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Abstract

This paper reexamines the asymmetric impact of financial development on CO_2 emissions by including energy consumption and economic growth as additional determinants of environmental degradation. Bank-based and Stock market-based financial development indices have been generated by using Principal Component Analysis (PCA). The study covers the period of 1985-2014 using quarter frequency data. We apply the Fourier ADF (Enders and Lee, 2012) and NARDL (Shin et al. 2014) for unit root testing and asymmetric cointegration. The asymmetric causality (Hatemi-J, 2012) approach is applied in order to determine the casual relationship between the variables. Our results indicate the presence of asymmetric cointegration between financial development, energy consumption, economic growth and CO_2 emissions. Economic growth (positive shock) affects CO_2 emissions. The asymmetric effect of energy consumption on CO_2 emissions is positive. Bank-based financial development (positive shock) adds in CO_2 emissions. The symmetric causality analysis reveals bidirectional causality between economic growth and CO_2 emissions. The feedback effect also exists between energy consumption and CO_2 emissions. Bank-based financial development is cause of CO_2 emissions.

Keywords: Financial development, Growth, Energy, CO_2 emissions

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This paper reexamines the asymmetric impact of financial development on CO_2 emissions by including energy consumption and economic growth as additional determinants of environmental degradation. Bank-based and Stock market-based financial development indices have been generated by using Principal Component Analysis (PCA). The study covers the period of 1985-2014 using quarter frequency data. We apply the Fourier ADF (Enders and Lee, 2012) and NARDL (Shin et al. 2014) for unit root testing and asymmetric cointegration. The asymmetric causality (Hatemi-J, 2012) approach is applied in order to determine the casual relationship between the variables. Our results indicate the presence of asymmetric cointegration between financial development, energy consumption, economic growth and CO_2 emissions. Economic growth (positive shock) affects CO_2 emissions. The asymmetric effect of energy consumption on CO_2 emissions is positive. Bank-based financial development (positive shock) adds in CO_2 emissions. The symmetric causality analysis reveals bidirectional causality between economic growth and CO_2 emissions. The feedback effect also exists between energy consumption and CO_2 emissions. Bank-based financial development is cause of CO_2 emissions.

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1. Introduction

Though, economic development is a long process that promises standard of living but causes environmental degradation. A rich literature is available on the relationship between environmental degradation and economic development termed as Environmental Kuznets curve (EKC) floated by Grossman and Krueger, (1991)[1]. The EKC hypothesis predicts that economic growth is initially accompanied with environmental degradation but environmental quality starts to improve as economy achieves the threshold level of per capita income (see for details; Stern 2004, Carson 2010). This notion has been empirically supported by various studies by Aldy (2005) for US states, Acaravci and Ozturk (2010) for European countries, Apergis and Ozturk (2015) for Asian countries, Jebli et al. (2016) for OECD countries and so on. On similar lines, exiting energy economics literature provides a plenty of studies investigating the EKC hypothesis using time series for case of individual countries. For instance, Akbostanci et al. (2009), Iwata et al. (2010), Shahbaz et al. (2012), Tiwari et al. (2013), Lau et al. (2014) and, Ozturk and Al-Mulali (2015) who document the validation of the EKC for Turkey, France, Pakistan, India, Malaysia and Cambodia, respectively. Tamazian et al. (2009) argue that the ignorance of financial development in carbon emissions function misleads empirical results. Later on, Tamazian et al. (2009) exposed that financial development is potential factor of economic growth, energy consumption and carbon emissions. They argued that financial sector development affect environmental quality via scale effect (domestic output expansion), business effect (increase in investment activities) and wealth effect (developed efficient stock market).

[1] Achieving sustainable economic development as well as better living standard with positive environmental outcomes has been desire of developing countries.

The purpose of this study is to examine the relationship between financial development and CO_2 emissions rather than investigation of the EKC hypothesis empirically. This notion is empirically investigated by Tamazian et al. (2009) for BRIC countries as if financial development impacts carbon emissions or not. They argued that developed financial markets help in reducing financing costs, channelize financial resources, so that they may purchase new equipment and invest in new projects, and then derives energy demand and affect CO_2 emissions. Furthermore, their analysis indicates that financial development promotes investment in energy efficient technology and hence reduces carbon emissions. Tamazian and Rao, (2010) examine the association between financial development and environmental degradation by incorporating institutional quality in carbon emissions function. They found that financial development increases environmental quality via lowering CO_2 emissions in the countries which have strong institutions and vice versa. Similarly, Frankel and Romer (1999) explain that financial development attracts foreign direct investments and consequently higher research and development activities leads to better environmental conditions. Wang and Jin, (2007) and Bello and Abimbola, (2010) confirm that financial development induces listed companies to use energy efficient technology and consequently reduces carbon emissions. Zhang and Lin, (2011) contributed in ongoing debate of financial development-CO_2 emissions nexus by separating efficiency and scale effects.

