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Abstract: The present study aims to investigate the relationship between economic growth, energy intensity, financial development and CO$_2$ emissions over the period of 1971-2009 in case of Portugal. The stationarity analysis is conducted by applying Zivot-Andrews unit root test and ARDL bounds testing approach for long run relationship between the variables. The direction of causal relationship between the series is examined by VECM Granger causality approach and robustness of causality analysis is tested by innovative accounting approach (IAA).

Our results confirmed that the variables are cointegrated for long run relationship. The empirical findings of this study reported that economic growth and energy intensity increase CO$_2$ emissions, while financial development condenses it. The VECM causality analysis showed the feedback hypothesis between energy intensity and CO$_2$ emissions, while economic growth and financial development Granger-cause CO$_2$ emissions.

Keywords: Growth, Energy, Financial Development, CO$_2$ Emissions.
**Introduction**

The analysis of Portuguese energy system enables us in suggesting an appropriate energy and environmental policy to sustain economic growth as well as to improve the environmental quality for better living standards in the country. In these days, Portugal’s economy is under debate on the basis of two hot issues; how its economy is growing for the last two decades and following political agenda of Kyoto Protocol reductions in emissions of greenhouse gases. So, adoption of energy and environmental policy in Portuguese economy can affect the policy targets imposed by European Union. This entails that there is a tradeoff between the efficient use of energy including environmental quality and sustained economic growth in the long span of time.

Since 1986, the more concern has been paid on energy security, environmental protection and economic growth, after the inclusion of Portugal as a member in European Union. The surface area of Portuguese economy is 92,000 square kilometers with a population of around 10.7 million. After accessed to European Union, Portugal has been diversifying herself by developing service-based economy, for instance; telecommunications, finance, transportation, and energy sectors. These services have enhanced international competitiveness that resulting in stimulated economic growth. Portugal was recognized as a rapid growing economy among the member countries of European Union after 1990s, although energy market in the country is relatively small and has a limited access to the domestic energy resources.

Due to limited availability of energy resources, per capita energy consumption is low in Portugal as compared to other EU member countries, although energy consumption is growing higher than the growth of GDP per capita. But rising trend of primary and final energy intensities result in absolute energy intensity. Absolute energy intensity is upsetting the environmental situation,
which seems to be unfavorable for Portugal relatively to other EU member countries. The pattern of energy is based on oil products, although Portugal has not much her owned fossil energy resources but due to sustained economic growth, domestic energy resources such as, hydroelectric and biomasses are utilized to meet the rising demand of the country.

Following the terms of the EU allocation agreement, it is required to analyze whether Portugal can fulfill the targets set by European Union by preventing the hike in greenhouse gases emissions up to 40 per cent, for the period of 2008-2012 or not. The principal cause of the rise in CO$_2$ emissions is the rapid use of fossil fuel. Portugal contributed 74.6 per cent to total greenhouse gases emissions in 2000. Due to fossil fuel consumption in 1990-2000, only 43.6 per cent of CO$_2$ emissions were increased. This shows that target to increase CO$_2$ emissions up to 40 per cent in 2008-2012 would not be fulfilled. During the era of 1990s, fossil fuel consumption raised CO$_2$ emissions to 90-91 per cent and carbon emissions were increased to 44.5 per cent. This implies that it is difficult for Portuguese economy to reduce present CO$_2$ emissions up to 40 per cent. That is why; rising trend of carbon emissions is the most important issue in the current political debate. The most important challenge for energy policy making authorities is to introduce new measures that can help in reducing energy emissions.

The present study investigates the relationship between economic growth, energy intensity financial development and CO$_2$ emissions using the annual data of Portuguese economy over the period of 1971-2009. Due to our limited knowledge, this study may be pioneering effort on this topic for the economy of Portugal and it has five fold contribution to the energy literature by applying: (i) Zivot-Andrews [1] structural break unit root test; (ii), ARDL bounds testing
approach to cointegration for long run relationship between the variables; (iii), OLS and ECM for long run and short run impacts (iv) VECM Granger causality approach for causal relationship and (v) Innovative Accounting Approach (IAA) to test the robustness of causality analysis.

Our empirical findings show that cointegration is found for long run relationship among the variables such as; economic growth, energy intensity, financial development and CO₂ emissions in case of Portugal. A rise in economic growth and energy intensity (financial development) increases (condenses) CO₂ emissions. The causality analysis reveals that bidirectional causal relationship is found between CO₂ emissions and energy intensity while economic growth and financial development Granger-cause CO₂ emissions. These results may provide new avenues for policy makers to design a comprehensive economic, financial and environmental plan to sustain economic growth as well as, to help the Portuguese economy in attaining Kyoto Protocol targets.

II. Literature Review
First strand of existing energy literature deals with wide range of mixed result studies about energy consumption and economic growth nexus. Now a days, energy-growth relation has been empirically investigated extensively since the pioneering study conducted by Kraft and Kraft [2]. The empirical findings of the existence energy literature are not unambiguous due to the use of various econometrical approaches such as; correlation analysis, simple regressions, bivariate causality, unit root testing, multivariate cointegration, panel cointegration, vector error correction modeling (VECM) and innovative accounting approach to detect the direction of causality between economic growth and energy consumption (Chontanawat et al. [3]). These inconclusive empirical evidences could not help to economic policy architects in articulating a comprehensive
energy plan to sustain long run economic growth (Payne, [4] and Ozturk, [5]). The appropriate knowledge about direction of causality between energy consumption and economic growth is very important regarding theoretical and policy point of view (Ghali and El-Sakka, [6]).

In recent studies, Payne [4] and Ozturk [5] reviewed the existing literature between energy consumption and economic growth nexus and provided four empirical competing hypotheses for said issue. Such as; (i) growth hypothesis i.e. energy consumption Granger causes economic growth implies that energy reduction policies should be discouraged and new sources of energy must be explored, (ii) if causality is found running from economic growth to energy consumption, then energy reduction policies would not have adverse affect on economic growth because economic growth of the country does not seem to be dependent on energy, (iii) feedback hypothesis implies the interdependence of energy consumption and economic growth. A rise in economic growth leads to increase in energy demand, which in return stimulates economic growth. In such a situation, energy conservation policies are detrimental for economic growth and (iv) no causality between energy consumption and economic growth infers neutrality hypothesis indicating that energy and growth are not interdependent. The adoption of conservation and exploration of energy policies will not favorable affect the economic growth.

