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The impact of financial development, income, energy and trade on carbon emissions: Evidence from the Indian economy

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Abstract

This paper examines the long-run equilibrium and the existence and direction of a causal relationship between carbon emissions, financial development, economic growth, energy consumption and trade openness for India in a multivariate framework. The results suggest that there is strong evidence on the long run and causal relationships between per capita carbon emissions, per capita real income, the square of per capita real income, per capita energy use, financial development and trade openness. The results also confirm the existence of EKC hypothesis in the Indian economy. Further, causality tests also indicate that there was a unidirectional Granger causality running from per capita real income, per capita energy consumption, and financial development to per capita carbon emissions, all without feedback. The evidence seems to suggest that financial system should take into account the environment aspect in their current operations. The findings of this study may be of great importance for policy and decision-makers in order to develop energy policies for India that contribute to curb carbon emissions while preserving economic growth.

Keywords: Carbon emissions, Financial development, Growth, Energy consumption, Trade.

JEL classification: C32, O53, Q43, Q53, Q56

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1. Introduction

Climate change and global warming are the greatest and most controversial environmental issues of our times. There is broad consensus among scientists that accumulated carbon dioxide emitted from the burning of fossil fuels, along with contributions from other human-induced greenhouse gas emissions, are warming the atmosphere and oceans of the earth (IPCC, 2007). The global effects of climate change are already apparent in increasing the frequency of extreme weather events, altering precipitation patterns, heightening storm intensity, reversing ocean currents and a rising seal level. These changes, in turn, can have significant impacts on the functioning of ecosystems, the viability of wildlife, and the well-being of humans.

With the world's second largest population and over 1.1 billion people, India is one of the lowest Greenhouse Gas emitters in the world on a per-capita basis. Its emission of 1.18 tonnes of carbon equivalent per capita in 2008 was nearly one-fourth of the corresponding global average of 4.38 tonnes. However, India is highly vulnerable to climate change, as a large population are dependent on agriculture and forestry for livelihood. The Indian economy is also dependent on natural resources and any adverse impact on these and related sectors will negate government's efforts to eradicate poverty and ensure sustainable livelihood for the population.

India accords high priority to its development. The economy has been growing, on average, at 7.7% per year between 2000 and 2007, and fossil-fuel carbon emissions have increased by 125% between 1950 and 2008, becoming the world's third largest fossil-fuel CO_2-emitting country. As outlined in India's 12th Five Year Plan (2012–2017), the government of India has provisionally set a 9% GDP growth target, which will require energy supply to grow at 6.5% per year. Being aware of achieving its growth trajectory in an environmentally sustainable manner, India has announced in December 2009 that it would aim to reduce the emissions intensity of its GDP by 20-25 percent from 2005 levels by 2020. Therefore, India is faced with the challenge of identifying common ground between climate change policy and economic growth and pursuing measures that achieve both.

However, to control the greenhouse gas emissions and to ensure the sustainability of the economic development, it is important to better understand the inter-temporal links in the environment-energy-income nexus. In the literature, there have been few researches to explore the relationship between these variables in the case of India. Ghosh (2009) investigated the causal relationship between carbon emissions and economic growth using ARDL bounds testing approach complemented by Johansen–Juselius maximum likelihood procedure in a multivariate framework by incorporating energy supply, investment and employment. The result revealed the absence of long-run causality between carbon emissions and economic growth; however a bi-directional short-run causality between the two is found. Alam et al. (2011) applied the Toda and Yamamoto causality test to examine the dynamic relationship between carbon emissions, economic growth, energy consumption, labour forces and gross fixed capital formation. They found a bi-directional Granger causality between energy consumption and carbon emissions in the long run but neither carbon emissions nor energy consumption causes movements in economic growth. Jayanthakumaran et al. (2012) analyzed the long-run relationship of carbon emissions and other variables such as growth, energy, trade and endogenously determined structural breaks. They found evidence for the existence of an EKC hypothesis for India. However, they failed to derive a clear picture regarding the association of structural change and carbon emissions.

This paper extends the above-mentioned multivariate framework further by including the impacts of financial development into the nexus. To the best of our knowledge, there has never been an attempt to investigate the causes of carbon emissions for India by taking into account the financial development and using single country data. This study tries to fulfil this gap. In this respect, we argue that the analysis of the relationship between carbon emissions and financial development may reduce the problems of omitted variable bias in econometric estimation. This attempt may also be of great importance for policy and decision-makers to better apprehend the determinants of carbon emissions in order to develop effective energy policies that will palliate the impacts of human activities, and thereby contribute to curb carbon emissions while preserving economic growth.

The remainder of the paper is organized as follows. Section 2 presents a brief literature review related with financial development and carbon emissions. Section 3 describes the data and methodology. Empirical results are given in section 4 while the summary and the concluding remarks are outlined in Section 5.

2. A brief literature review

The impact of financial development on environmental conditions has gained increasing attention in the recent literature. Yuxiang and Chen (2011) used provincial data of Chinese economy to examine the impact of financial development on industrial pollutants and found improvements in environment due to financial development. They claimed that financial development improves environmental quality by increasing income and capitalization, exploiting new technology and implementing regulations regarding environment. Jalil and Feridun (2011) investigated the impact of financial development, economic growth and energy consumption on CO_2 emissions in the case of China from 1953 to 2006. The results of the analysis revealed a negative sign for the coefficient of financial development, suggesting that financial development in China has not taken place at the expense of environmental pollution. On the contrary, it is found that financial development save environment from degradation. Moreover, the results confirm the existence of a long-run relationship between carbon emissions, income, energy consumption and trade openness while supporting the presence of EKC hypothesis. Similarly, Zhang (2011) explored the effect of financial development on carbon emissions. Results indicated that, first, China's financial development constitutes an important driver for carbon emissions increase, which should be taken into account when carbon emissions demand is projected. Second, the influence of financial intermediation scale on carbon emissions outweighs that of other financial development indicators but its efficiency's influence appears by far weaker although it may cause the change of carbon emissions statistically. Third, China's stock market scale has relatively larger influence on carbon emissions but the influence of its efficiency is very limited. Finally, among financial development indicators, China's FDI exerts the least influence on the change of carbon emissions, due to its relatively smaller volume compared with income. Ozturk and Acaravci (2013) examined the causal relationship between financial development, openness, economic growth, energy consumption and carbon emissions in Turkey for the 1960–2007 period. Empirical results yielded evidence of a long-run relationship between carbon emissions, energy consumption, income, openness ratio and financial development. The results also supported the validity of EKC hypothesis in Turkish economy. However, financial development has no significant effect on carbon emissions in the long- run.

