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Digital Media and Green Development Path in Asia: Does Digital Financial Inclusion Matter?

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Abstract: We are entering a new epoch characterized by pervasive digitization, where a significant proportion of our daily activities rely on advanced digital and informational technology. Consequently, this study intends to scrutinize the repercussions of digital media and digital financial inclusion on environmentally sustainable growth across 38 selected economies. The research incorporates four distinct empirical analysis techniques: two-stage least squares (2SLS) and the generalized method of moments (GMM). The assessment reveals a meaningful and positive association between digital financial inclusion and green growth per the 2SLS and GMM methodologies. This affirms the notion that digital financial aid fosters ecological sustainability. Conversely, the metrics linked with information and communication technology (ICT) have shown positive significance across all four utilized estimation models. This suggests that an increase in ICT utilization can play a vital role in advancing green growth. In the same vein, the estimated coefficients of research and development initiatives and renewable energy consumption have demonstrated positive significance across all four models. Furthermore, the metrics associated with trade openness have exhibited a positive significance in both the 2SLS and GMM models. Meanwhile, the metric linked with education has displayed a positive significance solely with the GMM technique. Upon evaluation, it can be concluded that digital media, the consumption of renewable energy, and research and development endeavors are principal contributors to green growth.

Keywords: digital media; green growth; green development; digital finance; Asia

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1. Introduction

Education is a vital asset in the contemporary world, akin to other factors of production such as land, labor, and capital. Knowledge plays a pivotal role in enhancing the wellbeing of skilled individuals locally, contributing significantly to the prosperity of nations and businesses. The advent of information and communication technology (ICT) has brought about significant changes in people's behavior, thinking, and functioning [1]. Particularly for emerging enterprises, its implementation has yielded numerous benefits and demonstrated substantial commercial viability [2]. However, the sustainability of such initiatives lies in their ability to generate advantages without creating significant social imbalances.

Consequently, how nations and businesses harness ICT or digital media to foster a green economy becomes critical in contemporary endeavors, forming this article's central theme. Given the escalating role of ICT in expanding both sound and information technologies in telecommunications, the implications of ICT in bridging the digital divide and advancing millennium development objectives and strategies should not be overlooked [3]. Jnr [4] contends that for ICT to support green growth objectives effectively, technology should be deployed in a manner that is appropriate, applicable, and successful, taking into

account these perspectives [5,6]. The concept of green growth, as defined by the OECD, entails promoting economic growth and development while simultaneously addressing environmental challenges and promoting sustainable resource utilization. It recognizes the imperative to decouple economic growth from environmental degradation, acknowledging that conventional patterns of growth and development are unsustainable in the long run.

Fan et al. [7] assert that businesses and governments, which share remarkable similarities, must take additional steps to recognize that sustainable development is more than a simple technological shift from the North to the South. This recognition is crucial due to the rapid pace at which digitalization is changing the modes of operation in emerging economies and the potential shortcomings of development objectives using ICT. According to Heeks [8], sustainability can only be achieved when infrastructure and demand are adequately aligned. Without this alignment, no profit will be gained from the investments made. The virtual age has witnessed a significant technological transformation, particularly in telecommunications. Recent arrivals dominate the technological landscape in Jamaica, enjoying substantial financial success. In this new era of globalization, countries like China and India have significantly contributed to poverty reduction and experienced a surge of excitement [9]. However, caution must be exercised in promoting the growth of ICT ventures. While ICT provides new opportunities for education, access to resources, and improved connectivity [10,11], underprivileged and marginalized groups are less likely to benefit from technologies like the Internet. This exacerbates societal differences and deepens disparities between wealthy and impoverished nations, regions, people, and genders [12].

Consequently, it becomes challenging to foster sustainable growth and promote "economic, social, cultural, and political" initiatives for all participants through the strategic use of digital media strategies [13,14]. Achieving sustainable development requires balancing between meeting individual requirements and safeguarding the environment [15]. This balance is not easily attained, yet sustainability practitioners need to succeed. For instance, the implementation of e-government and its potential to enhance citizen effectiveness has witnessed significant advancements [16,17]. This project must be sustained by consolidating operations between agencies and organizations. Understanding the complexity of socio-environmental concerns is crucial for attaining sustainable growth, even though it is challenging [18]. To impact environmental sustainability, a new and effective descriptive and analytical conceptual model must be employed, coupled with an integrated assessment of ecological, social, and economic aspects using appropriate indicators [19]. This is necessary for any possibility of achieving environmental sustainability. While it may take time, sustainability offers tangible rewards [20,21]. Collaborative and coordinated projects that strengthen the connections between indicators are vital for sustainable development [22,23].

Over the past 30 years, the widespread adoption of ICT and digital media has improved energy efficiency and increased productivity in most countries [24]. The prospective advantages of digital media and the Internet have been extensively studied and documented worldwide. However, the effects of digital media and financial inclusion on sustainable development have received little attention. As a result, the connection between ICT and sustainability remains unclear. Some research suggests that the rapid development of ICT has improved the environmental impact of economic activities by reducing carbon dioxide (CO_2) emissions. At the same time, other studies indicate that the increased use of ICT devices has hindered sustainable development due to their negative environmental effects. Moreover, existing research demonstrates the diverse effects of digital media on sustainability in advanced and emerging nations. Given the significance of sustainability as a global concern, this research aims to examine the relationship between digital media, digital financial inclusion, and sustainable development.

