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Synergies between Trade Openness, Financial Inclusions, and Climate Change Mitigation in China

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Abstract
The objective of the study is to appraise the role of financial inclusions in green initiatives, technological advances, and renewable energy sources in CO_2 emission-reduction. The study also examined the relationships between sustainable financing, sustainable technology advances, renewable energy, and CO_2 reduction using sophisticated panel data estimation CUP-FM, CUP-BC, and DSU methods. NARDL's nonlinear framework, CADF and CIPS have been applied for error correction-based panel cointegration and second serration panel unit root tests the data set from 2005 to 2023 of eighteen countries. Sustainable finance methods support sustainable projects including energy-efficient technologies and increase the asymmetric coefficients. The results reveal that sustainable technological innovation boosts economic growth, and helps in CO_2 emissions reduction. Renewal energy reduces CO_2 footprints and improves financial inclusions in low-carbon economies. More research is being done on eco-friendly solutions and how they encourage awareness and sustainability. According to the study results, government investments in green energy technology and renewable energy production sources can effectively reduce CO2 emissions, thus contributing to a future that prioritizes these goals.
Keywords: *Financial inclusions, trade openness, renewal energy, NARDL, CUP-FM, DSUR, CUP-BC*

1. Introduction

The 2015 UN Sustainable expansion Goals (SDGs) guide energy, industry, and infrastructure expansion. SDGs and Paris Agreement are essential to fighting climate change and lowering CO_2 emissions. FI's goals stress clean and renewable energy, greenhouse gas reduction, and sustainable practices [1], [2]. CO_2 reduction is a Paris Agreement and SDG priority, renewable energy investments, technology improvements, and sustainable practices across all industries are needed [3], [4]. The project tested global transition by integrating SDGs with Paris Agreement. Promotes sustainability, climate change mitigation, and low-carbon economy [5], [6]. CO2 reduction—balancing carbon emissions with removal or decrease—is the goal of global climate change efforts. Numerous impacts result from CO2 reduction. [7]. Reducing CO2 immediately reduces greenhouse gas emissions. Renewable energy may significantly lower a nation's carbon footprint Mert, Bölük [8]. It reduces climate change's sea level rise, weather, and temperatures. Air and water quality increases with carbon decrease. Li et al. improve trade openness ecosystems and population health [9]. CO2 reduction drives Clean and Sustainable Technology investments. Green funding redistributes funds for green projects. Renewable energy, energy efficiency, and sustainable transportation create jobs Paramati [10]. Efficiency and cost-effectiveness of green technology may enhance the economy. Energy security, resilience, and cheaper prices boost the economy.

Su et al (2011). Green money can also fund pollution management and environmental conservation, providing long-term benefits. Local communities trade transparently Wang & Wang [12]. Significant political influence of CO2 decreases worldwide. To reduce CO2 emissions, countries limit emissions and promote green investments. Energy efficiency, renewable energy, and sustainability programs benefit from carbon emissions financial inclusions taxes Ding et al. 2013 [13]. Financial inclusions must balance trade, growth, and urban CO2 reduction. Oil price volatility affects energy source cost competitiveness. Lin et al 2014. Rising oil prices may encourage renewable energy. Environmental fees are vital to governments' finances. Open finance promotes sustainable investments and behavior Zhang et al. [15]. Per capita income frequently correlates with FI's ability to deploy energy-efficient and renewable energy solutions, which accelerates CO2 reduction Paramati et al. [10]. Through financial assistance, policy openness, and incentives, governments can encourage carbon-neutral activities. Wang and Wang [12]. Green money gives supporting to exchange transparency, environmentally friendly power, energy productivity, and economical practices to lessen CO2 emissions Mama et al. [7]. Green funding is fundamental for worldwide CO2 decrease and maintainability endeavors Jin et al. [16]. Monetary incorporations should push green advancements to diminish CO2 emanations. This peculiarity influences a few parts of manageability. CO2 decrease benefits from development The Zhang-Xie threesome [15]. Low-carbon innovation incorporate energy-productive arrangements and sustainable power quickly lessen net discharges, working on monetary considerations of CO2 decrease. Cai et al. [17]. Through monetary incorporations and green ecological safeguarding, this innovation decreases natural and energy requests. Zeng et al. [18]. As indicated by Li et al. [9], the environmentally friendly power is pivotal to CO2 decrease. Supplanting of dirtying energy sources with spotless, maintainable choices diminishes fossil fuel byproducts essentially Mert and Bölük [8]. Exchange receptiveness speculations sustainable power sources advance long haul CO2 decrease in countries and networks, encouraging a cooperative connection between energy age and natural preservation Dahal, et al. [19].

