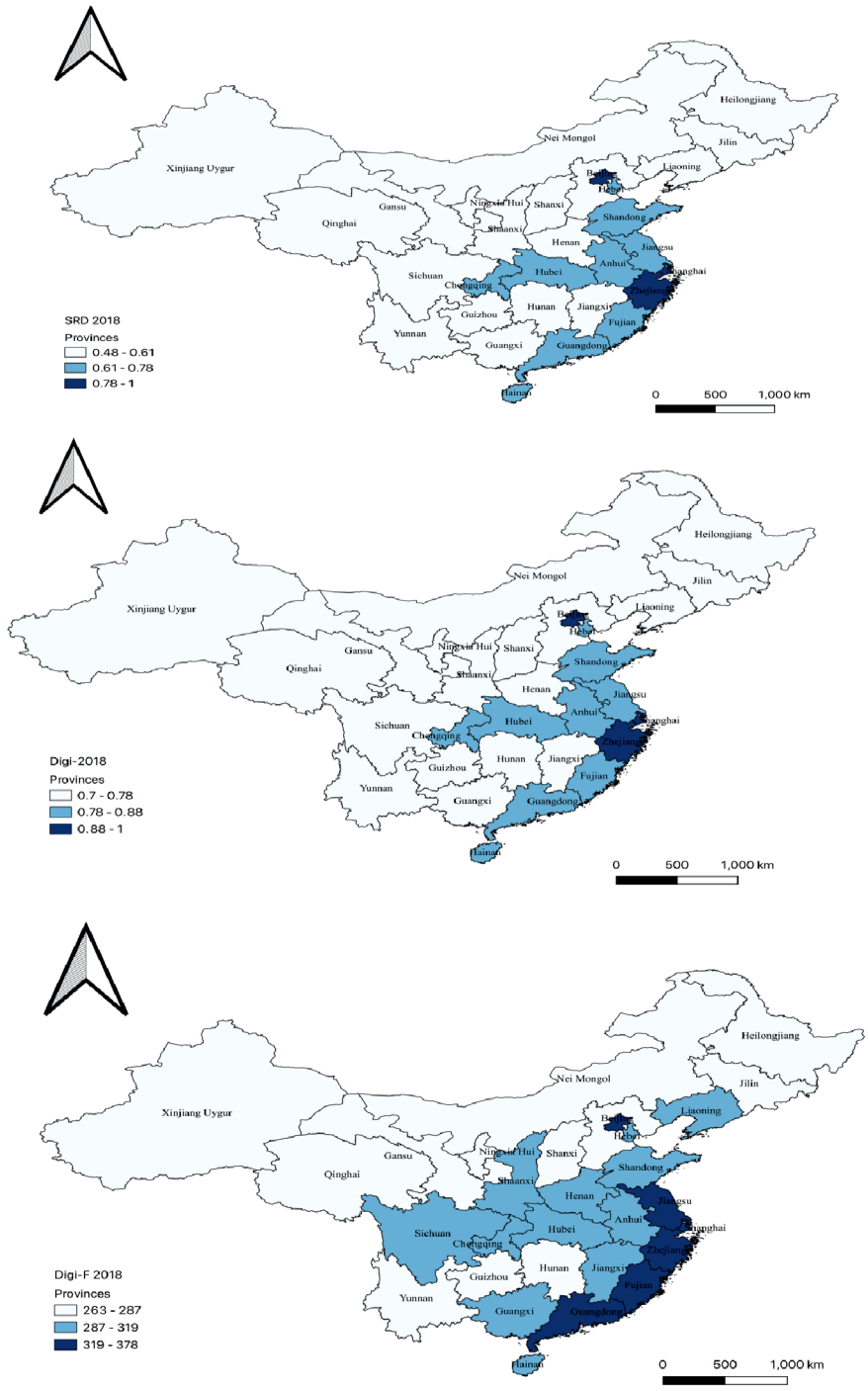


Fig. 5. Spatial-temporal evolution trend of SRD, Digi-E and Digi-F in 2018.

their digitalization, financial inclusion and SRD.

In Fig. 5, it is observed that most of the provinces have approached their good level of SRD in 2018, while only 9 of them have medium level of digitalization. Here it is also observed that approaching a high and medium level of Digi-F in the provinces has supported the impact of digitalization to achieve a good level of SRD (not less than 0.48). It could be said that the increase in digitalization, sustainable development, and Digi-F positively contributes to the relationship between digitalization and SRD.