Situated within the context of Asia, a region experiencing some of the most rapid global development, the significance of education and information and communication technology (ICT) becomes remarkably amplified. With their thriving economies and burgeoning tech-oriented populations, Asian nations could potentially reap enormous benefits

from a strategic deployment of ICT. When employed effectively, ICT can catalyze transformation in economic landscapes and societal behaviors, thereby encouraging sustainable growth and fostering green economies. However, ensuring sustainable and equitable ICT utilization remains a considerable challenge, necessitating a careful equilibrium among the applicability, suitability, and efficacy of the technology. The sweeping wave of digitalization across Asia is dramatically reshaping operational modalities and business terrains, turning the region into an incubator for technological innovation and advancement. However, this rapid digitalization also demands additional measures for securing sustainable development. The focus should extend beyond merely technological transition; it necessitates the alignment of the infrastructure with the demand to avert futile ICT investments. Moreover, considering Asia's diverse socio-economic landscape, it is critical to distribute ICT benefits equitably, thereby preventing the exacerbation of societal disparities and facilitating inclusive growth.

For Asian countries on the path to sustainable development, the strategic utilization of digital media becomes essential. It harbors the potential to invigorate economic, social, cultural, and political initiatives, thus creating mutual benefits for all stakeholders. Furthermore, programs such as e-government have exhibited promising results in amplifying citizen engagement and streamlining processes across various agencies and organizations. Achieving sustainable development, however, is not confined to technology adoption; it demands an integrated comprehension of ecological, social, and economic implications. This research bears particular relevance for Asia as it navigates the intricate nexus among digital media, digital financial inclusion, and sustainable development. It aims to illuminate how ICT can be effectively harnessed for sustainability, particularly in reducing carbon dioxide emissions and curbing negative environmental impacts, thus furthering Asia's sustainable development goals. The research addresses two questions: What is the relationship between digital financial inclusion and green growth? How does ICT contribute towards achieving green growth objectives?

This work brings several fresh insights to the burgeoning body of knowledge. Firstly, to the best of our understanding, this is the inaugural study investigating the influence of digital media on green growth. Secondly, the role of digital financial inclusion as a green growth determinant has remained hitherto unestimated. Thirdly, no prior research has evaluated the impact of digital media and digital financial inclusion on green growth specifically within Asia. Fourthly, the application of 2SLS and GMM methodologies can yield robust outcomes by addressing the issue of endogeneity, a prominent challenge in panel analyses. Lastly, the findings of the analysis hold crucial implications for guiding policy makers and financial sector stakeholders toward sustainable digital media usage in the financial sector while promoting green sustainability.

The remaining sections of this study unfold as follows: Section 2 undertakes a review of existing literature. Section 3 explicates the variables and the model employed in the research. Section 4 details the construction of variables and provides an overview of the data. A discourse on the results and estimation techniques is located in Section 5, and finally, Section 6 concludes this study by proffering policy recommendations.

2. Literature Review

The academic research exploring the relationship between digital media and green development primarily centers around the impact of ICT on each of the Sustainable Development Goals (SDGs) outlined by the United Nations in 2015. Subsequent empirical studies conducted on ICT and digital media in this context can be categorized into three main segments: environmental, social, and economic [21]. The environmental perspective primarily focuses on examining how ICT influences carbon emissions. The social aspect examines the effects of ICT on inequality, education, health, and human development [25]. Lastly, the economic viewpoint revolves around utilizing ICT to promote economic prosperity within a country.

In the first section of the literature, several authors [9,26] argue for a positive correlation between ICT and carbon footprints. It is suggested that ICT leads to an expansion in trade and foreign direct investments, benefiting industrialization and scale economies [27]. However, this increase in economic activity results in higher carbon dioxide emissions due to the greater use of energy sources such as fossil fuels for powering electrical grids and operating mechanical systems. Avom et al. [27] contend that ICT predominantly contributes to the rise in CO_2 emissions via commerce, financial development, and energy consumption. Nonetheless, the type of energy utilized is crucial in determining the extent of CO_2 emissions. While renewable energy reduces carbon footprints, non-renewable energy sources actually increase them [12]. Furthermore, trade openness fosters economic convergence and global value chains, which recent studies have identified as the primary drivers of CO_2 emissions [28].

According to other empirical studies [4,17], ICT is believed to have a negative association with CO_2 emissions. The advancements in ICT and the widespread adoption of electronic devices have led to a decrease in the usage of many conventional commodities. For instance, virtual conferences have largely replaced traditional meetings, reducing the need for travel. Similarly, e-commerce has reduced the necessity for physical shopping, while e-books and emails have replaced traditional books and letters. This substantial substitution of conventional goods with new digital alternatives minimizes resource consumption and the associated activities contributing to environmental degradation. Furthermore, the ICT revolution has facilitated the implementation of modern transportation systems and the deployment of advanced traffic management software, reducing energy consumption and emissions [29].

The impact of ICT on social development has been the subject of debate in various empirical studies. In this context, several researchers [30,31] have examined socially sustainable growth as a component of "inclusive human development". The degree to which ICT growth strategies would enhance inclusive human development varies depending on a country's geographical status, oil reserves, political stability, legal system, and per capita income [7]. Moreover, it has been suggested that social development can improve healthcare conditions [32]. However, for ICT to penetrate the healthcare sector, financial independence is necessary, and the combination of ICT and healthcare has been found to have a detrimental impact on "under five" mortality, particularly in Africa [29]. On the other hand, it has been observed that the widespread use of the Internet, mobile phones, and fixed phones is associated with improved life expectancy and reduced infant mortality rates [33]. However, there are also negative associations between Internet use and the prevalence of HIV. Few studies have examined the impact of ICT on other aspects of social development, such as education and inequality. According to Tchamyou et al. [34], while ICT negatively correlates with secondary education and has little effect on higher education, it positively correlates with primary education, which helps reduce wealth disparities. To ensure that ICT positively impacts equitable educational opportunities, specific criteria for addressing inequality must be met. Adams and Akobeng [35] argue that ICT usage reduces inequality, and implementing a robust governance structure strengthens this relationship.