On contrary, Sadorsky (2010) and Zhang (2011) argue that financial development may contribute to CO_2 emissions. Stock market development helps public companies to reduce financing costs, enlarge financing channels, share operational risk and find a balance between assets and liabilities, in order to acquire new installations, and allocate resources for the implementation of new projects, ultimately increasing energy consumption and carbon emissions. Foreign direct investments (FDIs) enhance economic growth, in the light of new carbon emissions. Apart from that, Zhang (2011) document that financial intermediation allows the purchase of household items (i.e. cars, houses, air conditioners and washing machines, etc.) which consume energy and add in carbon emissions. Al-Mulali et al. (2016) empirically investigate the nexus between financial development and carbon emissions for European countries. They noted that financial development impedes environmental quality by increasing carbon emissions.

The existing literature also provides studies showing insignificant effect of financial development on carbon emissions. For example, Ozturk and Acaravci, (2013) investigate the relationship between financial development and carbon emissions by incorporating economic growth, energy consumption and trade openness in emissions function. Their empirical evidence shows that financial development insignificantly impacts the environmental quality for Turkish economy. In case of the US economy, Dogan and Turkekul (2016) examined the relationship between financial development and carbon emissions. Their analysis showed that financial development has positive but insignificant impact on CO_2 emissions. Omri et al. (2015) consider the relationship between financial development and carbon emissions by applying simultaneous equation system for MENA region. Their empirical analysis indicates positive but insignificant impact of financial development in environmental degradation for Bahrain, Kuwait, Qatar and Saudi Arabia. Similarly, Ziaei (2015) also reported that financial development impact environmental degradation positively but insignificantly for European, East Asian and Oceania countries.

In case of Pakistan, Javid and Sharif (2016) followed Shahbaz et al. (2012) and incorporated financial development as additional factor of economic growth, energy consumption and CO_2 emissions in the EKC function. Their results indicate positive effect of energy consumption on carbon emissions. They found inverted-U shaped relationship between economic growth and carbon emissions which confirms the presence of the EKC hypothesis in Pakistan. Their empirical analysis further exposes that financial development impedes environmental quality by increasing carbon emissions. The causality analysis indicates presence of feedback effect between financial development and carbon emissions. Recently, Abbasi and Riaz, (2016) re-investigated the association between financial development and carbon emissions by incorporating foreign direct investment in CO_2 emissions function. They use total credit, domestic credit and market capitalization as indicator of financial development[2]. Their empirical analysis indicates that financial development indicators have positive but insignificant impact on carbon emissions in full sample (1971-2011) while in reduced sample (1988-2011), total credit is negatively associated with carbon emissions. They also note that economic growth increases environmental degradation by stimulating carbon emissions. For more details, the summary of studies on financial development-emissions nexus is provided in Table-1.

Moreover, inappropriate use of financial development proxies has also helped in providing biased empirical results while investigating financial development-carbon emissions nexus. For example, Khan et al. (2014) by using some financial and economic variable such as (M_2) and (M3), domestic credit to private sector, FDI, explored their link with carbon emissions in South Asia and found positive impact of all variables on carbon emissions in long-run. Lee and Chen, (2015) examined the relationship between financial development and carbon emissions by using data of OECD countries through panel FMOLS approach. They use domestic

[2] The use of these indicators together in a regression may create a problem of multi-colinearity due to presence of highly correlation among total credit, domestic credit and market capitalization. The presence of multi-colinearity misleads empirical results (Polat et al. 2015).

credit to private sector as measure of financial development and found that financial development is improving environmental quality. Ziaei (2015) used domestic credit to private sector and stock market turnover ratio as proxies for financial development and found conflicting effect of financial development on energy consumption and hence on CO_2 emissions. Chang (2015) used five indicator of financial development to examine its effect on carbon emissions and found biased relationship between financial development and environmental degradation[3]. This leads to use compressive measure of financial development to avoid multi-colinearity and achieve unbiased empirical evidence.

Over the period of time, Pakistan has implemented numerous economic policies such as structural adjustment program (SAP) to cover the episodes of slower economic growth, budget deficit and poverty alleviation. The implementation of SAP affected our fiscal policies over the period. Pakistan has also faced the geopolitical tensions such as terrorism due to collation with the USA during Afghan war. Structural changes in business cycle have occurred in Pakistan due to implementation of numerous economic policies and external shocks also affect Pakistan's economy due to economic, social and political globalization. Pakistan's inflation is sensitive to exchange rate and production cost is affected by crude oil prices in international oil market. Due to these factors, non-linearity (asymmetries) may be driven in macroeconomic variables. The asymmetries in macroeconomic variables may arise due to interest rate differentials across countries, economic phases (boom or depression, recession or recovery), oil prices mechanism in international oil market[4], international trade and, supply and demand of domestic products in local and international markets, and allocation of credit to private sector to stimulate business at

[3] Chang, (2015) used Domestic credit to the private sector, Domestic credit provided by the banking sector, total value of stocks traded., ratio of total value of stocks traded to stock market capitalization and net inflows of foreign direct investment.

[4] Pakistan spends much money to import oil from international market for maintaining sustainable economic growth.

small, medium as well as large levels is also conditioned with interest rate in local market. Last but not least, there are many hidden factors that may be cause of asymmetries in time series data.