For cross-country case studies, Talukdar and Mesner (2001) examined the impact of private sector involvement on carbon emissions using data from 44 developing countries over nine years (1987–95). They found that both foreign direct investments and domestic financial capital markets in an economy are likely to have positive impacts on the environment. Claessens and Feijen (2007) analyzed the role of governance in reducing CO_2 emissions and reported that with the help of more advanced governance firms can lower growth of carbon emissions. They suggested that financial development might stimulate the performance of firms due to the adoption of energy efficient technologies, which reduce carbon emissions. Tamazian et al. (2009) investigated the linkage between financial development, economic development and environmental quality for BRIC countries using panel data over period 1992–2004. Their results revealed that higher degree of economic and financial development decreases the environmental degradation. Tamazian et al. (2010) tested the role of economic, financial and institutional developments on environmental degradation with a sample of 24 transition countries for the period from 1993 to 2004. Their findings showed that financial liberalization may be harmful for environmental quality if it is not accomplished in a strong institutional framework. In addition, the findings confirm the existence of an EKC.

India is included in some of the above-mentioned panel data studies. However, it is widely recognized that any potential inference drawn from these cross-country studies provides only a general understanding of the linkage between the variables, and thus are unable to offer much guidance on policy implications for each country (Stern et al., 1996; Lindmark, 2002; Ang, 2008). Hence, the aim of this research is to investigate the impact of financial development on carbon emissions in the case of India.

3. Methodology and data

Following the empirical literature in energy economics, it is plausible to form the long-run relationship between carbon emissions, economic growth, energy consumption, financial development and foreign trade in linear logarithmic quadratic form, with a view of testing the long-run and causal relationships between these variables in India, as follows:

$$CO_{2t} = \beta_0 + \alpha_Y Y_t + \alpha_{Y^2} Y_t^2 + \alpha_E E_t + \alpha_F F_t + \alpha_T T_t + \varepsilon_t \tag{1}$$

where t and ε denote time and error, respectively. CO_2 is carbon emissions (measured in metric tons per capita), Y indicates per capita real GDP (measured in local constant currency) , Y^2 is the square of per capita real income, E means the energy consumption (measured as kg of oil equivalent per capita), which is used as a proxy for economic growth, F stands for financial development that is the total value of domestic credit to private sector[1][2] as a share of

[1] Domestic credit to private sector refers to financial resources provided to the private sector, such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable, that establish a claim for repayment.

[2] In the literature, there are many proxies used for representing financial development. For example, the monetary aggregate M2 as a ratio of nominal GDP is used in measuring financial deepening. However, the availability of foreign funds in the financial system makes the monetary aggregate an inappropriate measure of financial development. Another commonly used variable is the ratio of deposit liabilities to nominal GDP, which captures the broad money stock excluding currency in circulation. But, this measure doesn't take into account the allocation of capital. Several studies have also employed the ratio of commercial bank assets divided by commercial bank plus central bank assets which measures the importance of the commercial banks in the financial system. In this study, we use the domestic credit to private sector as a percentage of GDP, which constitutes the most common variable used in the literature to represent financial development. In fact, this measure represents more accurately the role of financial intermediaries in channelling funds to private markets participant.

GDP, and T represents trade openness, which is the total value of exports and imports as a share of GDP.

The parameters α_Y, α_{Y^2}, α_E, α_F and α_T are the long-term elasticity estimators of CO_2 emissions with respect to per capita real GDP, the square of per capita real GDP, the per capita energy consumption, financial development and the trade openness, respectively. The EKC hypothesis suggests that $\alpha_Y > 0$ and $\alpha_{Y^2} < 0$. α_Y being positive reveals the phenomenon wherein as income increases, the CO_2 emissions increase as well; α_{Y^2} being negative reflects the inverted-U curve-shaped pattern of the EKC, where once income passes the threshold, the CO_2 emissions will decrease. The expected sign of β_e is positive. Because a higher level of energy consumption should result in greater economic activity and stimulates CO_2 emissions.

Financial development may be harmful for environmental quality $\alpha_F > 0$, otherwise $\alpha_F < 0$ if the focus of financial sector is to improve environmental quality by enabling firms in adopting advanced cleaner and environment friendly techniques.

α_T is expected to be negative or positive, depending on the level of economic development stage of a country. In general, developing countries, which are abundant in labour and natural resources, attempt to promote heavy industries, which usually are pollution-intensive, by accepting foreign direct investment of developed countries. In contrast, developed countries change from energy-intensive industries to services and knowledge-based technology-intensive industries, which are environmentally cleaner. (Grossman and Krueger, 1995)

The sample period runs from 1970 to 2008 based on the annual times series data availability. The data originate from the world development indicator data base (CD-ROM, 2010), the World Bank. All variables are employed with their natural logarithms form to reduce heteroskedasticity and to obtain the growth rate of the relevant variables by their differenced logarithms.

3.1. Estimation strategy

This study employs the Autoregressive Distributed Lag (ARDL) bounds testing procedure recently developed by Pesaran et al. (2001). The ARDL has several advantages over other techniques of cointegration such as Engle and Granger (1987) and Johansen and Juselius (1990). First, it can be applied irrespective of whether the underlying variables are I(0), I(1) or a combination of both (Pesaran and Pesaran, 1997). Second, the ARDL procedure is statistically more significant approach to determine the cointegration relation in small samples to those of the Johensen and Juselius cointegration technique (Pesaran and Shin, 1999). Third, even where some of the model regressors are endogenous, the bounds testing approach generally provides unbiased long-run estimates and valid t-statistics (Narayan, 2005). Forth, the model takes a sufficient number of lags to capture the data generating process in a general to specific modeling frameworks (Laurenceson and Chai, 2003). Fifth, the error correction model (ECM) can be derived from ARDL through a simple linear transformation, which integrates short run adjustments with long run equilibrium without losing long run information (Pesaran and Shin, 1999).