2. Literature Review

A few countries are attempting to foster a manageable monetary framework that focuses on financial development, social prosperity, and ecological insurance [20]. Reinforcing green money [21,22] can assist with advancing fair monetary turn of events. The World Financial Exchange Transparency Green Venture Report characterizes environmentally friendly power, energy productivity, manageable transportation, and strong waste gathering (barring atomic and hydropower) as green speculations [23]. Glomsrød and Wei [24] found that manageable money helps the economy. These discoveries propose that feasible money can speed up a low-carbon future [24]. Green cash added to monetary considerations and reasonable advancement [25]. Xue et al. [7] found that green subsidizing advances carbon catch speculations and exploration, decreasing fossil fuel byproducts. Green money is an essential need for CO2 decrease in numerous nations exchange straightforwardly. Wang and Wang [12] found that green money guides social assets to advance green turn of events and dispense more assets to contamination control and natural assurance, lessening fossil fuel byproducts per yield unit and expanding territorial carbon evacuation limit, diminishing CO2 emissions. Jin et al. [16] characterized green money as interests in harmless to the ecosystem maintainable advancement projects, and its development can assist with lessening CO2 emissions. Sun, et al. [26] saw that feasible money decreases country-level contamination. By expanding environmentally friendly power utilization by 1%, can decrease carbon dioxide emanations by 0.103%. Tooth et al. [27] found that green money and energy effectiveness decrease fossil fuel byproducts without easing back financial development. Lin et al. [14] found that green money and RE speculations can help exchange transparency, the climate, and maintainable turn of events. Wang et al. [28] observed that green money is the best monetary answer for limit fossil fuel byproducts. In China, [29] concentrated on the possible capability of manageable money in CO2 decrease and found that maintainable money increments energy productivity in the energy blend. Monetary consideration and public-private speculation through green funding were found in another review [30]. Monetary possibilities for CO2 control drive to CO2 Decrease. Related discoveries were found in [31]. The OECD [16] found that EPU harms monetary incorporations and CO2 decrease. The review speculated the accompanying from the writing: Estimation of exchange receptiveness.

Hypothesis H_{01}: There is a strong correlation between green finance and the reduction of CO_2 emissions.

According to Wang, et al. [32], [33], financial inclusions is necessary to assure energy and resource security and reduce environmental deterioration. STI boosts trade openness in the energy sector, a key economic driver, beyond its environmental impact. Hung [34] studied STI's tremendous effect on CO2 reduction. Researchers have examined how green technology affects carbon emissions in China and Turkey data show its importance in CO_2 reduction [35], [36]. Renewable energy and green finance are vital to CO2 reduction [37]. Qamruzzaman, et al. [38] sustainable technology breakthroughs excel at reducing CO2 emissions. Sustainable technological breakthroughs work best in countries with robust economies Fakher et al. [39]. Nizam, et al. [40] revealed how sustainable technological advances reduce greenhouse gas emissions. Mechanical advances can further develop energy frameworks and backing maintainable improvement by decreasing carbon dioxide emanations, Su et al., [11]. These upgrades have fundamentally decreased fossil fuel byproducts in cutting edge economies, Zhang et al., [15]. The low-carbon innovation improvement and dissemination straightforwardly decrease net emanations, bringing down CO2 [17]. Green innovation advancement could in a roundabout way influence fossil fuel byproduct effectiveness by impacting monetary development and urbanization, as per Dong et al., [13]. Gao, et al. [41] found that fossil fuel byproduct decrease requires green innovation advancement. Green innovation development centers green ecological assurance, which can decrease energy and natural tensions Zeng et al. [18]. Paramati et al., [10] found that putting vigorously in green innovation development diminishes fossil fuel byproducts. Zeng et al. [18] discoveries are educational, uncovering a vertical direction in manageable innovation developments levels, though joined by generally low advancement viability in China's Western territories. [42] highlights the cooperative connection between green money and maintainable turn of events, proclaiming. In light of existing writing, the Accompanying speculation has been laid out Exchange transparency experimental evaluation.

