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Digital Financial Inclusion and Environmental Sustainability Nexus: Evidence from South Asian Economies

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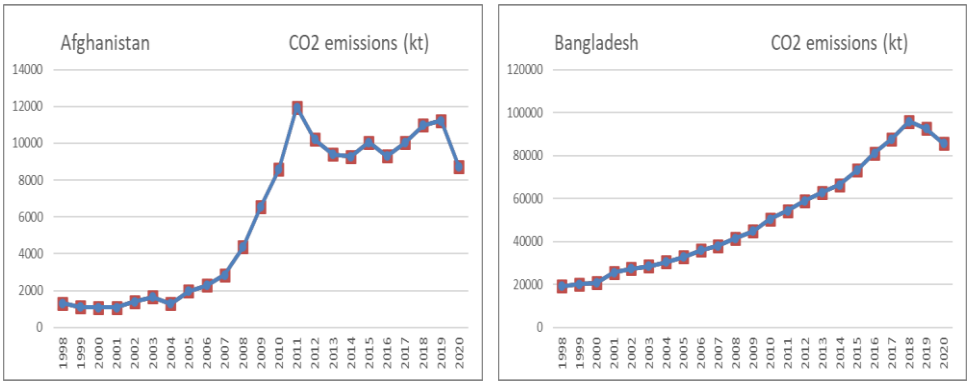
Abstract

The concept of digital financial inclusion (DFI) has gained considerable attention in recent years due to its emergence as a prominent development strategy in several nations. While environmental sustainability is one of the biggest aims of the earth today. This study examines the impact of DFI on the environmental sustainability of the South Asian region (Pakistan, India, Bangladesh and Afghanistan) from 2011 to 2021. Using STATA, the study employed the generalized method of moments (GMM) technique, and the empirical evidence demonstrates that DFI has a significant negative impact on environmental sustainability by increasing CO2 emissions. In addition, study indicates that the growing number of internet users and renewable energy consumption have a substantial adverse effect on CO2 emissions per capita. This suggests that the increased use of the internet and renewable energy consumption contribute to environmental sustainability. On the other hand, Population growth also has a significant negative impact on CO2 emissions per capita and GDP growth and industrialization has no significant impact on environmental sustainability. These findings indicate that policymakers in the South Asian region should design policies that promote DFI and the use of new technology in such a way that stimulate business activities and achieve environmental sustainability.

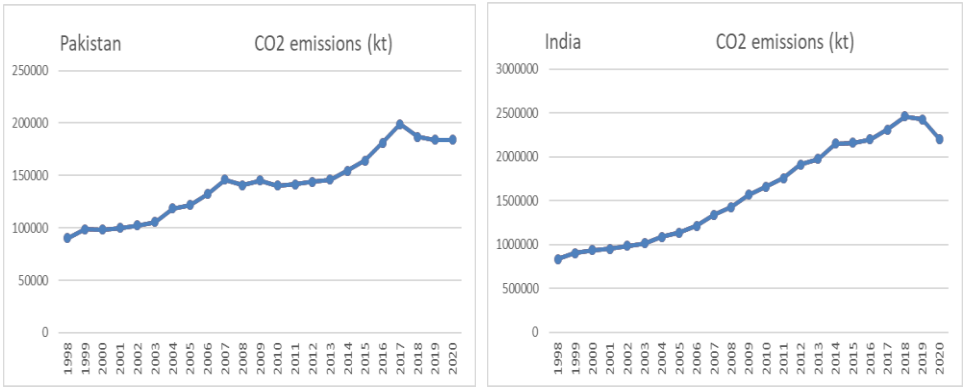
Keywords: Digital financial inclusion, CO_2 emissions, industrialization, internet users, renewable energy consumption, urbanization.

1. Introduction

In the modern era, environmental sustainability has emerged as a primary area of policy concern for governments worldwide. Rapid industrialization, growing population and rapid urbanization have all contributed to a significant increase in the demand for natural resources (Bhattacharya et al., 2016; Lei et al., 2023; Shahbaz et al., 2014). In this perspective, achieving environmental sustainability is essential for the sustainable management of the demand for natural resources, which in turn is essential for ensuring the existence of the global ecosystem. Despite the fact that environmental pollution is a significant issue worldwide, but South Asian nations have much greater hurdles in addressing pollution. For example, India is more contaminated, and its yearly CO_2 emission level is higher than the annual volume of CO_2 generated by all South Asian nations (Mehmood et al., 2023; Rahman et al., 2020). Similarly, Pakistan and Bangladesh have also struggled to slow their carbon output growth as they have become more dependent on unclean fuels. According to Xue et al. (2021) South Asian macroeconomic programs prioritize economic expansion over environmental protection. Therefore, mostly rely on fossil fuels for energy requirements. Fossil fuels provide a large share of energy generation in these nations, both native and imported. The reliance on fossil fuels has led to economic progress in certain nations but has also caused significant environmental issues. Although this region has emerged as the fastest growing region in the world, it is home to approximately one-quarter of the world's population and forty percent of the world's poor people reside there. Hence, it must maintain sustainable development to improve living standards and alleviate poverty (Sahoo & Dash, 2012). Economic expansion enables industrialization and urbanization, leading to the exploitation and use of natural resources like coal, gas, and oil, which may cause environmental degradation. As a result, all South Asian countries are increasingly at risk from a wide range of climate-related difficulties.