The literature also shows that ignoring the presence of asymmetries or non-linearity in macroeconomic variables may provide biased empirical results. This study is a comprehensive effort to fulfill this gap in existing energy literature. This study contributes in existing energy literature by four folds: (i) we generate financial development (bank-based financial development, stock market-based financial development) index by considering three indicators from banking sector (M_2, M_3 and domestic credit to private sector) and three from stock market (stock market capitalization, stock market traded value and stock market turnover) by employing Principal Component Analysis (PCA). The study covers the period of 1985-2014 using quarter frequency data. (ii) We apply the Fourier ADF (Enders and Lee, 2012) in order to examine the integrating properties of the variables to accommodate the possible nonlinearities. (iii) The NARDL cointegration approach developed by Shin et al. (2014) is used to examine asymmetric cointegration between the variables. (iv) The asymmetric causality (Hatemi-J, 2012) approach is applied in order to determine the casual relationship between the variables. Our results indicate presence of asymmetric cointegration between financial development, energy consumption, economic growth and CO_2 emissions. Economic growth (positive shock) affects CO_2 emissions. The asymmetric effect of energy consumption on CO_2 emissions is positive. Bank-based financial development (positive shock) adds in CO_2 emissions. The symmetric causality analysis reveals bidirectional causality between economic growth and CO_2 emissions. Feedback effect also exists between energy consumption and CO_2 emissions. Bank-based financial development (positive shocks) is cause of CO_2 emissions.

Table 1: Summary of Studies on Financial development-Emissions Nexus

No.	Authors	Time Period	Country	Methodology	FD Measure	Hypothesis	Causality
1.	Tamazian et al. (2009)	1992-2004	BRIC	SRM	SMC, DBA, FDI	FD decreases EQ	….
2.	Tamazian and Rao (2010)	1993-2004	24 TE	G MM	FL, FDI	FD decreases EQ	….
3.	Jalil and Feridun, (2010)	1953-2006	China	ARDL	LL, DC, FDI	FD improves EQ	….
4.	Zhang, (2011)	1980-2010	China	VAR	BL, SMC, SMB, FDI	FD decreases EQ	….
5.	Ozturk and Acaravci, (2013)	1960-2007	Turkey	ARDL, VECM	DC	Insignificant	$FD \rightarrow CO_2$
6.	Shahbaz et al. (2013a)	1971-2011	Malaysia	ARDL, VECM	DC, FDI	FD decreases EQ	$FD \leftrightarrow CO_2$
7.	Shahbaz et al. (2013b)	1965-2008	South Africa	ARDL, VECM	DC	FD improves EQ	….
8.	Boutabba, (2014)	1971-2008	India	ARDL, VECM	DC	FD decreases EQ	$FD \rightarrow CO_2$
9.	Salahuddin et al. (2015)	1980-2012	GCC	DOLS, FMOLS	DC	FD improves EQ	$FD \neq CO_2$
10.	Lee et al. (2015)	1971-2007	OECD	FMOLS	DC	FD improves EQ	….
11.	Omri et al. (2015)	1990-2011	12 MENA	PSE	DC, FDI	FD decreases EQ	….
12.	Ziaei (2015)	1989-2011	EU, EA, OC	IRF	DC, TR	Insignificant	….
13.	Charfeddine and Khediri (2016)	1975-2012	UAE	ARDL, VECM	DC	FD decreases EQ	$FD \rightarrow CO_2$
14.	Javed and Sharif (2016)	1972-2013	Pakistan	ARDL, VECM	DC	FD decreases EQ	$FD \leftrightarrow CO_2$
15.	Dogan and Turkekul, (2016)	1960-2010	USA	ARDL, VECM	DC	Insignificant	$FD \leftrightarrow CO_2$
16.	Al-Mulali et al. (2016)	1990-2013	EU	FMOLS, VECM	DC	FD decreases EQ	$FD \leftrightarrow CO_2$
17.	Shahbaz et al. (2016)	1971-2011	Portugal	ARDL, VECM	DC	FD improves EQ	$FD \rightarrow CO_2$

Note: DBA (deposit money bank assets), FL (financial liberalization), LL (Liquid liabilities), DC (domestic credit to private sector), FDI (Foreign direct investment), BL (sum of bank loans), SMC (stock market capitalization), SMB (bond in stock market), TR (stock market traded value), FD (financial development), EQ (environmental quality), CO_2 (CO_2 emissions), GMM (Generalized Moments Method), ARDL (autoregressive distributed lag model), VAR (vector auto-regression), VECM (vector error correction Granger causality), DOLS (dynamic ordinary least square), FMOLS (Fullimodified ordinary least square), UAE (United Arab Emirates), GCC (Gulf countries council), EU (European Union), EA (East Asia), OC (Oceania countries) and MENA (Middle East and North America).

