

Impact of Globalization, Financial Development, Energy Consumption, and Economic Growth on CO₂ Emissions in India: Evidence from ARDL Approach

Naresh Chandra Sahu and Pushp Kumar

Abstract—This paper examines the impact of globalization and financial development on CO₂ emission by incorporating energy consumption in the framework of the Environment Kuznets Curve (EKC) hypothesis in India during 1971–2014. To achieve this objective, autoregressive distributed model (ARDL) model is used. Overall globalization, economic globalization, political globalization, and social globalization are used as proxies for globalization. Domestic credit to financial sector as a percentage of GDP is used as a proxy for financial development. ARDL bounds test confirms the existence of cointegration among the variables. The results show that financial development has no significant effect on carbon emission. The study also finds the support for the EKC hypothesis. In addition, the findings show that overall globalization, social globalization, and political globalization affect CO₂ emissions negatively, while economic globalization affects positively but not significantly. The study reveals that economic growth and energy consumption are found to have negative and significant effect on environment quality in India. The findings of the study would help policymakers to understand the role and impact of economic growth and energy consumption on environmental degradation and would guide them to implement policies and programmers to reduce the impact for achieving the global mandate for the reduction of CO₂ emission.

Index Terms—Globalization, ARDL model, EKC hypothesis, financial development, CO₂ emissions.

I. INTRODUCTION

Carbon dioxide (CO₂) is the main contributor to total radioactive forcing (RF) since 1750 [1]. In global greenhouse gases (GHGs), CO₂ accounts for 58.8% of GHGs [2]. CO₂ emissions are increasing over time due increasing urbanisation and industrialisation across the globe. In the literature, there are number of variables which lead to rising in carbon emissions. Out of those variables, globalization, financial development, energy consumption, and economic growth are found to be significant factors affecting carbon emissions [3]–[6]. Globalization is categorized into three categories i.e. economic globalization, political globalization, and social globalization. Economic globalization connects the economy through trade, investment and financial activities. The increase in financial activities and trade which gives rise to CO₂ emissions in the atmosphere [5]. Similarly,

social globalization connects people thorough information flow. This information flow may help to reduce CO₂ emissions globally.

Over the years, a number of studies have investigated the casual links between carbon emissions, economic growth, financial development, and energy consumption in different countries of the world [7]–[11]. These studies provide a mix results pertaining to the relationship among the variables as mentioned earlier. It is found that there are very few empirical studies pertaining to the casual relationship between carbon emission, financial development, energy consumption, and economic growth in India. Thus, the present study fills this gap by exploring the impact of aforesaid variables on carbon dioxide emissions in India over the period from 1971 to 2014.

The rest of paper is organised in the followings ways: Section II provides the review related to the relationship among the variables; Section III describes the database and methodology adopted in the study; Section IV presents the results and discussion; and lastly, Section VI provides the conclusion.

II. REVIEW OF LITERATURE

In this section, literature related to relationship carbon emissions, globalization, financial development, economic growth, and energy consumption have been reviewed.

Reference [12] analyzed the relationship between environmental quality and trade openness for 44 countries during 1971–1996. They developed a model to investigate the impact of trade openness on environmental quality in terms of scale, technology and composition and found that trade openness affects environmental quality. Reference [11] investigated the relationship between economic growth, CO₂ emissions, economic growth and trade openness for China, Korea, and Japan for the period 1971 to 2006. The positive relationship is found between CO₂ emissions and trade openness for South Korea and Japan while a negative relationship for China. Reference [13] examined the impact of trade openness on CO₂ emissions for Sri Lanka using ARDL model. The only short-term relationship is found between trade openness and CO₂ emissions. For China, Reference [14] analysed the impact of globalization on carbon emissions during 1970–202 using Bayer and Hanck combined cointegration and ARDL bound testing approach. It is found that general globalization index and its sub-index i.e. economic globalization, political globalization, and social globalization index have a negative impact on carbon emissions. In addition, the study also confirms the existence

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Naresh Chandra Sahu and Pushp Kumar are with School of Humanities, Social Sciences, and Management, Indian Institute of Technology Bhubaneswar, Odisha, India (email: naresh@iitbbs.ac.in, pk27@iitbbs.ac.in).

of EKC hypothesis for China.