Source: World Development Indicators



Source: World Development Indicators

To overcome this environmental sustainability issue, governments are implementing various strategies that enable economic development and environmental sustainability. Among the G-7 Countries the member countries are imposing environmental taxes to make it more expensive to pollute the environment. This initiative encourages countries to use green and renewable energy sources, thereby reducing CO_2 emissions (Xie & Jamaani, 2022). According to the Porter hypothesis, besides rigorous environmental rules, effective policies should promote green innovation. Green innovation is essential for diminishing the detrimental effects of CO_2 emissions on our environment (Porter & Linde, 1995). The modern industrial period has transformed the globe into a quickly evolving society that is highly dependent on the development of technology and robotic intelligence. Now, technologies have established as essential components of enterprises, households, and industries, and this has enabled them to maintain their capacity to have an impact on society, cultures, and economies (Suki et al., 2022). Beside these, many studies in existing literature are exploring different factors that are enabling environmental sustainability such as clean energy consumption (Jie et al., 2023) environmental innovation (Lei et al., 2023), green finance (Tariq & Hassan, 2023), digitalization and financial development (Karlilar et al., 2023), green technology (Rauf et al., 2023; Sharif et al., 2023; Xu et al., 2023), green investment (Wan et al., 2022) , FDI (Ali et al., 2023) and digital financial inclusion (Cheng et al., 2024; Yang et al., 2024).

However, emerging nations worldwide are confronted with the dual concerns of environmental degradation and economic instability. Such as South Asia and Sub-Saharan Africa have a significant prevalence of poverty, illiteracy, and elevated rates of infant and maternal mortality. According to Alimi (2015) to facilitate sustainable economic development, enhance income levels, alleviate poverty, foster entrepreneurship, and stimulate job creation, it is necessary for a financial system to include more individuals

within its framework. In this perspective, the concept of inclusive finance was first introduced by the UN and World Bank in 2005 while promoting the "International Year of Microcredit" (Y. Liu et al., 2021b). It was presented as a financial system that aims to steadily and efficiently deliver full services to all segments and demographics within society (Kshetri, 2020; Y. Liu et al., 2021a). Inclusive finance aims to continuously progress financial services availability through economic infrastructure development, enabling timely and efficient assistance for all social groups, with a focus on underserved areas and affordable services.

On the other side, accessibility to financial services facilitates and enhances manufacturing and industrial activities, potentially resulting in elevated levels of CO_2 emissions and contributing to global warming. Although Asia is widely recognized as the most dynamic area globally, characterized by its remarkable economic growth and the presence of the fastest-growing economies. Despite substantial advancements in the realm of financial inclusion, the issue of financial exclusion continues to pose a serious barrier within the area. A considerable proportion of the global population, over one billion individuals, lacks access to formal financial services. This marginalized group faces the absence of official job opportunities, the absence of bank accounts, and limited capacity to engage in both online and offline paid labor endeavors (Le et al., 2020). In this perspective, it is necessary to establish a system that not only offers financial services to people and organizations but also fosters economic development and promotes environmental sustainability. According to Knaack and Gruin (2021) digitalization of financial inclusion is a cost-effective technique to give financial services to people and enterprises that were excluded from such services. Digitalization of financial services or DFI is not only offers financial services to people and enterprises that are excluded from the traditional financial system, but also enhances economic development (Emara & El Said, 2021) and environmental sustainability (Zheng & Li, 2022).

The concept of DFI has emerged as a vital tool to promote financial access to individuals and businesses, such as banking, savings, insurance, and credit, through digital means. It refers to the acceptance of digital technologies to enhance the outreach and accessibility of financial services to individuals and businesses who have limited access to banking services. Recently, DFI has emerged as a key tool for promoting economic growth (Emara & El Said, 2021), bank stability and environmental sustainability (Salman & Ismael, 2023) in emerging economies. The stability of the banking sector is crucial for economic growth and development, and DFI can help promote this stability by improving access to financial services and reducing the risk of bank failures. Additionally, DFI can help promote economic growth by giving access to capital for small businesses and entrepreneurs, increasing financial literacy, and promoting financial inclusion among marginalized communities. Environmental sustainability is also a key concern in the 21st century, and DFI can play a role in improving sustainability by reducing the need for physical

infrastructure and promoting the use of digital technologies that are more environmentally friendly than traditional banking methods.