2. Financial Development and CO_2 Emissions in Pakistan

Under Structural Adjustment Program (SAP) of IMF, Pakistan started introducing financial reforms in the late 1980s. Pakistan availed loan of $150 million in 1989 and $200 million in 1997 under Financial Sector Adjustment Loan Scheme. In 1995 another episode of loans was provided to Pakistan amounting $216 million under Financial Sector Deepening and Intermediation Project. World Bank also issued $300 million in 2001 under Financial Structure Restructuring and Privatization Project in 2001. The core objective of these reforms was to move towards market based exchange rate system, and market based management of credit and monetary system. Further for the improvement in regulations, competition, efficiency and productivity of financial sector, consequently privatization of banks, opening of new commercial banks, and investment and microfinance banks started their operations in Pakistan. In this regard, the liberalized policy was adopted to flourish private domestic banks and foreign banks. These reforms were also made to rationalize the rate of interest in three dimensions i.e. public debt, concessional rates, caps on lending and deposit rates. Federal Investment Bonds were introduced and later replaced by Pakistan Investment Bonds of five and ten years (Zaidi, 2005). To the end of Monetary and Credit Management, credit ceiling was replaced by Credit Deposit Ratio (CDR) in 1995. Open Market Operation became effective through market based monetary management and reserve repo transaction was practiced to correct deviation in money supply (Hanif, 2002). Prudential regulations were settled for prescribed credit and for limits of risk exposure. Regulations to check money laundering and payments of dividend were also formulated.

Capital market reforms ensured instilling competition and broadened market base. After financial liberalization, not only tremendous growth but also instability in stock market was observed. There has been only one stock market i.e. Karachi Stock Exchange for a long period of time till financial liberalization. After political unrest in 1970s and nationalization policy, Karachi Stock Exchange (KSE) gained its momentum when more companies were listed on KSE but enduring political unrest and martial law regime badly affected the stock market of Pakistan. The decade of 1990s was the recovery period of stock market which opened new doors for investment but inconsistent performance of stock market was witnessed due to continuing political instability, inflation, unemployment, terrorism and budget deficit etc. Volatility in financial sector badly affected investment environment, economic growth and hence CO_2 emissions. Pakistan's joining hand with US on war against terror, after 9/11 aggravated peace condition as well as volatility in financial variables. The average behavior of financial variable in other developing countries instigated Pakistan to develop its financial sector.

Notably, Pakistan ranks 31^{st} in emitting CO_2 emissions in the world. According to US Energy Information Administration, Pakistan has increased CO_2 emissions eight times more than it was in 1971. The recent information of World Health Organization (2015) indicates that among the highest 20 most polluted cities, Karachi is ranked at 5, Peshawar is at 6 and Rawalpindi is at 7 in the world. Pakistan has been signatory of Kyoto Protocol since 2005 that promises to enforce Clean Development Mechanism for mitigation of GHGs.

2.1 Financial Development Index

Many researchers such as Gantman and Dabós (2012), Karima and Ken (2008), Masih et al. (2009), Liang and Jian-Zhou (2010) and Narayan and Narayan (2013) have used various indicators of financial development such as domestic credit provided by the banking sector as share of GDP, liquid liabilities as share of GDP, domestic credit to private sector as share of GDP, market capitalization as share of GDP, turnover ratio as share of GDP and value of share trade as share of GDP, commercial bank assets (commercial central bank assets) and broad money /narrow money. We find that all these measures are inappropriate to capture financial sector development. These measures of financial sector development may be highly correlated and provide biased empirical results due to the presence of multi-colinearity (Tyavambiza and Nyangara, 2015).

For appropriate measure of financial sector development, we apply the Principal Component Analysis (PCA) to generate financial development (bank-based financial development index, stock market-based financial development index). The PCA seems to overcome multi-colinearity problem. The money supply in economy is captured by money and quasi money (M_2), volume of financial sector is indicated by liquid liabilities as share of GDP (M_3), domestic credit to private sector shows the allocation of savings to private sector for investment ventures, stock market size is captured by stock market capitalization, stock market traded value and stock market turnover illustrate the profitability in stock markets. These variables may generate a multi-colinearity problem if these are used together in a regression (Polat et al. 2015)[5]. The PCA transforms correlated variables into small uncorrelated variables keeping original data as it exists.

Table 2 (lower segment) reports the pair-wise correlations. The results show the positive correlation of M_2, M_3 with DC. Similarly, correlation of SM, ST and TR with DC is positive. On similar lines, SM, ST and TR are positively correlated with M_2 and M_3. The positive correlation exists between SM and ST and similar inference is found between ST and TR. This presence of high correlations between the variable may cause a multi-colinearity problem which further

[5] We have transformed all the variables into real terms and converted into per capita units by dividing each series on total population.

misleads the empirical results. This problem is resolved by employing PCA to formulate a comprehensive financial development index. The results are reported in Table 1. The first principal component explains 57.94% of standard deviation in all variables while the second principal explains 26.32% of overall standard deviation.

