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Is Fintech the New Path to Sustainable Resource Utilization and Economic Development?

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Abstract: *Sustainability has become an important topic due to the environmental damage caused by economic activity. In this scenario, fintech can help achieve improved resource utilization and green economic development. Even though fintech and sustainability are amongst the main policy areas, they have rarely been assessed together. So the purpose of our research is to improve understanding of this relationship. This study uses panel data from 66 countries for the 2010-2021 period to develop a green growth (GG) index. Regression results show that availability of secure technology, Internet popularization, R&D expenditure, energy supply, industry value added, technological exports and GDP growth have positive effects on green growth. Conversely, unemployment and air pollution have negative effects. Overall, results show that there is a positive impact of fintech on resource use and green growth. Importantly, this research highlights the need for regulators and policy makers to promote application of fintech for achieving greener economic growth.*

Keywords: Fintech, Sustainable development, Green growth index, Financial development, Innovation.

JEL Classification: O3, O4, G0

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1. Introduction

Sustainability has become an increasingly important topic due to the depletion of natural resources and the climate change effects of unsustainable economic activity. Since economic development is accompanied by environmental damage, this type of progress is not sustainable. So economies today need to ensure the sustainability of their activities (Kusi-Sarpong et al., 2022) and businesses are looking for developments that can help them conduct sustainable operations (Kusi-Sarpong et al., 2022). This is why it has become essential to pursue green economic development in which resources are used more efficiently (Organization for Economic Cooperation and Development, 2009). This development concept was first presented by United Nations Economic and Social Commission for Asia and the Pacific in 2005, in order to explore the related opportunities. After that, green economic development received support through research across the world. This topic has attracted the attention of scholars and is highly relevant for research today. United Nations (UN) has provided an important framework of related objectives and criteria, known as Sustainable Development Goals (SDGs), which was adopted in 2015. In this agenda, SDG 7 revolves around affordable clean energy, SDG 12 focuses on responsible production as well as consumption and SDG 13 highlights climate action. In addition, the Paris Agreement was adopted at the 2015 UN Climate Change Conference. This was an international treaty designed to control global warming. It was a milestone in the climate change process because, for the first time, a binding agreement brought all nations into the common cause of curbing climate change.

Today, businesses and economies are facing rising pressure from regulators, activists and consumers to make their operations sustainable through measures such as improved resource utilization (European Union, 2020) and green organizations are being supported by their stakeholders (Forbes Africa, 2018). In this context, sustainable development has become one of the most important goals (Arner et al., 2020). Operations are considered sustainable if they are economically feasible, environmentally friendly and/or socially responsible (Jamali, 2006; Kshetri, 2021). Environmental sustainability includes measures taken up by organizations to manage natural resources productively (Ones & Dilchert, 2012). These actions include, but are not limited to, utilization of renewable energy sources (Al-Amin et al., 2015) such as solar power. Supporting research has found that renewable energy use is negatively related to carbon dioxide emissions (Nguyen & Kakinaka, 2019) which are harmful for the environment (Upadhyay et al., 2021). Importantly, sustainable business strategies help earn profit without negative effects on the environment (Kumar & Vidhyalakshmi, 2012) so represent a win-win scenario.

Technology helps businesses in multiple areas such as data gathering, processing and organizing (Kumar & Vidhyalakshmi, 2012). This can include data related to an organization's impact on the natural environment. Relevant studies have revealed that technologies can have a positive impact on green economic development (Koren & Tenreyro, 2013; Ulucak, 2020; Wang et al., 2019). Technological advancement can help achieve economic development sustainably and even improve environmental health (Tian & Liu, 2019). Technologies can help achieve SDGs linked to the environment, by highlighting problems and taking required actions in real time (Tsolakis et al., 2021).

In the area of technology, fintech is a relevant topic. Fintech refers to financial innovation produced through technology that creates new business models, applications, processes or products that can have important effects on financial markets, institutions or services (Financial Stability Board, 2016). So fintech can be considered a type of technological advancement (Zhou et al., 2022). It is the convergence of multiple technologies, such as mobile devices and wireless networks (Croutzet & Dabbous, 2021). It includes blockchain, artificial intelligence, security, Internet of Things (IoT) and cloud computing.

