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Green Finance, Renewable Energy, and CO₂ Emissions in South Asia: The Moderating Role of Natural Resources and the Importance of Cross-Sectional Dependence Correction

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ABSTRACT

This paper examines how individual and interactive factors, such as green finance, renewable energy consumption, and total natural resource rents influence CO₂ emissions in South Asian countries, employing annual panel data spanning the time period 2004 to 2022 in four countries. Using cross-sectional dependence and serial autocorrelation corrected Driscoll–Kraay two-way fixed effects estimator, we find that, remarkably, green finance, natural resource rents from renewables and total natural resource rents all have statistically significant negative impacts on CO₂ emissions, whereas FDI, GDP growth and urban population have statistically significant positive impacts. Most importantly, the interaction terms of the green finance with renewable energy consumption (GF_REC) and with natural resource rents (GF_TNR) both appear positive and significant moderators, suggesting that green finance acts as a facilitator of emissions indirectly in both cases when it is not combined with other emissions reduction measures. The results are particularly relevant for the architecture of climate finance, resource governance, and designing integrated environmental policies in South Asia.

Keywords: Green Finance, Renewable Energy Consumption, CO₂ Emissions, Natural Resource Rents, Pollution Haven Hypothesis, Driscoll–Kraay Estimator, South Asia, Fixed Effects, Environmental Kuznets Curve

1. INTRODUCTION

Green finance has become a key part of the global policy agenda due to the challenges and the growing economic impact of environmental degradation and climate change. Green finance, defined as financing mechanisms like green bonds, climate-linked loans, sustainable investment funds and concessional financing based on environmental performance, is considered to be a tool for allocating private and public funds towards low-carbon economic activity. However, the empirical literature on the effect of green finance on carbon dioxide (CO₂) emissions is still weak, fragile and ambiguous, and especially so in the context of developing countries. This paper fills this gap and studies the impacts of



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green finance on CO₂ emissions in the South Asian region, which is characterized as economic growth at a rapid pace, high dependence on fossil fuels, high vulnerability to climatic risks, and still emerging but growing green finance markets.

The application of green finance tools in South Asia (Bangladesh, India, Nepal and Sri Lanka in this study) is a particularly important and under-researched laboratory. About one-quarter of the global population resides in the region, and the region contributes a substantial proportion of global CO₂ emissions, mainly from coal burning, growing industrialisation and the rapidly increasing use of energy in urban areas. At the same time, some of the world's loftiest renewable energy targets are found in South Asia, with India's goal of achieving 500 GW of non-fossil fuel power generation by 2030, Bangladesh's renewable energy action plan, and Pakistan's renewable energy policy framework all pointing to a desire to make a break from carbon emissions. While green finance is seen as a key enabler to reach these targets, there is no empirical evidence if financial instruments to support environmental sustainability have actually led to a decrease in the emissions at the macroeconomic level in this region or not.

This paper has three unique contributions to the literature. First, it presents a panel econometric analysis of the relationship between green finance and emissions in South Asian countries in a fixed-effects framework, which explicitly captures country-specific unobserved heterogeneity, which is an important consideration given the diversity in institutional and climatic conditions and development across South Asian economies. Second, it adds two interaction terms to the analysis: green finance interacted with renewable energy consumption (GF_REC) and green finance interacted with natural resource rents (GF_TNR) to explore whether the impact of green finance on emissions depends on the energy mix and resource dependence of the host economy. Third, it illustrates how the methodological need to control for cross sectional dependence, by using Driscoll–Kraay standard errors, yields important results in terms of standard errors; in particular, it shows that standard fixed-effects estimation results in standard errors that are much too large and in inferences about the significance of all explanatory variables other than FDI.

The remainder of the paper is organised as follows. The theoretical and empirical literature review is conducted in section 2 on green finance, renewable energy, natural resources and environmental quality. The data, variables and econometric methodology are presented in Section 3. The results of both the standard fixed-effects model and the Driscoll–Kraay model are presented and interpreted in Section 4. The results of the study are considered in terms of their substantive and methodological significance in Section 5. The paper ends with policy recommendations and directions for future research in Section 6.

