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Financial Inclusion and CO_2 Emissions: Examining Linkages in South Asian Countries

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Abstract

This study aims to investigate the impact of financial inclusion, together with urbanization, trade openness, industrialization and energy intensity on environmental quality as proxied by CO_2 emissions in South Asian countries from 2004 to 2018. This study constructed a multidimensional time-varying financial inclusion index to measure the level of financial inclusion. The long-run association between financial inclusion and CO_2 emissions is examined by using the Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) approaches. The findings show that financial inclusion is increasing CO_2 emissions. Similarly, energy consumption and urbanization have a positive impact on carbon emissions. Industrialization and trade openness have a negative impact on carbon emissions. Further, the Dumitrescu-Hurlin panel causality test shows that financial inclusion is the main cause of CO_2 emissions. On the base of the findings, it is recommended that the South Asian governments and policymakers must adopt greener environmental policies.

Keywords: Financial Inclusion, Financial Inclusion Index, CO_2 emissions

JEL: O43, G21, Q53

1. Introduction

One of the World's most urgent concerns is to reduce carbon emissions (i.e. CO_2). Environmental activists, economists, and policymakers around the World are now more aware of environmental pollution and its adverse effects on climate change. The extreme release of greenhouse gasses, particularly CO_2 emissions, is widely believed to be the major contributor to global warming (United States Environmental Protection Agency, 2023; Jones et al.2023; Anderson et al. 2016). As a result, various countries have proposed policies and regulations to combat global warming while pursuing economic growth.

There are many factors that contribute to CO_2 emissions in the world. Many studies have focused on the factors that influence CO_2

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emissions, such as industrialization, population growth, urbanization, trade openness, etc (Cetin and Ecevit, 2015; Ertugrul et al. 2016; Cetin et al. 2018; Anwar et al. 2020; Mahmood et al. 2020; Aslam et al. 2021; Cetin et al. 2023). which are interrelated and interdependent in many situations. According to some recent studies, financial development is another important factor that has a direct effect on CO_2 emissions. The impact of financial development may be positive (Cetin et al. 2023; Jiang and Ma, 2019; Lu, 2018; Bekhet et al. 2017; Shahbaz et al. 2016) and negative impact (Sadorsky, 2010; Saide and Mbarek, 2017; Dogan and Seker, 2016; Zaidi et al. 2019) on carbon emissions (more in literature review section). Furthermore, financial inclusion is an essential indicator of financial development since it encourages banking institutions to expand. A recent study has evidenced that people who are excluded from banking services as the main reason for poverty and financial inclusion can help to alleviate poverty (Burges and Pande, 2005; Banerjee and Newman, 1993; Yunus, 1997; Sethy et al. 2023). The number of studies examining the positive and negative effects of financial development on climate change has been large and increasing. But due to the lack of suitable data on financial inclusion (FI), studies on the importance of FI in combating climate change is very rare.

The influence of FI on CO_2 emissions can be both positive and negative as already stated. An inclusive financial system or financial inclusion makes it easier for businesses and individuals to access appropriate and affordable financial products, making green technology investment more feasible. In this regard, FI has a positive impact on the environment as a tool for increasing access to, availability of, and use of cleaner technologies and better environmental practices. This can reduce bad effects of climate change (Innovations for Poverty Action (IPA), 2017).

Promoting financial inclusion programs and providing ‘green loans’ (i.e., credit to use environmentally friendly products such as solar energy, eco-friendly seeds, and fertilizer, etc.) is especially important for poor farmers who may not have access to credit to invest in better environmental practices and renewable energy technologies, such as solar technology which is not only cheap but also emits less CO_2 emissions (Innovation for Poverty Action, 2017). According to Baulch et al. (2018), financial limitations (such as restricted access to credit, lack of government subsidies, and limited bank financing option) are important obstacles to the adoption of solar systems in Vietnam. These are some of the ways that affordable financial products and services (i.e., green loans) will encourage the use of renewable energy technology and the introduction of environmentally friendly services which reduce CO_2 emissions. So, financial inclusion is important to reduce carbon emissions.

However, financial inclusion may also have a negative impact on carbon emissions. Better financial systems and improved access to banking services, can increase industrial and many other economic activities in the country, which could lead to higher CO_2 emissions via higher urbanization, transportation, use of electricity etc. (Jensen, 1996). In addition to, higher inclusive finance may allow consumers to buy high energy consumption consumer goods such as automobiles, air conditioners etc. These energy-intensive consumer goods are now posing a threat to the clean environment in many countries (Frankel and Romer, 1999). According to a recent study, financial inclusion increased CO_2 emissions in Asia from 2004 to 2014 (Le et al., 2020).

Since financial inclusion also plays an important role in carbon emissions, it is important to examine their linkages, particularly for South Asian countries where studies are very rare on the present topic. South Asian countries have a long history of promoting inclusive banking structures. Its member countries are culturally and economically diverse but share common concern about financial inclusion in terms of access, usage and quality. In addition, it has been the home of one of the pioneering innovations in financial inclusion-microfinance that also helped reduce poverty and gender gaps. Recent IMF studies show that South Asian countries can reap a growth dividend from improving financial inclusion (Almekinders et al. 2022). However, despite important achievements in financial inclusion, these countries still suffer from many issues for both financially excluded and included people. In addition, historically, the consumption and reliance on fossil fuels in South Asian countries have been generally on the rise (Vilaysouk et al. 2017). South Asia is observed to be one of the world's most sensitive regions to global warming (World Bank, 2019; Asian Development Bank, 2017). Recently, climate change is estimated to impact over 800 million people directly by 2050, which will continue to burden South Asian economies (World Bank, 2019). Against this background, the present study proceeds to examine the linkages of financial inclusion and CO_2 emissions in seven South Asian countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Pakistan, and Sri Lanka).

Contributions of the study

The present study contributes to the existing literature in the following ways: *First*, it has investigated the impact of financial inclusion on CO_2 emissions in South Asian countries using the Pedroni panel cointegration test to check the long-run connection among study variables. *Second*, the FMOLS (Fully Modified Ordinary Least Squares method), and DOLS (Dynamic Ordinary Least Squares) approaches have been adopted to show the long-run elasticity between financial inclusion and CO_2 emissions for the period from 2004 to 2018. *Third*, this study has used the Dumitrescu-Hurlin panel causality tests to determine the causal relation between two key variables: financial inclusion and CO_2 emissions.To the best of our knowledge, this is the first study to examine the linkages between financial inclusion and CO_2 emissions in South Asian countries during 2004 to 2018 by using suitable econometric methods.