Basically, the ARDL approach to cointegration involves two steps for estimating long-run relationship. The first step is to investigate the existence of long-run relationship among all variables in the equation under estimation. If there is an evidence of cointegration between variables, the second step is to estimate the long-run and short-run models.

3.2. Stationarity

As discussed earlier, the ARDL bounds testing procedure can be applied irrespective of whether the variables are I(0), I(1) (Pesaran and Pesaran, 1997). However, according to Ouattara (2004), in the presence of I(2) variables the computed F-statistics provided by Pesaran et al. (2001) become invalid. This is because the bounds test is based on the assumption that the variables should be I(0) or I(1). Therefore, the implementation of unit root tests in the ARDL procedure is necessary to ensure that none of the variables is integrated at an order of I(2) or beyond.

It is well known that the presence of structural breaks in the series may bias the results toward non rejection of the null hypothesis of a unit root when there is none. This consideration is of particular importance since the economic system in India has been subject to some drastic changes in policy and regulations. An alternative to the unit root test against a single-break stationarity was proposed by Zivot and Andrews (1992). It was extended to a two-break stationarity alternative by Lumsdaine and Papell (1997) and up to five-break stationarity alternative, with a priori unknown number of breaks, by Kapetanios (2005). However, these tests maintain the linearity assumption under the unit root null hypothesis. If a break exists under the null of a unit root, it will exhibit size distortions that not only ''over-reject'' the null hypothesis of a unit root, but also will tend to estimate the break point incorrectly. To overcome this problem, Lee and Strazicich (2003, 2004) have developed an alternative (at most two) endogenous break unit root test that uses the Lagrange Multiplier (LM) test statistic, and allows for breaks both under null and alternative hypothesis. Thus, rejection of the unit root null based on LM test provides quite strong evidence of stationarity.

Lee and Strazicich (2003, 2004) unit-root test consider the data generating process as follows:

$$\Delta y_t = \delta' \Delta Z_t + \phi \widetilde{S}_{t-1} + u_t$$

Where $\widetilde{S}_t = y_t - \widetilde{\psi}_x - Z_t \widetilde{\delta} (t = 2,...T)$ and Z_t is a vector of exogenous variables defined by the DGP; $\widetilde{\delta}$ is the vector of coefficients in the regression of Δy_t on ΔZ_t respectively with Δ the difference operator; and $\widetilde{\psi}_x = y_1 - Z_1 \widetilde{\delta}$, with y_1 and Z_1 the first observations of y_t and Z_t respectively. The unit-root null hypothesis is described by $\phi = 0$. The augmented terms $\Delta \widetilde{S}_{t-j}, j = 1,...k,$ terms were included to correct for serial correlation. The value of k is determined by the general-to-specific search procedure. To endogenously determine the location of the break (T_B), the LM unit-root searches for all possible break points for the minimum (the most negative) unit-root t-test statistic, as follows:

$$Inf\, \widetilde{\tau}(\widetilde{\lambda}) = Inf_{\lambda}\, \widetilde{\tau}(\lambda); \ \lambda = \frac{T_B}{T}$$

The critical values of the endogenous two-break LM unit-root test are reported in Lee and Strazicich (2003) and the critical values of the one-break LM unit-root test are tabulated in Lee and Strazicich (2004).

In the present study, when the two-break LM test results showed that only one structural break is significant to at least the 10 per cent level for some series, we perform the one-break LM test of Lee and Strazicich (2004). This was done not only because the one-break LM test appears more appropriate in this case, but also because we wanted to determine if including two breaks instead of one can adversely affect the power to reject the unit root hypothesis for these countries. For the same reason, when the one-break or two-break LM test results showed that no break is significant, we employ the Augmented Dickey–Fuller (ADF), Phillips–Perron, Augmented Dickey–Fuller GLS (ADF-GLS), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit-root techniques. The first three techniques test the null hypothesis of a unit root against the alternative of stationarity. The KPSS method tests the hypothesis that the series is stationary against the alternative of non-stationarity.

3.3. Cointegration analysis

The ARDL procedure involves the estimation of eq. (1) as follows:

$$\Delta CO_{2t} = a_0 + \sum_{i=1}^{p} a_{1i}\Delta CO_{2t-i} + \sum_{i=0}^{p} a_{2i}\Delta Y_{t-i} + \sum_{i=0}^{p} a_{3i}\Delta Y_{t-i}^2 + \sum_{i=0}^{p} a_{4i}\Delta E_{t-i} + \sum_{i=0}^{p} a_{5i}\Delta F_{t-i} + \sum_{i=0}^{p} a_{6i}\Delta T_{t-1}$$
$$+\lambda_1 CO_{2t-1} + \lambda_2 Y_{t-1} + \lambda_3 Y_{t-1}^2 + \lambda_4 E_{t-1} + \lambda_5 F_{t-1} + \lambda_6 T_{t-1} + \mu_t \quad (2)$$

where Δ denotes the first difference operator, a_0 is the drift component, et μ_t is the usual white noise residuals, and the variables CO_2, Y, Y^2, E, F and T are as defined earlier. The terms with summation signs represent the error correction dynamics, while the second part of the equation with λ corresponds to the long run relationship. This equation incorporates the time trend variable to capture the autonomous time-related changes.

The ARDL method estimates $(p + 1)^k$ number of regressions in order to obtain the optimal lag length for each variable, where p is the maximum number of lags to be used and k is the number of variables in the equation. An appropriate lag selection based on a criterion such as Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC). The bounds testing procedure is based on the joint F-statistic or Wald statistic that is tested the null hypothesis of no cointegration.