2. LITERATURE REVIEW

2.1 *Green Finance and Environmental Outcomes*

Green finance has become a new area of research between finance and environmental policy. In general, green finance is a term used to describe financial products and services that allocate capital to activities that have a benefit to the environment, such as investments in renewable energy, energy efficiency, sustainable agriculture and pollution control (UNEP, 2016). Institutional frameworks for the definition and verification of green financial instruments have been introduced by the International Capital Market Association (2021) and the Sustainable Finance Disclosure Regulation of the European Union, but coverage is not comprehensive in developing economies.



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There are multiple pathways in which theoretical arguments for green finance's CO₂ reduction action work. On the one hand, green finance products can help lower the cost of capital for renewable energy and green infrastructure investments, thereby diverting investments away from fossil-fuel intensive activities (Sachs et al., 2019). Second, there is the risk that environmental, social, and governance (ESG) criteria incorporated in green finance contractual conditions could induce borrowers and investees to use cleaner production technologies (Flammer, 2021). Third, green bonds and other bond types can provide a reputation-based incentive to environmental performance for both issuers and investors, thereby decreasing the risk of “greenwashing” in the long run (Tang and Zhang, 2020).

There is emerging empirical evidence supporting the relationship between green finance and emissions, albeit scarce. Based on data for the Chinese provincial panel, Zhang et al. (2021) show that green credit is an effective measure in reducing CO₂ emissions; Taghizadeh-Hesary and Yoshino (2019) identify the role of green finance in supporting the adoption of renewable energy in the Asia-Pacific economies. Lee and Lee (2022) study green bonds and conclude that there is a slight, but statistically significant, negative impact on carbon emissions at the national level in 38 economies. But, as Tolliver et al. (2020) note, the emission reducing effect of green bonds can be misleading because the “additionality” of green bonds, or the fact that they are for new projects, is not easily provable. Islam et al. (2022) and Awan et al. (2022) describe the early development of a green finance market in the South Asian region, but report that the volume of green financial flows is still short of what is needed to support the region's climate commitments.

2.2 Renewable Energy Consumption and Emissions

The linkage between renewable energy use and CO₂ emissions is easy to understand: If renewable energy is used in place of fossil fuel use, then the carbon intensity of energy generation is reduced which in turn lowers aggregate emissions. In practice, the evidence strongly supports this link, but the size of the impact is quite large and varies significantly across countries, over time and depending on estimation techniques. Longrun cointegrating relationships between renewable energy and CO₂ emissions are found for the panels of developed and developing economies respectively by Apergis and Payne (2010) and (2012). Dogan and Seker (2016) conclude that the importance of renewable energy for CO₂ emissions is high for a panel of countries across the European Union, and this import significance is accentuated by its interaction with trade openness. Bölük and Mert (2014) report a significant and negative correlation between renewable energy and emissions in European economies, which aligns with the clean energy substitution effect.

The renewable energy-emissions relation is a complex connection in the south Asian setting. First, however, the share of renewable energy in the total generation portfolio is still low compared to its potential and coal is the major portion of electricity generation in India and Pakistan. Secondly, the new renewable capacity can be installed with the fossil fuels being used without any displacement, which is known as the rebound effect and was observed by Shafiei and Salim (2014). Third, the data on renewable energy in the South Asian countries have historically been of varying quality and reliability, which can lead to measurement error that can reduce the estimated coefficients. The interaction of green finance and renewable energy consumption (GF_REC) examines the potential of the direct emissions-reduction impact of renewables deployment to be amplified or moderated by the use of financial instruments specifically designed to promote renewables.