In case of Portugal, few studies investigated the relationship between energy consumption and economic growth. For instance, Narayan and Prasad [7] investigated the direction of causality between both variables by applying bootstrapping causality approach¹. Chontanawat et al. [3] examined the causal relationship between energy consumption and economic growth by applying bivariate system using cross section data of 100 developed and developing countries including
Portugal. Their empirical exercise indicated that energy consumption Granger causes economic growth in case of Portugal. On same line, Shahbaz et al. [8] re-examined the relationship between energy consumption, economic growth and employment and reported the feedback hypothesis between energy consumption and economic growth. This implies that new sources of energy should be explored to spur economic growth in Portuguese economy. Fuinhas and Marques [9] examined relationship between energy use and economic growth in Portugal, Italy, Greece, Spain and Turkey applying ARDL bounds testing and VECM Granger causality approach for long run and causal relationship between the variables. Their empirical findings confirmed that variables are cointegrated for long run relationship while feedback hypothesis is validated between energy consumption and economic growth. Later on, Behemiria and Mansob [10] applied VECM and Toda-Yamamato [11] Granger causality approaches to test the relationship between crude oil consumption and economic growth. They reported the bidirectional causality between both variables, which implies that energy conservation policies should be discouraged.

Second strand of existing literature on this topic provides empirical evidence on the relationship between economic growth and CO$_2$ emissions i.e. so called environmental Kuznets curve (EKC). The EKC hypothesis postulates that relationship between economic growth and CO$_2$ emissions is non-linear and inverted-U shaped. This implies that economic growth is linked with an increase in CO$_2$ emissions initially and declines it, once economy matures$^2$. Existing studies including Hettige et al. [12], Cropper and Griffiths [13], Selden and Song [14], Grossman and Kueger [15], and Martinez-Zarzoso and Bengochea-Morancho [16], among others investigated the relationship between income and emissions and validated the existence of EKC. But Dinda and
Coonndoo [17] used panel data and provided ambiguous results about economic growth and CO₂ emissions relationship. Recently, various studies validated the environmental Kuznets curve (EKC) using cross-sectional data, for instance, Lean and Smyth [18] for ASEAN; Apergis and Payne [19-20] for Central America and commonwealth of independent states; Pao and Tsai [21] for BRIC countries; Acaravci and Ozturk [22] for Denmark and Italy; Pao et al. [23] for Russia; Iwata [24] for 28 countries and Wang [25] for 138 developing and developing countries etc. But using time series data, Machado [26], Mongelli et al. [27], Ang [28-29], Song et al. [30], Jalil and Mahmud [31]; Shiyi [32]; Dhakal [33], Halicioglu [34], Ozturk and Acaravci [35]; Alam et al. [37], Fodha and Zaghdoud [38], Nasir and Rehman [39] and Shahbaz et al. [40] also supported the empirical presence of environmental Kuznets curve (EKC) for Brazil, Italy, France, Malaysia, China, India, Tunisia and Pakistan.

Third strand deals with case country studies, for example in case of United States, Soytas et al. [41] investigated the dynamic relationship between CO₂ emissions, income and energy consumption. Their results showed that CO₂ emissions Granger causes income and energy consumption contributes to CO₂ emissions. A same exercise conducted by Ang [28-29] in France and Malaysia. The results indicated that economic growth Granger causes energy consumption and carbon emissions in France and in Malaysia, unidirectional causality is found running from economic growth to energy consumption. Chebbi [42] collected the Tunisian data to investigate causal relationship between energy consumption, income and CO₂ emissions. The empirical evidence indicated that energy consumption stimulates economic growth which Granger causes CO₂ emissions. In case of India, Gosh [43] investigated the causal relationship between income and CO₂ emissions by incorporating investment and employment as additional determinants of
CO₂ emissions but reported no causality between income and CO₂ emissions. Chang [44] applied multivariate causality test to examine causal relation between economic growth, energy consumption and CO₂ emissions using Chinese time series data. The finings of the study revealed that economic growth Granger causes energy consumption that leads to CO₂ emissions. Using Turkish data, Halicioglu [34] also reported feedback hypothesis between economic growth and CO₂ emissions. In case of South Africa, Menyah and Wolde-Rufael [45] concluded that energy consumption Granger causes CO₂ emissions and resulting in economic growth is being Granger caused by CO₂ emissions. On contrarily, Odhiambo [46] reinvestigated the causality between energy consumption, economic growth and CO₂ emissions and unidirectional causality also found running from economic growth to CO₂ emissions. Similarly, Alam et al. [37] examined the link between energy consumption, economic growth and energy pollutants in case of India. Their empirical evidence revealed the bidirectional causal relationship between energy consumption and CO₂ emissions while neutral hypothesis exists between CO₂ emissions and economic growth. In case of Bangladesh, Alam et al. [47] detected the causal relationship between these variables and opined that variables are cointegrated for long run. These long run results are robust confirmed by ARDL bounds testing. Their VECM causality analysis reported the presence of feedback hypothesis between energy consumption and CO₂ emissions, while unidirectional causality is found running from CO₂ emissions to economic growth. In case of Greece, Hatzigeorgiou et al. [48] applied VECM Granger causality test to investigate the causality between energy intensity, income and CO₂ emissions by applying Johansen multivariate cointegration approach. Their results concluded the existence of long run relationship between the series. The VECM granger causality analysis reported that
unidirectional causality is found running from economic growth to energy intensity and CO₂ emissions, while feedback hypothesis exists between energy intensity and CO₂ emissions.

In fourth strand of economic literature, Tamazian et al. [49] paid their attention to test the affect of other potential determinants of CO₂ emissions such as economic, institutional, financial variables. In their pioneering effort, Tamazian et al. [49] investigated the impact of economic development as well as financial development on CO₂ emissions in case of Brazil, Russia, India, China, Untied States and Japan and later on Tamazian and Rao [50] examined the role of institutions on CO₂ emissions. Their empirical evidence reported that economic development, trade openness, financial development and institutions play their role to control environment from degradation while supporting the presence of EKC hypothesis. Additionally, Claessens and Feijen [51] explored the role of governance in reducing CO₂ emissions and reported that with the help of more advanced governance; enterprises can lower growth of CO₂ emissions. So, financial development may stimulate the performance of firms due to the adoption of energy efficient technologies which reduce carbon emissions. In case of China, Yuxiang and Chen [52] argued that financial sector polices enables the firms to utilize advanced technology which emits less CO₂ emissions and enhances domestic production. They also claim that financial development promotes capitalization and financial regulations that favor environmental quality. Later on, Jalil and Feridun [53] tested the impact of economic growth, energy consumption and financial development on carbon emissions in case of China. They disclosed that energy consumption, economic growth and trade openness are harmful for environmental quality. On contrary, financial development and foreign direct investment save environment from degradation. Recently, Zhang [54] reinvestigated the finance-environment nexus and concluded that financial
development increases CO$_2$ emissions due to inefficient allocation of financial resources to enterprises. In case of Sub Saharan African countries, Al-mulali and Sab [55] examined the dynamic relationship between energy consumption, income, financial development and CO$_2$ emissions by incorporating investment and employment as potential determinants of domestic production. Their empirical exercise reported that energy consumption spurs economic growth. A rise in economic growth and energy consumption add in the demand of financial services and hence financial development that increases the improvements in environmental quality by controlling CO$_2$ emissions through the implementation of well-organized and transparent financial policies.