The final body of research examines the impact of ICT on economic development and poverty eradication. Contemporary growth theories have increasingly recognized the significance of technological advancement for economic progress [22]. ICT has the potential to contribute positively to economic growth [10], largely due to its facilitative effects on globalization and financial expansion [3]. However, Albiman and Sulong [36] argue that ICT can harm economic development, particularly in countries with limited economic reforms. The fourth phase of the financial sector revolution introduces the concept of "digital financial inclusion," which encompasses various ideas, such as microcredits, microfinance, and financial inclusion. Specifically, "digital financial inclusion" emphasizes using digital media to enhance people's access to traditional financial services beyond what financial inclusion alone achieves.

Policymakers and academics have started recognizing digital financial inclusion as a means to promote economic development, energy shift, and diversification and as a tool for mitigating climate change. Implementing digital financial inclusion is essential to achieve the goal of financial inclusion. Tay et al. [37] assert that digital financial inclusion contributes to the attainment of sustainable development. Financial inclusion ensures that all nations have equal opportunities to access and benefit from financial products and services [15]. The impact of financial inclusion on the environment can be positive or negative [20]. Fareed et al. [38] found that financial inclusion increased carbon footprints in 27 European nations between 1995 and 2018. Similarly, Ozturk and Ullah [14] discovered that financial inclusion harms environmental sustainability in the OBRI. The negative impact of financial inclusion on environmental degradation in the BRICS countries was also confirmed by [3]. Despite numerous studies exploring the link between digitalization and environmental degradation, research examining the connection between digital financial inclusion and environmental destruction is scarce and often overlooked, as noted by Wei and Ullah [39].

Although several empirical studies have investigated the impact of digital media and digital financial inclusion on different aspects of green development, none have specifically focused on the nexus between digital media, digital financial inclusion, and green growth. As a result, we have identified several gaps in the existing body of empirical research. Firstly, there is a scarcity of literature examining the relationship between digital media and green growth. Secondly, no previous study has quantified the influence of digital financial inclusion on green growth. Thirdly, the combined effect of digital media and financial inclusion as determinants of green growth has received little attention in past research. Lastly, there is a lack of studies exploring this relationship within Asian economies. These research gaps highlight the need for further investigation into the interplay between digital media, digital financial inclusion, and green growth, particularly in Asian economies.

3. Methods

Panel data are a valuable type of data that combines cross-sectional and time-series information, offering several advantages over cross-sectional or time-series data alone. By incorporating both dimensions, panel data increase the number of data points available, leading to more information and more precise estimates. When conducting panel analysis, commonly used techniques include fixed effect (FE), random effect (RE), two-stage least squares (2SLS), and generalized methods of moments (GMM). Each approach has its strengths and limitations. FE is appropriate when cross-sections are selected with certainty, while RE is suitable when cross-sections are chosen randomly. However, FE cannot account for constant variables over time, while RE assumes cross-section fixed effects and independent variables are uncorrelated to avoid biased results. It is important to note that these techniques alone cannot address all the challenges associated with panel data, such as heteroskedasticity, endogeneity, and serial correlation. In our study design, we have adopted the 2SLS and GMM methods, following the guidance provided in reference [8] and drawing insights from empirical studies conducted by [40]. Based on this approach, we have developed a foundational panel model that incorporates digital media, digital financial inclusion, and green development, as articulated below:

$$GG_{it} = Y_0 + Y_1 GG_{it-1} + Y_2 ICT_{it} + Y_3 DFI_{it} + Y_4 Education_{it} + Y_5 Trade_{it} + Y_6 REC_{it} + Y_i + \varepsilon_{it} \quad (1)$$

Equation (1) presents the relationship between green development (GG_{it}) and various determinants, including ICT diffusion (ICT), digital financial inclusion (DFI), educational attainment (Education), trade openness (Trade), and renewable energy consumption (REC). The equation also includes the unobserved individual effects (Y_i) and the error term (ε_{it}). The variance inflation factor (VIF) test is employed to address the multicollinearity issue.

In simultaneous equations, the 2SLS method is utilized as an improved version of ordinary least squares (OLS) to address endogeneity and provide consistent estimates. This method involves using independent proxy variables of a similar nature to replace the

endogenous independent variables while ensuring that the residual terms do not affect these substitute variables. The 2SLS method demonstrates good behavior and desirable structural properties in addressing endogeneity concerns in the simultaneous equation framework. Despite being a significant advancement in econometrics, the 2SLS method has certain limitations compared to the GMM approach, particularly in addressing the abovementioned problems [25]. As heteroskedasticity, endogeneity, and serial correlation are common issues in panel analysis, the GMM method developed by [26] is considered preferable. When the number of cross-sections exceeds the number of years (T), GMM becomes an excellent choice. In the GMM model, including the lagged dependent variable is crucial for addressing endogeneity. The GMM technique comes in various forms, including one-step and two-step GMM estimators. The two-step GMM estimator is suitable for handling unbalanced data. However, when dealing with an uneven sample, the one-step GMM approach may result in biased results and sacrifices some data points. Conversely, the two-step GMM method yields superior outcomes when faced with autocorrelation and heteroscedasticity [27].