The rest of the article is organized as follows: Section 2 contains a review of the literature. Section 3 presents theoretical arguments. Section 4 explains the current status of carbon emissions in South Asian countries. Section 5 presents the methodology, model specification and data sources. Section 6 presents the empirical findings and discussion. Finally, section 7 gives the conclusion, policy implication and limitations.

2. Review of literature

As stated above, the number of studies examining the positive and negative effects of financial development on climate change has been vast and increasing. But studies that consider the impact of financial inclusion on CO_2 emissions are very rare, mainly due to a lack of suitable data on formal financial services indicators.

Researchers have proposed mixed views on the impact of financial development on

CO_2 emissions from a theoretical point of view. According to a few researchers (Dasgupta et. al.2001; Islam et al. 2013; Dogan and Seker 2016), financial development can reduce CO_2 emissions due to the following factors: (a) to minimize manufacturing expenses and improve product market effectiveness, a business unit must periodically upgrade production technologies and equipment, which requires sufficient funding. Financial organizations may enable the business unit to complete these projects by efficiently easing their funding limitations, lowering energy costs, and reducing carbon emissions indirectly. (b) to combat environmental degradation, governments generally initiate a variety of environment-friendly programs, encourage overall industrial renovation, and promote the use of renewable energy. Formal financial institutions supply sufficient funds for the action of environmentally friendly initiatives, which could help to enhance environment friendly infrastructure and, in turn, minimize carbon emissions.

Other researchers (Sadorsky, 2010; Zhang, 2011) believe that financial development contributes to increased CO_2 emissions due to the following factors: (a) a well-functioning banking system can efficiently expand funding networks, allowing businesses to take capital at much lower prices, allowing to expand their production size, further it leads to increasing carbon emissions. (b) Similarly, it will be able to offer more and better consumer credit services, allowing them to engage in spending habits and encouraging them to buy more goods: cars, refrigerators, etc. These will have a significant impact on the growth of social consumption, resulting in increased carbon emissions. In addition, some studies evidenced that energy consumptions, urbanization, and trade openness are the main determinants of environmental pollution (Cetin and Ecevit 2015; Cetin et al. 2015; Seker et al. 2015; Ertugrul et al. 2016; Cetin et al. 2018; Cetin and Yuksel 2018). These studies have confirmed that energy consumptions, urbanization, and trade openness are increasing carbon emissions.

Financial development reduces carbon emissions

Studies conducted by Claessens and Feijen (2006) and Tamazian and Rao (2010) have evidenced that financial sector development is expected to provide better banking services for environmentally friendly initiatives at a lower cost and as a result, it reduces energy pollution. Similarly, some studies also evidence that financial development reduces CO_2 emission and so it increases environmental quality (King and Levine 1993; Tadesse 2005; Jalil and Feridum 2011; Kumbaroglu et al. 2008).

A study was conducted by Dogan et al. (2016) on CO_2 emissions from 1960 to 2010 in the USA and they used ARDL (the autoregressive distributed lag model), VECM (the vector error correction mechanism model) and granger causality tests. Their empirical results revealed that different improvement in the financial sector has little influence on CO_2 emissions. In addition, their findings confirm that financial development plays a major role to reduce CO_2 emissions. Using GMM (the generalized method of moments) model, Saidi et al. (2017) proved the influence of control variables on CO_2 emissions in 19 emerging economies. Their empirical result confirms that financial development minimized environmental degradation from 1990 to 2013. Zhou et al.'s (2019) study evidenced that loan size had a negative effect on CO_2 emissions in high-energy industries in China. Similarly, Zaidi et al. (2019) conducted a study on CO_2

emissions in 17 APEC (Asia-Pacific Economic Cooperation) countries from 1990 to 2016. They used CUP-BC (continuously updated bias-corrected) and CUP-FM (continuously updated fully modified) methods and their empirical findings showed that financial sector improvement has the potential to minimize CO_2 emissions in the long-term. Cetin et al.'s (2022) study evidenced that financial development and renewable energy consumption reduce carbon dioxide emissions. In addition, economic growth, urbanization and trade openness deteriorate the environmental quality in sample countries from 1990 to 2018.

Financial development (FD) increases carbon emission (CO_2)

Some studies also have evidenced that financial development increases CO_2 emissions (Sadorsky 2010; Zhang 2011; Gokmenoglu et al. 2015; Chang 2015; Bekhet et al. 2017; Saud et al. 2018). Cetin and Ecevit (2017) confirm that financial development, economic growth and trade openness positively affect carbon emissions in Turkey from 1960 to 2011. Shah et al. (2019) observed the association between financial development, institutions, and environment in 101 countries over the period of 1995-2017. Their study confirms that a positive association exists between financial development and CO_2 emissions. Saud et al. (2019) examined the relationship between financial development, income level, and environmental quality in Central and Eastern European countries from 1980 to 2016. Their empirical results show that financial development and income level negatively impact on environmental quality. According to their study, these two factors are the main drivers of high CO_2 emissions.

Some recent studies have evidenced that financial development increases CO_2 emissions (Ahmed et al. 2020; Gok 2020; Bayar et al. 2020; Shoaib et al. 2020; Ahmad et al.2020; Saud et al. 2020; Ozturk et al. (2022); Saud et al. 2023). A recent study by Saud et al. (2023) confirms that there is negative long-run relationship of economic complexity (*i.e.,* financial development and economic growth) with carbon dioxide emissions (CO_2) and the ecological foot print in MENA countries from 1980 to 2020. Cetin et al. (2023) used PCSE and FGLS estimation methods and their empirical results confirm that globalization and energy consumption have a negative impact on environmental pollution, while economic growth and financial development have a positive impact. This implies that globalization and energy consumption reduce environmental pollution while economic growth and financial development increasing environmental pollution from 1991 to 2018 in sample countries.