The existing review of literature failed to provide any study in case of Portugal which discusses the causality between energy intensity, economic growth, financial development and CO$_2$ emissions. Only, Hatzigeorgiou et al. [48] empirically investigated the said issue for Greek economy but did not pay their attention to include financial development as a potential determinant of CO$_2$ emissions. Financial development may affect CO$_2$ emissions by stimulating economic activity and encouraging the enterprises to use advanced technology for the enhancement of domestic production that saves the environment from degradation. The exact direction of causality between economic growth and CO$_2$ emissions has major policy implications to expedite economic growth by controlling carbon emissions in case of Portugal. The unidirectional causality running from carbon emissions to economic growth implies that we have to sacrifice economic growth to lower energy pollutants. An efficient energy policy must be implemented which may not have detrimental impact on economic growth if economic growth Granger causes carbon emissions. So, CO$_2$ emissions can be reduced without fall in economic
growth. The policy regarding environment may be adopted to improve the environmental quality if there is no causal relationship between income and CO₂ emissions then environmental policy does not have adverse impact on economic growth. But reductions in CO₂ emissions may have negative affect on economic growth if feedback hypothesis exists between both the variables. The present study is an effort to fill the gap in energy literature regarding the case study of Portugal.

III. Modelling Framework and Data Collection

Existing literature provides various empirical studies investigating the dynamic relationship between economic growth, energy consumption and CO₂ emissions. For instance, Ang [28-29] for France and Malaysia; Soytas et al. [41] for United States; Zhang and Cheng [56], Chang [44] and Wang et al. (2011) for China; Halicioglu (2009) and, Ozturk and Acaravci [58] for Turkey; Pao and Tsai [59] for Brazil and Alam et al. [37, 47] for India and Bangladesh examined causal relationship between the series. Some studies included other potential determents of CO₂ emissions such as capital by Xepapadeas [60] and latter on by Menyah and Wolde-Rufael [45], fossil fuels consumption by Lotfalipour et al. [61], coal consumption by Bloch et al. [62], electricity consumption by Lean and Smyth [18], openness and urbanisation by Hossain [63], foreign direct investment by Pao and Tsai [64], energy intensity by Roca and AlcaHntara [65] and latter on by Hatzigeorgiou et al. [48].

Tamazian et al. [49] and Tamazian and Rao, [50] added financial development as potential determinant of CO₂ emissions. Latter on, Yuxiang and Chen [52], Jalil and Feridun [53] and Zhang [54] investigated the empirical relationship between financial development and energy
pollutants. Sound and development financial markets stimulate capitalization by attracting local and foreign investors to accelerate economic growth (Frankel and Romer, [66]). Financial development allocates financial resources to firms to utilize environment-friendly technology (Frankel and Rose, [67]) which uses energy efficiently (Sadorsky, [68-69]) and emits less carbon emissions (Tamazian et al. [49] and, Tamazian and Rao, [50]). However, financial development harms environment by increasing CO₂ emissions through the growth of industrial sector. Following above discussion, we investigate the relationship between economic growth, energy intensity, financial development and CO₂ emissions. The general form of our empirical model can be written in the following way:

\[ C_t = f(E_t, Y_t, F_t) \]  

(1)

Now we transform all the series into logarithms to attain direct elasticities. The empirical equation is modelled as follows:

\[ \ln C_t = \alpha_0 + \alpha_E \ln E_t + \alpha_Y \ln Y_t + \alpha_F \ln F_t + \mu_t \]  

(2)

Where \( C_t \) is CO₂ emissions (measured in kt) per capita, \( E_t \) is energy intensity per capita, \( F_t \) is financial development proxies by real domestic credit to private sector per capita and \( Y_t \) real GDP per capita is used as a proxy of economic growth. Finally, \( \mu_t \) is error term assumed to be normally distributed with zero mean and constant variance. We presume that a rise in energy intensity will increase carbon emissions and \( \alpha_E > 0 \). \( \alpha_Y > 0 \), an increase in economic growth is linked with high CO₂ emissions otherwise \( \alpha_Y < 0 \). Sound financial sector may act as conduits by enabling firms in adopting advanced cleaner and environment friendly techniques (Talukdar and
Meisner, [70]) to save environment from degradation and $\alpha_r < 0$ otherwise $\alpha_r > 0$ if the focus of financial sector is to boost industrial sector.

The data on real GDP per capita, energy intensity per capita, domestic credit to private sector per capita and CO$_2$ emissions (measured in kt) per capita has been collected from world development indicators (CD-ROM). The data sample of the present study is 1971-2009.

### III.1. Estimation Strategy

Numerous unit root tests are available in applied economics to test the stationarity properties of the variables. These unit tests are ADF by Dickey and Fuller [71], P-P by Philips and Perron [72], KPSS by Kwiatkowski et al. [73], DF-GLS by Elliott et al. [74] and Ng-Perron by Ng-Perron [75]. These tests provide biased and spurious results due to not having information about structural break points occurred in series. In doing so, Zivot-Andrews [1] developed three models to test the stationarity properties of the variables in the presence of structural break point in the series: (i) this model allows a one-time change in variables at level form, (ii) this model permits a one-time change in the slope of the trend component i.e. function and (iii) model has one-time change both in intercept and trend function of the variables to be used for empirical propose. Zivot-Andrews [1] followed three models to check the hypothesis of one-time structural break in the series as follows:

\[ \Delta x_t = a + a x_{t-1} + b t + c D U_t + \sum_{j=1}^k d_j \Delta x_{t-j} + \mu_t \]  \hspace{1cm} (3)

\[ \Delta x_t = b + b x_{t-1} + c t + b D T_t + \sum_{j=1}^k d_j \Delta x_{t-j} + \mu_t \]  \hspace{1cm} (4)
\[ \Delta x_t = c + cx_{t-1} + ct + dDU_t + dDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \]  \tag{5}

Where dummy variable is indicated by \( DU_t \) showing mean shift occurred at each point with time break while trend shift variables are shown by \( DT_t \). So,

\[
DU_t = \begin{cases} 
1 & \text{if } t > TB \\
0 & \text{if } t < TB 
\end{cases}
\]

and

\[
DT_t = \begin{cases} 
 t - TB & \text{if } t > TB \\
0 & \text{if } t < TB 
\end{cases}
\]

The null hypothesis of unit root break date is \( c = 0 \) which indicates that series is not stationary with a drift not having information about structural break point while \( c < 0 \) hypothesis implies that the variable is found to be trend-stationary with one unknown time break. Zivot-Andrews unit root test fixes all points as potential for possible time break and provides estimation through regression analysis for all possible break points successively. Then, this unit root test selects that time break which decreases one-sided t-statistic to test \( \hat{c} = c - 1 \). Zivot-Andrews intimates that in the presence of end points, asymptotic distribution of the statistics is diverged to infinity point. It is necessary to choose a region where end points of sample period are excluded. Further, we followed the Zivot-Andrews suggested “trimming regions” i.e. (0.15T, 0.85T).