2.3 Natural Resources, the Resource Curse, and Emissions

Theoretically the impacts of natural resource dependence on the environment are ambiguous. On the other hand, CO₂ emissions are directly produced during the processes



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of resource extraction, especially of fossil fuels, and a carbon-intensive economic base that is not easily decarbonised is created. Alternatively, rents from natural resource extraction can provide the funds for environmental protection, green infrastructure, and technology upgrading if managed properly using the right institutional structure (Bhattacharyya and Hodler, 2014). The resource curse literature, which Ross (2015) reviewed comprehensively, finds that dependence on natural resources often leads to weak governance, Dutch disease dynamics, and slower long run economic growth, all of which can indirectly have a negative impact on environmental outcomes by lowering the ability to implement environmental regulations and implement clean technology.

There is limited empirical evidence in South Asia about the natural resource–emissions relationship. Pakistan has natural gas reserves that can be exploited and lead to domestic emissions, and Bangladesh has reserves of coal that are important to its domestic emissions, as well as its energy security. The interaction term GF_TNR examines the interaction between NFRs and emissions, and asks if the adoption of GFIs has an effect on the overall relationship between the two or if it is a complementary resource that does not significantly affect the environmental impacts of resource extraction.

2.4 FDI, Trade Openness, GDP Growth, and Urbanisation

Environmental regulation is weak in the host countries, and the pollution haven hypothesis (Copeland and Taylor, 1994) states that the net consequence is that the volume of FDI flowing to the host countries will increase environmental pollution. The relationship between FDI and emissions in panels set up in developing countries is generally found to be positive, as suggested by empirical evidence (Pao and Tsai, 2011; Omri et al., 2014), although the conclusions are subject to varying results depending on the extent of countries included and estimation method. The theoretical impact of trade openness is ambiguous via scale, composition, and technique effects (Antweiler et al., 2001); empirically, its sign is contingent on cleaner technology being embodied in trade flows and on the ability of regulatory capacity to track trade-induced economic growth.

Growth and urbanisation tend to be closely intertwined drivers of energy demand and emissions. The Environmental Kuznets Curve (EKC) hypothesis (Grossman and Krueger, 1991) suggests that there is an inverted-U relationship between income growth and environmental degradation: that is, emissions will increase with the growth of income up to a certain threshold and then decline. Urbanisation is linked to more energy aggregate consumption due to greater transport needs, more heating and cooling needs, and more industrial energy consumption, but also energy that is used more efficiently on a per capita basis in urban areas than in rural areas. The emissions impacts of urban population growth are directly relevant in South Asia with high urbanisation rates, especially in India, Pakistan and Bangladesh.

Cross sectional dependence is an omnipresent problem in panels of geographically and economically close countries. Pesaran (2004) shows that ignoring CSD leads to unreliable inference, usually leading to larger standard errors and lower test power. Trade and financial flows, and the shared monsoon climate characteristics, are likely to generate strong common factors, which fixed-effects estimators ignore, through the close linkages among South Asian economies. Driscoll and Kraay (1998) propose a non-parametric covariance matrix estimator which is consistent under the assumption of cross-sectional dependence, heteroskedasticity and serial autocorrelation of arbitrary form, which are all well suited to the case of the South Asian panel considered here.

Recent literature have discussed many aspects related to renewable energy, and total natural resources for Asian region (Akbar et al., 2026a; Akbar et al. 2026b; Akbar et



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al., 2025a; Akbar et al., 2025b; Akbar et al., 2025c; Akbar et al., 2025d; Akbar et al., 2025e; Akbar et al., 2025f).

3. DATA AND METHODOLOGY

3.1 Data and Variables

The empirical analysis involves using the annual panel data of four economies of South Asia¹, Bangladesh, India, Nepal and Sri Lanka from 2004-2022. CO₂ emissions (kg CO₂ per capita) are the dependent variable from World Bank World Development Indicators (WDI) and International Renewable Energy Agency (IRENA). Explanation for the use of per capita emissions as the dependent variable: the use of per capita emissions alone is in line with the convention in the EKC literature and is a means to normalise for the population size of the countries under consideration. All continuous variables used for explanation are logged to allow for interpretation of elasticity and interaction terms are formed from the log of the variables.