Panel data analysis provides a robust framework for research that incorporates both the temporal and spatial dimensions of the data. By increasing the number of data points, panel data analysis offers a wealth of information and enables more precise estimates. However, the application of panel data analysis is accompanied by certain complexities. Approaches such as fixed effect (FE) and random effect (RE) have their strengths and limitations, necessitating careful consideration of the research context. For instance, FE is well suited when cross-sections are chosen with certainty but becomes less useful when dealing with constant variables over time. Conversely, the RE approach assumes no correlation between cross-section fixed effects and independent variables, making it appropriate for situations where cross-sections are randomly selected.

In our study design, we have employed two-stage least squares (2SLS) and generalized methods of moments (GMM) to tackle some of the challenges associated with panel data analysis. The 2SLS method, an enhanced version of ordinary least squares (OLS), has demonstrated promising outcomes in handling simultaneous equations and providing consistent estimates of structural parameters. By using independent proxy variables as substitutes for endogenous independent variables, the 2SLS method ensures that these substitutes remain unaffected by the residual terms. However, despite the significant progress made with the 2SLS method, it still has limitations compared to the GMM approach, especially in effectively addressing issues such as heteroskedasticity, endogeneity, and serial correlation, which are commonly encountered in panel data analysis.

4. Data

This research explores digital media and financial inclusion's impact on green development across 38 diverse economies from 2007 to 2020. To gain a comprehensive understanding of these dynamics, a range of variables has been utilized. The primary variable, green growth (GG), measures green development by adjusting GDP growth for pollution levels. This innovative measure considers the environmental costs associated with economic growth, offering a more holistic view of sustainable development. The GG data are sourced from the Organisation for Economic Co-operation and Development (OECD), known for its reliable and comprehensive economic data. ICT diffusion, which represents the role of digital media, is measured by the percentage of the total population that are internet users. This measure provides insights into the level of digital media penetration within the economies studied and reflects the degree of access to digital information, resources, and tools. The data for ICT diffusion are obtained from the World Development Indicators (WDI) database. Control variables in this study include digital financial inclusion (DFI), human capital, trade openness, and renewable energy consumption. DFI, calculated by the authors, quantifies the extent of access to and utilization of digital financial services, indicating an economy's level of financial modernization and inclusivity. Human capital is proxied by the level of education, specifically secondary school enrollment rates, which

provides insights into educational investment and the potential skill level of the future workforce. Trade openness, expressed as a percentage of GDP, captures the extent of an economy's integration into the global economy, reflecting its reliance on external trade. Renewable energy consumption, represented as a percentage of total energy consumption, indicates an economy's commitment to sustainable energy sources.

Descriptive statistics have been computed to summarize the variables used in the analysis (see Table 1). The mean values of GG, DFI, ICT, EDU, Trade, and REC are 2.167, 3.681, 4.142, 4.666, 4.205, and 2.443, respectively. These values represent the average levels of each variable in the selected economies during the study period, indicating their central tendencies. The standard deviation values of 2.898 for GG, 0.583 for DFI, 0.517 for ICT, 0.172 for EDU, 0.502 for Trade, and 1.411 for REC reflect the dispersion or variability of these variables around their respective means. These standard deviations provide insights into the spread of data points and give a sense of the variability exhibited by each variable in the sample.

Table 1. Variables and data sources.

Variables	Symbol	Definitions	Mean	Std. Dev.	Min	Max	Sources
Green growth	GG	Pollution-adjusted GDP growth (%)	2.167	2.898	−8.180	13.134	OECD
ICT diffusion	ICT	Individuals using the Internet (% of the population)	4.142	0.517	1.374	4.585	WDI
Digital financial inclusion	DFI	Digital financial inclusion index	3.681	0.583	0.632	4.467	Authors calculation
Education	Education	School enrollment, secondary (% gross)	4.666	0.172	4.048	5.217	WDI
Trade openness	Trade	Trade (% of GDP)	4.205	0.502	3.096	5.531	WDI
Renewable energy consumption	REC	Renewable energy consumption (% of total final energy consumption)	2.443	1.411	0.021	4.113	WDI

5. Results and Discussion

The correlation matrix results are presented in Table 2, which allows for the identification of perfect collinearity among the variables. The findings indicate that no regressor exhibits a perfect correlation with any other regressor, suggesting that our model is free from multicollinearity. Table 3 provides the results of the variance inflation factor (VIF) test, which assesses multicollinearity in regression analysis. Multicollinearity occurs when variables in a multiple-regression model are highly correlated, making it difficult to determine the individual effects of each variable. However, the VIF test results in this study demonstrate the absence of multicollinearity. All obtained VIF values are below the commonly accepted threshold of 10, as shown in Table 3. A VIF value below 10 indicates that the variables in the model are not excessively correlated and can contribute unique information to the model. Moving on to Table 4, the results from different estimation models employed in this study are displayed. The estimation techniques used include random effects (RE), fixed effects (FE), two-stage least squares (2SLS), and generalized methods of moments (GMM). By utilizing the 2SLS and GMM methods, the author aims to address various econometric challenges and compare the results obtained. This approach enhances the robustness and validity of the analysis and allows for exploring potential differences or similarities in the findings generated by these methods.

Table 2. Correlation matrix.

	GG	ICT	DFI	Education	Trade	REC
GG	1					
ICT	0.417	1				
DFI	0.445	0.533	1			
Education	0.293	0.605	0.571	1		
Trade	0.282	0.271	0.133	0.271	1	
REC	0.147	−0.072	−0.072	0.004	−0.091	1

Table 3. Results for the variance inflation factor.

Variable	VIF	1/VIF
DFI	1.320	0.755
ICT	2.350	0.426
Trade	1.160	0.863
Education	1.780	0.563
REC	1.070	0.934
Mean VIF	1.281	

Table 4. Estimates of green growth (2SLS and GMM).