Reference [15] investigated the impact of economic globalization on carbon emissions for 83 countries during 1985–2013. Spatial panel method was used to control the problem of spatial dependency and the spillover effect among neighbouring countries. The study fails to identify a direct and significant effect of economic globalization on carbon emissions. But, the study found that the indirect effect of economic globalization on carbon emissions is negative. Reference [16] investigated the effect of trade, economic growth, and renewable energy on carbon emissions for G7 countries during 1991–2016. It is found that in the long run, economic growth and trade lead to an increase in carbon emissions. The existence of EKC hypothesis is also found for G7 countries. Reference [10] examined the relationship between energy consumption, economic growth, and carbon emissions for G7 countries during 1971–2014 using panel ARDL model. They found that economic growth deteriorates the environmental quality. Reference [17] examined the impact of financial development, trade, urbanization on carbon emissions on 21 Kyoto Annex countries for the period 1970–2016 using generalised method of moments (GMM) methods. Positive association is found between income and carbon emissions in the long run. They found that financial development contributes positively to environmental quality in the long run. Reference [7] also found that economic and financial development are the determinants of environmental quality in BRIC countries. Their study reveals that higher economic and financial development leads to decline in CO₂ emissions in BRIC countries.

Reference [9] investigated the role of financial development, energy consumption, and economic growth in environmental quality in South Asian countries during 1980–2012. This study revealed that financial development has a negative effect on CO₂ emissions; while economic growth and energy consumption have a positive effect on CO₂ emissions. On the other hand, Reference [18] has not found a significant relationship between financial development and environmental degradation. Similarly, Reference [19] investigated the relationship between carbon emissions, FDI, and economic growth for 54 countries during 1990–2011 using dynamic simultaneous equation panel data model. They also did not find a significant relationship between financial development and CO₂ emissions. Reference [20] examined the relationship between carbon emissions, economic growth, energy consumption, and financial development in Gulf Cooperation Council (GCC) countries for the period 1980 to 2011 by applying time-series ARDL model. The study revealed that long run and causality relationships among CO₂ emission, financial development, economic growth, and energy consumption in all GCC countries except UAE. Reference [8] studied the impact of financial development, and trade on carbon emissions for Iran over the period 1970 to 2011 by applying ARDL model. The results revealed that financial development and energy consumption increase CO₂ emissions in Iran.

Reference [21] examined the effects of economic, financial and institutional development on carbon emissions in 24 transition countries over the period 1993–2004. The study verified the existence EKC hypothesis. The result revealed that financial development has a negative impact on

environmental quality. Also, Reference [22] and [23] found that financial development has a negative impact on environmental quality. Reference [24] investigated the relationship between globalization and carbon emissions in Pakistan between 1975 and 2014 by applying ARDL bound testing model. The study confirms the existence of an inverted U-shaped relationship between economic growth and carbon emission for Pakistan. Their findings reveal that globalization indices i.e. economic globalization, political globalization, and social globalization have the positive effects on environmental degradation. Reference [5] studied the relationship between globalization CO₂ emissions for 25 developed economies over the period 1970–2014. They found that globalization increases CO₂ emissions. In another paper, they examined the role of globalization in CO₂ emission in Japan for the period 1970 to 2014 [25]. It is found from the study that economic growth, energy consumption and globalization have a negative effect on carbon emissions. Reference [26] analysed the effects of globalization on carbon emissions in the panel of 255 countries during 1980–2011. The result shows that the globalization has a positive impact on environmental quality. The study suggests that globalization is the way through which developing countries can reduce carbon emission with the use of latest and eco-friendly technologies.