Green finance (lgf) is calculated based on an indicator of green financial development which is derived from country-level statistics on green bond issuance, climate-related bank lending, and sustainable investment flows, following the method of Taghizadeh-Hesary and Yoshino (2019) and Islam et al. (2022). Renewable energy consumption (IREC) is the proportion of renewables in total final energy consumption, from WDI. Oil, natural gas, and coal rents, mineral rents, and forest rents are total natural resource rents (ltnvr) as a percentage of GDP from WDI. GDP growth (lgdp) is the percentage change in real per capita GDP on an annual basis. Foreign direct investment (lfdi) is net inflows as a percentage of GDP. The sum of exports and imports as a percentage of GDP (lto) is trade openness. Urban population (lup): Percent of population living in urban areas. Two interaction terms are built: GF_REC (lgf × IREC) and GF_TNR (lgf × ltnvr) to explain the conditional effects of green finance on the energy mix and resource rents of the host economy.

Table 1: Descriptive Statistics (in log)

Variable	Definition		Source	Obs	Mean	Std. dev.	Min	Max
lfdi	Foreign	Direct	WDI	76	-0.228	0.992	-4.605	1.286
	Investment Inflow							
lup	Urban Population		WDI	76	3.186	0.306	2.697	3.682
lto	Trade Openness		WDI	76	3.783	0.210	3.268	4.376
IREC	Renewable Energy		WDI	76	3.904	0.377	3.219	4.514
lco2	CO ₂ omission		WDI	76	4.152	2.196	0.997	7.916
lgdp	Growth	Domestic	WDI	76	25.734	1.650	23.453	28.721
	Product							
lgf	Green Finance		IRENA	76	8.962	1.937	6.496	12.731
ltnvr	Total	Natural	WDI	76	-0.283	1.234	-2.813	1.962
	Resources							

3.2 Econometric Specification

The baseline econometric specification is a two-way fixed-effects panel model with country and year fixed effects:

$$lCO_{2it} = \alpha_i + \lambda_t + \beta_1 lgf_{it} + \beta_2 IREC_{it} + \beta_3 ltnvr_{it} + \beta_4 GF_REC_{it} + \beta_5 GF_TNR_{it} + \beta_6 lgdp_{it} + \beta_7 lfdi_{it} + \beta_8 lto_{it} + \beta_9 lup_{it} + \varepsilon_{it} \quad (1)$$

where α_i represents country fixed effects, which take into account unobserved country-specific factors such as geographic endowments, historical industrial structure and

¹ Pakistan has been reclassified by moving it from South Asia region into the Middle East and North Africa Region.



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baseline institutional quality, and λ_t represents year fixed effects reflecting common time shocks such as international climate agreements, oil prices, or commodity price cycles. ε_{it} is the idiosyncratic error term. All time-invariant country-level confounders are captured by country fixed effects and so the identification is limited to variation in outcomes within the country over time.

The interaction term GF_REC assesses the interaction between green finance and the level of renewable energy use – a negative interaction would indicate complementarity (that the green finance effect is greater than the fossil fuel effect), whereas a positive interaction would suggest scale effects (that the green finance effect is reduced in the presence of clean energy) or that clean energy receives green finance while not being matched by a decrease in fossil fuel consumption. A positive interaction between green finance and natural resource rents would imply that green finance does not reduce the carbon intensity of resource-based activities, whereas a negative interaction would suggest that green finance steers a natural resource economy towards cleaner activities.

3.3 Treatment of Cross-Sectional Dependence

A serious issue in estimating equation (1) is the effect of the cross-sectional dependence (CSD), which could arise from the fact that shocks within a country's boundary are not independent and that shocks within neighbouring countries' boundaries are correlated via common economic linkages, climate systems, policy spillovers, etc. There are strong common factor dynamics between the South Asian economies because of their bilateral trade, remittance flows and shared monsoon precipitation patterns. The null of cross-sectional independence is rejected in South Asian macro panels in the prior literature, and the CD test developed by Pesaran (2004) was used to check whether CSD exists in the panel residuals.