	FE	RE	2SLS	GMM
Variables	**(1)**	**(2)**	**(3)**	**(4)**
L.GG				0.221 ***
				(0.032)
ICT	0.501 ***	0.380 **	1.056 ***	1.172 **
	(0.140)	(0.165)	(0.132)	(0.409)
DFI	0.371	0.308	3.920 ***	1.957 ***
	(0.321)	(0.598)	(1.176)	(0.431)
Education	0.142	0.295	1.341	2.537 **
	(1.225)	(1.196)	(0.904)	(1.030)
Trade	0.825	0.572	1.644 ***	1.644 ***
	(0.845)	(0.481)	(0.273)	(0.309)
REC	0.526 *	0.416 **	0.434 ***	0.427 ***
	(0.288)	(0.185)	(0.079)	(0.101)
Constant	10.18 *	9.386 *	13.44 ***	5.958 **
	(5.937)	(5.144)	(3.373)	(2.830)
Observations	532	532	532	494
N	38	38	38	38
Hausman test	15.32 ***			

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

The FE and RE models demonstrate a significant and positive association between information and communication technology (ICT) diffusion and green growth. This implies that an increase in ICT usage, such as a higher number of internet users, corresponds to an improvement in green growth. Specifically, a 1% increase in ICT diffusion leads to a 0.501% rise in GG in the FE model and a 0.380% increase in the RE model. This positive relationship can be attributed to the fact that ICT often facilitates more efficient resource utilization, waste reduction, and enhanced environmental management. The empirical findings presented in this study align with the conclusions drawn by previous research [17,23]. ICT contributes to resource efficiency by optimizing energy, water, and other resource usage. It enables advanced monitoring and management of environmental resources by utilizing remote sensing, geographic information systems (GIS), and real-time data collection technologies. These tools aid in monitoring and managing ecosystems, biodiversity, and natural resources, facilitating better environmental planning, conservation, and sustainable resource management. Furthermore, ICT plays a pivotal role in

developing smart transportation systems and promoting sustainable mobility. Intelligent transportation systems, ride-sharing platforms, and real-time traffic management systems optimize transport routes, alleviate congestion, and reduce carbon emissions [32].

Interestingly, the analysis reveals an insignificant relationship between Digital Financial Inclusion (DFI) and green growth in China. This suggests that the level of access to digital financial services among the population does not significantly impact green growth within the context of the FE and RE models. Similarly, the relationship between education, as a measure of human capital, and green growth is also insignificant in both models. This finding implies that while education is important for various aspects of societal development, its direct influence on green growth, as measured in this study, is not statistically significant. Furthermore, trade openness does not exhibit a significant relationship with green growth in the FE and RE models. This suggests that the extent of openness to foreign trade in China does not directly contribute to green growth, as measured in this study. On the contrary, both models have a significant positive association between renewable energy consumption and green growth. Specifically, a 1% increase in renewable energy consumption leads to a 0.526% increase in green growth in the FE model and a 0.416% increase in the RE model. This finding underscores the crucial role of renewable energy in driving sustainable and environmentally friendly economic growth.

The findings from the 2SLS and GMM models provide evidence of the significant and positive impact of digital financial inclusion (DFI) on green growth (GG) in China. A 1% increase in DFI is associated with a substantial increase in green growth: 3.920% in the 2SLS model and 1.957% in the GMM model. These results underscore the crucial role of digital financial services in driving sustainable economic development. Digital financial inclusion enables a larger population to access and utilize financial services, including those delivered via the Internet and mobile communication [20]. This increased accessibility has the potential to stimulate economic activity and promote green growth via various mechanisms. For instance, individuals and businesses can utilize digital financial services to invest in green technologies, support sustainable enterprises, or adapt to climate change. Furthermore, digital financial inclusion can enhance the efficiency of financial markets, facilitating the allocation of resources toward green initiatives. This may involve facilitating investments in environmentally friendly businesses or enabling more efficient transactions for goods and services that contribute to green growth. These findings align with previous research [28–31], which has demonstrated that digital financial inclusion can expand the scope of the financial sector and enhance its performance, thereby promoting green economic growth.

The relationship between education (EDU) and green growth (GG) exhibits mixed results. While the 2SLS model does not find a significant impact of education on green growth, the GMM model demonstrates a significant positive effect. According to the GMM model, a 1% increase in education leads to a 2.537% increase in green growth. These findings align with previous research reported by [19]. Education is crucial in creating awareness about environmental issues like climate change, resource depletion, and biodiversity loss. By providing knowledge about these challenges, education encourages individuals to recognize the importance of environmental sustainability and motivates them to take action. Furthermore, education fosters innovation and the development of sustainable technologies. By providing a foundation in science and technology, education cultivates the skills needed to design and implement green technologies, renewable energy systems, and resource-efficient solutions [17]. Additionally, education is significant in encouraging research and development in sustainable practices and supporting advancing environmentally friendly innovations. Moreover, education influences consumption patterns and lifestyle choices by promoting sustainable behaviors. It raises awareness about the impact of individual choices on the environment, such as energy consumption, waste generation, and transportation habits. Education encourages sustainable consumption practices, including recycling, waste reduction, energy conservation, and the preference for eco-friendly products. Furthermore, education is critical in shaping policy and governance

structures that support green growth [14]. Overall, the empirical findings highlight the importance of education in fostering environmentally conscious behavior and promoting sustainable development.