Technology, including fintech tools, is the main driver of Industry 4.0 (Li et al., 2017; Upadhyay et al., 2021). Industry 4.0 can be linked to the objectives of the circular economy (de Sousa Jabbour et al., 2018b) as it provides opportunities to achieve economic progress while preserving the environment (Beier et al., 2020). An important part of such an economy is the agenda of cleaner operations (Ghisellini et al., 2016; Hens et al., 2021) and sustainability (Geissdoerfer et al., 2017). Fintech can play a role in improving circular economy practices (Pizzi et al., 2021) as enterprises can improve their sustainability by utilizing Industry 4.0 technologies (Soni et al., 2022). Specifically, adoption of Industry 4.0 technologies by organizations helps increase sustainability by automating and simplifying processes (Abdel-Basset et al., 2020; Jia et al., 2020a; Soni et al., 2022).

Fintech is an important topic because it is a source of new services that are designed to increase the adoption of sustainable business models (Pizzi et al., 2021). Fintech can be applied in different economic sectors (Hur & Lim, 2017) to increase business sustainability (Lim et al., 2017). This financial development can promote renewable energy and make energy efficiency initiatives more accessible (Kim & Park, 2016; Tamazian et al., 2009). In fintech, innovation is achieved through artificial intelligence, cloud computing, blockchain and other technologies (Zhou et al., 2022). So it can be concluded that fintech supports sustainable resource use and economic development (Moro-Visconti et al., 2020). Importantly, it has been recognized by UN as one of the central innovations that can help reach SDGs (Merello et al., 2022).

Fintech offers valuable opportunities to improve the financial sector (Arner et al., 2020) because it supports green financial operations (Zhou et al., 2022) through tools such as green credit and investment (Ahmed & Huo, 2020; Cao et al., 2021; Zhou et al., 2022). Fintech can be used to reach the SDGs directly, through better financial and regulatory systems that are aligned with these objectives or indirectly as it provides affordable clean energy (Arner et al., 2020). In addition, fintech can indirectly take climate action by contributing to sustainable technology development.

Related research has found that fintech affects consumption, saving and investment in renewable energy (through tools such as blockchain-based renewable energy certificates) so fintech development has a positive relationship with renewable energy utilization (Arner et al., 2020; Croutzet & Dabbous, 2021). It should also be noted that the interaction of financial development with technological innovation can decrease the volatility in green development (Cao et al., 2021).

For analyzing the impact of fintech on sustainable economic development, we have used panel data from 66 countries for the 2010-2021 period and have also developed a green growth index. This data has been analyzed using simple OLS regression. Some important results have been obtained. GDP per capita growth, carbon emissions and the total energy supply have a strong positive relationship with the GG index. Urban population growth, industry value added growth and R&D expenditure have a positive relationship with green growth. Population growth, tourism and ICT exports are amongst the positive determinants of GG. There is a negative association between unemployment and green growth. Air pollution has a negative correlation with GG Index. Availability of secured internet servers is a positive determinant of GG Index and Internet popularization leads to sustainable development.

These results have multiple practical implications. First, economic and financial policy makers should promote the implementation of fintech for achieving improved resource use and green economic growth. Second, relevant policy makers should ensure that the necessary arrangements have been made for successful implementation of fintech. Third, government authorities can utilize fintech for smoother enforcement of environmental laws. Fourth, fintech supports organizations that want to conduct green operations so business managers should utilize these options. Fifth, marketing managers should highlight the benefits of fintech products, to increase acceptance and popularity of these offerings.

Our research has made multiple contributions to the topic. There is a clear dearth of studies exploring usability of blockchain technology in real-world scenarios (Zhao et al., 2019) and the sustainability implications of blockchain are just an emerging topic in business management (Saberi et al., 2019). So this study has generated valuable results. Fintech and sustainability are amongst the main policy areas for most national governments yet few have linked the two (Arner et al., 2020; Yang et al., 2021; Zhou et al., 2022). Importantly, our study has linked these topics to provide a conceptual contribution.

The next section presents the theoretical background and a review of relevant literature. Sections 3 and 4 describe the data and methodology, respectively. After that, the results are presented and discussed. The paper ends with a conclusion, implications and future research suggestions.

2. Literature review

2.1. The links between fintech tools and sustainable economic development

In the context of fintech, one of the most popular tools is blockchain (Babich & Hilary, 2018). This is a new technology for sharing information by linking databases in a decentralized, peer-to-peer, open-access network (Upadhyay et al., 2021). Recent studies have revealed that blockchain can play an important role in increasing business sustainability so it can help address environmental challenges (Gurtu & Johny, 2019; Kouhizadeh & Sarkis, 2018; Kshetri, 2021). Blockchain can make economic activity cleaner and also help attain harmony between the economy and environment so it is a source of support for the ethical business agenda (Upadhyay et al., 2021).