Pesaran et al. (2001) and Narayan (2005) individually report two sets of critical values for a given significance level. One set of critical values assumes that all variables included in the ARDL model are I(0), while the other is calculated on the assumption that the variables are I(1). If the computed test statistic exceeds the upper critical bounds value, then the H0 hypothesis is rejected. If the F-statistic falls into the bounds then the cointegration test becomes inconclusive. If the F-statistic is lower than the lower bounds value, then the null hypothesis of no cointegration cannot be rejected. Two sets of critical values are reported in Narayan (2005) for sample sizes ranging from 30 observations to 80 observations. Given the relatively small sample size in the present study (38 observations), we extract appropriate critical values from Narayan (2005).

Having found that there exists a long-run relationship between the variables, the next step is to estimate the error-correction model:

$$\Delta CO_{2t} = a_0 + \sum_{i=1}^{p} a_{1i}\Delta CO2_{2t-i} + \sum_{i=0}^{p} a_{2i}\Delta Y_{t-i} + \sum_{i=0}^{p} a_{3i}\Delta Y_{t-i}^2 + \sum_{i=0}^{p} a_{4i}\Delta E_{t-i} + \sum_{i=0}^{p} a_{5i}\Delta F_{t-i}$$
$$+\sum_{i=0}^{p} a_{6i}\Delta T_{t-i} + \eta_1 ECT_{t-1} + \mu_{1t} \quad (3)$$

where η measures the speed of adjustment to obtain equilibrium in the event of shock(s) to the system and ECT_{t-1} is the residuals that are obtained from the estimated cointegration model of Eq.(1).

To gauge the adequacy of the specification of the model, diagnostic and stability tests are conducted. Diagnostic tests examine the model for serial correlation, functional form, non-normality and heteroscedasticity. As suggested by Pesaran and Pesaran (1997), the stability of the short-run and long run coefficients are checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests proposed by Brown et al. (1975). The CUSUM and CUSUMSQ statistics are updated recursively and plotted against the breaks points. If the plots of the CUSUM and CUSUMSQ statistics stay within the critical bonds of a 5% level of significance, the null hypothesis of all coefficients in the given regression is stable and cannot be rejected.

3.4. Granger causality

The ARDL method tests the existence or absence of cointegration relationship between variables, but not the direction of causality. If we do not find any evidence for cointegration among the variables then the specification of the Granger causality test will be a vector autoregression (VAR) in first difference form. However, if we find evidence for cointegration then we need to augment the Granger-type causality test model with a one period lagged error correction term (*ECT_{t-1}*). This is an important step because Engel and Granger (1987) caution that if the series are integrated of order one, in the presence of cointegration VAR estimation in first differences will be misleading. The augmented form of Granger causality test with ECM is formulated in multivariate qth order of VECM model as follows:

$$(1-B)\begin{bmatrix} CO_{2t} \\ Y_t \\ Y_t^2 \\ E_t \\ F_t \\ T_t \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \\ b_6 \end{bmatrix} + \sum_{i=1}^{q}(1-B)\begin{bmatrix} c_{11,i}\, c_{12,i}\, c_{13,i}\, c_{14,i}\, c_{15,i}\, c_{16,i} \\ c_{21,i}\, c_{22,i}\, c_{23,i}\, c_{24,i}\, c_{25,i}\, c_{26,i} \\ c_{31,i}\, c_{32,i}\, c_{33,i}\, c_{34,i}\, c_{35,i}\, c_{36,i} \\ c_{41,i}\, c_{42,i}\, c_{43,i}\, c_{44,i}\, c_{45,i}\, c_{46,i} \\ c_{51,i}\, c_{52,i}\, c_{53,i}\, c_{54,i}\, c_{55,i}\, c_{56,i} \\ c_{61,i}\, c_{62,i}\, c_{63,i}\, c_{64,i}\, c_{65,i}\, c_{66,i} \end{bmatrix}\begin{bmatrix} CO_{2t-i} \\ Y_{t-i} \\ Y_{t-i}^2 \\ E_{t-i} \\ F_{t-i} \\ T_{t-i} \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix}\left[ECT_{t-1}\right] + \begin{bmatrix} \gamma_{1t} \\ \gamma_{2t} \\ \gamma_{3t} \\ \gamma_{4t} \\ \gamma_{5t} \\ \gamma_{6t} \end{bmatrix} \quad (4)$$

where (1-B) is the lag operator, ECT is the lagged error-correction term and γ_t's serially independent random errors with mean zero and finite covariance matrix.

The VECM allows us to capture both the short-run and long-run Granger causality. The short-run causal effects can be obtained by the F-test of the lagged explanatory variables, while the t-statistics on the coefficient of the lagged error correction term indicates the significance of the long-run causal effect.

4. Empirical results and discussion

4.1. Unit root tests

Table 1 reports the unit root results from the two-and one-break LM tests. We tested each variable for a unit root using the two-break LM test at the 1-, 5- and 10 percent levels of significance. As noted above, when this test showed that only one structural break is significant we employed the one-break LM test at the same levels of significance. In order to determine the number of lags, we used a "general to specific" procedure at each combination of break points for the two-break test, and at each single break point for the one-break test.

Table 1. Conventional unit root tests

	ADF		PP		KPSS		ADF-GLS	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
	Test statistics	Test statistics	Test statistics	Test statistics	Test statistics	Test statistics	Test statistics	Test statistics
Y^2	3.187	– 2.980***	5.779	– 3.026***	0.729***	0.352	1.272	– 1.933***
E	3.357	– 2.523**	7.450	– 2.354**	0.744***	0.331	0.520	– 4.635***
F	2.016	– 2.142**	2.920	– 4.11***	0.659**	0.167	1.569	– 3.123***

Note : ADF: Augmented Dickey–Fuller test. PP: Phillips–Perron test. KPSS: Kwiatkowski–Phillips–Schmidt–Shin. ADF–GLS: Elliot– Rothenberg–Stock Dickey–Fuller GLS detrended. ADF, PP and DF–GLS critical values are taken from MacKinnon (1991). KPSS critical values are sourced from Kwiatkowski et al. (1992). All null hypotheses except KPSS are unit root; while, in KPSS null is stationarity. ***: Rejection of the null hypothesis at the 1% significance level, **: Rejection at 5%, and *: Rejection at 10%.