Hypothesis H_{02}: Innovation in sustainable technology innovations, and finance have strong impact CO_2 reduction

Renewal energy consumption and trade openness CO_2 Reduction are crucial to combating climate change and fostering sustainable development. Renewable energy from wind, solar, hydro, and thermal power helps reduce carbon emissions and advance forwards CO_2 reduction [44]. CO_2 emissions contribute significantly to global warming, making trade openness a priority for governments, organizations, and citizens worldwide [45]. Renewal Energy could greatly cut greenhouse gas emissions and help reduce CO_2 emissions [46, 47]. The pollution-reducing benefits of switching to renewable energy sources have been extensively studied. Countries drastically lower their carbon footprints by prioritizing renewable energy [48]. By increasing renewable energy consumption, many nations and areas have made headway toward CO2 reduction [49]. For monetary incorporations to overcome any barrier among guarantees and genuine advancement toward net-zero CO2 emissions, investigate and carry out without carbon sustainable power sources [50-53]. The connection between environmentally friendly power and fossil fuel byproducts is muddled, and energy effectiveness is urgent [54]. Monetary incorporations accomplish feasible turn of events, sustainable power utilization is vital as it assists with lessening fossil fuel byproducts Yu, et al. [55]. The advancing environmentally friendly power sources can possibly accomplish CO2 decrease, and speculation is created as environmentally friendly power frameworks as follows:

Hypothesis H_{03}: The sustainable investments in renewal energy have a positive contribution in the CO_2 reduction.

3. Methods and Research Designs

3.1 Data Collection

The study has collected the data from 2005 to 2023 the eighteen countries having high rate of CO_2 emission. The data related to dependent variable "CO_2 emissions" has been collected from World Bank database https://databank.worldbank.org.com. The dependent variables such as "sustainable finance (SF), sustainable technology innovations (STI), renewal energy (RE), financial inclusions (FI), and trade openness (TO)," data has been from International monetary fund database https://www.imf.org and World Bank database https://databank.worldbank.org.

3.2 Research Design

Green financing, technological innovation, and renewable energy are examined to see how they reduce CO_2 emissions in the top eighteen CO_2-emitting countries. Trade openness focuses a generalized empirical equation (1) is given as follows:

$$CO_2 = SF, STI, RE \tag{1}$$

Trade openness and financial inclusions considerably affect carbon emissions [56]. FI and TO affect CO_2 emissions differently depending on the economy. Therefore, equation (1) has been extended to include FI and TO, and Equation (2) is developed as:

$$CO_2 = SF, STI, RE, FI, TO \tag{2}$$

Where SF, RE, STI, TO, and FI represent CO_2 reduction, sustainable finance, sustainable technological innovation, renewal energy, financial inclusions, and trade openness.