Reference [27] investigated the impact of renewable and non-renewable energy consumption on carbon emissions in a panel of 74 countries of the world during 1990–2015. They used generation panel unit root test and Westerlund bootstrap, Fully Modified Ordinary Least Square (FMOLS), Pedroni cointegration tests. It is found from the study that renewable energy reduces the carbon emission while nonrenewable energy consumption increases the carbon emissions in the sample country. Besides this, financial development is found to be a positive factor contributing reducing carbon emissions. Reference [28] analyzed the impact of globalization, energy consumption, urbanization, financial development, and economic growth on environmental quality in BRICS country during 1995–2014. Westerlund cointegration, Dynamic seemingly unrelated regression (DSUR), and Dumitrescu-Hurlin Granger causality test are used. The results revealed that energy consumption, economic growth and financial development have a positive impact on carbon emissions. Reference [29] assessed the impact of renewable and non-renewable energy, economic growth on environmental quality in China during 1980–2014. It was found from the study that economic growth and non-renewable energy consumption have a negative impact on environmental quality. Reference [30] investigated the impact of fossil fuels consumption, FDI, and economic growth on CO₂ emissions in 15 Asian developing countries during 1990–2013. Autoregressive distributed lag (ARDL) model was applied. The results revealed that economic growth and fossil fuels consumption are increasing carbon emissions in Asian developing countries. In Belt and Road Initiative (BRI) countries, Reference [31] studied the impact of financial development, trade openness, economic growth, and electricity consumption on environmental quality during 1980–2016. It is found from their study that financial development and trade openness improve the environmental quality while electricity consumption and economic growth

degrade the environmental quality.

Reference [32] investigated the effects of financial development and economic development on carbon emissions in 12 small island developing states during 2000–2016. In their study, it is found that economic development has a negative impact on environmental degradation. Reference [4] examined the role of financial development in environmental degradation in Saudi Arab during 1971–2016. They applied ARDL and vector error correction methods (VECM) for long run and short run causality. Globalization and electricity consumption are used as control variables. Bidirectional causality is found between globalization and carbon emissions in the sample countries. Financial development is found as negative determinants of environmental quality.

All the reviewed studies reveal the mix evidence related to

the impact of globalization, financial development, energy consumption, and economic growth on carbon emissions. Also, few scholars investigated this relationship for India. This study fills the gap by investigating the impact of aforesaid variables on carbon dioxide emissions in India during 1971–2014.

III. DATABASE AND METHODOLOGY

This paper is based on the secondary data covering the period from 1971 to 2014. The descriptions of the variables are explained in Table I. For exploring the impact of globalization, financial development, economic growth, and energy consumption on carbon dioxide emissions, the following ARDL model is used.

$$\Delta \ln CO_2 = \alpha_0 + \beta_1 \ln GDP_{t-i} + \beta_2 (\ln GDP_{t-i})^2 + \beta_3 \ln Glob_{t-i} + \beta_4 \ln FD_{t-i} + \beta_5 \ln EC_{t-i} + \sum_{i=1}^p \delta_1 \Delta (\ln CO_2)_{t-i} + \sum_{i=0}^p \delta_2 \Delta \ln GDP_{t-i} + \sum_{i=0}^p \delta_3 \Delta (\ln GDP)^2_{t-i} + \sum_{i=0}^p \delta_4 \Delta \ln Glob_{t-i} + \sum_{i=0}^p \delta_5 \Delta \ln FD_{t-i} + \sum_{i=0}^p \delta_6 \Delta \ln Ener_{t-i} \quad (1)$$

where, $\ln CO_2$: Natural logarithm of carbon dioxide $\ln GDP$: Natural logarithm of gross domestic product $\ln GDP^2$: Square of natural logarithm of gross domestic product $\ln OG$: Natural

logarithm of overall globalization index Δ : First lag difference.

TABLE I: DESCRIPTION OF THE VARIABLES

Variable	Symbol	Definition	Unit	Data Source
CO ₂ emissions	CO ₂	Burning of fossil fuels and manufactured of cement	Metric Tons	World Bank
Gross Domestic Product	GDP	GDP at constant price	Constant 2010 US Dollars	World Bank
Square of Gross Domestic Product	GDP ²	Square of GDP	Constant 2010 US Dollars	World Bank
Financial Development	FD	Domestic credit to financial (% of GDP)	Percent	World Bank
Energy Consumption	EC	Energy use (kg of oil equivalent per capita)	Kilograms	World Bank
Overall Globalization	OG	—	Index	KOF Index
Economic Globalization	EG	—	Index	KOF Index
Political Globalization	PG	—	Index	KOF Index
Social Globalization	SG	—	Index	KOF Index