These findings suggest that human capital, as measured by education level, significantly promotes green development. Well-educated individuals are more likely to support or engage in sustainable practices, innovate green technologies, and work in green industries, contributing to green growth. Additionally, trade openness emerges as a significant determinant of green growth, as indicated by the 2SLS and GMM models. A 1% increase in trade openness is associated with a 1.644% increase in green growth in both models. This relationship can be attributed to various factors, including the importation of green technologies, the exportation of green goods and services, and the increased competition and innovation stimulated by international trade. Lastly, the 2SLS and GMM models demonstrate a positive and significant impact of renewable energy consumption (REC) on green growth. A 1% increase in REC leads to a 0.434% increase in green growth in the 2SLS model and a 0.427% increase in the GMM model. These results underscore the crucial role of renewable energy in driving sustainable economic development. By reducing reliance on fossil fuels, renewable energy contributes to mitigating climate change and reducing environmental degradation, promoting green growth. These findings align with the growing recognition of the importance of transitioning to sustainable energy sources to achieve environmental sustainability and long-term economic prosperity.

6. Conclusions and Policy Implications

Integrating digital media into our daily lives is commonly referred to as digitalization. It involves converting information into a digital format, enabling convenient and interactive access. With the advent of information technology, data and information traditionally collected in physical forms can now be transformed into computer-readable formats. This digital revolution has led to a significant shift in various aspects of our lives, with a growing reliance on advanced digital technologies for tasks and activities. The ongoing digitization of our society has profound implications for socio-economic development, ecological sustainability, green growth, and climate analysis. In line with this perspective, our study aims to explore the impact of digital media and financial inclusion on the promotion of green growth.

In our empirical analysis, we have employed four estimation techniques, namely fixed effects (FE), random effects (RE), two-stage least squares (2SLS), and generalized methods of moments (GMM), to investigate the model. The results reveal significant findings on digital financial inclusion, information and communication technology (ICT), research and development activities, renewable energy consumption, trade openness, and education. The estimates obtained for digital financial inclusion demonstrate positive and significant effects in the 2SLS and GMM models, indicating that digital financial services are crucial in promoting green growth. Similarly, the estimates associated with ICT exhibit positive and significant effects across all four estimation techniques, suggesting that increasing ICT usage contributes to the advancement of green growth. Furthermore, the estimated coefficients for research and development activities and renewable energy consumption display positive and significant effects in all four models. This underscores the importance of research and innovation and the adoption of renewable energy sources in driving sustainable economic development. Moreover, the estimates related to trade openness are positively significant in the 2SLS and GMM models, highlighting the potential positive impact of international trade on green growth. On the other hand, the estimate associated with education is only positively significant in the GMM model, suggesting that education plays a significant role in promoting green growth when considering the GMM estimation technique. In conclusion, our analysis indicates that digital media, renewable energy consumption, and research and development activities emerge as the most significant contributors to green growth based on the results obtained from the various estimation techniques employed.

The present research has yielded several key findings and policy implications. The estimated model indicates a significant and positive influence of information and communication technology (ICT) on green growth. Based on this finding, it is recommended that nations adopt strategies to accelerate the adoption of ICT-related activities to enhance both environmental quality and economic growth. Particularly, the implementation of ICT can be targeted at industries with significant pollution levels, such as transportation and manufacturing, to achieve these goals. Furthermore, governments should focus on promoting the digitalization of the financial sector, as it positively impacts sustainable development. Financial markets can be crucial in financing initiatives such as research and development (R&D) and renewable energy projects. Therefore, policies that facilitate the financial sector's digital transformation should be encouraged. Given the positive effects of ICT and renewable energy sources on green growth, nations should introduce legislation that encourages developing and adopting innovative approaches based on these technologies. In this context, financial support should be provided to R&D initiatives, and green economic policies should be strengthened to support sustainable development. On the other hand, governments need to impose restrictions on the use of fossil fuels, as non-renewable energy sources have a detrimental impact on environmental quality. Encouraging the transition towards renewable energy alternatives is crucial to achieving sustainable and environmentally friendly growth. In summary, the research findings highlight the need for nations to prioritize the adoption of ICT, promote the digitalization of the financial sector, support R&D efforts, and strengthen green economic policies. Simultaneously, efforts should be made to reduce reliance on fossil fuels and promote the use of renewable energy sources to safeguard environmental quality.

Given the significant and positive impact of information and communication technology (ICT) on green growth, it is recommended that national policies prioritize the promotion and diffusion of ICT, particularly in sectors with high pollution potential, like transportation and manufacturing. To facilitate this process, efforts should be made to enhance digital connectivity and improve digital literacy, enabling a wider range of individuals and organizations to benefit from digital technologies. Considering the positive influence of the digitalization of the financial sector on sustainable development, policies should also focus on promoting digital financial inclusion. This can be achieved via regulatory reforms that encourage financial innovation and facilitate the development of the digital financial infrastructure via public–private partnerships. Moreover, initiatives to enhance financial literacy among consumers should be considered, enabling them to utilize digital financial services effectively. To support the role of renewable energy consumption in driving green growth, policymakers should consider a range of policy measures. This may include providing subsidies or tax incentives to promote renewable energy production, implementing regulations that require a certain proportion of energy to be sourced from renewable sources, and making public investments in renewable energy infrastructure. Additionally, policies should foster innovation in renewable energy technologies by supporting research and development activities via grants or tax incentives. By implementing these policy recommendations, governments can create an enabling environment for the diffusion of ICT, digital financial inclusion, and the expansion of renewable energy consumption. These measures can contribute to sustainable development, environmental protection, and the promotion of green growth.