## Spatial Model Results of Impact of Digi-E on SRD

Before proceeding towards the spatial Durbin model analysis, we have checked the spatial autocorrelation between the Digi-E and SRD by employing two types of weights: economic geography nested (W1) and distance matrix (W2). In this regard, the outcomes of Moran's I test have revealed that all the indices are significant at the 5% level of significance (Table 6), and it describes that the Digi-E and SRD are space-dependent.

## Spatial Regression Results Regarding the Individual and Combined Effect of Digi-E, Digi-F and SRD

As recommended by Elhorst et al. [85] for fixed effects, this study used both Hausman and LM tests. The conversion of the spatial econometric model into SAR and SEM models supports the choice of separate fixed effects. The Digi-E and Digi-F coefficient values were slightly higher than those observed in Table 7. Moreover, the spatial autoregressive coefficient of SRD was positive and significant ($p<0.01$). The individual impact of Digi-E on SRD implies a positive spatial spillover impact on the provinces' SRD. The degree of influence of Digi-E on SRD was higher under W2 (economic distance weight).

We have analyzed the robustness of our empirical results by changing the dependent variable. We have analyzed the robustness of our empirical results by

Table 6. Moran's, I test of Digi-E and SRD.

| Year | Digi-E | | SRD | |
|---|---|---|---|---|
| Spatial Matrix | W1 | W2 | W1 | W2 |
| 2011 | 0.342* (2.780) | 0.327* (4.192) | 0.539*(6.866) | 0.512*(5.505) |
| 2012 | 0.402* (4.102) | 0.398*(4.795) | 0.547*(7.207) | 0.520*(4.333) |
| 2013 | 0.372* (4.482) | 0.342*(3.758) | 0.563*(6.608) | 0.523*(3.289) |
| 2014 | 0.274* (3.079) | 0.236*(3.065) | 0.573*(6.070) | 0.542*(6.949) |
| 2015 | 0.574* (6.674) | 0.503*(5.988) | 0.582*(6.614) | 0.551*(2.355) |
| 2016 | 0.327*(3.893) | 0.309*(4.612) | 0.612*(3.363) | 0.560*(5.657) |
| 2017 | 0.273* (3.640) | 0.265*(4.732) | 0.578*(3.341) | 0.489*(2.843) |
| 2018 | 0.208* (3.250) | 0.187*(5.844) | 0.563*(5.027) | 0.473*(3.403) |
| 2019 | 0.311* (5.456) | 0.278*(6.465) | 0.547*(3.180) | 0.468*(2.476) |
| 2020 | 0.284* (6.311) | 0.255*(4.474) | 0.531*(2.289) | 0.463*(2.601) |
| 2021 | 0.193* (5.676) | 0.134*(6.091) | 0.519*(2.746) | 0.457*(3.570) |

Values in parenthesis describe standard errors. *, and ** shows significance level at 1% and 5% respectively.

Table 7. Spatial regression results.

| Variables | W1 | | | W2 | | |
|---|---|---|---|---|---|---|
| L.SRD | 1.263* (0.382) | 1.216* (0.339) | 1.173* (0.291) | 1.37* (0.567) | 1.392* (0.754) | 1.423* (0.839) |
| Digi-EI | 0.673* (0.182) | | 0.473* (0.044) | 0.928* (0.046) | | 0.674* (0.075) |
| Digi-Fi | | 0.365* (0.073) | 0.298* (0.078) | | 0.873* (0.087) | 0.746* (0.087) |
| Digi-EI ′ Digi-FI | | | 0.556* (0.092) | | | 0.891* (0.065) |
| Control variables | Yes | Yes | Yes | Yes | Yes | Yes |
| | 0.687* (0.043) | 0.573* (0.058) | 0.639* (0.063) | 1.302* (0.74) | 1.289* (0.832) | 1.273* (0.843) |
| Time effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Individual effect | Yes | Yes | Yes | Yes | Yes | Yes |
| LR(Lag) | 67.45* | 56.76 | 45.98 | 55.46 | 67.43 | 58.92 |
| LR (error) | 67.14* | 59.64 | 43.66 | 53.76 | 59.54 | 64.78 |
| Wald (lag) | 66.83* | 68.92 | 50.63 | 60.12 | 66.82 | 59.74 |
| Wald(error) | 65.74* | 48.75 | 52.18 | 61.73 | 63.72 | 77.56 |
| R2 | 0.684 | 0.619 | 0.726 | 0.639 | 0.592 | 0.721 |

Values in parenthesis describe standard error. *, and ** shows significance level at 1% and 5% respectively.

changing the dependent variable (Table 8). We have considered the dimensions of SRD, such as economics and environment, in one index called green eco-growth, and for social dimensions, HDI was considered. The regression results confirmed the positive impact of digitalization (Digi-E) on dimensions of SRD, which revealed that our empirical results are robust. Moreover, the positive impact of Digi-F on the economy also confirmed the moderating role of Digi-F between digitalization and SRD.