As shown in table 1, the unit root hypothesis with two structural breaks cannot be rejected for CO_2 in level. Similar results were found for Y and T, all of which have experienced one break in their term structures. However, if we take the first differences, the unit root null for all the series can be rejected at the 1% level, suggesting thereby that they are integrated of order 1,i.e. I(1).

Table 2 presents the ADF, PP, KPSS and ADF-GRS test results for Y^2, E and F, for which the results from the two- and one-break LM tests showed no significant breaks. The results reveal that all the four tests almost unanimously indicate that all variables are non-stationary in their level data. However, the stationarity property is found in the first difference of the variables in 5% or 1% critical level.

Table 2. Two/one-break minimum LM Unit-Root tests

	Level			First Difference		
	t	**TB1**	**TB2**	**t**	**TB1**	**TB2**
CO_2	– 5.182	1986	2000	– 7.310***	1975	2000
Y	– 3.055	1989	-	– 7.266***	1990	-
T	– 4.665	1980	-	– 5.369***	1981	-

Note: Results are based on the model C, which allows for two changes in the level and trend of the series. ***: Rejection of the null hypothesis at the 1% significance level, and **: Rejection at 5%.

While the first structural break for CO_2 in 1986 is inexplicable in terms of energy consumption, the second in 2000 reflects the steadily increase of energy use since the late 1990s which contributes to the increase of carbon emissions.

The break date of 1989 for Y shows an upward trend, which may be related to the economic reforms undertaken by Rajiv Ghandi soon after taking over as Prime Minister in 1985. Reforms include abolition of licences for some industries, sale of shares in selected public enterprises, remove of price controls and establishment of the Stock Exchange Board of India

The break date of 1983 for T coincides with the second oil shock, which deteriorated India's terms of trade as well as its balance-of-payment.

As none of the variables is integrated of order two, the ARDL bounds procedure can be used to examine the existence of a long-run relationship in the following step.

4.2. Cointegration test results

The cointegration test under the bounds testing approach involves comparing the F-statistics against critical values. Given that the value of the F-statistic is sensitive to the number of lags imposed each time on the differenced variables (Bahmani- Oskooee and Goswami,2003), we select the optimal order of lags of the model based on the Akaike Information (AIC) and the Schwarz–Bayesian(SBC) information criteria as suggested by Pesaran et al.(2001). The results of the lag selection criteria indicate that the optimal number of lags is one.

The calculated F-statistics, together with the critical values, are reported in Table 3. The F-test has a non-standard distribution that depends on four factors, namely (i) the order of variables included in the ARDL model, (ii) the number of explanatory variables,(iii)whether the ARDL model includes an intercept and/or time trends, and (iv) the sample size.

Table 3. The results of *F*-test for cointegration

Model	F-statistics	Conclusion
$F(CO_2 / Y\ Y^2\ E\ F\ T)$	5.34	Cointegration

Note: The critical value ranges of *F*-statistics are 2.306-3.353, 2.734-3.920 and 3.657-5.256 at 10%, 5% and 1% level of significances, respectively, which are taken from Appendix in Narayan (2005).

The calculated F-statistic $F(CO_2 / Y\ Y^2\ E\ F\ T) = 5.34$ is greater than the upper bound of the critical value of 5.256 at the 1% significance level. Hence, we conclude that at the 1% level, the null hypothesis of no cointegration among variables cannot be accepted.

4.3. Long- and short-run elasticities

Given the existence of a long-run relationship, in the next step, the ARDL cointegration procedure was implemented to estimate the parameters of the Eq. (2). The AIC criterion has been utilized to find the coefficients of the level variables. Because, AIC is known as parsimonious model, as selecting the smallest possible lag length and it minimizes the loss of degree of freedom as well.

The long-run results are reported in table 4. Except for the coefficient of *T* in the model, all estimated coefficients are statistically significant and have correct signs as expected, supporting the evidence of a long-run relationship among the variables.

Table 4. Long-run estimation results

Regressor	Coefficient
Y	11.965***
	(1.645)
Y^2	– 0.606***
	(0.077)
E	1.705***
	(0.276)
F	0.182***
	(0.024)
T	0.047
	(0.037)
Constant	– 70.044***
	(7.303)

Note: The asterisks *** is 1% significant level. The numbers in parentheses are standard errors.

Both linear and non-linear terms of real GDP provide evidence in supporting inverted-U relationship between economic growth and CO_2 emissions. The result indicates that a 1% rise in real GDP will raise CO_2 emissions by 11.965% at the 1% significance level while negative sign of squared term seems to corroborate the delinking of CO_2 emissions and real GDP at the higher level of income. These evidences support the EKC hypothesis, revealing that CO_2 emissions increase in the initial stage of economic growth and decline after a threshold point, i.e 19,380 Indian Rupee. This finding is consistent with Joyanthakumaran et al. (2012), whose study does not include financial development and with that various studies which examine the relationship between GDP growth and CO_2 emissions such as Song et al. (2008), Halicioglu (2009), Fodha and Zaghdoud (2010), Lean and Smyth (2010) and Ozturk and Acaravci (2013) and Shahbaz et al. (2012).

The results indicate that financial development has a long-run positive impact on per capita CO2 emissions. A 1% increase in domestic credit to private sector will lead to about 0.182 % increase in per capita CO_2 emissions, which is significant at the 1% level. This suggests that financial development improves environmental degradation. This finding differ with Tamazian et al. (2009) and Ozturk and Acaravci (2013) but lends support to Zhang (2011), who note that the bank loans provide solid support for companies to access external finance and enhance investment scale. This boosts economic growth and carbon emissions which depend on the bank asset scale expansion.