The study provides numerous significant advances to the existing body of knowledge in the field of environmental economics. Prior studies have investigated the relationship between CO_2 emissions, fossil fuel energy use, and economic development in developing and emerging nations. However, there is a significant gap in literature in examining this relationship among South Asian countries. The research specifically examines the influence of digital inclusive finance, industrialization, and population growth on carbon dioxide CO_2 emissions in these nations. The study presents a measure, the "digital inclusive finance index", specifically designed for the South Asian region.

Furthermore, several previous studies have failed to consider the problem of endogeneity, resulting in biased calculations and empirical findings. Our empirical research effectively tackles the issue of endogeneity by using instrumental techniques. Furthermore, in addition to digital inclusive finance, the research examines many factors that influence carbon emissions in South Asian nations, such as population growth, industrialization, and GDP. The results have significant implications for guiding policy improvements in South Asian nations to accord with the sustainable development goals (SDGs). Specifically, the study suggests how to improve policies to correspond with SDG 7 (clean, cheap energy), SDG 9 (industry, innovation and infrastructure) and SDG 12 (sustainable production and consumption) more effectively. The study proposes the connection between industrialization, population growth, and carbon emissions at the policy level to support the policies contributing towards the achievement of the Sustainable Development Goals (SDGs).

The remaining parts of the paper are structured in the following manner. The next part explores the literature review, while the analytical framework, data, and econometric methods are then described. The empirical results and their associated discussion are reported in the section under "Results and Discussion". The research ends with the last part, which includes the results and policy implications.

2. Literature Review and Hypothesis Development

Environmental degradation is an important issue that poses a serious threat to our planet's well-being. In the existing literature, there are several studies that are investigating the factors influencing environmental sustainability. Among these, DFI is also a prominent factor that is currently under consideration by many researchers. The concept of DFI has emerged as a crucial and innovative component of the financial system, facilitating the access of financial services via a dependable digital payment infrastructure. DFI encompasses the provision of financial services via the Internet, hence facilitating the participation of those who are now marginalized from conventional financial services (Ozili, 2018). There are two schools of thought among researchers about the association between DFI and environmental sustainability. First one revealed that DFI transforms conventional methods with the introduction of innovative technologies and improves

environmental sustainability (Salman & Ismael, 2023). The second school of thought supports the view that DFI may stimulate economic development, resulting in an increase in CO_2 emissions (Ozturk & Ullah, 2022a)**.** As a result, it is difficult to predict how the DFI will impact CO_2 emissions.

The first notion is explained by many researchers as digitalization in financial institutions enhances financial development, which improves the environmental sustainability by diminishing the per capita energy consumption (Qin et al., 2021; Shahbaz et al., 2018). Similarly, some studies find that DFI contributes to the improvement of per capita GDP, consequently, decrease the energy consumption (Ali et al., 2021; Qin et al., 2019). According to Zheng and Li (2022) the increase in digital finance use and digitalization may reduce CO_2 emissions by reducing energy consumption and improving per capita income. DFI has a greater effect on CO_2 emissions when used for payments and investments. Further studies revealed that DFI had a bigger influence on CO_2 emissions in moderately developed parts of China, particularly in the central region. Another study finds that financial technology has the potential to assist nations in their transition to a green economy by expanding the availability of funding for environmentally friendly initiatives and decreasing the transaction costs involved with financing green development projects (Udeagha & Ngepah, 2023). Similarly, another study revealed that digital finance integrates conventional banking with contemporary information science and technology, thereby enabling the provision of intelligent, online and paperless financial services. Digital finance has the potential to mitigate the need for travel and the use of paper, while simultaneously fostering the growth of environmentally friendly financial services. Furthermore, it serves as a catalyst for individuals to prioritize environmental conservation in their daily lives, thus leading to a decrease in CO_2 emissions (Gapp et al., 2022; Xue et al., 2022). Severo et al. (2019) revealed that enterprises should consider the use of environmentally friendly technology, as it contributes to the attainment of comprehensive environmental performance. Financial technologies (FinTech) play a significant role in facilitating the attainment of environmental sustainability goals by banking institutions via the integration of eco-friendly technology into their operational processes. In this perspective, Li et al. (2021) find that inclusive digital finance plays a crucial role in mitigating CO_2 emissions by offering investors a wide range of financial instruments that effectively enhance the funds allocated towards green technology efforts, hence curbing CO_2 emissions.