Table 1: Principal Component Analysis

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion	
1	3.4762	1.8971	0.5794	3.4762	0.5794	
2	1.5790	0.9605	0.2632	5.0553	0.8426	
3	0.6185	0.3777	0.1031	5.6738	0.9456	
4	0.2408	0.1864	0.0401	5.9146	0.9858	
5	0.0543	0.0233	0.0091	5.9690	0.9948	
6	0.0309	---	0.0052	6.0000	1.0000	
a). Eigenvectors (loadings)						
Variable	**PC 1**	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**
DC	0.4644	-0.0890	-0.4379	0.6923	-0.0966	0.3095
M2	0.4473	0.4111	0.1463	0.0939	-0.3810	-0.6748
M3	0.2283	0.6766	0.3579	0.0485	0.4539	0.3917
SM	0.4786	0.0517	-0.3454	-0.7046	-0.2374	0.3098
ST	0.4531	-0.3998	-0.0172	-0.1077	0.7029	-0.3589
TR	0.3124	-0.4500	0.7341	0.0365	-0.2982	0.2655
b). Ordinary correlations						
Variables	**DC**	**M_2**	**M_3**	**SM**	**ST**	**TR**
DC	1.0000					
M_2	0.6359	1.0000				
M_3	0.1859	0.8103	1.0000			
SM	0.7458	0.7290	0.3483	1.0000		
ST	0.7674	0.4339	0.0596	0.7307	1.0000	
TR	0.3791	0.2615	0.0740	0.3264	0.7532	1.0000

Note: DC, M2, M3, SM, ST and TR indicates domestic credit to private sector, money and quasi money, liquid liabilities, stock market capitalization, stock market traded value and stock market turnover respectively.

3. Model construction, methodological framework and data

3.1. Model construction

Numerous studies investigated the relationship between financial development and CO_2 emissions but provide mixed empirical results. In case of Pakistan, we extend the carbon emissions function used by Nasir and Rehman (2011) and Shahbaz et al. (2012) by incorporating financial development as additional determinants of economic growth and hence CO_2 emissions. The general form of carbon emissions function is modeled as following:

$$C_t = f(F_t, E_t, Y_t) \tag{1}$$

All the variables are transformed into logarithmic form. The log-linear functional form of empirical equation as constructed as following:

$$\ln C_t = \beta_1 + \beta_2 \ln F_t + \beta_3 \ln E_t + \beta_4 \ln Y_t + \mu_t \tag{2}$$

where, $\ln$, C_t, F_t, E_t and Y_t are natural log of CO_2 emissions, financial development, economic growth and energy consumption. μ_t is error term in *t* time period. All the series have been converted into per capita units except financial development indices.

3.2 Unit root tests

For empirical investigation of dynamic relationship among financial development, energy consumption, economic growth and CO_2 emissions, we follow FADF (Fourier Augmented Dickey-Fuller) unit root test. This test applies procedure suggested by Enders and Lee, (2012) by using a selected frequency component of a Fourier ADF function to estimate the deterministic component of the model. Fourier estimation can be used to explore the unknown multiple breaks in a nonlinear ways (Enders and Lee, 2012). The merit of the test is that it avoids the problem of losing power due to the use of several dummy variables in the model. The nonlinear Fourier ADF test (τ_{DF}) can be represented as follow:

$$\Delta X_t = \rho X_{t-1} + c_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + \sum_{i=1}^{l} c_i \Delta X_{t-i} + e_t \tag{3}$$

In equation (3) γ and k represents parameters and frequency respectively for the estimation of Fourier test. The Fourier ADF (τ_{DF}) test establishes null hypothesis for the t-statistics as ρ = 0. Fourier ADF incorporates standard ADF stationary process as a special case by taking trigonometric terms equal to zero i.e. $\gamma_1 = \gamma_2 = 0$. We can use F-statistics when trigonometric terms are included in the model (Enders and Lees, 2012). The null hypothesis of non linearity is tested using F-test. The optimal lag length is selected using the Akaike Information Criterion (AIC). The acceptance and rejection of F-statistics determines the selection between nonlinear and linear ADF unit root test. If null hypothesis stands rejected then we pick non-linear Fourier ADF test and in other way we use ADF test (Enders and Lee, 2012).

3.3. Nonlinear ARDL specifications

This study investigates the short-and-long run asymmetric association between financial development, energy consumption, economic growth and CO_2 emissions by using the NARDL (nonlinear autoregressive distributed lag) developed by (Shin et al. 2014) with positive and negative partial sum decompositions of financial development, energy consumption and economic growth. This approach has the advantage to discriminate between short-run and long-run asymmetric response of changes in CO_2 emissions to financial development, energy consumption and economic growth. The change in concerned variable (financial development, energy consumption and economic growth) is expressed as the first difference of logarithmic transformation of this variable. The asymmetric cointegrating relationship can be expressed as follows:

$$Y_t = \beta_1 C_t^+ + \beta_2 C_t^- + \beta_3 F_t^+ + \beta_4 F_t^- + \beta_5 E_t^+ + \beta_6 E_t^- + \beta_7 Y_t^+ + \beta_8 Y_t^- + \mu_t \qquad (4)$$

where Y_t represents economic growth, C_t represents CO_2 emissions and F_t is financial development (bank-based, stock market-based, overall), and E_t is energy consumption. The $^+$ and $^-$ show the partial sum process of negative and positive changes in CO_2 emissions, financial development, energy consumption and economic growth while β_s are long- run parameters of the associated asymmetric effects. The extension of proposed ARDL model by Shin et al. (2014) represents asymmetric error correction model as following:

$$\Delta Y_t = \vartheta + pY_{t-1} + \theta^+ \sum X^+_{i,t-1} + \theta^- \sum X^-_{i,\,t-1} + \sum_{i=1}^{p-1} \gamma_i Y_{t-1} + \sum_{i=1}^{p-1} \varphi_i X_{i,\,t-1} + \sum_{i=0}^{q-1} (\varphi_i^+ \Delta \sum X^+_{t-1} + \varphi_i^- \Delta \sum X^-_{t-1}) + \mu_t \quad (5)$$