Amongst the challenges in achieving sustainable production are information transparency, security and traceability so blockchain can contribute to sustainability by helping businesses improve information sharing amongst their supply chain partners (Kusi-Sarpong et al., 2022). Supply chains using blockchain technology are safer, more reliable and more traceable (Orji et al., 2020) so help overcome this challenge. Better sharing of knowledge helps to identify waste in business processes and lower the cost of production (Yeoh, 2017), improving sustainability. Blockchain is also useful for detecting and preventing unsustainable business activity in supply chains (Mackey & Nayyar, 2017).

Most business executives have been engaged in this technology (Garner, 2018) which shows its increasing popularity. This adoption of blockchain can help an economy in achieving low-carbon performance (Fernando et al., 2021; Upadhyay et al., 2021) as the technology is useful for actions such as analyzing carbon footprints (Pan et al., 2019). Further, blockchain technology can support development of renewable energy for the global goal of carbon reduction (Wang & Su, 2020). Blockchain, with its precision and transparency, helps avoid fraud which means there is lower risk of data manipulation (Fernando et al., 2021) by organizations attempting to conceal their role in environmental destruction.

Artificial intelligence (AI) is a computer science used for the development and utilization of intelligent systems or machines that are based on human reasoning, learning and problem-solving (Feldman, 2001; Liengpunsakul, 2021; Simmons & Chappell, 1988). Examples of AI range from Apple's Siri to more complicated systems such as self-driving cars (Liengpunsakul, 2021). Now machines and robotics are solving problems linked with human intelligence in the past, which helps explain the increasing popularity of AI and why it has become a fact of life in modern high-tech societies (Goralski & Tan, 2020). AI also helps conduct complex work at levels beyond human skills (Ojokoh et al., 2020).

Machine learning, a key element of AI, is a set of mathematical processes or algorithms generated by learning from data and it has become a powerful tool that is altering many fields (Liengpunsakul, 2021). Importantly, research has analyzed the role that AI can play in sustainable development and has found that most of the SDGs can be supported by this technology (Vinuesa et al., 2020; World Economic Forum, 2020). One reason behind the increasing popularity of AI is that it can be utilized for data analysis to help solve the unique problems of sustainable economic development (Ojokoh et al., 2020).

Other important elements of fintech are security and IoT. Fintech is designed to ensure that data is managed in a secure way so it is viewed as a powerful tool that offers security also (Upadhyay et al., 2021) in the context of sustainable development. For example, blockchain technology has such a high level of security that it cannot be hacked (Fernando et al., 2021). One reason for why blockchain has attracted academic and business interest is that it supports the confidentiality of data and information (Lin et al., 2018). IoT can be utilized to support fintech – for example, in the context of monitoring energy consumption in real time (Fernando et al., 2021) to help control an organization's environmental impact. IoT is considered one of the essential parts of the infrastructure that is valuable for a stronger sustainable impact (Bibri, 2018).

Fintech includes cloud computing as well, that provides opportunities for sustainable business operations with improved resource utilization and higher profitability (Barnatt, 2010; Grossman, 2009; Kumar & Vidhyalakshmi, 2012; Zissis & Lekkas, 2012). The green benefits of cloud computing are related to effective resource utilization, efficient systems and carbon neutrality (Zissis & Lekkas, 2012). Cloud computing helps build green supply chains through travel reduction, data center removal and replacement of physical items (Barnatt, 2010; Marston et al., 2011).

This discussion shows that fintech supports green finance activity. Green finance is important because it plays an important role in high-quality economic development (Yang et al., 2021). It is a financial strategy that plays an important role in the sustainable development of an economy and has been adopted across the world (Akomea-Frimpong et al., 2021; Cheung & Hong, 2020; Sachs et al., 2019). Green finance aims to provide financial services for projects, with environmental protection as its central part (Wang & Zhi, 2016; Zhou et al., 2020). Fintech supports green finance by lowering information asymmetry, increasing efficiency and helping environmentally sustainable businesses obtain financial resources which generates quality development ultimately (Yang et al., 2021). It can also support green finance by helping enterprises, investors and customers with more efficient green finance offerings (An et al., 2021). Fintech offers the advantages of greater control over customers' personal finance and speed in operations so it can help environmentally sustainable companies obtain financial resources in a faster and cheaper way (Yang et al., 2021). Green finance allows businesses with green management strategies to obtain loans of significant amounts (Shu et al., 2016; Xing et al., 2020) which encourages these organizations to move to lower energy consumption and pollution. Fintech is also being utilized by businesses to encourage customers to participate in green finance projects, by offering rewards for environmentally sustainable behaviours (UNFCCC, 2019). Green finance also allows stakeholders to supervise a project's operations and guarantee that the project meets green standards (An et al., 2021). Importantly, green finance helps in the utilization of non-fossil energy sources (Ren et al., 2020). because financial institutions have control over the credit required for purchasing new green energy assets (Yang et al., 2021).