The results show that energy consumption has as expected a long-run negative impact on per capita CO_2 emissions. A 1% increase in energy consumption will lead to a 1.705% increase in the CO_2 emissions, which is significant at the 1% level. This finding is in line with that of Jayanthakumaran et al. (2012). However, the sign of trade openness is positive but not significant in the long run. This result is consistent with Jayanthakumaran et al. (2012) findings for India.

The short run dynamics results are reported in Table 5. The signs of coefficients of Y and Y^2 support again the EKC hypothesis in the short run and are significant at 1% level respectively. The short-run elasticity of CO_2 emissions, with respect to energy consumption, is 1.038 and statistically significant at 1% level. It implies that a 1% increase in energy consumption will raise CO2 emissions by 1.038% over the short run. The elasticity of CO_2 emissions with respect to openness ratio or to financial development in the short run is positive but not statistically significant. The finding on the insignificance of the openness trade ratio is consistent with that of Jalil and Mahmud (2009) for China.

Table 5. Short-run estimation results

Regressor	Coefficient
ΔY	7.613***
	(2.375)
ΔY^2	– 0.382***
	(0.121)
ΔE	1.038***
	(0.325)
ΔF	– 0.015
	(0.065)
ΔT	– 0.049
	(0.055)
ΔConstant	0.024**
	(0.009)
ECM(– 1)	– 0.645***
	(0.152)
$\overline{R}^2$	0.499
S.E of regression	0.021
Diagnostic tests (p-value)	
Serial correlation	0.127
Functional form	0.323
Normality	0.089
Heteroscedasticity	0.422

Note: The asterisks *** and ** are 1% and 5% significant levels, respectively. The numbers in parentheses are standard errors. Δ is the first difference operator. Both the S.E of regression and adjusted R^2 are "goodness of fit measures", where SE of regression should be as small as possible and adjusted R^2 be as close to unity as possible. The serial correlation is tested by the Lagrange Multiplier test of residual serial correlation (The null is no serial correlation). The functional form is based on the Ramsey's Reset test using the square of the fitted values (the null is no specification errors and is conducted for one fitted term using LR). The normality test is based on a test of skewness and kurtosis of residuals. The heteroscedasticity is tested by the White test with cross terms and null is no heteroscedasticity.

The coefficients on the lagged error correction term are significant with the correct sign at the 1% level, which confirms the results from the bounds test for cointegration. The coefficient of – 0.645 suggest that a deviation from the long run equilibrium level of CO_2 emissions in one year is corrected by 64.5% over the following year.

The diagnostic tests for the model are as presented at the bottom of table. Only the normality is violated and there is no neglected autocorrelation or heteroscedasticity present in the residuals of the model across the sample period. Hence, the outcome of the diagnostic tests indicates that the model have the desired econometric properties.

The graphs representing the CUSUM and CUSUM of squares tests are presented in Figs. 1 and 2. As can be seen from the following Figs., the plots of CUSUM and CUSUMSQ statistics are well within the critical bounds, implying that all coefficients in the error-correction model are relatively stable.

Figure 1. Plot of CUSUM

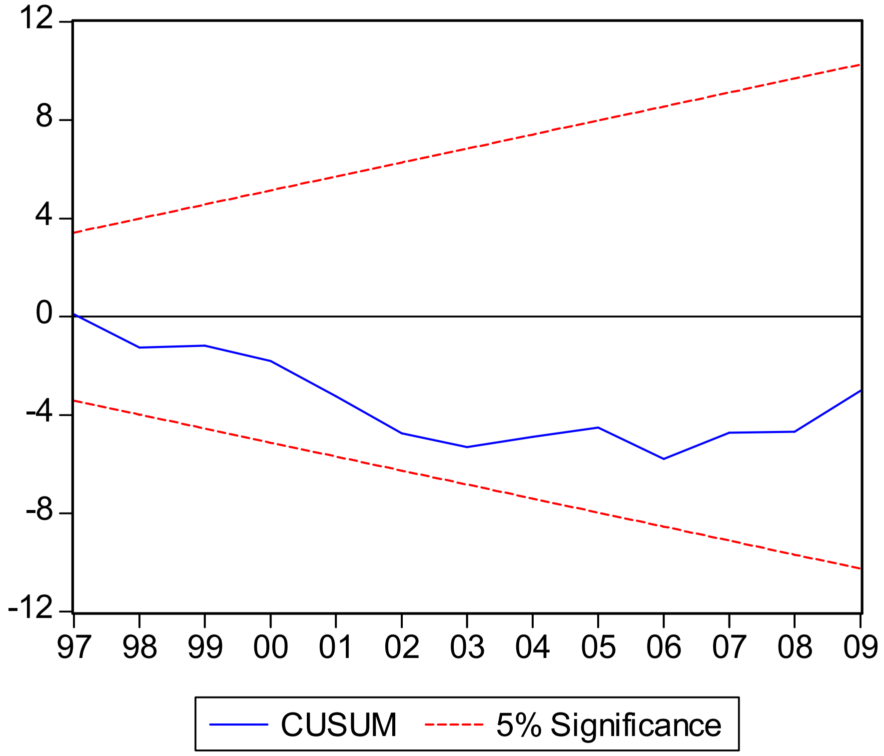
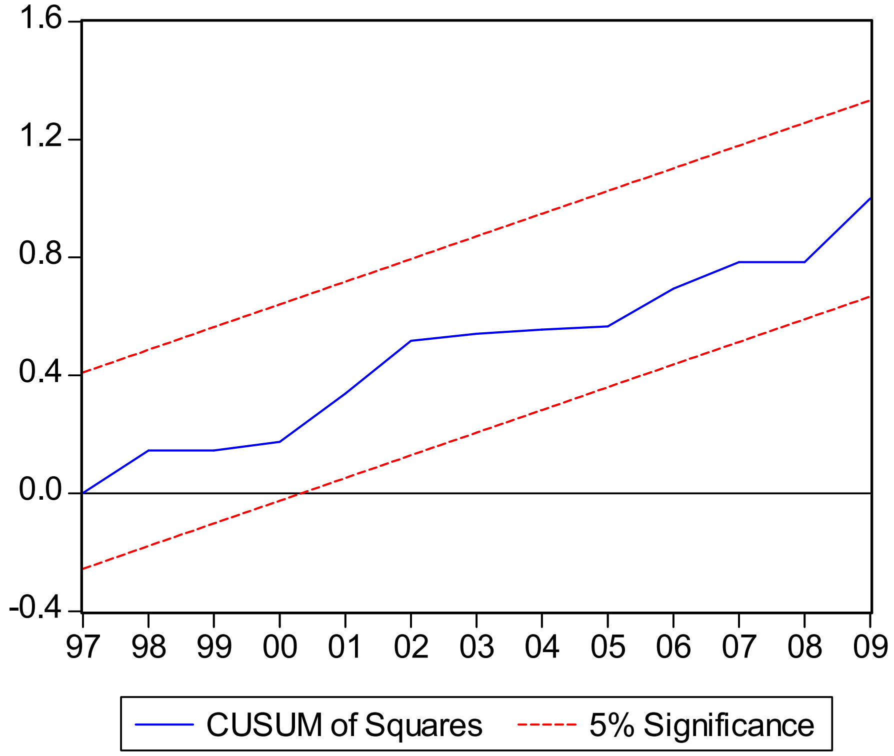