In Equation (5) p and q represent lag orders for the variables which can be estimated through regression and further decomposes into the partial sum process of negative and positive changes. We can test the long run relationship between dependent and independent variables with the levels of Y_t *and* $\theta^+ \sum X^+_{t-1} + \theta^- \sum X^-_{t-1}$ i.e. (Y_t *and* $C_t^+ + C_t^- + F_t^+ + F_t^- + E_t^+ + E_t^- + Y_t^+ + Y_t^-$). The ($\rho = \theta^+ = \theta^- = 0$) uses for F_{PSS}- statistic as proposed by Pesran et al. (2001) and Shin et al. (2014). For testing the null hypothesis $\rho = 0$ against $\rho < 0$ we use t_{BDM} statistic proposed by Banerjee et al. (1998). The long-run asymmetric coefficients are estimated on the basis of $L_{mi^+} = \hat{\theta}^+/\rho$ and $L_{mi^-} = \ddot{\theta}^-/\rho$. Further we apply Wald test to estimate long-run asymmetry $\theta = \theta^+ = \theta^-$ and short-rum asymmetry from the two alternative forms i.e. $\varphi_i^+ = \varphi_i^-$ for all $i = 1, \ldots, q-1$ or $\sum_{i=0}^{q-1} \varphi_i^+ = \sum\_(i=0)\^(q-1)$. For the estimation of asymmetric dynamic multiplier effects we can uses following equation.

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial cr_{t+j}}{\partial mi_t^+} \text{ and } m_h^- = \sum_{j=0}^{h} \frac{\partial cr_{t+j}}{\partial mi_t^-} \text{ for } h = 0,1,2 \ldots$$
as $h \to \infty$, then $m_h^+ \to L_{mi^+}$ and $m_h^- \to L_{mi^-}$.

3.4. Asymmetric Causality

To determine the direction of causal relationship between concerned variables, we use asymmetric causality test proposed by Hatemi-J (2012). This test takes the basis of Toda-Yamamoto (1995) for causality analysis by taking nonlinear effects and discriminates between the impact of negative and positive shocks. Hatemi-J (2012) believes that integrated variables can be expressed as a random walk process in general form as following:

$$Y_t = Y_{t-1} + e_{1t} = Y_0 + \sum_{t=1}^{t} e_{1i} \text{ and } X_t = X_{t-1} + e_{2t} = X_0 + \sum_{t=1}^{t} e_{2i} \quad (6)$$

where $t = 1,2,\ldots,T$, Y_0 and X_0 show initial values and e_{1t} and e_{2t} are the error terms respectively. $e_{1i}^+ = max(e_{1i},0)$, $e_{2i}^+ = max(e_{2i},0)$, $e_{1i}^- = min(e_{1i},0)$ and $e_{2i}^- = min(e_{2i},0)$ represents positive and negative shocks respectively. Further it is shown by $Y_t = Y_{t-1} + e_{1t} = Y_0 + \sum_{t=1}^{t} e_{1i}^+ + \sum_{t=1}^{t} e_{1i}^-$ and $X_t = X_{t-1} + e_{2t} = X_0 + \sum_{t=1}^{t} e_{2i}^+ + \sum_{t=1}^{t} e_{2i}^-$. To capture the effects of positive and negative shocks of all variables, it can be expressed in cumulative form as following:

$$Y_t^+ = \sum_{i=1}^{t} e_{1i}^+,\ Y_t^- = \sum_{i=1}^{t} e_{1i}^-,\ C_t^+ = \sum_{i=1}^{t} e_{2i}^+ \text{ and } C_t^- = \sum_{i=1}^{t} e_{2i}^-,\ F_t^+ = \sum_{i=1}^{t} e_{3i}^+$$
$$F_t^- = \sum_{i=1}^{t} e_{3i}^-,\ \sum_{i=1}^{t} e_{5i}^-\ E_t^+ = \sum_{i=1}^{t} e_{6i}^+,\ E_t^- = \sum_{i=1}^{t} e_{6i}^-.$$

The positive and negative component indicates asymmetric causality among variables (Hatemi-J, 2012). This test can be applicable by using VAR (Vector autoregressive) model with order of p. The optimal lag length can be selected by using criteria suggested by (Hatemi-J, 2003, 2008).