3.3 Econometric Model Explanation

STIRPAT and IPAT models are used hypothetical framework to assess human exercise's environmental consequences [58], [59]. Trade openness means "Stochastic Impacts by Regression on Population, Affluence, and Technology." population, income, and technology affect the environment, according to the model. Following is the IPT model's mathematical equation:

$$I = P \times A \times T \tag{3}$$

CO_2 reduction and water pollution are "I" environmental effects. Population size, "P", is the number of people in an area. "A" represents per-person consumption and economic activity, or affluence. Trade openness technology determines manufacturing and consumption technologies' efficacy and sustainability. Population expansion, affluence-induced consumption, and technology efficiency affect the environment [60]. Researching these components' interconnections can reveal environmental change's causes [58]. Trade openness solutions for sustainable development can be established with this knowledge. The PAT equation is:

$$I = a \times P^b \times A^c \times T^d \times \varepsilon \tag{4}$$

Observing the literature [61], The following is a possible rewrite of Equation (4) using the log formation:

$$\ln I = a + b\ln P + c\ln A + d\ln T + \varepsilon \tag{5}$$

Trade openness the flexible and open STIRPAT approach allows dynamic control factor adjustments based on research. Rewriting the previous equation with explained and explanatory variables yields the following.

$$lnCO_2 = \alpha + \beta_1 lnSF + \beta_2 lnSTI + \beta_3 lnRE + \beta_4 lnTO + \beta_5 lnFI + \epsilon \tag{6}$$

lnSTI measures a country's eco-friendly technological advancement in sustainable technology creation and use. A one-unit increase in green technology innovation leads to an estimated CO2 decrease (β_2). Renewable energy adoption can improve financial inclusions, reduce carbon emissions, and encourage CO_2 reduction, leading to a positive β_3 sign. A one-unit expansion in exchange transparency is projected to lessen CO2 emissions, as estimated by the regular logarithm coefficient β_4. Indication of β_4 is obscure and changes in terms of professional career qualities. Trade openness might affect β_4 positively or negatively, depending on the data context, and lnTO tracks financial inclusions state. Figure 2 represents the theoretical framework of the research.

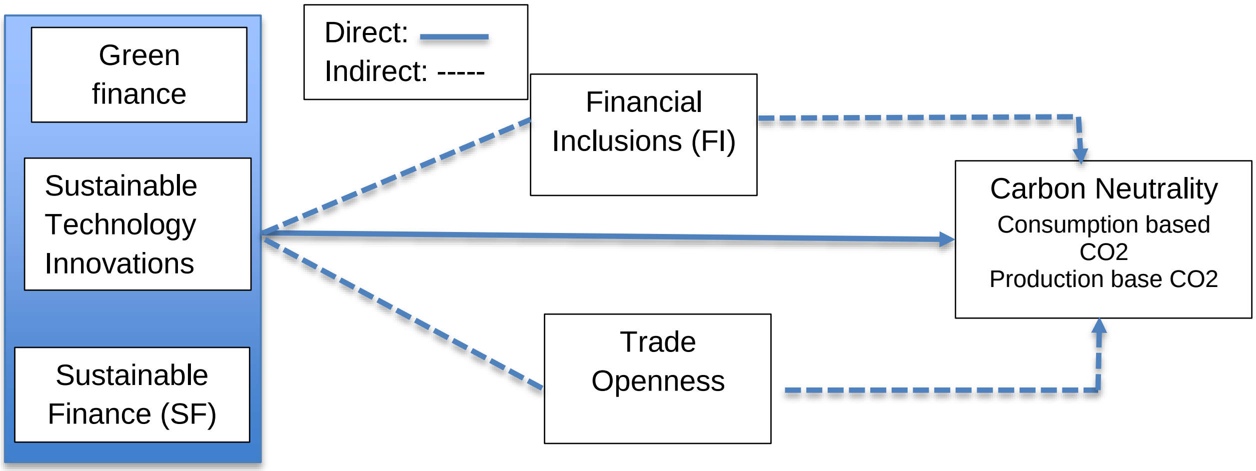

Figure 1. Conceptual framework and empirical nexus

Increasing financial inclusions by one unit reduces CO_2 emissions (β_5). The trajectory of trade openness is unexpected and circumstantial.