Conversely, studies have shown that the presence of financial services facilitates the enhancement of manufacturing and industrial processes, potentially resulting in higher levels of CO_2 emissions. Such as study shows that financial inclusion facilitates the use of financial services and the integration of people into the financial system, which is crucial for contemporary economies. Therefore, this incorporation enables easier access to funding for investment in important projects, therefore promoting economic activity and

subsequently resulting in heightened CO_2 emissions (Ozturk & Ullah, 2022b). Based on above literature survey, it is concluded that DFI ultimately fosters consumer involvement in environmental conservation endeavors by enhancing consumers understanding of the significance of adopting eco-friendly practices, such as reducing paper use, and promoting the transition to a cashless society via the utilization of online digital payment gateways.

Previous empirical research on the link between the environment, industrialization, and population growth has neglected the influence of financial inclusion, especially in the case of South Asian nations worried about environmental sustainability. The objective of this research is to fill this gap by examining the connections among digital financial inclusion, industrialization, Population Growth, and GDP per capita in South Asian nations. The data used for the development of Digital Financial Inclusion (DFI) index originates from the "Financial Access Survey" (FAS-IMF) and the central banks of each individual nation. Prior research has made use of digital financial inclusion data in certain panel settings. However, none of these previous studies have investigated this connection in country-specific contexts or specifically within South Asian nations. Additionally, environmental policy studies often neglect important factors such as the industrialization and the urbanization. While the connection between growth and emissions is important, previous research mostly used energy use to connect the variables. Population growth and other important factors were sometimes disregarded. The objective of this research is to fill the gaps in the existing empirical literature by conducting a thorough investigation, specifically focusing on South Asian nations. So, it is hypothesized that;

- *Hypothesis: Digital financial inclusion has a significant positive impact on environmental sustainability.*

2.1 Theoretical Framework

The financial sector has a crucial role in enabling transactions, mobilizing and using savings, and observing the flow of funds towards productive activities (Ahmad et al., 2022). The development of the financial sector is linked to financial inclusion, which ultimately stimulates the bank stability and economic growth. However, it is found that improved accessibility of financial services leads to an increase in conventional commercial and industrial activities, therefore contributing to a rise in CO_2 emissions. On the other side, studies revealed that financial inclusion is seen to have the potential to enhance environmental quality. Individuals and organizations may get advantages from financial inclusion via enhanced accessibility to financial services, hence facilitating the acceptance of environmentally sustainable technology. Moreover, improved accessibility of financial services is particularly significant for farmers and low-income families who may face a shortage of funds and credit facilities required to engage in environmentally friendly energy solutions. These technologies offer cheaper energy alternatives to fossil fuels while minimizing pollution (IEA, 2019).

On the other side, conventional financial inclusion stimulates industrial and manufacturing endeavors, resulting in increased energy consumption that may contribute to heightened

pollution levels. It may also expedite the process of obtaining financial resources, enabling consumers to purchase energy-intensive products such as air conditioners, vehicles, and refrigerators, which can contribute to an increase in CO2 emissions. In this perspective, the literature suggests that technological progress plays a vital role in advancing both financial inclusion and environmental sustainability (Ahmad et al., 2022). Such as study revealed that DFI transforms conventional methods with the introduction of innovative technologies and improves environmental sustainability (Salman & Ismael, 2023). This assumption is also supported by environmental Kuznets curve (EKC). The EKC Hypothesis identifies the relationship of economic growth and environmental sustainability using three phases namely; pre-industrial, industrial, and post-industrial. During first phase countries prioritizes economic expansion over environmental sustainability resulting environmental degradation. After reaching a certain degree of economic advancement during the industrial period (phase 2), countries prioritize activities and methods that promote sustainable economic growth without negatively affecting the environment. The third or postindustrial phase prioritizes environmental sustainability over economic development. At this point, the government recognizes that environmental degradation causes economic costs like inequality and poverty. During this era, governments develop strategies that enhance the use of innovative technologies to enhance environmental sustainability.

Similarly, this relationship is also supported by "pollution halo hypothesis" which states that the technological innovation in an economy stimulate environmental sustainability. However, some studies support the view that DFI may stimulate economic development, resulting in an increase in CO_2 emissions (Ozturk & Ullah, 2022a)**.** As a result, it is challenging to predict how the DFI will impact CO_2 emissions. This research is an attempt to examines the impact of DFI on the mitigation of carbon dioxide (CO2) emissions in South Asia.