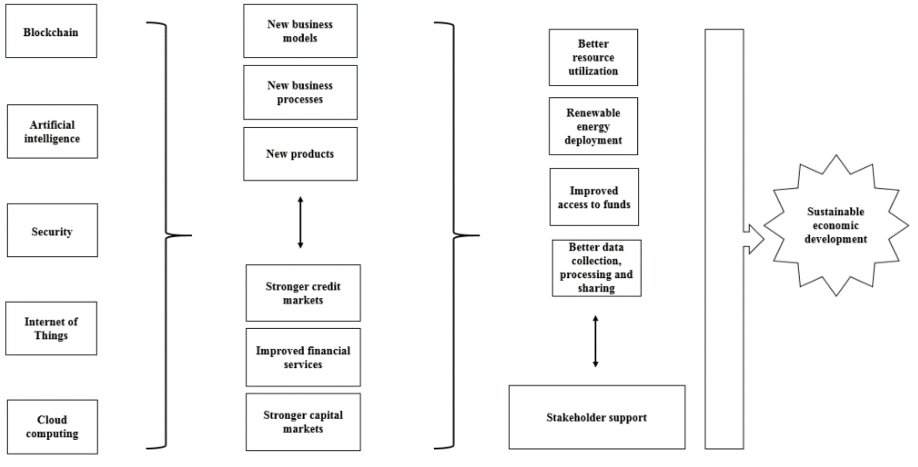
Based on this discussion, the hypothesis below has been developed.

H_1: There is a positive relationship between fintech and sustainable economic development.

The dynamic capabilities theory (DCT) is helpful for achieving organizational objectives in an increasingly demanding economic environment (Teece et al., 1997). It has been asserted that an enterprise's long-term performance is rooted in development of its dynamic capabilities (Helfat et al., 2007; Teece et al., 1997; Winter, 2003). So this theory has been applied in research, for making strategic decisions in different business scenarios (Barreto, 2010; Teece & Pisano, 1994; Teece et al., 1997) such as those related to environmental sustainability. In the context of DCT, dynamic capabilities can be defined as an organization's capacity to improve, reconfigure and combine its abilities to address a quickly changing environment. Kusi-Sarpong et al. (2022) have argued that implementation of fintech is a dynamic capability and such abilities can help an enterprise achieve performance objectives and sustainability simultaneously. Businesses can also utilize their dynamic capabilities to alter operations that are not sustainable (Wu et al., 2013). Keeping in mind our research topic and this discussion of relevant literature, we have selected DCT as the appropriate theoretical framework.

Therefore, this research model is supported by a combination of IDT and the business technology adoption model. In the adoption model, three factors explain the utilization and impact of technology (Iacovou et al., 1995). These factors are perceived benefits, organizational readiness and external pressure. Perceived benefits can be direct or indirect (Pfeiffer, 1992). Direct advantages refer to increased efficiency of the organization while indirect advantages refer to improved processes and relationships. Readiness is the level of financial and technological resources of the organization while external pressure to adopt includes competitive and trading partner forces. Impact refers to the benefits from utilizing a technology.

Figure 1: Conceptual model



2.2. Sustainable economic growth and green growth

Sustainable growth simply asks about how much economic growth can be or has been achieved by protecting the environment simultaneously. The literature began by building an association between the environment and economic growth (Ekins, 2002) and gradually started generating questions on economic development, highlighted as being the only criterion of sustainable economic progress (Liu et al., 2002). The literature has also proposed environmental protection as an important indicator of growth (Liu et al., 2002). Scholars have argued that the green growth concept allows one to link the economy and environment by assessing multiple stakeholder views (Vazquez-Brust et al., 2012). Green growth theory implies economic progress with environmental protection (Hickel & Kallis, 2020).

3. Data

This goal of this research is to find out how fintech contributes to green growth. For this purpose, we have analyzed panel data from 66 countries (across MENA, G9, OECD and South Asia) for the 2010-2021 period. Table 1 provides details of the sample economies. Their selection is based on availability of data. In our model, fintech is the main independent variable and is measured by two proxies. These are Automated Teller Machines (ATMs) per 100 000 adults (Anarfo & Abor, 2020; Li et al., 2022) and secure internet servers per million population (Meiling et al., 2021). ATMs are an indicator of financial inclusion and higher inclusion can provide the funds required for investing in cleaner technologies (Feng et al., 2022). Details about the independent variables are given in Table 2.