As per the above analysis of literature, the effect of financial development on CO_2 emissions are still a topic of discussion. The connection between financial development and CO_2 emissions is a complex matter because it is very difficult to explain. Particularly, theoretical analysis shows that financial development has both positive and negative consequences for carbon emissions. However, according to empirical studies, the impact of financial development on CO_2 emissions differs across nations and states. In fact, it partially validates the theoretical studies' point of view, since it is fair to understand how both positive and negative effects vary across countries.

Linkages between financial inclusion (FI) and CO_2 emissions

From the above review of literature, we have come know that there are a number of theoretical as well as empirical studies which have examined the influence of financial development on CO_2 emissions in different countries of the World. But the number of studies on the impact of FI on carbon emissions is very rare, mainly due to a lack of suitable data on formal financial services. In theory, the effect of FI may be positive and negative on CO_2 emissions.

Till now, there are limited empirical studies that investigated the effects of financial inclusion on CO_2 emissions in South Asian countries. Using the principal component analysis (PCA) technique and Hoechel (2007) procedure, Le et al. (2020) investigated the influence of financial inclusion on CO_2 emissions in 31 Asian countries from 2004 to 2014. Their empirical studies evidenced that financial inclusion could increase more CO_2 emissions in Asian countries. Similarly, a recent study was conducted on the influence of FI on CO_2 emissions for 26 countries in Asia. Using the PCA technique, the study evidenced that there exists a positive influence of FI on CO_2 emissions in the long-run (Hussain et al. 2021). A study was conducted by Zaidi et al. (2021) on the effects of FI on CO_2 emissions in OECD (Organization for Economic Cooperation and Development) countries from 2004 to 2017. They used the PCA technique and the CS-ARDL (Cross-sectional-autoregressive-distributed lag) technique and the results confirm that there exists a positive link between FI and carbon emissions. That means FI increases carbon emissions. Using panel quartile regression analysis and cointegration tests, Qin et al. (2021) investigated the effects of FI on carbon emissions in E7 countries from 2004 to 2016. Their findings confirm that FI reduces carbon emissions. A recent study was conducted by Singh et al. (2022) on the impact of financial inclusion on carbon emissions in India from 2008 to 2018. They used the PCA and ARDL methodology, and their results confirm that financial inclusion and growth lead to increased carbon emissions in India. Ali et al. (2022) investigated the impact of natural resources and financial inclusion on ecological footprint in ECOWAS (Economic Community of West African Countries) economies from 1990 to 2016. The result of this study reveals that financial inclusion increases the ecological footprint. Wang et al. (2022) used a spatial econometric model based on the dataset of 284 prefecture-level cities in China. Their study confirms that digital financial inclusion positively impacts CO_2 emissions of local cities and negatively impacts neighboring cities in China. Mehmood (2022) investigated the impact of financial inclusion, renewable energy, globalization, and economic growth on carbon dioxide emissions from 1990 to 2017. The result of the study confirms that financial inclusion is increasing carbon dioxide emissions. Liu et al. (2022) used five different proxies of financial inclusion and ARDL methodology to investigate the impact of financial inclusion on CO_2 emissions. Their study confirms the favorable impact of financial inclusion on environmental quality in China. Baskaya et al. (2022) confirm that financial inclusion and renewable energy consumption have a negative impact on CO_2 emissions levels in BRICS countries. In their research, Zhang et al. (2022) suggests that financial inclusion does not lead to increased carbon emission efficiency in China. Instead, they found that financial inclusion may decrease the efficiency of carbon emissions.

This implies that financial inclusion may be associated with higher carbon emissions or a less effective use of resources in reducing emissions.

Finally, it can be seen that many studies on the impact of financial inclusion on CO_2 emissions confirm that financial inclusion positively impacts CO_2 emissions (Le et al. 2020; Hussain et al. 2021; Singh et al. 2022; Wang et al. 2022; Ali et al. 2022; Mehmood 2022; Liu et al. 2022). In addition, Ogede and Tiamiyu (2023) confirm that financial inclusion increases carbon emissions while urbanization and energy intensity reduce carbon emissions in Sub-Saharan African countries. Tsimisaraka et al. (2023) employed the CS-ARDL approach and their result confirms the positive impact of financial inclusion on CO_2 emissions while globalization has a little impact on CO_2 emissions in One-Belt-One-Road (OBOR) regions from 2004 to 2019. Digital financial inclusion reduces households' carbon emissions through electricity consumptions and natural gas consumptions from 2011 to 2020 in 30 Chinese provinces (Zhou et al. 2023).

Previous studies used the Principal Component Analysis technique to measure the level of financial inclusion (Let et al. 2020; Hussain et al. 2021; Zaidi et al. 2021; Singh et al. 2022; Hussain et al. 2023) and they used limited financial inclusion related variables. But the present research differs from many of the previous studies for mainly four reasons already stated in section 2.

The present study suggests two hypotheses based on the above arguments derived from literature review and theoretical supports.

Hypothesis:

H0: Financial inclusion (FI) decreases the carbon emissions

H1: Financial inclusion (FI) increases the carbon emissions

3. Financial inclusion (FI) on carbon emissions: Theoretical argument

A theoretical connection between financial inclusion and CO_2 emissions is explained in Figure 1. Financial inclusion can increase or decrease CO_2 emissions through access to an affordable cost of credit and access to attractive financial products.

The logic goes in the following ways. First, easy access to suitable and affordable financial services (i.e., green loans) encourages the investment in green technology, and eco-friendly products such as solar energy, wind energy, and eco-friendly seeds, etc. which further reduce CO_2 emissions. On the other hand, a better financial system or inclusive financial system can improve the accessibility of banking products, which in turn increases energy-consuming goods like automobiles, refrigerators and air conditioners, etc., and manufacturing and industrial activities. Finally, it increases CO_2 emissions and global warming. So, both trends are possible.

4. Current status of carbon emissions in South Asian countries

Figure 2 shows that Asia is the World's largest CO_2 emitter, contributing to nearly one-third of all global CO_2 emissions from 2009 to 2019. Figure 3 shows the rising trend in carbon dioxide (*i.e.*, CO_2) emissions in SAARC (South Asian Association for Regional Cooperation) countries from 1990 to 2019. The trend line of carbon emissions has been increasing in all South Asian countries due to the rapid growth of urbanization and increasing energy consumption by industries and transport.