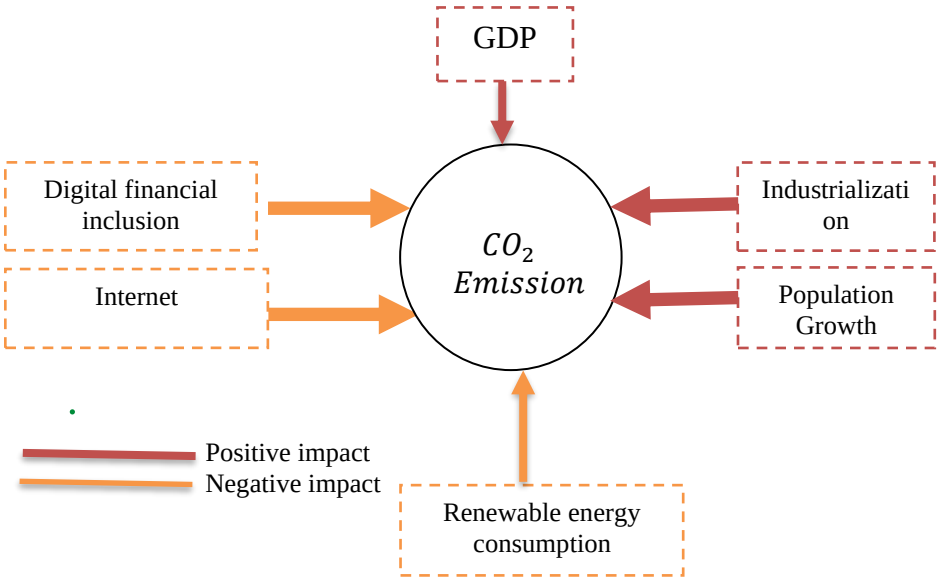


Figure 1: Theoretical Framework of Digital Financial Inclusion, Macroeconomic Variables, and Environmental Sustainability

3. Data and Methodologies

3.1 Data Sources

This study investigates the role of DFI in reducing CO_2 emissions in the South Asian region. The data pertaining to CO_2 emissions, Internet, Renewable consumption, Population growth, industrialization, and economic growth were obtained from the "World Bank Development Indicators" (WDI). The data used for the development of DFI indices are derived from the "Financial Access Survey" (FAS-IMF) and from the respective central banks of each country. It is important to highlight that complete information is only accessible for four countries: Afghanistan, Bangladesh, India, and Pakistan from 2011 to 2021, owing to limitations in data availability. Information pertaining to the chosen variables for additional nations in the region is not accessible.

3.2 The Construction of the Digital Financial Inclusion Index

The DFI index for selected South Asian countries is constructed using data from the IMF, comprising the period of 2011 to 2021. Due to the unavailability of the data, the present study has only used seven indicators. These indicators are divided into two groups. The first indicator group is proxies for digital financial supply outreach, and the second indicator group is proxies for digital financial usage. For the first dimension, we used the

"Number of ATMs per 100,000 adults" and "Mobile money agents per 100,000 adults". For the second dimension, we use five indicators. These are the "number of debit cards and credit cards per 1000 adults", mobile money account per 1000 adults, number of mobile money transactions per 1000 adults and the value of mobile money transactions percentage of GDP. To develop the DFI index using these indicators, we use the principal components analysis (PCA) technique. PCA is considered as an effective technique to develop index for different indicators.

Table 1: Variables, Notations and Data Sources

Variable	Notation	Description	Data Source
Dependent Variable			
Environmental sustainability	CO2	CO2 emissions (metric tons per capita)	World Development Indicators (WDI, 2021)
Independent Variables			
Digital financial inclusion	DFI	Developed Index	Financial access survey (IMF 2022)
Control Variables			
Internet	INT	Individuals using the Internet (% of population)	World Development Indicators (WDI, 2021)
Renewable Energy consumption	REC	Renewable energy consumption (% of total final energy consumption)	World Development Indicators (WDI, 2021)
Population growth	PG	Population growth (annual %)	World Development Indicators (WDI, 2021)
Industrialization	IND	Industry (including construction), value added (% of GDP)	World Development Indicators (WDI, 2021)
GDP	GDP	GDP growth (annual %)	World Development Indicators (WDI, 2021)

3.3 Model Specification

we use the following model to examine the impact of digital DFI on environmental sustainability by controlling Internet, renewable energy consumption, GDP, industrialization and population growth;

$$CO_{2,it} = \beta_o + \beta_1 DFI_{i,t} + \beta_2 INT_{i,t} + \beta_3 REC_{i,t} + \beta_4 GDP_{i,t} + \beta_5 IND_{i,t} + \beta_6 PG_{i,t} + \varepsilon_{i,t}$$

In the given equation, the subscripts "i" and "t" are used to represent the country and year, respectively. The carbon dioxide (CO_2) emissions denoted as $CO_{2,it}$ and is measured in "metric tons per capita" for a particular country "i" and year "t". The explanatory variable in this study is digital financial inclusion, represented as $DFI_{i,t}$. Whereas control variables are included: internet ($INT_{i,t}$), Renewable energy ($REC_{i,t}$, GDP growth (annual %) $GDP_{i,t}$, Industrialization ($IND_{i,t}$) and Population growth $PG_{i,t}$. The intercept is measured by the coefficient β0, whereas the coefficients β1, β2, and β3 indicate the vector of coefficients associated with the DFI and control variables, respectively. The error term is represented by the symbol ε_{it}.