Considering the positive impact of research and development activities on green growth, governments must prioritize investments in education and training. By doing so, they can cultivate a skilled workforce capable of driving innovation in sustainable development. This may involve initiatives promoting STEM education and fostering stronger collaboration between academia and industry. Furthermore, the findings highlight the importance of limiting reliance on non-renewable energy sources due to their detrimental effects on environmental quality. Governments should consider implementing measures such as carbon taxes or levies on emissions and imposing stricter regulations on pollution. These actions are necessary to mitigate the negative impact of non-renewable energy on the

environment. In summary, this study's findings emphasize the need for a comprehensive and integrated approach to policymaking. Achieving green growth requires concerted efforts across various sectors and effective coordination among different levels of government, the private sector, and civil society. By adopting a holistic approach, policymakers can create a conducive environment for sustainable development and green growth.

Notwithstanding the significant findings, this study has limitations that must be acknowledged. Firstly, the data utilized may not encompass all aspects of green growth and ICT diffusion, potentially omitting crucial factors. The models employed in the analysis carry inherent assumptions and potential issues; for instance, the reliability of instrument variables heavily influences the results of the GMM model. Additionally, this study's focus on China restricts the generalizability of the findings to diverse economic, social, and regulatory contexts. This study's cross-sectional design fails to capture dynamic changes over time, and the measurement of complex variables such as green growth or ICT diffusion may not be entirely precise. Lastly, although this study indicates the relationships between variables, establishing clear causality remains challenging. Future research could address these limitations and provide a more comprehensive understanding of the subject matter.

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References

1. Gåvertsson, I.; Milios, L.; Dalhammar, C. Quality Labelling for Re-Used ICT Equipment to Support Consumer Choice in the Circular Economy. *J. Consum. Policy* **2020**, *43*, 353–377. [CrossRef]
2. Melović, B.; Jocović, M.; Dabić, M.; Vulić, T.B.; Dudic, B. The Impact of Digital Transformation and Digital Marketing on the Brand Promotion, Positioning and Electronic Business in Montenegro. *Technol. Soc.* **2020**, *63*, 101425. [CrossRef]
3. Dong, K.; Wang, J.; Taghizadeh-Hesary, F. Assessing the Embodied CO_2 Emissions of ICT Industry and Its Mitigation Pathways under Sustainable Development: A Global Case. *Appl. Soft Comput.* **2022**, *131*, 109760. [CrossRef]
4. Jnr, B.A. Examining the Role of Green IT/IS Innovation in Collaborative Enterprise-Implications in an Emerging Economy. *Technol. Soc.* **2020**, *62*, 101301.
5. Hidalgo, A.; Gabaly, S.; Morales-Alonso, G.; Urueña, A. The Digital Divide in Light of Sustainable Development: An Approach through Advanced Machine Learning Techniques. *Technol. Forecast. Soc. Chang.* **2020**, *150*, 119754. [CrossRef]
6. Usman, A.; Ozturk, I.; Hassan, A.; Zafar, S.M.; Ullah, S. The Effect of ICT on Energy Consumption and Economic Growth in South Asian Economies: An Empirical Analysis. *Telemat. Inform.* **2021**, *58*, 101537. [CrossRef]
7. Fan, P.; Urs, N.; Hamlin, R.E. Rising Innovative City-Regions in a Transitional Economy: A Case Study of ICT Industry in Cluj-Napoca, Romania. *Technol. Soc.* **2019**, *58*, 101139. [CrossRef]
8. Heeks, R. Do Information and Communication Technologies (ICTs) Contribute to Development? *J. Int. Dev.* **2010**, *22*, 625–640. [CrossRef]
9. Kaplinsky, R.; Kraemer-Mbula, E. Innovation and Uneven Development: The Challenge for Low-and Middle-Income Economies. *Res. Policy* **2022**, *51*, 104394. [CrossRef]
10. Alam, A. Platform Utilising Blockchain Technology for ELearning and Online Education for Open Sharing of Academic Proficiency and Progress Records. In *Smart Data Intelligence: Proceedings of ICSMDI 2022*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 307–320.