## Discussion

Vast ED and fast-growing technology around the world attract the intentions of researchers and policymakers to maintain sustainable development. We considered the three basic dimensions of sustainable development, including economic, environmental, and social, to measure the SRD index. Thus, the current study is planned to explore the individual and synergistic impact of digitalization and Digi-F on the SRD of provinces. Based on the panel data of 30 Chinese provinces from 2011 to 2021, the SRD index was measured using principal component analysis (PCA), and the Digi-E index was measured using the panel entropy method. Some econometric models were employed to analyze the impact of the Digi-E and Digi-F on SRD.

The main findings revealed that the Digi-E significantly contributes to SRD. The spatial spillover influence of the Digi-E on sustainable development is explained by considering its impact on different aspects or economic activities of the region. By concentrating on energy consumption, it is possible to describe the positive and significant impact of the Digi-E on SRD. The Digi-E affects regional carbon emission efficiency by influencing energy consumption. The growing digitalization promotes the efficient use of energy sources [86] that directly control carbon emissions, which contributes to the environmental sustainability of the region.

Moreover, the phenomenon of digital servicing compels enterprises operating in the product industry to undergo a profound restructuring of their business model [87]. The process of transforming information and tasks [88, 89] has evolved into digitalization, wherein digital technologies are utilized to modify current procedures in order to enhance efficiency and improve customer value [89, 90]. This contributes directly to economic regional sustainability by enhancing business efficiency and also contributes to social regional sustainability by improving the customers' well-being. Nevertheless, it is worth noting that digital technologies have the potential to facilitate an extensive digital transformation of company structures through the adoption of a novel approach to value creation, delivery, and capture [91, 92]. Digital technologies have the potential to affect the manufacturing sector across various dimensions, ranging from modifying operational activities and procedures to facilitating a comprehensive organizational transformation with wide-ranging implications [92]. Thus, structural transformation through digitalization plays an important role in economic growth [93], which entails environmental sustainability as well as social sustainability. The digitalization of services also plays an important role in enhancing social sustainability by making the servitization more impressive to the community. Previous research on servitization has already emphasized the significance of technological advances, specifically technology that is digital, in facilitating service delivery [94]. However, the quick progression of digitalization is significantly altering the processes of product development, service provision, and the organizational framework and business models within firms [89, 95, 96]. Digitalization is a widespread phenomenon that entails significant enhancements in business operations and necessitates a shift in the servitization approach employed by product-based organizations [97-99]

Digitalization is a crucial element of the contemporary global economy, playing a significant role in enhancing resource management and efficiency [100], optimizing managerial frameworks [101], and facilitating structural transformations [102], which

Table 8. Robustness test of the impact of Digi-E and Digi-F.

| Variables | Green eco-growth | | | HDI | | |
|---|---|---|---|---|---|---|
| Digi-EI | 0.436*<br>(0.055) | | 0.573*<br>(0.022) | 0.172*<br>(0.011) | | 0.221*<br>(0.063) |
| Digi-FI | | 0.354*<br>(0.028) | 0.489*<br>(0.017) | | 0.263*<br>(0.081) | 0.309*<br>(0.042) |
| Digi-EI ´ Digi-FI | | | 0.661*<br>(0.059) | | | 0.447*<br>(0.038) |
| Control Variables | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| R2 | 0.662 | 0.617 | 0.692 | 0.66 | 0.681 | 0.711 |

*, and ** shows significance level at 1% and 5% respectively.

contribute to economic sustainability. Furthermore, the integration of technology not only increases the complexity of technological processes but also expedites creative thinking [103] and enhances the management of supply chains [104]. According to Neubert [105], the process of digitalization has a significant impact on the internationalization of companies and new businesses. Additionally, Alcácer and Cruz-Machado [106] argue that digitalization also plays a crucial role in the establishment of industrial ecosystems. Considering all these contributions of digitalization to economic sustainability, ensure its positive impact on SRD.

Education determines human capacity and ability to tackle both natural and societal difficulties. Digitalization is becoming increasingly important in improving the national educational system, modernizing and developing education, developing future educational opportunities, and bringing learning into line with science [107]. The advent of digitalization has brought about substantial transformations in the field of education. In developed nations, a standard educational setting encompasses a comprehensive range of electronic learning and instructional methods [108]. In today's world, the transmission of skills and knowledge occurs via computer-mediated communication and interconnected networks. This implies that there has been a complete transformation in the methods of delivering educational content and fostering skill development. The process of digitalizing education has been found to result in a heightened need for education, irrespective of an individual's age. Thus, digitization contributes to SRD by enhancing social sustainability.