3.4 Estimation Technique

Several estimation techniques have emerged that can deal with panel data. These techniques involve cointegration methods, pooled OLS, fixed effects (FE), random effects (RE), and instrumental variable models such as 2SLS and "Generalized methods of moments" (GMM). Among these, cointegration techniques are suitable when we have large numbers of time series. Beside this, pooled OLS is the more basic technique for panel data, as it also ignores the problem of heterogeneity. According to Gujarati & Porter (2009), the estimations obtained from a fixed effects model are biased because it eliminate the long-term impacts. In this situation, instrumental variable methods are more suitable that's also handle the problem of endogeneity. The present study first conducts preliminary tests, such as tests for multicollinearity, cross sectional dependence and slope heterogeneity and then uses the GMM estimation technique introduced by Arellano and Bond (1991) to find the best results. This method has the benefit of countering the problems of endogeneity and a restricted number of observations.

4. Results and Discussion

4.1 Preliminary Statistics

Table 2 presents the result of descriptive statistics. DFI values show a significant lower value in South Asian region, which shows that individuals and businesses are not significantly using the digital technologies. However, based on standard deviation, minimum and maximum values revealed a significant difference among countries in terms of GDP growth, level of industrialization and population growth.

Table 2: Descriptive Statistics

Variables	Mean	Std Dev.	Min	Max
CO2 emissions (Per capita)	.7902202	.5153182	.1977713	1.795595
DFI	5.590009	1.000001	-.778165	2.799702
Internet	16.14706	9.834776	4.5	46.31
Renewable Energy Consumption	32.28242	10.59923	12.61	48.52
GDP	4.667212	3.322789	-5.831053	12.75229
Industrialization	23.19654	6.10591	10.05187	33.31609
Population Growth	1.783575	.8887459	.7972161	4.077628
ATMs per 100,000 adults	8.807398	6.656874	.6158368	21.78005
Credit cards per 1,000 adults	13.0795	14.31186	.0187414	59.32066
Debit cards per 1,000 adults	238.2744	263.8225	3.978879	892.1747
Mobile money accounts per 1,000 adults	303.1484	434.0899	1.23	1917.036
Mobile money transaction per 1,000 adults	5168.22	7758.502	2	30809.84
Value of Transaction (% of GDP)	4.749052	6.09621	.0051975	21.81661
Mobile money agents per 100,000 adults	229.2342	277.5634	3	917.4192

Table 3 presents the result of the correlation analysis, which revealed that DFI has no significant relationship with CO_2 emissions per capita. Whereas, the internet, renewable energy consumption, industrialization, Number of ATMs, debit cards, credit cards, and mobile money accounts have a significant positive relationship with CO_2 emissions per capita. However, population growth shows a significant negative relationship with CO_2 emissions per capita. Besides this, digital financial inclusion has a positive relationship with the internet and industrialization.

Table 3: Correlation analysis

	1	2	3	4	5	6	7	8	09	10	11	12	13	14
DFI	1.0000													
Internet	0.3968***	1.0000												
REC	0.2562	0.0169**	1											
GDP	0.1433	-0.1047**	0.1051	1										
INDS	0.3544**	0.2960**	0.1357	0.4730***	1									
PG	-0.3683***	-0.4215***	-0.6726***	-0.2882	-0.6015***	1								
ATMs	0.0626	0.5908***	0.4094***	0.2049	0.4600***	-0.7170***	1							
Credit cards	-0.1024	0.6723***	0.3386**	0.0587	0.3972***	-0.6062***	0.8918***	1						
Debit cards	-0.1909	0.5476***	0.2924	0.1281	0.3395**	-0.5696***	0.9441***	0.9461***	1					
Mobile money accounts	0.3157**	0.9017***	0.1248	-0.0181	0.3558**	-0.4500***	0.6194***	0.7737***	0.6220***	1				
Mobile money transactions	0.9464***	0.5715***	0.0963	0.1611	0.4953***	-0.3767***	0.1671	0.0448	-0.0537	0.4678***	1			
Value of Transaction	1.0000***	0.3968***	0.2562	0.1433	0.3544	-0.3683***	0.0626	-0.1024	-0.1909	0.3157**	0.9464***	1		
Mobile money agents	0.9617***	0.4627***	0.1876	0.2276	0.4926***	-0.4578***	0.1444	-0.0125	-0.1049	0.3872***	0.9452***	0.9617***	1	
CO2	-0.2255	0.3242**	0.4038***	0.1896	0.3791**	-0.5850***	0.9079***	0.8516***	0.9220***	0.3819**	-0.1388	-0.2255	-0.1505	1

*Notes: ** $p < 0.05$, *** $p < 0.01$. DFI = digital financial inclusion, Inds= Industrialization, PG= Population growth, GDP = Gross domestic products (Annual growth %)*

Table 4 presents the VIF values used to assess the potential issue of multicollinearity. Since the VIF values are less than 10, it indicates that there is no issue of multicollinearity in the model. Table 5 presents the findings of the cross-sectional dependence test. where the null hypothesis states that there is no cross-sectional dependence among countries. However, a significant value against four variables suggests that there is cross-sectional dependence among countries in the South Asian region. Table 6 presents the result of slope heterogeneity test result, which shows that that the coefficients of each cross-section are similar and there is no issue slope heterogeneity. In this situation, we used the GMM estimation technique introduced by Arellano and Bond (1991) to find the best results.