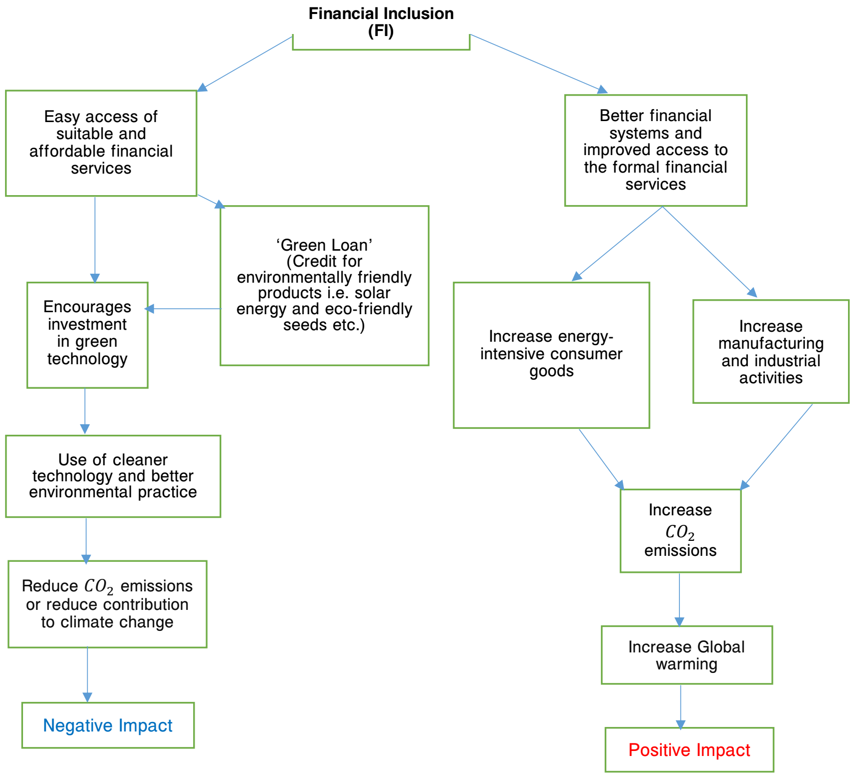

Figure 1. Positive and negative impact of financial inclusion on CO_2 emissions
Source: Designed by the authors based on the available literature

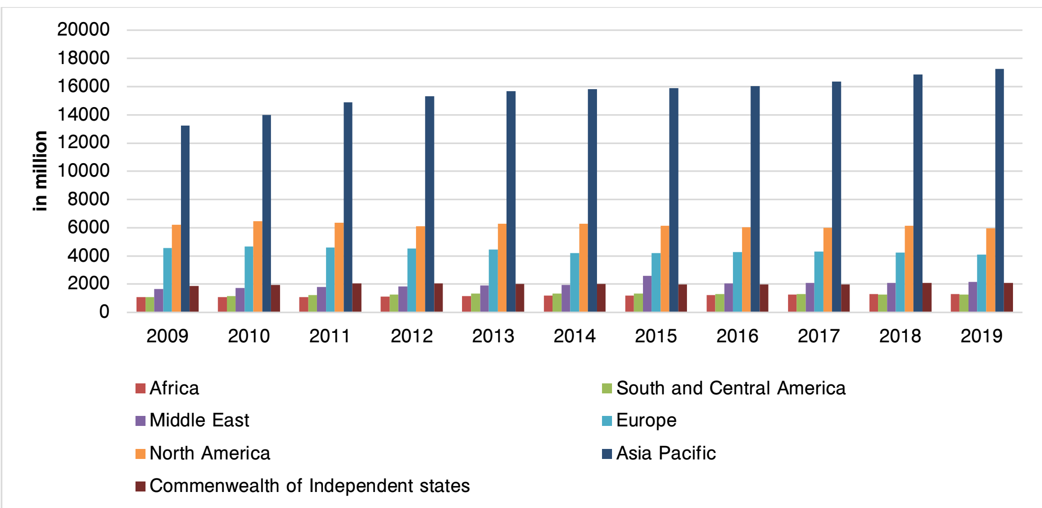

Figure 2. CO_2 emissions during 2009-2019 by region-wise (in million metric tons of CO2)
Source: Statista (https://www.statista.com/statistics/205966/world-carbon-dioxide-emissions-by-region/)

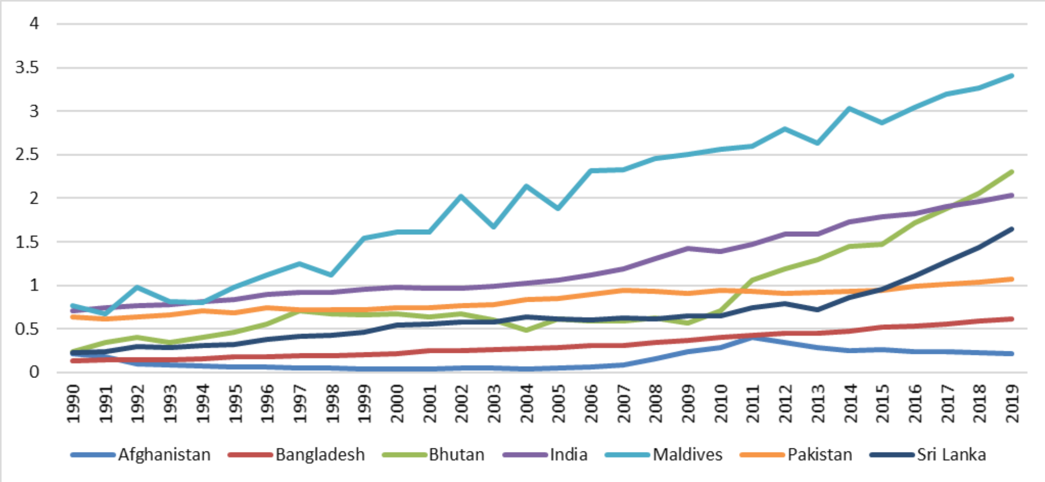

Figure 3. CO_2 emissions (metric tons per capita) in South Asian countries during 1990-2019

Note: Primary axis indicate metric tons per capita

Source: World Bank

5. Methodology

5.1. Construction of Financial Inclusion Index (FII)

For the present study, a multidimensional FII is constructed and it is based on the FII previously proposed by Sarma (2015). With the rising interest in financial inclusion across policymakers, a multiplicity of financial inclusion indicators has been developed (Sarma, 2008; Sethy, 2016; Sethy and Goyari, 2018; Sethi and Sethy, 2019; Sethy and Goyari, 2022; Sethi and Acharya, 2022; Sethy, 2023; Sethy and Goyari, 2023). The following are the steps to calculate the multidimensional FII.