After testing the stationarity properties of the series, we apply ARDL bounds testing approach developed by to Pesaran et al. [77] to investigate cointegration for long run relationship between economic growth, energy intensity, financial development and carbon emissions for Portuguese economy. Various cointegration approaches have been applied to test the presence of cointegration between the variables in numerous studies. These approaches are Engle and Granger [78]; Johansen and Juselius [79] and Phillips and Hansen [80] require that all the series
should be integrated at unique order of integration. The ARDL bounds testing approach is more appropriate as compared to other traditional cointegration approaches. For example, it seems flexible regarding the stationarity properties of the variables. This approach is more suitable once variables are found to be stationary at I(1) or I(0) or I(1)/I(0). The ARDL bounds testing approach provides efficient and consistent empirical evidence for small sample data (Smyth and Narayan, [81]) as in case of Portugal. This approach investigates short run as well as long run parameter instantaneously. The unrestricted error correction model (UECM) version of ARDL model is expressed as follows:

\[
\Delta \ln C_t = \beta_1 + \beta_T T + \beta_C \ln C_{t-1} + \beta_E \ln E_{t-1} + \beta_Y \ln Y_{t-1} + \beta_F \ln F_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln C_{t-i} + \\
+ \sum_{j=0}^{q} B_j \Delta \ln E_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln Y_{t-l} + \mu_t
\]  

\[(6)\]

\[
\Delta \ln E_i = \phi_1 + \phi_T T + \phi_C \ln C_{t-1} + \phi_E \ln E_{t-1} + \phi_Y \ln Y_{t-1} + \phi_F \ln F_{t-1} + \sum_{i=1}^{p} \phi_i \Delta \ln E_{t-i} + \\
+ \sum_{j=0}^{q} \phi_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \phi_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \phi_l \Delta \ln F_{t-l} + \mu_t
\]  

\[(7)\]

\[
\Delta \ln Y_t = \varphi_1 + \varphi_T T + \varphi_C \ln C_{t-1} + \varphi_E \ln E_{t-1} + \varphi_Y \ln Y_{t-1} + \varphi_F \ln F_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta \ln Y_{t-i} + \\
+ \sum_{j=0}^{q} \varphi_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \varphi_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \varphi_l \Delta \ln F_{t-l} + \mu_t
\]  

\[(8)\]

\[
\Delta \ln F_t = \theta_1 + \theta_T T + \theta_C \ln C_{t-1} + \theta_E \ln E_{t-1} + \theta_Y \ln Y_{t-1} + \theta_F \ln F_{t-1} + \sum_{i=1}^{p} \theta_i \Delta \ln F_{t-i} + \\
+ \sum_{j=0}^{q} \theta_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \theta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \theta_l \Delta \ln Y_{t-l} + \mu_t
\]  

\[(9)\]
The 1\textsuperscript{st} difference operator is shown by $\Delta$ and $\mu_i$ is for residual terms. The appropriate lag length of the first differenced regression is chosen on the basis of minimum value of Akaike information criteria (AIC). The F-statistic is much sensitive with lag order selection. The inappropriate lag length selection may provide misleading results. Pesaran et al. [77] developed an F-test to determine the joint significance of the coefficients of lagged level of the variables. For example, the hypothesis of no cointegration between the variables in equation (3) is $H_0: \beta_c = \beta_e = \beta_y = \beta_f = 0, H_0: \phi_c = \phi_e = \phi_y = \phi_f = 0, H_0: \theta_c = \theta_e = \theta_y = \theta_f = 0$, while hypothesis of cointegration is $H_0: \beta_c \neq \beta_e \neq \beta_y \neq \beta_f \neq 0, H_0: \phi_c \neq \phi_e \neq \phi_y \neq \phi_f \neq 0$.

Pesaran et al. [77] generated two asymptotic critical values i.e. upper critical bound (UCB) and lower critical bound (LCB), are used to take decisions whether cointegration exists or not between the series. The lower critical bound is used to test cointegration if all the series are integrated at I(0) otherwise we use upper critical bound (UCB). Our computed F-statistics are $F_{c}(C/E,Y,F), F_{e}(E/C,Y,F), F_{y}(Y/C,E,F)$ and $F_{f}(F/C,E,Y)$ for equations (6) to (9) respectively. The long run relationship between the variables exists if our calculated F-statistic is greater than upper critical bound (UCB). There is no cointegration between the series, if our calculated F-statistic does not exceed lower critical bound (LCB). Our decision regarding cointegration is inconclusive if calculated F-statistic falls between LCB and UCB. In such an environment, error correction method is an easy and suitable way to investigate cointegration between the variables. We have used critical bounds generated by Narayan [82] to test cointegration rather than Pesaran et al. [77] and Turner [83].
The directional of causality between economic growth, energy intensity, financial development and CO$_2$ emissions is investigated by applying VECM Granger causality approach after confirming the presence of cointegration between the variables. On the same lines, Granger [84] argued that vector error correction method (VECM) is more appropriate to examine the causality between the series if the variables are integrated at I(1). The VECM is restricted form of unrestricted VAR (vector autoregressive) and restriction is levied on the presence of long run relationship between the series. The system of error correction model (ECM) uses all the series endogenously. This system allows the predicted variable to explain itself both by its own lags and lags of forcing variables as-well-as error correction term and by residual term. The VECM equations are modeled as follows:

\[ \Delta \ln C_t = \alpha_{01} + \sum_{i=1}^{l} \alpha_{1i} \Delta \ln C_{t-i} + \sum_{j=0}^{m} \alpha_{22} \Delta \ln Y_{t-j} + \sum_{k=0}^{n} \alpha_{33} \Delta \ln E_{t-k} + \sum_{r=0}^{o} \alpha_{44} \Delta \ln F_{t-r} + \eta_1 ECT_{t-1} + \mu_i \] (10)