Table 1: Variance Inflation Factor

Variable	VIF	1/VIF
DFI	1.40	0.714799
Internet	1.89	0.529421
GDP	1.44	0.693681
INDS	2.44	0.410472
PG	4.95	0.201965
REC	3.01	0.332248
Mean VIF	**2.52**	

Table 2: Cross-section Dependence Test

Variable	Pesaran CD	*P*-Value	Corr.
DFI	3.84	0.000	0.473
Internet	7.72	0.000	0.950
CO2 (Per capita)	1.76	0.078	0.217
GDP	4.06	0.000	0.500
INDS	-0.32	0.749	-0.039
PG	2.84	0.005	0.349
REC	0.14	0.887	0.017

Table 3: Slope Homogeneity Test

Statistics	Values	p-value
$\sim\Delta$	0.697	0.486
$\sim\Delta$ adjusted	1.335	0.182

4.2 Generalized Method of Moments (GMM)

The estimations about the relationship of DFI and CO_2 emission per capita are shown in Table 7. Based on these results, it is evident that the estimated coefficients of DFI exhibit

a positive and statistically significant relationship using GMM technique. However, a small value of Beta shows that digitization in the banking industry resulting a minor impact on CO_2 emissions. We also find the impact of traditional financial inclusion on CO_2 emission and revealed that traditional financial inclusion also significantly increases the CO_2 emission. Further, an increase in internet, renewable energy consumption and population growth revealed a significant negative impact on CO_2 emission per capita. However, GDP growth and industrialization show no significant impact on CO_2 emissions. Similarly, we also check the impact of each indicator of DFI on environmental sustainability and find that increasing number of ATMs and Debit cards, number and value of mobile money transactions have significant positive impact on CO_2 emissions. Other indicators show no significant impact on CO_2 emissions.

Table 4: Digital Financial Inclusion and Environmental Sustainability (GMM)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
DFI	.0272907**				
Internet	-.0048973***	-.0040134	-.0045489***	-.0034576***	-.0040573***
REC	-.0084961**	-.0151105	-.0107818***	-.0114432***	-.0143779***
GDP	.0016387	.0003941	.0008928	.0016765	.000799
IND	-.0012918	-.0020358	.0008928	-.0017124	-.0024701
PG	-.0714633**	-.0310213	-.0489509	-.051847	-.0275748
TFI		.0352706**			
ATMs			.00867**		
Credit cards				-.0001843	
Debit cards					.0001598*
Mobile money accounts					
Mobile money transactions					
Value of Transaction					
Mobile money agents					
_cons	.7488357***	.8553541***	.8227379***	.8177768***	.9963111***
Wald chi2	147.08 (0.0000)	**195.84 (0.0000)**	178.97 (0.0000)	144.83 (0.0000)	177.33 (0.0000)
Sargen test	27.3467 (0.5530)	34.23442 (0.2308)	33.68273 (0.2115)	31.20991 (0.3556)	33.91635 (0.2423)

Table 5: Digital Financial Inclusion and Environmental Sustainability (GMM)

Variable	Model 6	Model 7	Model 8	Model 9
DFI				
Internet	-.0036095**	-.0052367***	-.0048973***	-.0044511***
REC	-.0118309***	-.0085929**	-.0084961**	-.0086789**
GDP	.0016343	.0015402	.0016387	.0014429
IND	-.0018675	-.0020708	-.0012918	-.0016614
PG	-.050653	-.0711701**	-.0714633**	-.057545*
TFI				
ATMs				
Credit cards				
Debit cards				
Mobile money accounts	1.380006			
Mobile money transactions		3.440006*		
Value of Transaction			.0044767**	
Mobile money agents				.0000763
_cons	.8398938***	.7686732***	.7275758***	.7251357***
Wald chi2	145.80 (0.0000)	139.49 (0.0000)	147.08 (0.0000)	142.01 (0.0000)
Sargen test	31.43166 (0.3454)	27.3225 (0.5007)	27.3467 (0.5530)	29.06522 (0.4617)

Based on these results, we conclude that DFI contributes to enhancing CO_2 emissions in the South Asian region. DFI enables people and companies to use debit and credit cards, online payment methods, ATM withdrawals, and mobile accounts. This is achieved by minimizing the reliance on physical infrastructure and encouraging the adoption of digital technology. Consequently, the economy experiences an increase in transactions from both the demand and supply sides. This not only stimulates economic growth but also increase CO_2 emissions and promotes environmental pollution (Ullah et al., 2021). These results are supported by many studies in existing literature. Such as Ozturk and Ullah (2022b) found in their study that DFI improves economic growth and decreases environmental sustainability through stimulating CO_2 emissions. Similarly, many other studies support these findings and reveal that DFI is a significant source of CO_2 emissions (Yao & Tang, 2021; Zaidi et al., 2021).