3.3 Slop of Homogeneity (SHT) and Cross-Sectional Dependency Test (CSD)

The CSD, and SHT are used in econometrics and empirical research to evaluate assumptions and panel data analysis results [66]. The equations 7-11 have been written as follows:

$$X_{it} = \alpha_i + \beta_i y_{it} + \epsilon_{it} \qquad i= 1\ldots\ldots N,\ t=1\ldots\ldots T \tag{7}$$

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{IJ\underset{d}{\rightarrow}}X^2 N(N+1)2 \tag{8}$$

$$CD_{lm} = \sqrt{\frac{N}{N(N-1)}}\sum_{I=1}^{N-1}\sum_{J=i+1}^{N}\left(T\hat{\rho}_{ij} - 1\right) \tag{9}$$

$$CD_{lm} = \sqrt{\frac{2T}{N(N-1)}}\sum_{I=1}^{N-1}\sum_{J=i+1}^{N}\left(\hat{\rho}_{ij}\right) \tag{10}$$

$$CD_{lm} = \sqrt{\frac{2}{N(N-1)}}\sum_{I=1}^{N-1}\sum_{J=i+1}^{N}\left(\frac{(T-K)\hat{\rho}_{ij}^2 - u_{Tij}}{v_{Tij}^2}\right)\vec{d}\,(N,0) \tag{11}$$

4. Results and Discussions

4.1 CSD and SHT Tests

Table 1 represents the CSD test results and the homogeneity test slope. The dismissal of the invalid speculation, cross-sectional profanity, and incline of homogeneity are shown concerning the test insights of both CSD and SHT.

Table 1. Represents the results of CDS and SHT tests

	LM_{BP}	LM_{PS}	LM_{adj}	CD_{PS}	Variations	Adj. Δ
SF_1	432.585***	32.485***	244.233***	41.052***	85.479***	99.719***
SF_2	276.318***	45.166***	176.208***	40.35***	85.75***	92.952***
STI	404.456***	33.029***	154.341***	51.999***	91.988***	118.202***
RE	322.18***	45.488***	159.235***	20.844***	86.655***	129.109***
FI	216.87***	20.645***	239.279***	28.776***	88.307***	83.156***
TO	206.185***	43.93***	139.281***	25.328***	27.763***	76.856***

The aftereffects of the Discs and SHT examinations uncover genuinely huge discoveries across all classes, with SF1 and STI showing the most grounded prescient connections in view of their high scores in LMBP, LMPS, and LMadj. Changed scores (Adj. Δ) feature the most outstanding changes for STI (118.202) and RE (129.109), demonstrating these classes benefit altogether from change strategies, while TO displays somewhat lower scores and inconstancy, proposing more fragile prescient connections and more modest changes. High varieties in SF1 and STI propose more noteworthy heterogeneity in the information, while TO's lower changeability suggests more reliable examples. By and large, the investigation highlights solid model execution and basic contrasts across classes, with some requiring more significant changes than others. All test statistics are statistically significant at 1%.

Table 2. Presents the CADF and CIPS tests with panel unit root test results

Variables	$CADF_{\partial}$		$CIPS_{\partial}$		$CIPS_{\partial\,\&\,\tau}$		$CIPS_{\partial\,\&\,\tau}$	
	Level	**1st diff.**	**Level**	**1st diff.**	**Level**	**1st diff.**	**Level**	**1st diff.**
SF_1	-1.928	-5.987***	-0.923	-5.981***	-1.509	-7.437***	-1.715	-2.061***
SF_2	-1.904	-3.547***	-2.022	-4.588***	-2.493	-2.466***	-2.358	-2.741***
SF	-1.975	-5.085***	-2.135	-5.573***	-2.908	-5.894***	-2.96	-2.562***
STI	-1.285	-5.366***	-2.167	-4.73***	-1.025	-6.181***	-2.714	-3.337***
RE	-2.424	-7.932***	-2.736	-2.95***	-1.66	-7.931***	-2.081	-6.817***
FI	-1.224	-3.779***	-2.76	-6.826***	-1.362	-5.895***	-1.388	-6.438***
TO	-2.612	-2.56***	-1.559	-2.133***	-2.143	-3.477***	-1.508	-2.858***