Figure 2. Plot of CUSUMSQ



Therefore, this estimated model can be used for policy decision-making purposes such that the impact of policy changes considering income, energy use, financial development and openness trade will not cause major distortion in the level of CO_2 emissions, since the parameters in this model seems to follow a stable pattern during the estimation period.

Following Tamazian et al. (2009), we drop the energy variable from the model since it may explain most of the CO_2 emissions. Table 6 shows that the exclusion of energy variable does not affect the results.

Table 6. Long-run estimation results (energy consumption variable is removed)

Cointegration tests F-statistics	3.568
ARDL estimate	
Y	19.370***
	(1.121)
Y^2	– 0.937***
	(0.057)
E	–
F	0.173***
	(0.046)
T	0.078
	(0.055)
Constant	– 100.801***
	(5.502)
Error correction coefficient	
ECM(– 1)	– 0.521***
	(0.155)
Diagnostic tests (p-values)	
Serial correlation	0.489
Functional form	0.121
Normality	0.918
Heteroscedasticity	0.710

Note: The asterisks *** is 1% significant level. The critical value ranges of *F*-statistics are 2.427-3.395, 2.893-4.000 and 3.967-5.455 at 10%, 5% and 1% level of significances, respectively, which are taken from Appendix in Narayan (2005).The numbers in parentheses are standard errors. The serial correlation is tested by the Lagrange Multiplier test of residual serial correlation (The null is no serial correlation). The functional form is based on the Ramsey's Reset test using the square of the fitted values (the null is no specification errors and is conducted for one fitted term using LR). The normality test is based on a test of skewness and kurtosis of residuals. The heteroscedasticity is tested by the White test with cross terms and null is no heteroscedasticity.

4.4. Granger causality results

The existence of a cointegrating relationship among CO_2 emissions, income, energy consumption, financial development and trade suggests that there must be Granger causality in at least one direction, but it does not indicate the direction of temporal causality between the variables. We examine both short-run and long-run Granger causality in this section. As the lag order of Eq. 4 is 1, significance of the differenced variables can be measured directly through the corresponding t-statistic. Table 6 presents results of Granger causality in the short-and long-run.

Table 7. Granger causality results

Dependent Variables	Sources of causation						
	Short-run						Long-run
	ΔCO_2	ΔY	ΔY^2	ΔE	ΔF	ΔT	δ_i
ΔCO_2	_	-16.04***	0.856***	0.253	- 0.056	- 0.125**	- 0.564***
		(4.181)	(0.220)	(0.373)	(0.065)	(0.054)	(0.107)
ΔY	0.178	_	0.276	0.508	- 0.063	0.112	0.023
	(0.188)		(0.294)	(0.499)	(0.087)	(0.073)	(0.143)
ΔY^2	3.324	-109.538	_	9.598	-1.090	2.285	0.676
	(3.667)	(109.115)		(9.727)	(1.701)	(1.421)	(0.280)
ΔE	-0.217***	-3.491	0.196*	_	0.078**	-0.009	-0.083
	(0.074)	(2.191)	(0.115)		(0.034)	(0.029)	(0.056)
ΔF	0.171	-9.997	0.565	-1.190	_	0.105	-0.232
	(0.409)	(12.175)	(0.639)	(1.085)		(0.158)	(0.310)
ΔT	-0.105	-20.752	1.091	-2.335*	-0.376*	_	- 0.109
	(0.469)	(13.958)	(1.488)	(1.244)	(0.217)		(0.356)

Notes: *** and ** indicate that the null hypothesis of no causation is rejected at the 1% and 5% significance levels, respectively. The numbers in parentheses are standard errors. Δ is the first difference operator. The number of appropriate lag is one according to Akaike information criterion, Schwarz information criterion and Hannan–Quinn information criterion.

Beginning with the short-run effects, per capita real GDP, the square of per capita real GDP and Trade are statistically significant in the carbon emissions equation. This implies that real GDP, the square of per capita real GDP and Trade Granger cause par capita carbon emissions in the short-run. In the energy use equation, per capita carbon emissions, the square of per capita real GDP and financial development are statistically significant, implying that per capita carbon emissions, the square of per capita real GDP and financial development Granger cause per capita energy consumption in the short run. In trade equation, par capita energy consumption and financial development are significant at 10% level, while carbon emissions and economic growth appear to be statistically significant. In sum, in the short run there is unidirectional causality from per capita real income, the square of per capita real income and trade to per capita carbon emission, per capita carbon emissions, the square of per capita real income and financial development to energy use and financial development and energy use to trade.