Table 1: Countries included in the sample

Algeria	Israel	Ireland
Australia	Italy	Slovenia
Austria	Japan	Spain
Bahrain	Jordan	Sri Lanka
Bangladesh	Korea, Rep.	Sweden
Belgium	Kuwait	Switzerland
Brazil	Lebanon	Tajikistan
Canada	Libya	Tanzania
Chile	Luxembourg	Thailand
China	Malaysia	Ukraine
Colombia	Mexico	United Arab Emirates
Cyprus	Morocco	United Kingdom
Czech Republic	Netherlands	United States
Denmark	New Zealand	Venezuela, RB
Egypt, Arab Rep.	Norway	Vietnam
Finland	Oman	Yemen, Rep.
France	Pakistan	Iran, Islamic Rep.
Germany	Peru	Saudi Arabia
Greece	Philippines	Iraq
Hungary	Poland	Singapore
Iceland	Portugal	
India	Qatar	
Indonesia	Romania	

Table 2: Independent variables

	Variable name	Symbol	Definition	Source
Primary independent variable	Fintech	$Fintech$	Secure Internet servers per million population ATMs per 100,000 adults	WDI
	Population growth	$Populationgrowth$	Population growth (annual %)	WDI
	Unemployment	$Unemployment$	Unemployment, total (% of total labour force, national estimate)	WDI
	Tourism	$Tourism$	International tourism, number of arrivals	WDI
	Information and communication technology exports	$ICT\ exports$	Computer and communication exports (% of exports)	WDI
	Carbon dioxide emissions	CO_2	CO_2 emissions (kt)	WDI

3.1. Construction of Green Growth (GG) Index

Multiple variables have been used to capture the concept of green growth. For example, Kim et al. (2014) considered 12 indicators belonging to the areas of production, consumption and the environment. For this study, we have developed a green growth index by selecting multiple indicators relevant for economic development (Cao et al., 2021; Zhou et al., 2022). It should be noted here that through urban construction, the resource environment and financial support the three pillars of sustainable development (economic, environmental and social) have been incorporated. Variables used in building the GG index are presented in Table 3.

Table 3: Indicator system of green growth

Primary variable	Indicators	Unit	Source
Economic development	Per capita GDP growth	Annual %	WDI
Urban construction	Urban population growth	Annual %	WDI
Resource environment	Energy sustainability	Total primary energy supply, Tonnes of oil equivalent (TOE), millions	OECD statistics
	Air Pollution	Population exposed to levels exceeding WHO guideline value (% of total)	WDI
Financial support	Industry value added	Annual %	WDI
	Research and development expenditure	Annual % of GDP	WDI

Table 4: Correlations of components with GG Index

Variables	Correlation magnitude
1. GDP per capita	0.41
2. Urban population growth	0.77
3. Total energy supply	0.96
4. Pollution	-0.03
5. Industry value added annual growth	0.19
6. R&D expenditure	0.20

4. Methodology

The variables in Table 3 have been used to calculate the GG index by using Principal Component Analysis (PCA). This method is appropriate because these variables must have internal correlations and PCA helps in lowering the bias caused by using a certain variable as a proxy of another variable (Razzaq et al., 2021).

The econometric model we have used is presented below.

$$GG_{it} = \alpha_0 + \alpha_1 Fintech_{it} + \alpha_2 Populationgrowth_{it} + \alpha_3 Unemployment_{it} + \alpha_4 Tourism_{it} + \alpha_5 ICT\ exports_{it} + \alpha_6 CO2_{it} + \varepsilon$$

This shows that green growth is dependent on financial technology, population growth, unemployment, information and communication technology (ICT) exports and pollution.

The data has been analyzed using simple ordinary least squares (OLS) regression. The following regression models have been developed.

Model 1: Controlled for Internet servers only

Model 2: Added population growth

Model 3: Added unemployment

Model 4: Added tourism

Model 5: Added ICT exports

Model 6: Added CO_2 emissions

Carbon emissions are considered the main source of the greenhouse effect so have captured a lot of attention recently. Most of these emissions are generated by the consumption of fossil fuels, such as coal, for economic growth and development. In order to check robustness of our results, carbon emissions were added to the model to find out if digitalization of finance with economic development can cause a change in the GG index. The hypothesis below has been tested by using the econometric model.

$$H_0 = Digitalization\ of\ finance\ has\ a\ positive\ effect\ on\ green\ growth$$

$$H_1 = Digitalization\ of\ finance\ does\ not\ have\ a\ positive\ effect\ on\ green\ growth$$

5. Results and discussion

Tables 5a and 5b provide the descriptive statistics. Table 5a shows that GG dropped from 0.08 in 2010 to 0.027 in 2021. One possible reason is the increasing use of fossil fuels, leading to more industrialization and the associated carbon emissions. Another is the marked increase in ICT exports, from 36% in 2010 to 51% in 2021. Availability of secure internet servers increased from 19 000 in 2010 to 67 000 in 2015 and then to 1 200 000 in 2021. However, the average expenditure on research and development (R&D) remained almost stagnant. Despite more efforts by some economies towards green growth, pollution has not decreased. Statistics show that 80% of the population remained exposed to air pollution levels exceeding the limits provided by World Health Organization (WHO). These statistics and the literature directs our concerns towards how the emergence of fintech, starting in 2010, has helped economies achieve green growth.