The consequences of the board unit root tests utilizing CADF and CIPS (with capture just, and with block and pattern demonstrate that all factors (SF1, SF2, SF, STI, RE, FI, TO) are non-fixed at their levels however become fixed after first differencing, as proven by critical test values across all tests (signified by "***"). While the CADF test and the different CIPS arrangements yield somewhat unique test values, the end stays reliable, showing that the factors are incorporated of request I(1)). This example is common for monetary and monetary information, where first differencing is expected to accomplish stationarity. Striking patterns major areas of strength for incorporate subsequent to differencing for factors like SF1, SF2, and SF, while RE and STI display moderately nearer adherence to stationarity even at levels at times. In general, the outcomes affirm the requirement for differencing to address unit roots and guarantee dependable econometric displaying. Table 3 represents the test statistics of lengthy empirical connection with Models Production-CO_2 and Consuptio-CO_2.

Table 3. Results of panel cointegration test

Model	**SF--->RE**	**TO--->SF**	**SF--->FI**	**STI--->SF**	**FI--->SF**
Panel –A: SF portion by ingesting created CO2 emission					
GT	-26.484***	-35.626***	-35.02***	-8.462***	-24.848***
GA	-35.716***	-8.064***	-24.046***	-35.848***	-35.358***
PT	-8.062***	-24.635***	-26.436***	-8.528***	-24.635***
PA	-24.648***	-8.384***	-24.82***	-8.862***	-28.382***
MDF	-8.712***	-8.38***	-2.862***	28.302***	24.248***
DF	8.342***	-8.336***	-2.036***	6.36***	35.035***
ADF	28***	2.646***	20.424***	0.624***	-20.484***
UMDF	-2.46***	2.246***	-8.342***	4.271***	6.86***
UDF	-6.486***	24.852***	-4.71***	-6.628***	-6.624***
MDF	35.682***	0.356***	-0.062***	35.808***	4.24***
PP	35.606***	4.436***	24.02***	24.652***	-2.402***
ADF	8.62***	8.271***	35.436***	35.064***	24.871***

PAnel B: SF Production-based CO2 emission					
GT	-35.084***	-6.846***	-24.862***	-35.852***	-35.868***
GA	-35.652***	-6.086***	-24.048***	-6.036***	-24.64***
PT	-24.071***	-8.712***	-35.356***	-35.871***	-26.846***
PA	-24.716***	-20.286***	-35.471***	-4.624***	-35.86***
MDF	4.686***	-2.246***	35.606***	-4.842***	-6.712***
DF	2.636***	2.471***	2.64***	35.062***	28.068***
ADF	8.406***	0.046***	8.68***	26.08***	24.24***
UMDF	6.426***	-2.248***	6.646***	-6.356***	28.606***
UDF	24.64***	-6.402***	6.682***	35.48***	-6.871***
MDF	-8.626***	24.246***	8.286***	-0.402***	2.716***
PP	-4.835***	8.404***	8.462***	24.426***	4.471***
ADF	20.284***	24.271***	24.206***	26.624***	24.002***

The significances of the board cointegration tests areas of strength for show term balance connections among SF and FI, STI, RE, and TO, whether or not SF is estimated by creation-based CO2 emissions. Across the two models, the board values (Gt, Ga, Pt, Dad) reliably show profoundly critical outcomes at the 1% level, with powerful proof of cointegration. Be that as it may, measurements under KRCPT and PCT (e.g., MDF, DF, ADF, UDF) uncover blended signs, recommending fluctuation in the connections relying upon the test determinations and strategic subtleties. These discoveries highlight the intricate communications between maintainable money and key monetary and ecological variables, mirroring the nuanced effect of CO2 estimation approaches on the strength and course of these connections.