The digitalization of financial inclusion plays an important mediating role in the relationship between the Digi-E and SRD. Financial inclusion can be defined as the provision of suitable, affordable, equitable, and secure financial goods and services by general service providers [109]. Global progress in financial inclusion has yielded significant accomplishments, contributing to the amelioration of the living conditions of impoverished populations. The amalgamation of digital technology and financial inclusion plays a pivotal role in overcoming the financial exclusion faced by marginalized populations (social sustainability) residing in rural and county regions of China, including farmers and small-scale microenterprises. The implementation of Digi-F has the potential to significantly enhance economic growth (economic sustainability) and address challenges related to the development of agriculture and rural areas [110]. Larios-Hernandez [111] has demonstrated the entrepreneurial drive of both digital currency and digital financial technology in their pursuit of possibilities for individuals who are financially marginalized. Digital-based financial inclusion practices aim to integrate individuals from low-income backgrounds into worldwide patterns of capital accumulation. This approach is particularly effective in developing financialized subjectivities [112]. In contrast, the incorporation of Digi-F has the potential to enhance economic efficiency among different categories of stakeholders. The full realization of the anticipated advantages of Digi-F can be achieved by disregarding the expenses associated with digital transactional sites [70]. The use of a digital finance system enables the facilitation of financial transactions, leading to a subsequent increase in revenue from taxes. This, in turn, benefits governments by providing them with the ability to exert a direct impact through the orientation of their activities [113, 114]. According to Kemal's [115] research, the use of digital payment methods facilitates the secure and easy distribution of social funds to female recipients. In terms of protecting the environment, Digi-F has the potential to help industries grow, which could lead to a drop in the number of highly polluting industries and, in turn, a drop in carbon dioxide emissions [116, 117]. In addition, the implementation of Digi-F has the potential to enhance the extent of advances in technology. According to Yang and Li [118], the acquisition of technological advancements can be a viable approach to effectively mitigating $CO_2$ emissions.

## Conclusions

The study provides a new way of looking at SRD instead of only looking at the green economy. The SRD index was measured by employing the global principal component analysis (PCA) and considering its three dimensions, such as economic, environmental, and social sustainability. Furthermore, the role of the DE environment in SRD was explored after calculating the Digi-E index by adopting the panel entropy method based on the panel data of 30 provinces from 2011-2021. The moderating role of Digi-F was analyzed using the country-level data of the Peking University Digi-F Index of China. The benchmark regression and spatial Durbin model ensured the significant role of the Digi-E environment in SRD. There are several interesting conclusions drawn from the current study. First, a positive correlation between SRD and Digi-E was found. Digitalization is expected to enhance regional sustainable development. Second, the direct impact of Digi-E on SRD was significant and positive. Finally, we found a positive and significant moderating role for Digi-F in the relationship between Digi-E and SRD. Thus, the Digi-E can contribute significantly to SRD through Digi-F.

Based on the findings, the following policy implications are offered: The government needs to invest more in network infrastructure and connectivity services in order to attain full digitization, internet usage, and exposure to digital governance. The local government should increase its expenditure on science and technology, which must be sustainable development-oriented, by promoting user-friendly digital technologies. In order to provide robust support for the new approach to economic growth and development, governments should hasten the digital revolution and renovate

outdated infrastructure. Governments should adopt policies to expand access to digital financial services, with a focus on increasing their oversight of rural areas. By having access to suitable financial services and products, residents and SMEs are empowered to take unplanned, incremental steps towards the widespread adoption of economically viable, environmentally benign, and socially viable technology.

The current study also has some limitations. The study's 2011-2021 data may not incorporate the digital economy and regional sustainability advancements. Digi-E and SRD may change rapidly due to technology and regulation changes. Only looking at the Peking University Digi-F Index to determine how Digi- F affects regional development may leave out the greater financial issues that affect growth. This is because the index only examined certain financial inclusion factors. The paper uses benchmark regression and spatial Durbin models to show that the Digi-E environment affects SRD. It may be difficult to determine what caused what and how relationships are going. This constraint cautions against interpreting findings as causative links. While Digi-F moderates, the study may not fully reflect financial system intricacy and financial component interactions. This constraint may impede understanding how digital finance and the digital economy affect regional sustainability.

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## Conflicts of Interest

The authors declare no conflict of interest.

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