Table 5a: Descriptive statistics

Variable	Obs	Mean	Std dev	Min	Max
GG Index	643	3.14e-09	1.464	-1.855	9.13
Findex	643	8.66e-10	1.164	-1.878	9.957
Internet servers	726	340285.54	2512309.5	1	46678110
ATMs	675	69.589	52.31	1.08	288.59
ICT exports	730	39.986	20.867	-3.819	92.678
Per capita GDP growth	776	1.328	5.795	-50.734	85.688
Population growth	791	1.211	1.39	-4.17	11.483
Pollution	528	83.717	31.485	0	100
Unemployment	644	6.797	4.355	.1	27.47
Public expenditure R&D	539	1.499	1.136	.032	5.436
Expenditure on education	513	4.614	1.489	1.19	8.56
Tourism	666	23138396	39501460	104000	2.179e+08
CO_2 emissions	660	431484.39	1347520.4	1630	10707220
Total energy supply	693	167.413	446.924	1.951	3389.302

Table 5b: Descriptive statistics by a 5-year gap
Year : 2010

	Mean	SD
GG INDEX	.08	1.43
Findex	.33	.82
Internet servers	19181.87	95230.10
ATMs	64.70	54.55
ICT exports	36.54	19.99
Per capita GDP growth	2.48	3.62
Population growth annual	1.54	1.97
Pollution	87.1	28.44
Unemployment	6.99	4.00
Expenditure on R&D	1.43	1.06
Expenditure on education	4.67	1.52
Tourism	2021136	3757474
CO_2 emissions	404600	1226323
Total energy supply	158.525	413.53

Year: 2015

	Mean	SD
GG Index	.02	1.44
Findex	.18	.85
Internet supply	60900.04	255510.5
ATMs	71.39	53.60
ICT exports	37.94	20.38
Per capita GDP growth	1.48	5.50
Population growth	1.27	1.25
Pollution	82.63	32.98
Unemployment	7.21	4.62
Expenditure on R&D	1.45	1.10
Expenditure on education	4.61	1.35
Tourism	2385074	40327695
CO_2 emissions	432985	1356650
Total energy supply	168.5	456.45

Year: 2020

	Mean	SD
GG Index	.027	1.42
Findex	.81	1.48
Internet supply	1267029.3	5792371.9
ATMs	66.73	43.13
ICT exports	50.81	20.83
Per capita GDP growth	-5.57	5.15
Population growth	.915	.89
Pollution	84.56	38.27
Unemployment	6.45	3.899
Expenditure on R&D	1.79	1.337
Expenditure on education	4.2	1.605
Tourism	11124518	20877779
CO_2 emissions	5225821	12462541
Total energy supply	155.51	353.415

Table 6 shows that GDP per capita growth, CO_2 emissions and the total energy supply have a strong positive relationship with the GG index. A negative effect of emissions was expected, though, as it is a pollutant that can negatively affect economic activity (Borhan et al., 2012). It can also be observed that urban population growth, industry value added growth and R&D expenditure have a positive relationship with green growth. Population growth, tourism and ICT exports are amongst the positive determinants of GG (Li et al., 2022; Hickel et al., 2020). This indicates that population growth and technology together show the extent of human productivity in an economy. This higher productivity and economic activity support green growth. Aligned with this, a negative association has been noted between unemployment and green growth. Air pollution has a negative correlation with GG Index. Availability of secured internet servers remained a positive determinant of GG Index as all independent variables were added to the model and results showed that internet popularization leads to sustainable development (Shen et al., 2022). CO_2 emissions positively affect green growth, revealing that traditional growth modes may be better for escaping poverty and creating a path to sustainable development (Hao et al., 2021). It is important to add that, in the short term, there is a trade-off between green growth and poverty reduction (Hao et al., 2021). The related policies play an important role in addressing this trade-off (Hao et al., 2021). Research has found that green energy consumption generates economic growth but with high levels of pollution (Al-Mulali et al., 2012). So the relationship between green growth and environmental sustainability is not completely clear yet (Hao et al., 2021).