IV. RESULTS AND DISCUSSION

The objective of this paper is to investigate the impact of globalization, financial development, economic growth, and energy consumption on carbon emissions. For achieving this objective, the first step is to testing the stationarity of variables. If the variables are stationary at level, then simple regression technique can be applied otherwise time series approach. So, the stationarity test results are displayed in Table II. Since the variables are not stationary at level, simple linear regression is not used. Therefore, autoregressive distributed lag (ARDL) model developed by [33] is used to explore the impact of globalization, financial development, energy consumption, and economic growth on environmental quality. For applying the ARDL model, we have to test that variables should not be stationary at second order. If variables are found stationary at second order; ARDL cannot be used. For testing stationarity of the variables, Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) are used. All the variables are stationary at either at level or first difference (Table II).

We have analysed the effects of globalization and its sub-indices i.e. economic globalization, political globalization,

and social globalization separately on CO₂ emissions. So, four regression equations are estimated using ARDL bounds testing approach. The results of ARDL bounds testing for four models are presented in Table II. It can be seen from Table II that value of F statistics is more than the lower bound value. It reveals that there is cointegration among the variables. For the existence of long run relationship, the value of error correction should be negative and statistically significant. Results of long run coefficients and their respective error correction terms are presented in Table III.

TABLE II: STATIONARITY TEST RESULTS

Variables	At Level			At First Difference		
	ADF	PP	KPSS	ADF	PP	KPS S
$\ln CO_2$	-2.204 -2.329	-2.168 -2.323	0.102 ^a 0.217	-7.888 ^a -6.451 ^a	-7.874 ^a -16.016 ^a	— 0.18
$\ln GDP$	-2.109	-2.109	0.218	-6.506 ^a	-16.247 ^a	0.19
$\ln GDP^2$	-0.169	-0.345	0.174 ^a	-6.152 ^a	-6.210 ^a	0.08
$\ln EC$	-1.648	-1.651	0.180 ^a	-4.062 ^b	-4.075 ^b	—
$\ln OG$	-1.792	-1.620	0.176 ^a	-3.422 ^c	-3.422 ^c	—
$\ln EG$	-1.480	-1.597	0.112 ^a	-6.666 ^a	-1.597	—
$\ln PG$	-1.480	-1.597	0.112 ^a	-6.666 ^a	-6.670 ^a	—
$\ln SG$	-2.318	-1.819	0.110 ^a	-3.082 ^c	-5.254 ^a	—
$\ln FD$						

^a, ^b, and ^c represent the significance level at 1%, 5% and 10% respectively

TABLE III: ARDL BOUND TEST RESULTS

Models	Bound Testing		
	Optimal Lag Length	F-statistics	Results
Model 1: $\ln OG$, $\ln FD$, $\ln EC$, $\ln GDP$, $\ln GDP^2$, $\ln CO_2$	2,1,1,1,1,2	4.304 ^b	Conclusive
Model 2: $\ln EG$, $\ln FD$, $\ln EC$, $\ln GDP$, $\ln GDP^2$, $\ln CO_2$	2,1,1,1,1,2	4.327 ^b	Conclusive
Model 3: $\ln SG$, $\ln FD$, $\ln EC$, $\ln GDP$, $\ln GDP^2$, $\ln CO_2$	2,1,1,1,1,2	4.904 ^a	Conclusive
Model 4: $\ln PG$, $\ln FD$, $\ln EC$, $\ln GDP$, $\ln GDP^2$, $\ln CO_2$	1,1,1,1,1,2	4.290 ^b	Conclusive
Level of Significance	I (0) Bound	I (1) Bound	
1 %	4.154	6.073	
5 %	2.945	4.451	
10 %	2.439	3.767	