4.2 CUP-FM, CUP-BC, and DSUR without intuitive term

Table 4 presents the discoveries of the coefficients of logical factors on CO2 in board A, which centers around exchange transparency utilization in light of CO2 outflows, and board B looks at exchange receptiveness creation based CO2 discharges. The review discoveries uncovered exchange receptiveness green money has a huge effect chasing lessening CO2 emanations. SF controlled the CO2 outflow is esteemed in board A, and Board B is accounted for yield. The discoveries propose that SF assumes a crucial part in advancing CO2 decrease by driving the change to a low-carbon economy [29]. The coefficients of green mechanical development (STI) on CO2 were viewed as adversely huge with utilization-based CO2 and creation-based CO2, proposing STI intensifies ecological supportability through the supplanting of energy-effective innovation with show innovation having a more elevated level of energy utilization. The review uncovered a positive connection between recharging energy utilization and CO2 decrease, which is estimated by utilization-based CO2 and creation-based CO2, which is predictable in every one of the three assessments CUP-FM, CUP-BC, and DSUR.

Table 4. Represents the DSUR, CUP-BC, and CUP-FM tests results.

Details	CUP-FM			CUP-BC			DSUR		
	Coef.	**S.Err**	**T-S**	**Coef.**	**S.Err**	**T-S**	**Coef.**	**S.Err**	**T-S**
Consumption-based CO_2 emissions per capita (Panel A)									
TO	-0.0761	0.035	-1.9901	-0.4135	0.0155	-5.9351	-0.3493	0.0415	-9.1976
FI	-0.1193	0.0393	-3.3901	-0.3609	0.0333	-3.0417	-0.1079	0.0191	-5.4891
SF	-0.0997	0.0181	-5.3333	-0.1811	0.0391	-3.3181	-0.1413	0.0419	-3.81101
STI	0.4111	0.0351	3.7351	0.1511	0.0335	3.4861	0.1365	0.0369	3.9151
RE	0.0999	0.036	7.0511	0.1919	0.0348	3.0369	0.1936	0.0307	5.9055
Constant	10.115	0.36036	31.4893	11.769	0.36036	36.23496	10.999	0.36036	35.7541

Production-based CO_2 emissions per capita (Panel B)									
TO	-0.1036	0.0411	-3.7573	-0.1911	0.0305	-5.9393	-0.0979	0.0399	-1.1819
FI	-0.4135	0.0367	-7.0415	-0.3603	0.0148	-9.5413	-0.0976	0.035	-1.5811
SF	-0.4175	0.0136	-7.7619	-0.1478	0.0416	-5.3511	-0.1148	0.0397	-1.9311
STI	0.1411	0.0311	3.0769	0.1507	0.0351	3.41485	0.151	0.0365	5.4865
RE	0.0977	0.0151	3.9776	0.1416	0.0315	1.9048	0.4175	0.0341	5.8416
Constant	6.261	0.36036	33.4171	36.365	0.3601	81.1935	9.109	0.36036	33.1936

The consequences of the CUP-FM, CUP-BC, and DSUR assessments uncover huge connections between per capita CO2 emissions and SF, STI, RE, FI, and TO. For both emanation measures, SF, STI, and RE reliably show negative coefficients across all techniques, demonstrating their moderating impact on CO2 emissions, with beautifully and genuinely huge effects for STI and RE. On the other hand, FI and TO show positive coefficients, meaning their commitments to expanded CO2 emissions. The t-values further affirm the heartiness of these discoveries, with most factors keeping up with measurable importance across the CUP-FM, CUP-BC, and DSUR approaches. Prominently, the extents of the coefficients change, with CUP-BC frequently yielding bigger assessments, stressing the significance of strategic decision. The steady term (C) remains profoundly huge in all models, reflecting gauge emissions free of illustrative factors. These outcomes highlight the basic job of strategy driven drives in offsetting monetary variables with ecological supportability. The findings advocate that transformation to efficient energy sources from conventional energy mix positively supports achieving one of the desired SDGs. The use of renewable energy is crucial in achieving CO_2 reduction by reducing emissions in long-run.