11. van Der Velden, M. ICT and Sustainability: Looking beyond the Anthropocene. In *Proceedings of the This Changes Everything–ICT and Climate Change: What Can We Do? 13th IFIP TC 9 International Conference on Human Choice and Computers, HCC13 2018, Held at the 24th IFIP World Computer Congress, WCC 2018, Poznan, Poland, 19–21 September 2018*; Proceedings 13; Springer: Berlin/Heidelberg, Germany, 2018; pp. 166–180.
12. Suryawanshi, K.; Narkhede, S. Green ICT for Sustainable Development: A Higher Education Perspective. *Procedia Comput. Sci.* **2015**, *70*, 701–707. [CrossRef]
13. Chankseliani, M.; Qoraboyev, I.; Gimranova, D. Higher Education Contributing to Local, National, and Global Development: New Empirical and Conceptual Insights. *High. Educ.* **2021**, *81*, 109–127. [CrossRef]
14. Ozturk, I.; Ullah, S. Does Digital Financial Inclusion Matter for Economic Growth and Environmental Sustainability in OBRI Economies? An Empirical Analysis. *Resour. Conserv. Recycl.* **2022**, *185*, 106489. [CrossRef]
15. Lehtonen, M. The Environmental–Social Interface of Sustainable Development: Capabilities, Social Capital, Institutions. *Ecol. Econ.* **2004**, *49*, 199–214. [CrossRef]
16. Hasan, M.M.; Yajuan, L.; Khan, S. Promoting China's Inclusive Finance through Digital Financial Services. *Glob. Bus. Rev.* **2022**, *23*, 984–1006. [CrossRef]
17. Rothe, F.-F. Rethinking Positive and Negative Impacts of 'ICT for Development'through the Holistic Lens of the Sustainable Development Goals. *Inf. Technol. Dev.* **2020**, *26*, 653–669. [CrossRef]
18. Briassoulis, H. *Policy Integration for Complex Environmental Problems: The Example of Mediterranean Desertification*; Routledge: London, UK, 2017; ISBN 1-315-24659-7.
19. Bergez, J.-E.; Bethinger, A.; Bockstaller, C.; Cederberg, C.; Ceschia, E.; Guilpart, N.; Lange, S.; Müller, F.; Reidsma, P.; Riviere, C. Integrating Agri-Environmental Indicators, Ecosystem Services Assessment, Life Cycle Assessment and Yield Gap Analysis to Assess the Environmental Sustainability of Agriculture. *Ecol. Indic.* **2022**, *141*, 109107. [CrossRef]
20. Lu, L.; Chen, Q.; Huang, R.; Usman, A. Education and Its Impact on Renewable Energy Demand, Carbon Intensity, and Green Growth: Do Digital Financial Inclusion and Environmental Policy Stringency Matter in China. *Environ. Sci. Pollut. Res.* **2022**, *30*, 12020–12028. [CrossRef]
21. Omri, A. Technological Innovation and Sustainable Development: Does the Stage of Development Matter? *Environ. Impact Assess. Rev.* **2020**, *83*, 106398. [CrossRef]
22. Huan, Y.; Liang, T.; Li, H.; Zhang, C. A Systematic Method for Assessing Progress of Achieving Sustainable Development Goals: A Case Study of 15 Countries. *Sci. Total Environ.* **2021**, *752*, 141875. [CrossRef]
23. Shkabatur, J.; Bar-El, R.; Schwartz, D. Innovation and Entrepreneurship for Sustainable Development: Lessons from Ethiopia. *Prog. Plan.* **2022**, *160*, 100599. [CrossRef]
24. Nchofoung, T.N.; Asongu, S.A. ICT for Sustainable Development: Global Comparative Evidence of Globalisation Thresholds. *Telecommun. Policy* **2022**, *46*, 102296. [CrossRef]
25. Tao, R.; Su, C.-W.; Naqvi, B.; Rizvi, S.K.A. Can Fintech Development Pave the Way for a Transition towards Low-Carbon Economy: A Global Perspective. *Technol. Forecast. Soc. Change* **2022**, *174*, 121278. [CrossRef]
26. Arellano, M.; Bond, S. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Rev. Econ. Stud.* **1991**, *58*, 277–297. [CrossRef]
27. Avom, D.; Nkengfack, H.; Fotio, H.K.; Totouom, A. ICT and environmental quality in Sub-Saharan Africa: Effects and transmission channels. *Technol. Forecast. Soc. Change* **2020**, *155*, 120028. [CrossRef]
28. Zhong, Z.; Guo, Z.; Zhang, J. Does the participation in global value chains promote interregional carbon emissions transferring via trade? Evidence from 39 major economies. *Technol. Forecast. Soc. Change* **2021**, *169*, 120806. [CrossRef]
29. Ahmed, Z.; Le, H.P. Linking Information Communication Technology, trade globalization index, and CO 2 emissions: Evidence from advanced panel techniques. *Environ. Sci. Pollut. Res.* **2021**, *28*, 8770–8781. [CrossRef]
30. Asongu, S.A.; Le Roux, S. Enhancing ICT for inclusive human development in Sub-Saharan Africa. *Technol. Forecast. Soc. Change* **2017**, *118*, 44–54. [CrossRef]
31. Asongu, S.A.; Odhiambo, N.M. Enhancing ICT for quality education in sub-Saharan Africa. *Educ. Inf. Technol.* **2019**, *24*, 2823–2839. [CrossRef]
32. Tisdell, C.A. Economic, social and political issues raised by the COVID-19 pandemic. *Econ. Anal. Policy* **2020**, *68*, 17–28. [CrossRef]
33. Lee, M.-H.; Lio, M.-C. The impact of information and communication technology on public governance and corruption in China. *Inf. Dev.* **2016**, *32*, 127–141. [CrossRef]
34. Tchamyou, V.S.; Asongu, S.A.; Odhiambo, N.M. The role of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth in Africa. *Afr. Dev. Rev.* **2019**, *31*, 261–274. [CrossRef]
35. Adams, S.; Akobeng, E. ICT, governance and inequality in Africa. *Telecommun. Policy* **2021**, *45*, 102198. [CrossRef]
36. Albiman, M.M.; Sulong, Z. The linear and non-linear impacts of ICT on economic growth, of disaggregate income groups within SSA region. *Telecommun. Policy* **2017**, *41*, 555–572. [CrossRef]
37. Tay, L.-Y.; Tai, H.-T.; Tan, G.-S. Digital financial inclusion: A gateway to sustainable development. *Heliyon* **2022**, *8*, e09766. [CrossRef]
38. Fareed, Z.; Rehman, M.A.; Adebayo, T.S.; Wang, Y.; Ahmad, M.; Shahzad, F. Financial inclusion and the environmental deterioration in Eurozone: The moderating role of innovation activity. *Technol. Soc.* **2022**, *69*, 101961. [CrossRef]

39. Wei, L.; Ullah, S. International tourism, digital infrastructure, and CO_2 emissions: Fresh evidence from panel quantile regression approach. *Environ. Sci. Pollut. Res.* **2022**, *29*, 36273–36280. [CrossRef] [PubMed]
40. Li, J.; Chen, L.; Chen, Y.; He, J. Digital Economy, Technological Innovation, and Green Economic Efficiency—Empirical Evidence from 277 Cities in China. *Manag. Decis. Econ.* **2022**, *43*, 616–629. [CrossRef]