Step 1: This study initially calculates a dimension index for each dimension of financial inclusion in order to develop an index. We first define d_i:

$$d_i = w_i * \frac{A_i - m_i}{M_i - m_i} \tag{1}$$

Where,

w_i = Weight attached to the dimension i, $0 \leq w_i \leq 1$, A_i = Actual value of dimension i, m_i = Minimum value of dimension i, M_i = Maximum value of dimension i, d_i= Dimensions of financial inclusion i.

Formula (i) confirms that $0 \leq w_i \leq 1$ and here, n dimensions of financial inclusion are represented by a point X = (1, 2, 3…). Point 0 = (0, 0, 0…0) represents the worst situation, and Point W = (1, 2, 3 …) represents an ideal situation. Here we are taking W = 1 (equal weighting approach).

Step 2: We calculate X_1 based on d_i and W_i as shown below:

$$X_1 = \frac{\sqrt{d_1^2 + d_2^2 + d_3^2 + \ldots\ldots\ldots + d_n^2}}{\sqrt{w_1^2 + w_2^2 + w_3^2 + \ldots\ldots\ldots + w_n^2}} \tag{2}$$

Step 3: In the third step, we calculate X_2 based on d_i and W_i as shown below:

$$X_2 = 1 - \frac{\sqrt{(w_1 - d_1)^2 + (w_2 - d_2)^2 + (w_3 - d_3)^2 + \ldots\ldots\ldots + (w_n - d_n)^2}}{\sqrt{w_1^2 + w_2^2 + w_3^2 + \ldots\ldots\ldots + w_n^2}} \tag{3}$$

Step 4: We calculate the FII based on X_1 and X_2 as shown below:

$$FII = \frac{1}{2}(X_1 + X_2) \tag{4}$$

In formula (2), for financial inclusion index (FII), X_1 indicates the average of the Euclidian distance between X and 0. In formula (3), for FII, X_2 indicates the inverse Euclidian distance between X and W. Formula (4)[2] is the simple average of X_1 and X_2 which is the multidimensional Financial Inclusion Index used in the present study.

5.2. Model specification

The empirical model for estimating the effect of FI on CO_2 emissions in South Asia is described in this section. This study adopted a theoretical and empirical model that extends the "Stochastic impacts by regression on population, affluence and technology (STIRPAT)" model developed by Dietz and Rosa (1997) as given:

$$I = P.\,A.\,T \tag{5}$$

Where, *I* represent environmental impact, *P* represents population, *A* represents affluence and *T* represents technology or the environmental impact per unit of economic activity which is determined by the technology. Further, reformulation assumes a stochastic version of the model (1) as follows:

$$I_{i,t} = \alpha_{i,t} P_{i,t}^{\beta_1} A_{i,t}^{\beta_2} T_{i,t}^{\beta_3} \varepsilon_{i,t} \tag{6}$$

Where *I* represent the environmental effects, *P* represents population, *A* represents affluence and *T* represents technology, for county *i.* α represents specific effect. β_1, β_2, and β_3 are the elasticities of the impact of the environment (proxied by CO_2 emissions) with respect to *P*, *A* and *T*.

Mathematically, model (6) is transformed into a logarithmic form:

$$lnI_{i,t} = \alpha_{i,t} + \beta_1 lnP_{i,t} + \beta_2 lnA_{i,t} + \beta_3 lnT_{i,t} + \varepsilon_{i,t} \tag{7}$$

This study expands the basic STIRPAT model in (7) by taking into account different additional determinants that have been identified to have an impact on CO_2 emissions, such as financial inclusion (i.e., FII): access to banking services (Prabhakar et al, 2014; Le et al, 2020), urbanization (Cole and Neumayer, 2004; Shen and Saijo, 2008; Dhakal, 2009; Martinez-Zarzoso and Maruotti, 2011; Dash et al, 2020), trade openness (Sharma, 2011; Le et al,2020), industrialization (Dash et al, 2020) and energy intensity (Le et al,2020).

The baseline model of this study is thus the following.

$$ln(Co_2)_{i,t} = \alpha_0 + \beta_{i,t}(lnFII)_{i,t} + \sum_{t=1}^{t=n} \beta_{i,t}\, Controls_{i,t} + \alpha_{i,t} + \varepsilon_{i,t} \tag{8}$$

$$ln(Co_2)_{i,t} = \alpha_0 + \beta_1(lnFII)_{i,t} + \beta_2(lnURB)_{i,t} + \beta_3(lnTradeop)_{i,t} + \beta_4(lnIndustri)_{i,t} + \beta_5(lnEnerin)_{i,t} + \alpha_{i,t} + \varepsilon_{i,t} \tag{9}$$

Where, the dependent variable is $lnCO_2$ = log carbon dioxide emissions metric tons per capita. The independent variables are *FII* = a multidimensional financial inclusion index, *lnURB* = log of urbanization, *lnTradeop* = log of trade openness, *lnIndustri* = log of industrialization, *lnEnerin* = log of energy intensity, α_i = unseen effects and $\mu_{i,t}$ = error term, *t* = 1, 2, 3,..15 years and *i* = 1, 2, 3…n.

Here, FI is expected to reduce CO_2 emissions or it is negatively associated with CO_2 emissions because the easy access of suitable and affordable formal financial

[2] The FII presented in Sarma (2015), Sarma and Pais (2011), Sethy (2016), Sethy and Goyari (2018) was based on the distance from the ideal only.

services encourages investments in green technology and environment friendly products such as solar energy, eco-friendly seeds etc. reduce CO_2 emissions.

5.3. Data sources and variables

The study is based on 15 years of annual panel data from 2004 to 2018. By excluding Nepal (because of non-availability of consistent and uniform comparable data on formal financial services), the rest of the seven South Asia countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Pakistan, and Sri Lanka) are taken for the empirical research. The data set was collected using the FAS of IMF (Financial Access Survey of International Monetary Fund) and World Development Indicator (WDI). Table 1 and 2 provide an overview of the variables and their sources.