4.9 Discussions

The coefficients of SF computed from CUP-FM, CUP-BC, and DSUR are negative statistically significant at 1%, demonstrating that SF helps achieve the SDG target of environmental sustainability through CO_2 reduction, and these study findings match the literature [20]. SF asymmetry coefficients showed negative and statistically significant shocks in both empirical model estimates' long- and short-run horizons. SF shocks increase CO2 emissions and harm the ecosystem [43]. CO2 reduction and environmental sustainability require sustainable finance. Several arguments justify trade openness. Green money invests. Encourages renewable energy, energy efficiency, and environmental responsibility [62]. The study [43] advised SF to fund clean technology projects to reduce fossil fuel consumption. Sustainable financing also boosts economic growth and employment creation. Transition Low-carbon economies require new and expanding industries [47]. Green initiatives require sustainable money. Coastal fortifications, sustainable agriculture, and biodiversity conservation [37]. STI and carbon emission were negatively correlated by CUP-FM, CUP-BC, and DSUR coefficients, indicating technical innovation prevails. Energy efficiency and sustainability reduce CO2 emissions. Trade openness literature supports [3]. FI needs innovative greenhouse gas reduction technologies to fight climate change [18]. Renewable electricity from solar, wind, and hydroelectric sources is cutting-edge environmental technology. Due to extensive renewable energy use, global carbon emissions have reduced [48]. CUP-FM, CUP-BC, DSUR, and NARDL calculations reveal a favourable link between renewal energy and CO2 reduction. Renewable energy promotes sustainability and CO2 reduction [37]. Investment in SF sources reduces carbon emissions and improves innovation, finance, and economic growth.

3. Conclusions and Discussions

The study examined both consumption-based and production-based indicators to evaluate the effects of sustainable funding, technological progress, and clean energy on carbon emissions. The study highlighted the impact of sustainable finance on reducing CO_2 emissions and emphasized its vital role in mitigating CO2 emissions. It was evident how science fiction influenced the conversation on the urgent need to address climate change and promote carbon reduction. One significant factor in lowering CO_2 emissions is the long-term financial assistance provided by technology innovation. In low-carbon economies, there is a positive relationship between CO_2 emissions and sustainable financing. The growth in trade openness has positive effects on the decrease in CO_2 emissions as well. In low-carbon economies, the importance of sustainable technological breakthroughs in green energy generation is critical in reducing CO_2 emissions. Advocating for the reduction of CO_2 is crucial as it has a significant impact on reducing fossil fuel emissions and enhancing energy efficiency. It is important to prioritize the development of eco-friendly technology in order to reduce CO_2 emissions and promote sustainable long-term growth. The results clearly show a clear link between the adoption of renewable energy sources and the reduction of CO_2 emissions, as measured from both consumption and production perspectives. Using sustainable power sources is crucial for reducing our dependence on fossil fuels, which are a significant source of greenhouse gas emissions. Understanding the importance of securing viable financing is crucial for organizations looking to transition to sustainable energy sources. The global monetary system has a significant impact on CO_2 emissions. Understanding the importance of implementing sustainable financial practices and investing in methods that promote positive environmental outcomes is crucial. This highlights the importance of replacing petroleum-based energy sources with state-of-the-art green innovation. Through the investigation, it has been found that incorporating SF into the energy blend significantly enhances the likelihood of achieving sustainable practices and reducing CO2 emissions. Conducting construction estimates within the scope of SF consideration poses challenges to the goal of reducing CO2 emissions.

3.1 Future Research Suggestions

The research suggests that the importance of SF, and STI in CO_2 reduction and environmental sustainability. The researchers should address the climate change, governments should create favorable frameworks for green investments, legislate environmental responsibility legislation for financial firms in future research. Longitudinal impact analysis, comparative policy framework studies, regional analyses, financial regulation effects, stakeholder perspectives, renewable energy technological innovation, policy recommendations.

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