Table 6: OLS regression with secured Internet servers as the proxy for fintech[1]

Variables	1	2	3	4	5	6
Internet Servers	1.68e-07***	1.67e-07***	6.90e-07***	2.45e-07**	2.33e-07**	3.39e-08
	(2.95e-08)	(2.96e-08)	(1.12e-07)	(1.05e-07)	(1.05e-07)	(2.53e-08)
Population growth		-0.0218	-0.0905	0.0170	0.0589	0.0370**
		(0.0530)	(0.0719)	(0.0651)	(0.0681)	(0.0163)
Unemployment			-0.0648***	-0.0868***	-0.0849***	-0.0262***
			(0.0157)	(0.0143)	(0.0147)	(0.00362)
Tourism				1.64e-08***	1.64e-08***	6.80e-10*
				(1.47e-09)	(1.46e-09)	(4.11e-10)
ICT exports					0.00875**	0.00252***
					(0.00338)	(0.000816)
CO2 emissions						9.06e-07***
						(1.22e-08)
Constant	-0.0537	-0.0310	0.427*	0.207	-0.259	-0.398***
	(0.0646)	(0.0849)	(0.235)	(0.209)	(0.288)	(0.0692)
Observations	493	493	356	348	342	342
R-squared	0.062	0.062	0.152	0.375	0.393	0.965

[1] Numbers of observations have changed due to the missing values in the panel data of some variables as we move from Model 1 to Model 6.

Table 7: OLS regression with ATMs as the proxy for fintech

Variables	1	2	3	4	5	6
ATMs	-0.00522***	-0.00582***	-0.00609***	-0.00661***	-0.00649***	-0.00547***
	(0.00120)	(0.00126)	(0.00123)	(0.00120)	(0.00120)	(0.000670)
Population growth		-0.0731	-0.145**	-0.0537	-0.0317	-0.0670*
		(0.0482)	(0.0583)	(0.0580)	(0.0617)	(0.0344)
Unemployment			-0.0938***	-0.106***	-0.110***	-0.0586***
			(0.0143)	(0.0143)	(0.0148)	(0.00838)
Tourism				1.25e-08***	1.29e-08***	-2.31e-09**
				(1.67e-09)	(1.68e-09)	(1.04e-09)
ICT exports					0.00449	-0.00293
					(0.00328)	(0.00184)
CO_2 emissions						1.02e-06***
						(3.11e-08)
Constant	0.336***	0.471***	1.150***	0.875***	0.652***	0.540***
	(0.105)	(0.138)	(0.188)	(0.186)	(0.249)	(0.139)
Observations	607	607	520	508	495	495
R-squared	0.030	0.034	0.106	0.191	0.207	0.754

The Hausman test has generated $p<0.05$ that shows there are varying factors across countries and time periods. So time and country fixed effects have also been applied. Results are provided in Tables 8, 9 and 10. The results obtained by applying fixed effects are similar to the OLS results. When ATMs are used as a proxy of fintech, the effect on green growth is negative. This could be true because more financial inclusion increases the demand for energy-intensive products, leading to economic growth with higher pollution and reducing green growth (Feng et al., 2022). Further, availability of these financial services can increase economic activity and contribute to environmental damage (Tamazian et al., 2009). Internet has a positive effect on green economic activity. It can be utilized for real time monitoring and accurate predictions of the environment, providing a base for environmental protection and green development (Li et al., 2020). As a robustness check, carbon emissions were added to this model and the positive impact of emissions shows that there is a positive relationship between economic activity and green growth.

Table 8: Fixed effects with ATMs as the proxy

Variables	1	2	3	4	5	6
ATMs	-0.000240	-0.000350	-0.00104	0.000463	0.000413	0.00129
	(0.00114)	(0.00113)	(0.00149)	(0.00148)	(0.00149)	(0.00150)
Population growth		0.0847***	-0.0511	-0.0779	-0.0752	-0.0949*
		(0.0238)	(0.0457)	(0.0501)	(0.0507)	(0.0496)
Unemployment			-0.0251***	-0.0406***	-0.0399***	-0.0447***
			(0.00949)	(0.0106)	(0.0113)	(0.0110)
Tourism				0.0730**	2.47e-09	-1.30e-09
				(0.0331)	(4.60e-09)	(4.75e-09)
ICT exports					0.00525*	0.0102**
					(0.00268)	(0.00480)
CO_2 emissions				-0.0910**		-0.00528**
				(0.0388)		(0.00266)
Constant	-14.67*	-19.62**	-0.0516	-3.663		13.80
	(8.233)	(8.237)	(14.41)	(14.65)		(14.98)
Observations	477	477	385	385	385	385
Number of countries	59	59	59	59	59	59