5.4. Empirical methodology

This study initially used the time fixed effect estimation and time random effect estimation to ascertain the factors that influence CO_2 emissions. In our second attempt, we proceed to examine the long-run effects of financial inclusion on CO_2 emissions in South Asian countries. This relationship is investigated in the study by employing the Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) approaches. First, to determine whether stationarity exists in the data series of South Asian countries, the

Table 1. List of variables for constructing Financial Inclusion Index (FII)

Availability Indicators	Accessibility Indicators	Usage Indicators
Demographic Branch Penetration: (1) Number of bank branches per 1 lakh adults (2) Branches of Commercial Bank	*Geographic ATM Penetration:* (5) Number of ATMs per 1000 km^2	*Credit Penetration:* (7) Outstanding loans with Commercial Banks (8) Outstanding loans with Commercial Banks (% of GDP)
Demographic ATM Penetration: (3) ATMs per 1 lakh adults (4) Number of ATMs	*Geographic Branch Penetration:* (6) Branches of Commercial Bank per 1000 km^2	*Deposit Penetration:* (9) Outstanding deposits with Commercial Banks (10) Outstanding deposits with Commercial Banks (% of GDP)

Source: Financial Access Survey (FAS), IMF

Table 2. List of the variables used for empirical analysis

Variables	Unit	Source
Carbon dioxide emission (CO_2)	Metric tons per capita	WDI, World Bank
Financial inclusion (*FII*)	Index	Financial Access Survey, IMF
Urbanization (*URB*)	% of total population	WDI
Trade openness (*Tradeopen*)	Trade percentage of GDP	WDI
Industrialization (*Industri*)	% of total economic growth	WDI
Energy intensity (*Enerin*)	It is calculated as units of energy per unit of GDP.	WDI

panel unit root test is used. In this paper, we have used the Peseran and Shin (IPS) panel unit root test. The Pedroni (1999) cointegration test is then used to determine whether there is a long-run relationship between all variables.

5.4.1. FMOLS and DOLS Approaches

The long-run relationship between the variables is finally estimated using FMOLS and DOLS techniques. In addition, FMOLS and DOLS methods were employed to solve the endogeneity problem and remove the serial correlation present in the OLS method.

The FMOLS method is proposed by Philips and Moon (1999) and the FMOLS cointegrating equation is given in (10):

$$\hat{\beta}_{FMOLS} = = \frac{1}{N}\left[\{\sum_{t=1}^{T}(y_{it} - \bar{y_i})^2\}^{-1}\{\sum_{t=1}^{T}(y_{it} - \bar{y_i})\, z_{it}^{*} - T\hat{y_i}\right] \quad (10)$$

Where $z_{it}^{*} = y_{it} - \bar{y_i} - \left(\hat{\Omega}_{2\,1\,i} / \hat{\Omega}_{2\,2\,i}\right)\Delta y_{it}$ and $\hat{y_i} = \hat{\Gamma}_{2\,1\,i} + \hat{\Omega}^{0}_{2\,1\,i} - (\hat{\Omega}_{2\,1\,i} / \hat{\Omega}_{2\,2\,i})$ $(\hat{\Gamma}_{2\,1\,i} + \hat{\Omega}^{0}_{2\,1\,i})$.

The DOLS method is proposed by Stock and Watson (1993) and the DOLS cointegrating equation is given in (11):

$$b_{DOLS} = N^{-1}\sum_{i=0}^{n}(\sum_{t=1}^{T}\forall_{it}\forall'_{it})^{-1}(\sum_{t=1}^{T}\forall_{it}(z_{it} - \bar{z_i})) \quad (11)$$

Where, $\forall_{it}$ represents 2(K+1)×1 vector of explanatory variables including $(y_{it} - \bar{y_i}, \ldots,,, \Delta y_{i.j})$.

5.4.2. Dumitrescu-Hurlin (D-H) causality test

Dumitrescu Hurlin (2012) panel causality test is the methodology which detects the causal relationship between the panel variables. So, it is accepted as the extension version of the Granger causality test. It works better with unbalanced panel data and cross section dependency between countries. The equation of the DH panel causality test is demonstrated below in equation (12).

$$Y_{i,t} = a_i + \sum_{k=1}^{k}\gamma_i^{k}\, Y_{i,t-k} + \sum_{k=1}^{k}\beta_i^{k}\, X_{i,t-k} + \varepsilon_{i,t} \quad (12)$$

with i = 1,…., N and t = 1,…T

Where $X_{i,t}$ and $Y_{i,t}$ represent the stationary variables that are observed over t = 1, …T time periods, now for individuals i = 1,…. N a panel data set. So, the main purpose of this methodology is to find out whether X is the main cause of Y. In addition, a_i represents the time constant individual effects, γ^k is an autoregressive parameter and β^k is the coefficient of the variables. *k* represents the optimum lag interval.

The hypothesis statements used for the DH causality test are the following:

$H_0 : \beta_i = 0, \forall_i = 1,\ldots.N$

$H_1 : \beta_i = 0, \forall_i = 1,\ldots.N_1$

$\beta_{ii} \neq 0, \forall_i = N_1{+}1, N_1{+}2\ldots.., N$

6. Empirical findings and discussions

6.1. Descriptive statistics and correlation matrix

Table 3 presents the descriptive statistics and Table 4 shows the correlation results of the considered variables of the study for South Asian countries. The descriptive statistics results indicate that CO_2 emission varies from -3.0 to 1.2, with an average value 0.2 and standard deviation (SD) of 0.8. The coefficient of our key independent variable, financial inclusion (*i.e.,* FII) ranges from -6.0 to 0, with an average value of 1.0 and SD of 1.0. The correlation matrix results show that a positive correlation exists between financial inclusion and CO_2 emissions (i.e., 0.26). This implies that financial inclusion (i.e., access and use of banking products) leads to an increase in carbon emissions, which is a threat to decrease the air quality.

6.2. Panel unit roots results

Table 5 shows the results of the Im-Pesaran-Shin (IPS) unit root test. Here study variables such as CO_2 emissions, financial inclusion, energy intensity, industrialization, trade openness and urbanization are integrated of [I(1)]. The IPS unit root test result indicates that the variables are stationary at first difference but non-stationary at level. The results confirm the use of panel cointegration that requires the same order of integration.