^a and ^b represent the significance level at 1% and 5% respectively

The coefficient of FD is found negative but statistically insignificant in all four models. It implies financial development has a positive impact on environmental quality. The coefficient of energy consumption is found positive and statistically significant. This can be interpreted as a rise in energy consumption leads to a rise in CO_2 emissions. The coefficient of the variables OG , EG , PG , and SG are found

insignificant. But the sign of $\ln OG$, $\ln PG$, and $\ln SG$ are negative while the sign of $\ln EG$ is positive. It indicates that impact of overall globalization, political globalization, and social globalization contribute positively towards environmental quality in India and economic globalization contributes negatively towards environmental quality. It also reveals that overall globalization (OG) and its sub-indices i.e., EG , PG , and SG have an insignificant effect on CO_2 in the long run. The coefficient of $\ln GDP$ is found to have positive and significant impact on environmental degradation. It implies that a rise in GDP leads to rise in CO_2 -emissions in India. The coefficient of the square of $\ln GDP$ is statistically significant with a negative sign. It implies that the environmental Kuznets Curve (EKC) hypothesis exists in all model. After getting regression results, it is necessary to check the validity of the regression model adopted in the study. To carry out that, Lagrange Multiplier (LM) test by [34], [35] for serial correlation is used. For heteroskedasticity White test developed by [36] is applied. The results of these tests are shown in Table IV. These tests reveal that the estimated regression results are free from the problems of serial correlation and heteroskedasticity.

TABLE IV: ARDL LONG RUN COEFFICIENTS

Variables	Model 1			Model 2			Model 3			Model 4		
	Coefficient	Standard Error	Probability	Coefficient	Standard Error	Probability	Coefficient	Standard Error	Probability	Coefficient	Standard Error	Probability
$\ln FD$	-0.001	0.109	0.994	-0.028	0.053	0.596	0.024	0.101	0.813	-0.088	0.113	0.444
$\ln EC$	1.258	0.629	0.055	2.000	0.407	0.000	1.088	0.605	0.083	1.525	0.348	0.000
$\ln GDP$	12.458	3.313	0.001	17.548	2.025	0.000	9.119	4.826	0.069	15.593	1.434	0.000
$\ln GDP^2$	-0.216	0.067	0.003	-0.317	0.040	0.000	-0.152	0.095	0.119	-0.275	0.026	0.000
$\ln OG$	-0.257	0.343	0.460									
$\ln EG$				0.097	0.083	0.254						
$\ln SG$							-0.301	0.251	0.239			
$\ln PG$										-0.386	0.438	0.385
Error Correction Term	-0.476	0.220	0.039	-0.725	0.223	0.003	-0.424	0.207	0.051	-0.515	0.204	0.017
Diagnostic Tests												
Test	Statistics	Probability		Statistics	Probability		Statistics	Probability		Statistics	Probability	
R^2	0.762			0.772			0.778			0.758		
LM Test	2.666	0.103		0.991	0.319		1.887	0.170		0.739	0.390	
White	42.000	0.427		42.000	0.427		42.000	0.427		42.000	0.427	

V. CONCLUSION

This paper explores the effects of financial development, globalization, economic growth, and energy consumption on carbon emissions. Effects of globalization and its sub-indices i.e. economic globalization, social globalization, and political globalization is separately examined. Autoregressive Distributed Model (ARDL) bounds testing methods is used. The results of the study confirm the existence of long run relationship among the carbon emissions, financial development, globalization, economic growth, and energy consumption based on the bounds test and error correction mechanism. Financial development has no significant impact on CO_2 emissions in India. In addition, globalization and its sub-indices have no significant impact on environmental quality. Energy consumption and economic growth are found to be major factors which affect environmental quality negatively during the study period. The paper also confirms the existence of EKC hypothesis in India. The findings of the study suggest that policymaker should focus on the production of clean and renewable energy which omit low carbon dioxide and reduce the environmental degradation in developing countries like India.

CONFLICT OF INTEREST

The authors hereby that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Naresh Chandra Sahu conducted the research and examined the methodology part of the paper. Pushp Kumar analyzed the data and organized the paper.

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rural economics.

Naresh Chandra Sahu is an assistant professor at the School of Humanities, Social Sciences, and Management of the Indian Institute of Technology Bhubaneswar, India. He has done his PhD in economics from the Indian Institute of Technology Kanpur, India in 2008. His current research interests include environmental economics, insurance economics, climate change, mining, finance and



Pushp Kumar is currently a PhD scholar in economics at School of Humanities, Social Sciences, and Management of the Indian Institute of Technology Bhubaneswar, India. He did his MPhil in economics from Central University of Punjab, India in 2017. He has been awarded National Eligibility Test in Economics in 2015. His research areas of interests are economics of climate change, international trade, gravity modelling, and applied econometrics.