\[ \Delta \ln E = \beta_{11} + \sum_{i=1}^{l} \beta_{1i} \Delta \ln E_{t-i} + \sum_{j=0}^{m} \beta_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \beta_{33} \Delta \ln Y_{t-k} + \sum_{r=0}^{o} \beta_{44} \Delta \ln F_{t-r} + \eta_2 ECT_{t-1} + \mu_2 \] (11)

\[ \Delta \ln Y_t = \varphi_{01} + \sum_{i=1}^{l} \varphi_{1i} \Delta \ln Y_{t-i} + \sum_{j=0}^{m} \varphi_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \varphi_{33} \Delta \ln E_{t-k} + \sum_{r=0}^{o} \varphi_{44} \Delta \ln F_{t-r} + \eta_3 ECT_{t-1} + \mu_3 \] (12)

\[ \Delta \ln F_t = \rho_{11} + \sum_{i=1}^{l} \rho_{1i} \Delta \ln F_{t-i} + \sum_{j=0}^{m} \rho_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \rho_{33} \Delta \ln Y_{t-k} + \sum_{r=0}^{o} \rho_{44} \Delta \ln EF_{t-r} + \eta_4 ECT_{t-1} + \mu_4 \] (13)

Where \( \mu_i \) are random terms and supposed to be normally distributed with zero means and constant variances. The established long run relation between the series is further confirmed by the statistical significance of lagged error term i.e. \( ECT_{t-1} \). The estimates of \( ECT_{t-1} \) also shows the speeds of convergence from short run towards long run equilibrium path. The vector error
correction method (VECM) is appropriate to examine causality between the variables once series are found to be cointegrated and then causality must be found at least from one direction. The VECM also distinguishes causality relationships between short-and-long runs. The VECM is also used to detect the causality in long run, short run and joint i.e. short-and-long runs respectively.

The t-statistic of estimate of lagged error term i.e. $ECT_{t-1}$ with negative sign is used to test long run casual relation and the joint $\chi^2$ statistical significance of the estimates of first difference lagged independent variables is used to investigate short run causality. Economic growth Granger causes carbon emissions if $\alpha_{22,i} \neq 0 \forall i$, is found statistically significant. On contrary, if $\beta_{22,i} \neq 0 \forall i$, is statistically significant then causality runs from CO$_2$ emissions to economic growth. The rest of causality hypotheses can be inferred similarly. The joint causality i.e. long-and-short runs is investigated by using Wald or F-test on the joint significance of estimates of lagged terms of independent variables and error correction term. The presence of short-and-long run causality relation between the variables is known as measure of strong Granger-causality (Shahbaz et al. [8]).

IV. Results and their Discussions

We applied ARDL bound testing approach to examine the long run relationship between economic growth, energy intensity, financial development and CO$_2$ emissions in case of Portugal. The advantage of bounds testing is that it is flexible regarding the order of integration of the series. This requires that the variables should be integrated at I(0) or I(1) or I(0)/I(1). The
computation of ARDL F-statistic becomes useless if none of the variables is stationary at I(2) or beyond that order of integration. In doing so, we have applied Zivot-Andrews structural break trended unit root test to ensure that all the variables are integrated at I(0) or I(1) or I(0)/I(1). The results of Zivot-Andrews [1] structural break trended unit root test are reported in Table-1. Our empirical evidence discloses that all the series show unit root problem at their level but found to be integrated at I(1). This entails that the series are stationary at their first differenced form. So, unique level of the variables leads us to examine the existence of long run relationship between economic growth, energy intensity, financial development and CO$_2$ emissions by applying ARDL bounds testing approach to cointegration over the period of 1971-2009.

### Table-1: Zivot-Andrews Structural Break Trended Unit Root Test

<table>
<thead>
<tr>
<th>Variable</th>
<th>At Level</th>
<th>At $1^{\text{st}}$ Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-statistic</td>
<td>Time Break</td>
</tr>
<tr>
<td>ln $C_t$</td>
<td>-3.522 (2)</td>
<td>2001</td>
</tr>
<tr>
<td>ln $E_t$</td>
<td>-3.462 (2)</td>
<td>2002</td>
</tr>
<tr>
<td>ln $F_t$</td>
<td>-3.551 (3)</td>
<td>1990</td>
</tr>
<tr>
<td>ln $Y_t$</td>
<td>-3.729 (3)</td>
<td>2002</td>
</tr>
</tbody>
</table>

Note: * and *** represent significant at 1%, and 10% level of significance. Lag order is shown in parenthesis.

Before applying ARDL bounds testing, there is a pre-requisite to choose appropriate lag order of the variables to compute suitable ARDL F-statistic and to test whether cointegration exists between the variables or not. The computation of F-test is very much sensitive with the selection
of lag length (Ouattara, [86]). We chose lag length 2 following minimum value of akaike information criterion (AIC). The AIC criterion has superior power properties as compared to SBC and provides effective and reliable results which help in capturing the dynamic relationship between the series (Lütkepohl, [87]). The next step is to apply F-test investigating cointegration for long run between the variables. Table-2 reports the results of ARDL bounds testing approach to cointegration. The results showed that our calculated F-statistics are greater than upper critical bound at 1 per cent level, once we used CO₂ emissions and energy intensity are treated as predicted variables.
<table>
<thead>
<tr>
<th>Estimated Models</th>
<th>Optimal lag length</th>
<th>F-statistics</th>
<th>( \chi^2_{\text{NORMAL}} )</th>
<th>( \chi^2_{\text{ARCH}} )</th>
<th>( \chi^2_{\text{RESET}} )</th>
<th>( \chi^2_{\text{SERIAL}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_e(C/E,F,Y) )</td>
<td>2, 2, 2, 2</td>
<td>10.667*</td>
<td>0.3285</td>
<td>[1]: 0.7889</td>
<td>[1]: 0.9365</td>
<td>[1]: 0.2083; [2]: 0.7884</td>
</tr>
<tr>
<td>( F_e(E/C,F,Y) )</td>
<td>2, 2, 2, 1</td>
<td>14.158*</td>
<td>0.6448</td>
<td>[1]: 3.9821</td>
<td>[1]: 0.3746</td>
<td>[1]: 1.7145; [2]: 1.3143</td>
</tr>
<tr>
<td>( F_y(F/C,E,Y) )</td>
<td>2, 2, 2, 1</td>
<td>0.217</td>
<td>0.4757</td>
<td>[1]: 0.1547</td>
<td>[1]: 1.5110</td>
<td>[1]: 4.5934; [2]: 4.1174</td>
</tr>
<tr>
<td>( F_y(Y/C,E,Y) )</td>
<td>2, 2, 2, 2</td>
<td>2.705</td>
<td>0.2622</td>
<td>[1]: 0.9978</td>
<td>[1]: 2.9656</td>
<td>[1]: 0.0173; [2]: 0.0086</td>
</tr>
</tbody>
</table>

Significant level

<table>
<thead>
<tr>
<th>Critical values (T= 40)</th>
<th>Lower bounds I(0)</th>
<th>Upper bounds I(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 per cent level</td>
<td>7.527</td>
<td>8.803</td>
</tr>
<tr>
<td>5 per cent level</td>
<td>5.387</td>
<td>6.437</td>
</tr>
<tr>
<td>10 per cent level</td>
<td>4.447</td>
<td>5.420</td>
</tr>
</tbody>
</table>

Note: * represents significant at 1 per cent at level.
It leads us to reject the null hypothesis of no cointegration. This indicates that there are two cointegrating vectors. This confirms that the variables are cointegrated for long run relationship between economic growth, energy intensity, financial development and CO$_2$ emissions in case of Portugal.