6.3. Cointegration results

Our two key study variables (financial inclusion and carbon emissions) may be cointegrated after adjusting the impact of energy intensity, industrialization, trade openness and urbanization. Table 6 shows cointegration results for South Asian countries during the study period. The cointegration results confirm that financial inclusion and carbon emissions are cointegrated. Four Pedroni cointegration test statistics reject the null hypothesis of non-cointegration at 1 and 5 percent levels of significance. It means

Table 3. Descriptive statistics

	InCO_2	InFII	InEnerin	InIndustri	InTradeop	InURB
Mean	0.2	1.0	1.4	3.2	4.1	3.4
Median	0.1	0.8	1.3	3.3	4.0	3.5
SD	0.8	1.0	0.6	0.4	0.5	0.2
Min	-3.0	-6.0	0.2	2.1	3.2	2.9
Max	1.2	0.0	2.8	3.8	5.2	3.7
Skewness	0.7	2.4	0.7	1.0	0.4	0.9
Kurtosis	3.7	10.8	3.2	3.7	2.0	2.5
Observation	102	102	102	102	102	102

Source: Authors' estimations

Table 4. Correlation matrix

	InCO_2	InFII	InEnerin	InIndustri	InTradeop	InURB
In CO_2	1					
InFII	0.2602	1				
InEnerin	0.3824	-0.2394	1			
InIndustri	-0.3377	-0.1755	0.3896	1		
InTradeop	0.2362	0.0628	0.1817	-0.2524	1	
InURB	0.4871	0.1011	0.6009	-0.2466	0.1252	1

Source: Authors' estimations

that financial inclusion and CO_2 emissions in South Asian economies have a long run relationship. In addition, we believe that an inclusive financial system and its services will minimize CO_2 emissions in the long run if given proper cares in the current period.

6.4. FMOLS and DOLS results

Table 7 shows the FMOLS and DOLS results. The FMOLS results indicate that our key study variables of financial inclusion and CO_2 emissions are cointegrated, both of them have positive coefficients. This result implies that a 1 percent increase in financial inclusion (i.e., access and use of formal financial services) across the South Asian countries will result in about 0.18 percent increase in carbon emissions. Similarly, DOLS results indicate that FII and CO_2 emissions have long-run connections. The long-run coefficient indicates that 1 percent increase in financial inclusion will result in about 0.13 percent increase in carbon emissions. On the basis of these results, we accept the H_1 (alternative hypothesis) that financial inclusion positively affects carbon emissions. This set of result is consistent with other studies like Le et al. (2020), Hussain et al. (2021), Zaidi et al. (2021), Singh et al. (2022), Hussain et al. (2023) and Ogede and Tiamiyu (2023) on the influence of financial inclusion on CO_2 emissions. This result implies that, with an improved inclusive financial system, and affordable cost of availability and usage of financial services,

Table 5. IPS panel unit root test

Variables	lnCO_2	lnFII	lnEnerin	lnIndustri	lnTradeop	lnURB
Level	1.747 (0.959)	- 1.052 (0.146)	2.438 (0.992)	- 0.956 (0.169)	- 0.806 (0.210)	0.125 (0.550)
First differences	- 2.697*** (0.003)	- 4.035*** (0.000)	-4.651*** (0.000)	-5.023*** (0.000)	-4.918*** (0.000)	-23.333*** (0.000)

Note: *** indicates significance at 1 percent level of significance.

Source: Authors' estimations

Table 6. Pedroni panel cointegration estimations

	Statistics	Prob.
With Dimensions		
Panel *v*-Statistics	-2.128	0.997
Panel ρ Statistics	2.589	0.992
Panel Phillips-Perron*t*	0.867***	0.004
Panel Augmented Dickey Fuller *t*	0.728***	0.015
Between Dimensions		
Group ρ Statistics	3.533	0.999
Group Phillips-Perron*t*	-4.691***	0.000
Group Augmented Dickey-Fuller *t*	-1.888**	0.029

Note: *** and ** indicate significance at 1 and 5 % level of significance, respectively.

Source: Authors' estimations

citizens in South Asian countries can afford to purchase more energy consumption items like televisions, air conditioners, refrigerators, automobiles etc. and industrial activities may increase the CO_2 emissions over time.

In the FMOLS model results, it is observed that energy intensity and urbanization are cointegrated with CO_2 emissions positively in South Asian countries. The result shows that a 1 percent increase in energy intensity (i.e., energy consumption) would increase carbon emissions by about 0.76 percent. Similarly, a 1 per cent increase in urbanization would lead to an increase of about 2.33 percent in CO_2 emissions. Similarly, the DOLS model results show that energy intensity and urbanization are cointegrated and have a positive sign with CO_2 emissions. This result indicates that a 1 percent increase in energy consumption would increase CO_2 emissions by about 0.77 percent. Similarly, a 1 percent increase in urbanization would increase CO_2 emissions by about 2.78 percent. The above finding is in line with previous research of Cetin and Ecevit (2015), Ertugrul et al. (2016), Cetin et al. (2018), Sari et al. (2021), Cetin et al. (2022), and Khan et al. (2020).

Furthermore, results of the FMOLS model indicate that industrialization and CO_2 emissions are cointegrated. This long run coefficient of industrialization variable is negative. This negative sign indicates that a 1 percent increase in industrialization would reduce CO_2 emissions by about 0.79 percent during the study period. Similarly, the DOLS model results indicate that a 1 percent increase in industrialization would decrease carbon emissions by about 0.74 percent. This means that industrialization helps reduce carbon emissions by introducing technology that reduces energy consumption (Khan and Majeed 2023; Idowu et al. 2023). The results of the FMOLS model indicate that trade openness and carbon emissions are also cointegrated. The negative sign of the estimated coefficient shows that 1 percent increase in openness of trade with foreign countries would result in a reduction in carbon emissions by about 0.57 percent. Additionally, the DOLS model results also confirm that a 1 percent increase in trade openness would decrease carbon emissions by about 0.48 percent. This result is supported by (Zhang et al. 2017; Dou et al. 2021; Dauda et al. 2021;

Table 7. FMOLS and Panel DOLS estimations

Dependent Variable: lnCO_2	FMOLS			DOLS		
	Coefficients	t-Statistics	Prob.	Coefficients	t-Statistics	Prob.
lnFII	0.183**	2.291	0.024	0.132***	2.775	0.006
lnEnerin	0.764***	3.836	0.000	0.772***	4.230	0.000
lnIndustri	-0.785**	2.274	0.025	-0.738**	2.117	0.037
lnTradeop	- 0.569**	- 2.762	0.007	-0.478***	-2.492	0.014
lnURB	2.333**	2.471	0.015	2.786***	3.779	0.000
R^2		0.959			0.959	
Adj. R^2		0.954			0.954	

Notes: *** and ** indicate significance at 1 % and 5 % level of significance.