We estimate equation (1) two alternative ways of constructing the standard error. Standard within-group fixed-effects estimates with heteroskedasticity-robust standard errors are presented (Table 3) and assume cross sectional independence. Second, we use Driscoll and Kraay (1998) standard errors with a maximum lag of six periods (Table 4) that are consistent, non-parametrically, when cross-sectionally dependent, heteroskedastic and autocorrelated of arbitrary form. The Driscoll–Kraay (D-K) estimator, unlike other estimators considered in the literature, such as the Common Correlated Effects estimator, does not require the number of panels N to become very large to be consistent, a feature that is important for the present panel structure ($N = 4, T = 19$). The coefficients in Tables 3 and 4 are numerically the same, though the difference is in the standard errors and inference made.

4. RESULTS

4.1 Standard Fixed-Effects Estimates

Table 2 reports the outcome of the standard fixed-effects regression within the groups with heteroskedasticity robust standard errors. The within- R^2 for the model is 0.9075, which shows that the fixed effects and the covariates included in the model explain about 91 percent of the variation in CO_2 emissions within countries. The null of the joint F-test, that all the slope coefficients are zero ($F(9, 52) = 56.71, p < 0.001$) is rejected, thus establishing the overall significance of the specification.

Table 2: *Fixed-Effects (Within) Regression Results for CO_2 Emissions*

Variable	Coefficient	Std. Error	t	p
lgf (Green Finance)	-0.331	0.329	-1.01	0.319



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Variable	Coefficient	Std. Error	t	p
IREC (Renewable Energy)	-1.556	0.741	-2.10	0.041**
ltnvr (Natural Resources)	-0.517	0.337	-1.54	0.131
GF_REC (GF × REC)	0.166	0.085	1.95	0.057†
GF_TNR (GF × TNR)	0.030	0.033	0.92	0.362
lgdp (GDP Growth)	0.389	0.247	1.57	0.122
lfdi (FDI)	0.130	0.030	4.37	< 0.001***
lto (Trade Openness)	0.262	0.147	1.78	0.081†
lup (Urban Population)	0.908	0.559	1.62	0.111
Constant	-6.409	6.398	-1.00	0.321

Note. $N = 65$, number of groups = 4. Within- $R^2 = 0.9075$. $F(9, 52) = 56.71$, $p < 0.001$. Standard errors are heteroskedasticity-robust. All continuous variables are natural log-transformed; interaction terms are products of log-transformed variables. † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The results are very scanty under the standard fixed-effects specification. Green finance (lgf) has a negative but non-statistically significant effect on CO₂ emissions ($\beta = -0.331$, $p = 0.319$), indicating that there is no detectable effect on emissions reduction. Only main effect variable renewable energy consumption (IREC) is consistently significant, with a negative coefficient ($\beta = -1.556$, $p = 0.041$) implying that an increase in the share of renewable energy by one percent will lead to a decrease in per capita CO₂ emissions by 1.56 percent. There is no significant coefficient for total natural resource rents (ltnvr) which is negative ($\beta = -0.517$, $p = 0.131$). The interaction terms GF_REC ($\beta = 0.166$, $p = 0.057$) approach significance only in the former, and do not reach significance in the latter case. With respect to the control variables, only FDI (lfdi) has a conventional significance ($\beta = 0.130$, $p < 0.001$), whereas GDP growth, trade openness and urban population are not significant. The overall picture from Table 2 would suggest to the researcher that green finance has no impact on emissions, the natural resource is irrelevant and that most economic covariates are of no consequence—a picture which as shown in Table 3 is methodologically misleading.

4.2 Fixed-Effects Estimates with Driscoll–Kraay Standard Errors

The same fixed-effects regression is re-estimated in Table 3 with Driscoll–Kraay standard errors based on a maximum lag of six periods. All point estimates are the same as in Table 1 because the D-K correction is only on the variance-covariance matrix. The difference is that the standard errors are much smaller for most of the variables with D-K correction, leading to much higher t-statistics and to the rejection of the statistical insignificance null for most of the covariates. The F statistic for the joint test of the slope coefficients increases to $F(9, 17) = 1,320.51$ when the D-K framework is used, which again shows the high precision of the estimates.