Turning to the long-run causality result, the significance of the lagged error correction term in carbon emission equation provide the existence of a unidirectional long-run causality from per capita real GDP, the square of per capita real GDP, per capita energy use and financial development to per capita carbon emissions. The unidirectional causality running from per capita real income to CO_2 without feedback implies that emission reduction policies will not restrain economic growth and might be a viable policy tool for India to achieve its sustainable development in the long-run. This result differ with Ghosh (2010) for India but it is comparable to that found by the previous studies such as Jalil and Mahmud (2009) for China, Fodha and Zaghdoud (2010) for Tunisia, Lotfalipour et al.(2010) for Iran, Nasir and Rehman (2011) for Pakistan, Saboori et al. (2012) for Malaysia and Ozturk and Acaravci (2013) for Turkey.

We find that per capita energy consumption Granger causes per capita carbon emissions in the long run, but not vice versa. That is, an increase in energy consumption will boost carbon emissions. This implies that reducing energy use is an appropriate way to decrease carbon emissions. This is particularly important because India's primary energy mix is predominantly fossil fuel based and coal is the mainstay of the energy sector – accounting for 42% of primary energy demand and over 80% of electricity generation in 2008.

According to the International Energy Agency, India will double its coal consumption by 2035. That, in turn, means carbon emissions will keep growing substantially. However, it is assumed that any attempt at dealing with atmospheric pollution requires increasing the use of alternative sources of energy that are relatively free from pollutant emissions. In this way, the signing of the Indo-U.S nuclear deal[3] in October 2008 has opened up opportunities for the growth of nuclear power in India. Indeed, the country aims to increase its installed capacity from 4000 MW to 63000 MW by 2032. Moreover, within the National Action Plan for Climate Change (NAPCC) adopted in 2008, the national solar mission suggested an annual 1% increase in renewables' share of total electricity consumption in India for the next 10 years - implying a 15% total share by 2020. Great importance was particularly given to solar power, due to the fact that India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Furthermore, the National Mission for Enhanced Energy Efficiency proposed several targets for 2014- 2015: annual fuel savings of at least 23 Mtoe, a cumulative avoided electricity capacity addition of 19,000 MW and a CO_2 emission mitigation of 98 Mt.

On the causal relationship between financial development and carbon emissions, we find a unidirectional causality running from financial development to per capita carbon emissions without a feedback. This confirms that financial development contributes in enhancing carbon emissions by facilitating access to credit for companies[4] whose investment project are not necessarily environmentally friendly and for consumers purchasing a high-value and carbon intensive items such as houses, cars, heating and cooling systems, etc.

5. Conclusion

Climate change is a major challenge for developing countries like India, which are exposed to greater risk from this phenomenon. The climate change concerns of India led to the formulation of National Action Plan on Climate Change, which outlines eight missions that are adaptive as well as mitigative in nature. As part of international mitigation efforts, India

[3]The nuclear industry's development has been hamstrung by India's refusal to sign the Nuclear Non-Proliferation Treaty, cutting the country off from cooperation and assistance in civil nuclear technology. In 2008, India and the Nuclear suppliers' Group agreed on a waiver to the embargo on trade in nuclear technology.

[4]According to the World Bank's Doing Business 2011 Report, with an overall rank of 134, India was among the top 50 countries in terms of obtaining credit and protecting investors.

registered with the UNFCCC its voluntary endeavour to reduce the emissions intensity of its GDP by 20 - 25% by 2020 in comparison to the 2005 level even as it pursue the path of inclusive growth. Hence, it is important to better understand the causes of the greenhouse gas emissions for India in order to tackle these pollutant emissions and to ensure the sustainability of the economic development.

This paper examines the long-run equilibrium and the existence and direction of a causal relationship between carbons emissions, economic growth, energy consumption, financial development and trade openness for India during the period 1970-2008. Our main contribution to the literature is the analysis of the role of the financial development in carbon emissions. To examine this relationship, we use two-step procedure: In first step, we explore the cointegration between the variables by using ARDL bounds testing approach. Secondly, we employ a dynamic VEC model to test causal relationships between these variables as well as stability tests.

The results suggest that there is strong evidence on the long-run and causal relationships between per capita CO_2 emissions, per capita real GDP, the square of per capita real GDP, per capita energy use, financial development and trade openness. The results also confirm the existence of EKC hypothesis in Indian economy. Causality tests also indicate that there was a unidirectional Granger causality running from per capita real income, per capita energy consumption, and financial development to per capita carbon emissions, all without feedback. The evidence seems to suggest that emission reduction policies will not restrain economic growth and might be a viable policy tool for India to achieve its sustainable development in the long-run. This would require that India adopt alternatives sources of supply and increase energy efficiency across the energy value chain. In this respect, India has opened up gas reserves for exploration and production by private and foreign firms under the Open Acreage Licensing Policy and has fixed a target of 15% renewable contribution to the electricity generation mix by 2020. Moreover, Increases in energy efficiency are being targeted by the National Mission on Enhanced Energy Efficiency. However, the success of installed renewable capacity differs markedly on a state by state basis (the World Economic Forum report, 2012). States with large growth rates tend to have burgeoning renewable sectors – e.g. Gujarat and Maharashtra – while those with low growth rates, particularly those in the north-east, do not have an established renewable sector. This suggests that India should also consider creating a unified energy regulator to help align incentives between the states and the central government. Furthermore, Graus et al (2007) and Chikkatur (2008) outlined that the thermal efficiency of coal power plants in India is about 29-30%, while in developed countries a much higher level is achieved. This implies that India should adopt new technologies to improve the energy efficiency of power generation.

Otherwise, findings reveal that financial development has a long-run positive impact on per capita CO_2 emissions, suggesting that financial development improves environmental degradation. The policy advice is therefore financial system should take into account the environment aspect in their current operations. For example, banking system may encourage investments in energy efficient technology by offering interest discounts and including carbon related conditions in their financial products such as business vehicle and investment real estate term loans. Hence, a set of practical policies and incentives that promote more low-carbon finance is an important part of building up India’s resource-conserving society.

While the above analysis has provided interesting insights, it should be noted that the development of efficient energy policies, that will contribute to curb carbon emissions while preserving economic growth, needs to consider other variables than the underlying factors in our research. A promising extension of this work would be to consider the security of energy supply, rural development concerns, urbanization and other environmental variables in the case of India.

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