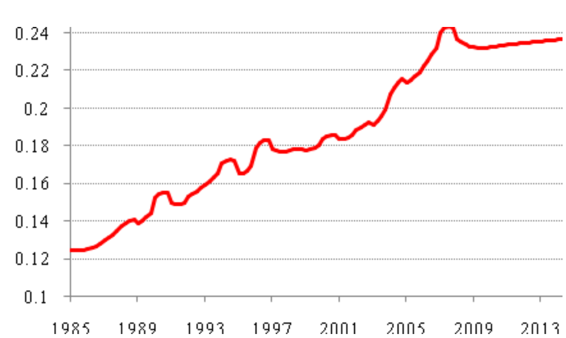
$$HJC = \ln(|\widehat{A}_j|) + q\left(\frac{n^2\ln T + 2n^2\ln(\ln T)}{2T}\right), q = 0, \ldots, p \quad (7)$$

Where $|\widehat{A}_j|$ is determinant in the VAR model of the obtained variance-covariance matrix of the error terms with lag order q and shows number of equations and T is the number of observation in the VAR model. The null hypothesis can be represented from the kth element $\sum X_{it}^{+}$ does not affect the ωth Y_t^{+} is defined as: H_0: the row ω, column k element in A_r equals zero for $r = 1, \ldots, p$. This hypothesis can be tested by using Wald test (Hatemi-J, 2012).

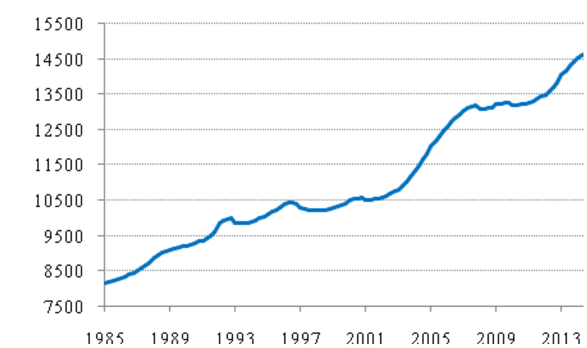
3.5. Data Collection

This study covers the time period of 1985-2014. We have employed Quadratic match-sum method to transform annual frequency data into quarter frequency following Sbia et al. (2014). The data on CO_2 emissions (metric tons per capita), energy consumption (kg of oil equivalent per capita), real GDP (per capita), money and quasi money (M_2), liquid liabilities (M_3), domestic credit to private sector, stock market capitalization, stock market traded value and stock market turnover has been collected from World Development Indicators (CD-ROM, 2015)[6]. Time trend of the variables is shown in Figure 1.

a). CO_2 Emissions

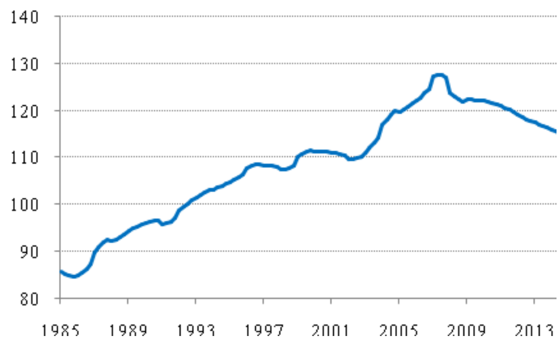


b). GDP per Capita

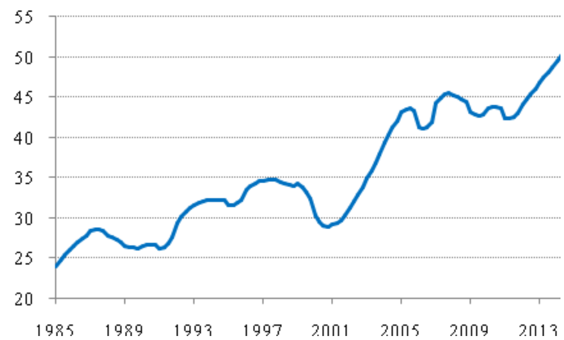


[6] All financial indicators have been transformed into real and per capita term for empirical analysis.

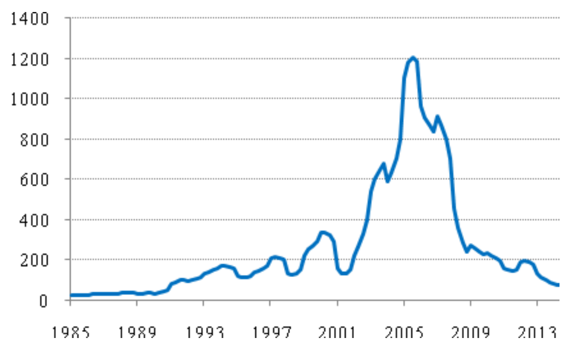
c). Energy Consumption



d). Financial Development (Bank-based)



e). Financial Development (stock market-based)



f). Financial Development (overall)