Table 3: Fixed-Effects Regression With Driscoll–Kraay Standard Errors (Lag 6) for CO₂ Emissions



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Variable	Coefficient	D-K Std. Error	t	p
lgf (Green Finance)	-0.331	0.090	-3.69	0.002***
IREC (Renewable Energy)	-1.556	0.436	-3.56	0.002***
ltnvr (Natural Resources)	-0.517	0.190	-2.72	0.014**
GF_REC (GF × REC)	0.166	0.034	4.89	< 0.001***
GF_TNR (GF × TNR)	0.030	0.013	2.35	0.031**
lgdp (GDP Growth)	0.389	0.145	2.67	0.016**
lfdi (FDI)	0.130	0.027	4.77	< 0.001***
lto (Trade Openness)	0.262	0.129	2.04	0.057†
lup (Urban Population)	0.908	0.239	3.79	0.001***
Constant	-6.409	5.243	-1.22	0.238

Note. N = 65, number of groups = 4. Within- $R^2 = 0.9075$. $F(9, 17) = 1,320.51$, $p < 0.001$. Driscoll–Kraay standard errors account for cross-sectional and temporal dependence with a maximum lag of 6. All continuous variables are natural log-transformed; interaction terms are products of log-transformed variables. † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Green finance (lgf) now turns out to be a statistically significant and negative determinant of CO₂ emissions ($\beta = -0.331$, $p = 0.002$), with a smaller standard error (0.329 to 0.090) after applying D-K correction to it. This result provides the first evidence that green finance has a meaningful emission reduction impact in South Asia which was masked by the inflated standard errors in the traditional specification. The negative and significant effect ($\beta = -1.556$, $p = 0.002$) of renewable energy consumption (IREC) remains unchanged, demonstrating the validity of the clean energy substitution mechanism. The presence of total natural resource rents (ltnvr) also is significant ($\beta = -0.517$, $p = 0.014$), with wealthier countries demonstrating lower CO₂ emissions, which may be due to the reallocation of resource rents to energy infrastructure investments or the fact that countries with higher natural resource wealth export more of their natural resource production in lower carbon-intensity sectors.

The robustness of the results obtained by both interaction terms is confirmed by the statistical significance of these variables according to the D-K standard errors. Beyond that, the interaction between green finance and renewable energy is significant and positive ($\beta = 0.166$, $p < 0.001$), suggesting that the impact of the two is greater than the sum of its parts and an interpretation is needed. This is further discussed in Section 5. The positive and significant relationship between GF_TNR and emissions, revealed by the correlation coefficient of 0.030 and a p value of 0.031, indicates that green finance partly compensates the direct negative impact of natural resource rents on emissions, perhaps because it is being used to finance the expansion of natural resource extraction operations under green finance without appropriate additionality controls.



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The GDP growth is significant and positive ($\beta = 0.389$, $p = 0.016$), which is in line with the scale effect of economic expansion in the pre EKC turning point phase. The results confirm the pollution haven theory in the SA context with strong positive and significant relationship of FDI ($\beta = 0.130$, $p < 0.001$). The urban population (lup) is now strongly significant ($\beta = 0.908$, $p = 0.001$) and as such, urbanisation is found to be driving energy demand and emissions growth in the region. The coefficient for the trade openness variable (lto) is not statistically significant at the conventional level ($\beta = 0.262$, $p = 0.057$), indicating that trade integration is related to slightly higher emissions, which follows the opposite direction from its relationship with the technique effect in this context.

5. DISCUSSION

5.1 *The Methodological Case for Driscoll–Kraay Correction*

The difference between the two tables is dramatic and is a telling reminder of the effects of neglecting the cross-sectional dependence of spatially and economically close panels. Table 2 only shows conventional statistical significance for two variables: lrec and lfdi. Seven of the nine slope coefficients in Table 3 are statistically significant at the 5 percent level or less. However, the point estimates are the same in both tables. This dramatic change in the inference is driven entirely by the correction of inflated standard errors due to the lack of independence of observations between South Asian countries, induced by common economic shocks, monsoon climate systems and policy spillovers.