Table 9: Fixed effects with Internet servers as the proxy

Variables	1	2	3	4	5	6
Internet servers	5.08e-06**	1.72e-06	1.85e-06*	1.83e-06*	1.53e-06*	1.25e-06*
	(2.16e-06)	(1.21e-06)	(1.09e-06)	(1.10e-06)	(1.07e-06)	(1.06e-06)
Population growth		0.539***	0.463***	0.462***	0.467***	0.468***
		(0.0204)	(0.0227)	(0.0230)	(0.0224)	(0.0220)
Unemployment			-0.00648	-0.0110*	-0.0114**	-0.0117**
			(0.00487)	(0.00577)	(0.00564)	(0.00555)
Tourism				9.91e-10	1.35e-09	9.10e-10
				(2.44e-09)	(2.43e-09)	(2.40e-09)
ICT exports					0.00477**	0.00491**
					(0.00236)	(0.00233)
CO_2 emissions						-2.61e-07***
						(8.51e-08)
Constant	112.2***	86.71***	88.20***	92.78***	94.42***	90.56***
	(13.62)	(7.643)	(7.122)	(8.661)	(9.152)	(9.096)
Observations	373	373	373	373	323	323
Number of countries	59	59	59	59	53	53

Table 10: Fixed effects with Findex as the proxy

Variables	1	2	3	4	5	6
Findex	0.163***	0.00360	0.0144	0.0155	0.0153	0.0208
	(0.0609)	(0.0343)	(0.0310)	(0.0312)	(0.0305)	(0.0300)
Population growth		0.544***	0.466***	0.464***	0.468***	0.469***
		(0.0206)	(0.0228)	(0.0231)	(0.0225)	(0.0221)
Unemployment			-0.00748	-0.0124**	-0.0126**	-0.0124**
			(0.00486)	(0.00572)	(0.00558)	(0.00548)
Tourism				3.37e-10	5.61e-10	1.92e-10
				(2.43e-09)	(2.42e-09)	(2.38e-09)
ICT exports					0.00385	0.00395*
					(0.00239)	(0.00235)
CO_2 emissions						-2.75e-07***
						(8.43e-08)
Constant	115.1***	80.37***	82.39***	86.05***	87.41***	85.06***
	(13.89)	(7.824)	(7.168)	(8.692)	(9.049)	(8.916)
Observations	368	368	368	350	350	350
Number of countries	56	56	55	54	53	53

6. Conclusion, implications and future research directions

Sustainability has become an important topic due to the environmental damage caused by economic activity. It has become essential to choose the path of green economic development. In this area, technologies can have a positive impact. Fintech is a valuable technological tool box that can be utilized to improve sustainability. For analyzing the impact of fintech on sustainable economic development, we have used panel data from 66 countries for the 2010-2021 period and have also developed a green growth index. Some important results have been obtained. GDP per capita growth, carbon emissions and the total energy supply have a strong positive relationship with the GG index. Urban population growth, industry value added growth and R&D expenditure have a positive relationship with green growth. Population growth, tourism and ICT exports are amongst the positive determinants of GG. There is a negative association between unemployment and green growth. Air pollution has a negative correlation with GG Index. Availability of secured internet servers is a positive determinant of GG Index and Internet popularization leads to sustainable development. Overall, there is a positive impact of fintech on green growth.

These results have multiple practical implications. First, economic and financial policy makers should promote the implementation of fintech for achieving green economic growth. For example, blockchain technology can be used to provide consumers with verifiable sustainability information so that they know they are buying products that are authentic in terms of being sustainable. This approach will encourage customers to purchase eco-friendly products. Second, the level of benefits obtained through fintech is impacted by the quality of required infrastructure. So the relevant policy makers should ensure that the necessary arrangements have been made for successful implementation of fintech. Third, government authorities can utilize fintech for smoother enforcement of environmental laws as it allows users to monitor performance in real time and make the required changes. Fourth, fintech supports organizations that want to conduct green operations because it provides options such as green funding. So business managers should utilize these options. Fifth, marketing managers should highlight the benefits offered by fintech products, such as privacy and security of consumers' information. This will help to increase acceptance and popularity of fintech offerings.

Although this study has provided useful results, it is not without limitations. These should be considered opportunities for further research on this topic. In the future, fintech can be measured using different proxies or indices. Endogenous problems caused by reverse causality demand an effective instrumental variable such as urban financial policy (Yao et al., 2021). So researchers can include these factors in their models. In addition, other elements of green growth (such as green bonds) can be explored.

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