**Table-3: Long-and-short Runs Analysis**

<table>
<thead>
<tr>
<th>Dependent variable = ln$C_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Run Analysis</td>
</tr>
<tr>
<td>Variables</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>ln$E_t$</td>
</tr>
<tr>
<td>ln$F_t$</td>
</tr>
<tr>
<td>ln$F_t^2$</td>
</tr>
<tr>
<td>ln$Y_t$</td>
</tr>
</tbody>
</table>

| Short Run Analysis |
| Variables | Coefficient | Std. Error | T-Statistic | Prob. values |
| Constant | -0.0023 | 0.0090 | -0.2601 | 0.7966 |
| ln$E_t$ | 0.8823* | 0.1391 | 6.3404 | 0.0000 |
| ln$F_t$ | -0.0399 | 0.0621 | -0.6423 | 0.5257 |
| ln$F_{t-1}$ | 0.1389*** | 0.0783 | 1.7735 | 0.0866 |
| ln$Y_t$ | 0.8774* | 0.2034 | 4.3138 | 0.0002 |
| ECM$_{t-1}$ | -0.9916* | 0.2183 | -4.5412 | 0.0001 |

| Test | F-statistic | Prob. value |
|---------------------------------------------|
| $\chi^2$ NORMAL | 0.3332 | 0.8464 |
| $\chi^2$ SERIAL | 0.1976 | 0.8218 |
| $\chi^2$ ARCH | 2.3768 | 0.1101 |
| $\chi^2$ WHITE | 0.5167 | 0.8614 |
| $\chi^2$ REMSAY | 0.8386 | 0.3676 |

Note: * and ** show significant at 1 and 5 per cent level of significance respectively.
After investigating long run relationship between the variables, next step is to examine marginal impacts of economic growth, energy intensity and financial development on CO₂ emissions. The results are reported in Table-3 indicated that energy intensity has positive and statistically significant impact on CO₂ emissions. This shows that an increase in energy intensity contributes to energy pollutants significantly. The results inferred that a 1 per cent rise in energy intensity is linked with a 0.9559 per cent increase in CO₂ emissions, all else same. The impact of financial development is negative and it is statistically significant at 1 per cent level of significance. It implies that a 0.0784 per cent decline in CO₂ emissions is linked with a 1 per cent increase in financial development. This exposes that financial sector development contributes in condensing CO₂ emissions by directing banks to provide loans to firms for those investment projects which are environment friendly. The relationship between economic growth and CO₂ emissions is positive and it is significant at 1 per cent level. Keeping other things same, a 1 per cent increase in economic growth raises CO₂ emissions by a 1.007 per cent. Our empirical exercise indicates that economic growth is a major contributor to CO₂ emissions after energy intensity in case of Portugal. Furthermore, our results confirmed the presence of inverted-U shape relationship between financial development and CO₂ emissions. The impact of linear and nonlinear terms of financial development is positive and negative on CO₂ emissions and it is statistically significant at 5 per cent and 1 per cent levels respectively. This entails that initially CO₂ emissions are positively linked with financial development and financial development starts to decline it once financial sector matures. It is suggested that financial sector should provide loans (subsidies) for energy efficient technologies and allocate funds to energy system for exploring new sources of energy such as renewables.
The short run results illustrated that energy intensity and economic growth have positive impact on carbon emissions and it is statistically significant at 1 per cent level of significance. It is found that energy intensity is major contributor to carbon emissions in short run. Financial sector development is negatively related with CO₂ emissions but insignificant. Surprisingly, financial sector development with lagged period also increases carbon emissions. The statistically significant estimate of lagged error term i.e. $ECM_{t-1}$ with negative sign corroborates our established long run relationship between economic growth, energy intensity, financial development and carbon emissions. The empirical evidence reported in Table-3 pointed out that coefficient of $ECM_{t-1}$ is -0.9916 which is statistically significant at 1 per cent level of significance. This concludes that changes in CO₂ emissions are corrected by 99 per cent every year in long run. It suggests that full convergence process will take more than a year to reach the stable path of equilibrium. This implies that adjustment process is very fast and significant for Portuguese economy in any shock to carbon emissions equation.

The plots of both CUSUM and CUSUMsq are shown by Figure-1 and 2 at 5 per cent level of significance. Results indicated that plots of both tests are within critical bounds at 5 per cent level of significance. The empirical evidence for diagnostic tests is detailed in Table-4. The results opined that short run model seems to pass all tests successfully such as test of normality, serial correlation, autoregressive conditional heteroskedasticity, white heteroskedasticity and specification of short run model. This indicated that there is no problem of non-normality of error term, no serial correlation between the variables as well as no evidence is found for autoregressive conditional heteroskedasticity. The variables are homoscedastic and functional form of short run model is well organized. The stability and sensitivity analysis favors that the
parameters of long run and short run ARDL and short run empirical evidence is consistent and stable for policy purpose regarding carbon emissions in case of Portugal.

**Figure-1 Plot of Cumulative Sum of Recursive Residuals**

The straight lines represent critical bounds at 5% significance level

**Figure-2 Plot of Cumulative Sum of Squares of Recursive Residuals**

The straight lines represent critical bounds at 5% significance level

The presence of cointegration for long run economic growth, energy intensity, financial development and carbon emissions leads us to implement the VECM Granger causality approach to analyze the direction of causal relationship between the series. The appropriate knowledge about the direction of causality between the variables helps policy making authorities in
articulating inclusive energy, economic, financial and environmental policy to sustain economic growth and improve the environmental quality over the long period of time. Granger [84] suggested that in the presence of cointegration, once variables are found to be stationary at unique order then VECM Granger causality framework is an appropriate approach to detect the long-and-short runs causal relationship between economic growth, energy intensity, financial development and carbon emissions. The Table-4 reports the results of Granger causality test.