Theoretically, the effect of cross-sectional dependence on creating a higher standard error is well understood (Driscoll and Kraay, 1998; Petersen, 2009). Conventional heteroskedasticity-robust standard errors overestimate the effective sample size because they assume that observations within the same panel are statistically independent, which is the case when there is a positive correlation among residuals across panels, as is the case in light of common macroeconomic shocks and climate systems among countries. This results in overly large estimates of variance and large standard errors, when compared with the true sampling error that is inherent in the coefficient estimates. By contrast, Driscoll–Kraay standard errors use the information in the residual covariance matrix, which is spatially and temporally structured, to estimate variances in a consistent way, irrespective of the nature of cross-sectional and serial dependence. The six periods lag used is conservative considering the length of the time series of the panel and consistent with other literature on panel analysis in South Asia (Hossain, 2011).

The practical consequence is clear: researchers who carry out studies on cross-sectionally dependent panels of geographically or economically close countries should perform the Pesaran (2004) CD test to test for cross-sectional dependence, and if this test fails the null hypothesis of independence, should use D-K standard errors or similar corrections. In the applied literature, while reporting only the Table 2 results is standard practice, it results in the wrong policy inference, that green finance does not seem to have a significant impact on emissions, which is not only imprecise but is in fact misleading.

5.2 *Green Finance as an Emissions-Reduction Mechanism*

A negative and significant coefficient of the lgf ($\beta = -0.331$, $p = 0.002$) shows that green finance has a significant and meaningful impact on emissions reduction in the South Asian economies. When read as an elasticity, the coefficient suggests that an elasticity of -0.33 implies for a 1 percent increase in the green financial flows, per capita CO₂ emissions will decrease by about 0.33 percent, on average, while other factors remain unchanged. This size is in line with the related literature in China (Zhang et al., 2021), and indicates that green finance is available in South Asia via the financial channel, that is, by lowering



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the cost of capital for low-carbon projects and imposing conditions that constrain the borrowing companies to cleaner production.

This positive and significant GF_REC interaction term ($\beta = 0.166$, $p < 0.001$) casts doubt on this rosy interpretation. The net effect of green finance on emissions is reduced when directed specifically towards the renewable energy industry, as there is a positive interaction. Another is that renewable energy investments using green instruments create a rebound effect: as renewable energy becomes cheaper than dirty energy, energy demand increases, and this effect dilutes the impact of actual substitution of clean for dirty energy. The second view is that 'green finance' for renewable energy can be used instead of, not alongside, direct control of fossil fuel use - and CO₂ emissions from fossil fuels can keep going up while renewable capacity grows. This follows the pattern seen in India and Pakistan, where new renewable power has mostly been used to meet the country's growing demand, and not to replace coal baseload. The policy lesson is obvious: green finance for renewables needs to go hand in hand with effective measures to cap fossil fuel use, such as coal phase-out pledges, carbon pricing or fossil fuel subsidy reform, to create net emissions reductions.

5.3 Natural Resource Rents, Green Finance, and the Interaction Effect

The negative main effect of natural resource rents (ltnvr) is significant ($\beta = -0.517$, $p = 0.014$) indicating that, holding other factors constant, an increase in TNR lowers CO₂ emissions. This outcome might seem counterintuitive, but can be understood in the context of South Asia. Higher resource rents, especially for natural gas which has a lower carbon intensity than coal, can result in lower average emissions per unit of energy used per country. Otherwise, resource rents can be used to finance tax expenditures for clean energy infrastructure, public transport, and energy efficiency schemes to lower overall emissions. This interpretation is supported by Sri Lanka's relatively high level of renewable energy intensity, which is largely due to natural resource rents from the hydroelectric potential.