On the other side, these findings contradict some other studies, which show that digital financial inclusion improves environmental sustainability. Such as Huang et al. (2022) states DFI achieves a substantial reduction in transaction costs and service requirements for microeconomic stakeholders by integrating digital technology with financial inclusion. This approach aligns with the goals of promoting environmentally friendly and low-carbon financial innovations (Agras & Chapman, 1999). These results are also presented by Chang et al. (2023) and further reveal that digital financial inclusion enhances transparency and accountability in financial affairs. Additionally, it has the capacity to promote international coordination and cooperation, enabling nations to collaborate in addressing global environmental issues. Another study further revealed that Increased availability of financial resources for environmentally friendly business activities and renewable energy projects might lead to a reduction in pollutant emissions (Chaudhry et al., 2022). Since DFI promotes financial access to individuals and businesses by using digital technologies. Additionally, studies explain that the banking sector plays a vital role in a nation's sustainability performance by using innovative technologies like green banking and internet banking, as well as supporting eco-friendly initiatives such as renewable energy and green industrial growth (Zheng et al., 2021).

A growing body of literature has revealed that both conventional financial inclusion and DFI enable people and organizations to have access to more cost-effective and affordable financial services and products. Increased financial inclusion may contribute to a greater adoption of eco-friendly technology, hence aiding in the reduction of environmental deterioration. On the other hand, if improved availability of financial services leads to an increase in conventional commercial and industrial activities, it may therefore contribute to a rise in CO_2 emissions (Hussain et al., 2022; N. Liu et al., 2022; Ren et al., 2023; Zaidi et al., 2021; Zheng & Li, 2022). Our study shows that the use of digital financial services has a vital role in decreasing environmental sustainability. Based on the environmental Kuznets curve (EKC), it is concluded that the South Asian region is in the pre-industrial and industrial development phases, and these countries are striving for economic development while ignoring environmental sustainability. On the other side, the adoptability of innovative technologies is also very low in this region due to a low level of financial literacy. Hence Both traditional and digital financial inclusion enhance economic development, resulting in the stimulation of CO2 emissions in the South Asian region.

5. Conclusion, Policy Recommendations and Limitations

The aim of this study is to investigate how DFI in banking sector matters for environmental sustainability in South Asian region. The study used data ranging from 2011 to 2021 and adopted GMM technique to analyze the data. DFI in the banking sector is measured by using Seven proxies and PCA technique is used to develop the index. Environmental sustainability is measured using "CO_2 emissions in metric tons per capita" for a particular country. Beside these, the study also used various control variables, such as industrialization, Population growth, GDP Growth, Renewable energy consumption and

internet users. The outcomes of this study using GMM technique revealed that DFI has a significant positive impact on CO_2 emissions, which revealed that an increase in DFI can decrease environmental sustainability. Beside this, GMM test revealed that the increasing number of internet users has significant negative impact on CO_2 emissions in metric tons per capita which revealed that the increasing use of internet improves the environmental sustainability. Similarly, renewable energy consumption and population growth also negative impact on CO_2 emissions. While GDP growth and industrialization have no significant impact on CO_2 emissions.

1.1. Implications

The research has significant policy implications for economies in South Asia. Firstly, governments in the South Asian region should prioritize the enhancement of the technological infrastructure for DFI by improving accessibility to mobile and internet services. Secondly, encourage the combination of financial services with new digital technologies and make more financial products available. This will keep a wider range of financial products that promote green transformation. Additionally, the quality of digital financial services needs to be improved, and a way needs to be found for the financial market and the environmental protection business to connect. At the same time, it's also important to lower the prices of financial services and business financing.

1.2. Limitations and future directions

The present research is subject to many limitations, one of which is the restricted dataset that only includes information from four nations (Afghanistan, Bangladesh, India and Pakistan). This constraint arises from the unavailability of data from four other countries. Despite the constraints associated with data unavailability, the empirical findings of this study might aid future researchers in conducting similar investigations in other areas such as MENA, SAARC, ASEAN, Asian, and emerging countries. Moreover, in the future, this inquiry may be conducted by including other factors and data, as well as expanding the sample size.

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