In long span of time, empirical evidence indicated that the bidirectional causal relationship is found between energy intensity and CO$_2$ emissions. This implies that efficient use of modern technology declines energy intensity that in resulting leads to lower CO$_2$ emissions during production process and vise versa. This finding is with the line of existing energy literature such as Papadopoulos and Haralambopoulos [89] and later on with Hatzigeorgiou et al. [48] in case of Greece. This implies that in current setup it is difficult for Portuguese economy to find decoupling carbon emissions. There is a need of overhauling energy structure to encourage energy efficient technologies by considering a number of policy reforms. The unidirectional causality is found running from economic growth to energy intensity also suggests adopting energy efficient technology which helps in enhancing domestic production but with less CO$_2$ emissions. Economic growth Granger causes CO$_2$ emissions.
### Table-4: The VECM Granger Causality Analysis

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Direction of Causality</th>
<th>Short Run</th>
<th>Long Run</th>
<th>Joint Long-and-Short Run Causality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\Delta \ln C_{t-1}$</td>
<td>$\Delta \ln E_{t-1}$</td>
<td>$\Delta \ln F_{t-1}$</td>
</tr>
<tr>
<td>$\Delta \ln C_{t}$</td>
<td>....</td>
<td>24.5188*</td>
<td>0.6861</td>
<td>27.8183*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.0000]</td>
<td>[0.5811]</td>
<td>[0.0000]</td>
</tr>
<tr>
<td>$\Delta \ln E_{t}$</td>
<td>28.6458*</td>
<td>....</td>
<td>0.9136</td>
<td>4.7349**</td>
</tr>
<tr>
<td></td>
<td>[0.0000]</td>
<td>[0.4123]</td>
<td>[0.0166]</td>
<td>[0.0166]</td>
</tr>
<tr>
<td>$\Delta \ln F_{t}$</td>
<td>0.0467</td>
<td>0.0175</td>
<td>....</td>
<td>0.5131</td>
</tr>
<tr>
<td></td>
<td>[0.9544]</td>
<td>[0.9825]</td>
<td>[0.6038]</td>
<td>[0.6038]</td>
</tr>
<tr>
<td>$\Delta \ln Y_{t}$</td>
<td>15.4471*</td>
<td>12.4398*</td>
<td>0.3213</td>
<td>....</td>
</tr>
<tr>
<td></td>
<td>[0.0000]</td>
<td>[0.0001]</td>
<td>[0.7277]</td>
<td>[0.7277]</td>
</tr>
</tbody>
</table>

Note: *, ** and *** show significance at 1, 5 and 10 per cent levels respectively.
This implies that a rise in economic activity raises more demand for energy and in resulting increases the CO₂ emissions. Our empirical evidence is contradictory with findings of Hatzigeorgiou et al. [48] who reported bidirectional causal relationship between economic growth and energy intensity. Finally, unidirectional causality is also found running from financial development to energy intensity. This supports the view argued by Shahbaz and Lean [90] that sound financial sector enables the firms to adopt advance and energy efficient technology during production process. Although, they reported that bidirectional causality exists between financial development and energy consumption in case of Tunisia. Finally, unidirectional causality is found runs from financial development to carbon emissions. This supports the argument that financial sector development lowers CO₂ emissions by encouraging the firms to adopt advanced technology which emits less carbon emissions during production. These results are consistent with energy literature such as Talukdar and Meisner, [70].

In short span of time, causality analysis exposed that economic growth and energy intensity Granger cause each other. The bidirectional causality is found between energy intensity and CO₂ emissions. The feedback hypothesis also exists between economic growth and CO₂ emissions. The joint long-and-short runs causality analysis also supports the empirical findings for long run as well as short run.

It is argued in economic literature that the Granger causality approaches such as VECM Granger causality test has some limitations. The causality test cannot capture the relative strength of causal relation between the variables beyond the selected time period. This weakens the reliability of causality results by VECM Granger approach. To solve this issue, we applied
innovative accounting approach (IAA) i.e. variance decomposition method and impulse response function. We have implemented the generalized forecast error variance decomposition method using vector autoregressive (VAR) system to test the strength of causal relationship between economic growth, energy intensity, financial development and CO2 emissions in case of Pakistan. The variance decomposition approach indicates the magnitude of the predicted error variance for a series accounted for by innovations from each of the independent variable over different time-horizons beyond the selected time period. It is pointed by Pesaran and Shin [91] that the generalized forecast error variance decomposition method shows proportional contribution in one variable due to innovative shocks stemming in other variables. The main advantage of this approach is that like orthogonalized forecast error variance decomposition approach; it is insensitive with ordering of the variables because ordering of the variables is uniquely determined by VAR system. Further, the generalized forecast error variance decomposition approach estimates the simultaneous shock affects. Engle and Granger [78] and Ibrahim [92] argued that with VAR framework, variance decomposition approach produces better results as compared to other traditional approaches.

The results of variance decomposition approach are describes in Table-5. The empirical evidence indicates that a 10.65 per cent portion of CO2 emissions is contributed by its own innovative shocks and one standard deviation shock in financial development explains energy pollutants by 59.96%. The implies that financial development plays vital role to improve the environmental quality by directing financial resources to projects where firms utilize advanced technology to enhance domestic production with less CO2 emissions.
### Table-5: Variance Decomposition Approach