The significant interaction effect between the green finance (GF) and resource (TNR) ($Z = +0.030$, $p = 0.031$) shows that, under certain conditions, the direct negative effect of resource rents on emissions is partially mitigated by green finance in resource-rich environments. This is consistent with the concern, raised in the green finance additionality literature (Tolliver et al., 2020) that green financial instruments could be used for green labelled projects that still support carbon-intensive resource extraction. South Asia state-owned energy companies could issue green bonds for natural gas that under lax verification standards finance activities that sustain not reduce fossil fuel infrastructure. This outcome underscores the need for increased verification and certification in South Asian green finance markets in line with the International Capital Market Association's (ICMA) Green Bond Principles (ICMA, 2021) and the Sustainable Finance Taxonomies in development by India, Bangladesh, and Sri Lanka.

5.4 FDI, Urbanisation, and the Emissions Scale Effect

The consistent result of the analysis is the strong support for the pollution haven hypothesis in South Asia on the basis of the robust positive relationship between FDI and CO₂ emissions ($\beta = 0.130$, $p < 0.001$) obtained in both estimation methods. Foreign investors seem to find their way into carbon-intensive production in South Asian economies where the environment is not as regulated as in their own countries. This is in line with the documented FDI flows in South Asian manufacturing which have been particularly found to be low in environmental compliance costs from origin countries in Bangladesh, India and Pakistan (Eskeland and Harrison, 2003 and Shahbaz et al., 2015).



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The positive and significant relationship between urban population and emissions ($\beta = 0.908$, $p = 0.001$) is indicative of the rapid urbanisation of South Asian region where the urban energy demand from transportation, air conditioning and industrial production is increasing at a higher rate than the efficiency gains can catch up. The size of this coefficient, an elasticity near unity, highlights how crucial urban energy governance is to South Asian climate strategy. South Asia urbanisation on such scale over the next 20 years is likely to get disproportionate emissions benefit for the cost of policies targeting urban energy systems, such as expansion of mass transit, building energy standards and urban tree coverage.

6. CONCLUSION

This paper presents a detailed panel econometric study of the determinants of CO₂ emissions in South Asia, exploring the impacts of green finance, renewables and natural resource rents on CO₂ on an individual and interactive basis. The analysis brings three main results.

The first methodological result is the most important one: standard errors obtained when ignoring cross sectional dependence in the South Asian panel are grossly overstated, giving a false impression of statistical insignificance for most of the explanatory variables. After adjusting for cross sectional and serial dependence with the Driscoll–Kraay standard errors, green finance, renewable energy, natural resource rents, GDP growth, FDI, and urbanisation become statistically significant factors affecting CO₂ emissions. Proximate economies researchers often have to perform cross-sectional dependence tests and correct for cross-sectional dependence on a regular basis before making policy conclusions.

Second, the substantive results confirm the emissions-reducing potential of green finance ($\beta = -0.331$, $p = 0.002$) and renewable energy consumption ($\beta = -1.556$, $p = 0.002$) in South Asia, and highlight that FDI and urbanisation are strong positive drivers of emissions, in line with the pollution haven hypothesis and the urban energy demand channel, respectively. The results suggest a more robust environmental component to the regulation of FDI and increased investment in urban energy infrastructure.

Last, and most relevant for policy, the positive interaction effects of the green finance and renewable energy (GF_REC) and the green finance and natural resource rents (GF_TNR) suggest that green finance is not a standalone measure, as its emissions reduction potential is reduced when it is not accompanied by any fossil fuel constraint, and the emissions reduction potential is diminished when it is not accompanied by any additionality verification for natural resource rents. The results call for integrated policy packages for green finance mobilisation and for more effective green finance certification standards to ensure true additionality in the South Asian markets.

There are some constraints of the current analysis that should be noted and are suggested for further studies. Panel size is necessarily small ($N = 4$), due to data availability constraints, and time series dimension is moderate. The results would be more generalizable if analyses were extended to additional economies in the South Asian region, as data becomes available. This green finance variable combines various types of green finance; future research is needed to break down the green bonds, green climate loans, and institutional sustainable investment variables to identify the most effective ones in terms of emission reduction. Lastly, dynamic panel methods which explicitly model the persistence of emissions levels, like system GMM, would complement the fixed-effects approach adopted here by dealing with the potential endogeneity of the regressors.

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