Source: Authors' estimations

Khan et al. 2022). These empirical results have useful policy implications for South Asian countries.

6.5. Dumitrescu-Hurlin (D-H) panel ganger causality results

Table 8 shows D-H granger causality test results. The results indicate that the null hypothesis of “financial inclusion does not cause CO_2 emissions” can be rejected for lag 2 since the probability value is very low (0.0006) and the alternative hypothesis is accepted. This indicates that financial inclusion is the main cause of CO_2 emissions (Le et al. 2020; Hussain et al. 2021; Zaidi et al. 2021; Singh et al. 2022; Hussain et al. 2023; Ogede and Tiamiyu 2023) in South Asian countries. In addition, the null hypothesis of “CO_2 emission does not cause financial inclusion” can be accepted for lag 2 since the probability value is very high (0.7037). Finally, the findings show that there is a unidirectional causality between financial inclusion and CO_2 emissions.

Furthermore, no causality is confirmed between energy intensity and CO_2 emissions because of high probability values. Therefore, we can accept the null hypothesis which states that energy intensity does not cause CO_2 emissions and vice-versa. Similarly, no causality is found between CO_2 emissions and trade openness because the probability values are high (0.7155 and 0.8073). This implies that CO_2 emission does not cause trade openness and vice-versa. However, causality results show that bidirectional causality exists between CO_2 emissions and industrialization. This result implies that industrialization is the main cause of CO_2 emissions (Zhang et al. 2009; Zhu et al. 2017) and CO_2 emissions is also main cause of industrialization. Therefore, we can reject the null hypothesis for lag 2 since the probability values are low. Similarly, bidirectional causality is found between urbanization and CO_2 emissions in South Asian countries.

Table 8. Dumitrescu-Hurlin causality results

The way of the relationship	Lag	W-Stat	Prob. values	Results
FI $\longrightarrow CO_2$	2	9.243***	0.0006	Financial inclusion is the main cause of CO_2 emissions
$CO_2 \longrightarrow$ FI	2	2.133	0.7037	CO_2 emissions does not cause financial inclusion
ENERIN $\longrightarrow CO_2$	2	4.33	0.6243	Energy intensity does not cause CO_2 emissions
$CO_2 \longrightarrow$ ENERIN	2	2.313	0.8043	CO_2 emissions does not cause energy intensity
TRADEOPEN $\longrightarrow CO_2$	2	3.266	0.7155	Trade openness does not cause CO_2 emissions
$CO_2 \longrightarrow$ TRADEOPEN	2	2.345	0.8073	CO_2 emissions does not cause trade openness
INDUSTRI $\longrightarrow CO_2$	2	5.194*	0.0076	Industrialization is the main cause of CO_2 emissions
$CO_2 \longrightarrow$ INDUSTRI	2	8.263***	0.0005	CO_2 emissions is main cause of industrialization
Urbanization $\longrightarrow CO_2$	2	8.627***	0.0005	Urbanization is the main cause of CO_2 emissions
$CO_2 \longrightarrow$ Urbanization	2	8.014***	0.0002	CO_2 emissions is the main cause of urbanization

Notes: ***, ** and * are statistical significance at the 1%, 5% and 10% levels, respectively. The p-values are based on the asymptotic normal distribution. FI: Financial inclusion

Source: Authors’ estimations

7. Conclusions

The main purpose of this paper was to examine the impact of financial inclusion on CO_2 emissions in South Asian countries during the period from 2004 to 2018. The study has used suitable and appropriate econometric methods. First, the UNDP method was used to develop a multidimensional Financial Inclusion Index (FII) for South Asian countries to measure the level of financial inclusion. Second, the fixed effect estimations were done and results indicate that financial inclusion has a positive impact on CO_2 emissions. This study then assessed the long-term relationship between financial inclusion and CO_2 emissions. For this, the study has used the FMOLS and DOLS approaches to examine the long-run elasticity of financial inclusion on CO_2 emissions. The empirical results have confirmed that financial inclusion has a positive and significant effect on CO_2 emissions in South Asian countries. The finding of this study is in line other studies like Le et al. 2020; Hussain et al. 2021; Zaidi et al. 2021; Singh et al. 2022; Wang et al. 2022; Ali et al. 2022; Mehmood 2022 and Liu et al. 2022; Hussain et al. 2023. This result implies that a better inclusive financial system and its services could increase CO_2 emissions in South Asian countries. Finally, this study has used the Dumitrescu-Hurlin causality test and the result shows that financial inclusion is the main cause of CO_2 emissions. This finding does not mean that we should reduce financial inclusion. Instead, governments should work to improve the inclusive finance system and access to credit in more environment friendly ways.

Policy Implications

Overall, findings of the study confirm that financial inclusion is increasing CO_2 emissions in South Asian countries. *First*, it suggests that financial inclusion should be viewed as a macroeconomic instrument as well as a strategy for minimizing global warming by stakeholders. *Second*, South Asian governments should attempt to make ecological financing more accessible and inclusive in order to help the poor and economically deprived people of society in dealing with growing CO_2 emissions. *Third*, individuals and small and medium-sized business should also have access to financing to participate in local CO_2 emissions reduction campaigns. *Fourth*, policy-makers also should promote energy efficiency with sustainable economic growth, environmental friendly industries and encourage more environmental friendly bank credit to improve environmental quality.

Limitations

The present study suffers from some limitations, the major one being the non-availability of consistent and uniform data for all financial inclusion index related variables for all sample countries. Moreover, this study has used panel data only. But analysis of time series data and primary survey data may be more effective and useful to provide specific policy recommendations.

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