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>$\ln C_t$</th>
<th>$\ln E_t$</th>
<th>$\ln F_t$</th>
<th>$\ln Y_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0522</td>
<td>100.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>2</td>
<td>0.0638</td>
<td>76.6092</td>
<td>2.1222</td>
<td>0.6995</td>
<td>20.5690</td>
</tr>
<tr>
<td>3</td>
<td>0.0748</td>
<td>63.4918</td>
<td>2.8381</td>
<td>2.5768</td>
<td>31.0931</td>
</tr>
<tr>
<td>4</td>
<td>0.0886</td>
<td>47.0122</td>
<td>6.6878</td>
<td>7.13683</td>
<td>39.1630</td>
</tr>
<tr>
<td>5</td>
<td>0.1021</td>
<td>36.3854</td>
<td>8.7809</td>
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<td>39.4889</td>
</tr>
<tr>
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<td>9.6342</td>
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<tr>
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<td>35.5941</td>
</tr>
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</tr>
<tr>
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</tr>
<tr>
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<td>23.0955</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>$\ln C_t$</th>
<th>$\ln E_t$</th>
<th>$\ln F_t$</th>
<th>$\ln Y_t$</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
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<table>
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<th>Period</th>
<th>S.E.</th>
<th>$\ln C_t$</th>
<th>$\ln E_t$</th>
<th>$\ln F_t$</th>
<th>$\ln Y_t$</th>
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</tr>
<tr>
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<td>0.4757</td>
<td>0.5709</td>
<td>89.5279</td>
<td>9.4252</td>
</tr>
</tbody>
</table>
The contribution of economic growth to CO₂ emissions is 23.09 per cent. This contribution in CO₂ emissions due to economic growth first rises, goes to peak point, and then starts to fall. This confirms the existence of inverted-U relationship between economic growth and CO₂ emissions in case of Portugal. A very little portion of CO₂ emissions is explained by innovative shocks stemming in energy intensity i.e. 6.28 per cent.
A 12.91 per cent portion of energy intensity is explained by one standard deviation shock in \( \text{CO}_2 \) emissions and 16.62 per cent portion is contributed to energy intensity by its own innovative shocks. A standard deviation shock stemming in financial development and economic growth attribute to energy intensity by 58.27 and 12.18 per cent respectively. A 37.50 per cent contribution exists in financial development by shocks stemming in economic growth. \( \text{CO}_2 \) emissions and energy intensity explain financial development minimally and one standard innovative shock stems in financial development explains itself by 54.06 per cent. The contribution of \( \text{CO}_2 \) emissions, energy intensity and financial development to economic growth 1.89, 12.33 and 36.17 per cent respectively and rest is being explained by its own standard innovative shocks. The existing empirical evidence confirms the feedback hypothesis between financial development and economic growth.

The impulse response function is alternate of variance decomposition approach and shows the reaction in one variable due to shocks stemming in other variables. The Figure-3 indicated the positive response in carbon emissions due to standard shocks stemming in economic growth and energy intensity while \( \text{CO}_2 \) emissions is negatively responded by financial development. This means that financial sector development contributes in condensing carbon emissions. The contribution of carbon emissions and economic growth is positive to energy intensity while financial development declines energy intensity due use of energy efficient technologies. The response of financial development is positive due to innovative shocks stemming in energy intensity and economic growth. A standard shock occurs in energy intensity stimulates economic growth while financial sector development declines it. This shows that financial development
does not contribute to economic growth. This confirms that current financial crisis in Europe has decayed economic activity in Portugal.

Figure-3: Impulse Response Function

V. Conclusion and Future Directions

This study investigated the dynamic relationship between economic growth, energy intensity, financial development and CO$_2$ emissions in case of Portuguese economy over the period of 1971-2009. For this purpose, we applied ARDL bounds testing approach to cointegration to
check the cointegration among the variables for long run, VECM Granger causality to test the direction of causal relationship between the variables and robustness of causality analysis was tested by applying innovative accounting approach (IAA).

Our results indicated that the variables are cointegrated for long run relationship. The empirical evidence showed that energy intensity increases carbon emissions and economic growth is a major contributor to CO₂ emissions. Financial sector development condenses carbon emissions and inverted-U shape relationship is confirmed between financial sector development and carbon emissions. This validates the contribution of financial sector to improve the quality of environment. The causality analysis exposed the bidirectional causality between energy intensity and carbon emissions. The unidirectional causal relation is found running from economic growth and financial development to CO₂ emissions. This implies that carbon emissions can be reduced at the cost of economic growth or energy efficient technologies should be encouraged to enhance domestic production with the help of financial sector. Economic growth and financial development Granger cause energy intensity which reveals that adoption of energy conservation would not adversely affect economic growth. Again, financial sector must fix her focus on the allocation of funds to those firms which adopt environment friendly technologies and encourage the firms to use more energy efficient technology for production purpose and hence to save environment from degradation.

The rising trend of carbon emissions in current momentum is a debatable issue in case of Portugal. To overcome this ambiguous (controversial) issue, there is a need of comprehensive economic, financial and energy policy reforms to sustain economic growth by developing
domestic financial sector. The present study can be augmented for future research by investigating the relationship between renewable energy consumption, nonrenewable energy consumption, economic growth and carbon emissions following (Tiwari, [93-94]). Other variables may also be included in model as potential determinants of carbon emissions such as urbanisation, (Hossain, [63]); trade openness, (Hossain, [63]); foreign direct investment, (Pao and Tsai, [21]); exchange rate / terms of trade (Jalil and Feridun, [31]); interest rate (Karanfil, [95]); population or population density (Himayatullah et al. [96]) and industrialization (Zhang, [54]) to examine relationship between economic growth, energy intensity and CO$_2$ emissions in case of Portugal.
Footnote

1. Narayan and Prasad [7] and Shahbaz et al. [8] used electricity consumption as an indicator of energy consumption to examine the energy-growth nexus.

2. At initial level of economic growth, a rise in income is linked with an increase in energy consumption that raises CO₂ emissions and hence environmental degradation. It implies that there is positive relationship between economic growth and CO₂ emissions at low level of income. After achieving certain of level of income, awareness about clean environment increases. This leads the government and people to increase their spending on environment protection and regulation. In such situation, environmental degradation and CO2 emissions tend to decrease. This show that how EKC is an inverted-U shape i.e. an increase in income shifts the positive link between economic growth and CO₂ to zero and then goes to negative relation between the both variables (Wang, [24]).

3. Akbostanci et al. [36] did not support their findings.

4. We used model-5 for empirical estimations following Sen [76].

5. Various unit root tests are available in economics literature to examine the stationarity properties of the series. These unit root tests are ADF (Dickey and Fuller, [71]), DF-GLS (Elliot et al. [74]); Ng-Perron (Ng and Perron, [75]) etc. These tests may provide biased and inconsistent empirical evidence regarding stationarity properties of the variables. The main reason is that ADF, DF-GLS and Ng-Perron do not seem to have information about structural breaks occurring in the time series data (Baum, [85]).

6. The results of lag order of the variables are available from authors upon request.

7. The statistically significance of lagged error term i.e. $ECM_{t-1}$ is a further proof of the existence of stable long run relationship between the series (Bannerjee et al. [88]).
Reference


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Appendix-A

Zivot-Andrews Structural Break Trended Unit Root Test at Level

Min breakpoint at 2001
Zivot-Andrews test for lnE, 1979-2004
Min breakpoint at 2002

Year

Breakpoint t-statistics


Zivot-Andrews test for lnF, 1979-2004
Min breakpoint at 1990

Year

Breakpoint t-statistics

Zivot-Andrews Structural Break Trended Unit Root Test at 1st Difference
Min breakpoint at 1991

Zivot-Andrews test for lnE, 1979-2004
Min breakpoint at 1996
Zivot-Andrews test for lnF, 1980-2004
Min breakpoint at 2000

Zivot-Andrews test for lnY, 1979-2004
Min breakpoint at 1990