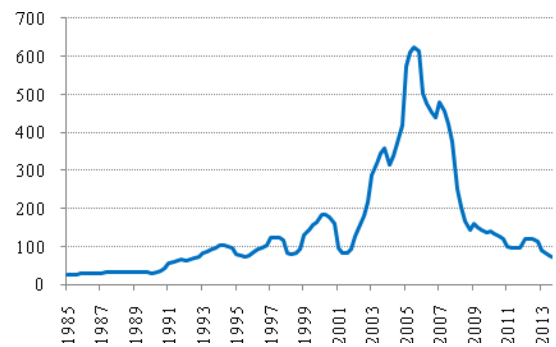


Figure 1: Financial development, Economic growth, CO_2 emissions trends in Pakistan

4. Findings and discussion

Table 2 reveals the descriptive statistics and pair-wise correlations. We find that economic growth is highly volatile compared to CO_2 emissions. Bank-based financial development is less volatile compared to stock market-based financial development and overall financial development. High standard deviation exists in energy consumption compared to CO_2 emissions. The distribution is termed as symmetric if distribution of data looks same on both sides of centre point i.e. bell-shaped curve. Third i.e. Skewness and fourth i.e. Kurtosis movements of the data show potential asymmetry of the data distribution (Table 2)[7]. This leads

[7] We could not find bell-shaped distribution of data. Results are available upon request from authors.

us to rely on asymmetric rather than symmetric empirical analysis. The J-B Statistic indicates the non-normal distribution of the data. The asymmetric ARDL solves the issue of non-normality by capturing the non-liberalities occurring in time series data (Shin et al. 2014). The correlation analysis indicates the positive correlation between economic growth and CO_2 emissions. The positive correlation exists between energy consumption and CO_2 emissions. Financial development (bank-based as well as stock market-based) is positively associated with CO_2 emissions. Energy consumption and financial development (bank-based as well as stock market-based) are positively correlated with economic growth. The positive correlation occurs between financial development (bank-based as well as stock market-based) and energy consumption. There is possibility of multi-colinearity between energy consumption and economic growth (financial development (bank-based as well as stock market-based) and energy consumption). Shin et al. (2014) argued that multi-colinearity issue can be solved by applying non-linear ARDL approach with appropriate lag order.

Table 2: Descriptive Statistics and Correlation Matrices

	$\ln C_t$	$\ln Y_t$	$\ln E_t$	$\ln FB_t$	$\ln FS_t$	$\ln F_t$
Mean	0.1877	11038.5	108.74	35.554	261.34	148.45
Maximum	0.2435	14754.0	127.70	51.358	1206.0	624.84
Minimum	0.1242	8157.2	84.682	23.968	23.969	23.967
Std. Dev.	0.0376	1836.7	11.620	7.4092	285.29	144.39
Skewness	-0.0349	0.3775	-0.4050	0.3480	1.7808	1.7613
Kurtosis	1.7216	1.9425	2.1769	1.8064	5.3230	5.2742
J-B Stats	8.1955**	8.4413**	6.6678**	9.5465***	90.414***	87.908***
	[0.0166]	[0.0146]	[0.0356]	[0.0084]	[0.0000]	[0.0000]
$\ln C_t$	1.0000					
$\ln Y_t$	0.9738***	1.0000				
	(46.516)					
$\ln E_t$	0.9634***	0.8921***	1.0000			
	(39.075)	(21.453)				
$\ln FB_t$	0.9455***	0.6659***	0.8674***	1.0000		
	(31.561)	(19.582)	(18.941)			
$\ln FS_t$	0.5119***	0.3961***	0.6262***	0.4623***	1.0000	

	(6.4731)	(4.6869)	(8.7259)	(5.6644)		
$\ln F_t$	0.5299***	0.4161***	0.6409***	0.4824***	0.8997***	1.0000
	(6.7885)	(4.9714)	(9.0700)	(5.9826)	(47.401)	

Note: J-B stands for Jarque-Bera test of normality. Numbers in () are the t values. *** indicate significance at 1% level.

Although, the asymmetric ARDL is not conditioned with testing the order of integration of the variables but it is necessary to ensure that none of the variables be stationary at 2nd difference i.e. I(2). The ADF unit root is unable to capture the unknown multiple structural breaks and non-linearity occurring in time series data which misleads the empirical results due low explanatory power. This problem is solved by applying FADF unit root test. We applied ADF and FADF unit root tests and results are reported in Table 3. As described in the methodology section, we follow a two step procedure to conclude on the unit root properties of data. First, FADF test is applied and possible non-linearity is tested though F($\tilde{k}$) statistics. We find that F-statistic of FADF fails to reject the null hypothesis i.e. time series is linear. Second, the findings of FADF test allow us to reply on empirical results reported by ADF unit root test. We find that CO_2 emissions, energy consumption, economic growth and financial development (bank-based, stock market-based) have unit root at level. The variables are found to stationary at first difference i.e. I(1).

Table 3: Unit root tests results

Variable	Nonlinear FADF						ADF	
	$\tilde{k}$	SSR	$\hat{l}$	AIC	F($\tilde{k}$)	τ_{DF}	Level	First diff.
$\ln C_t$	2	0.0060	5	-6.8510	2.6195	-1.3720	-1.9121	-3.5525***
$\ln Y_t$	2	0.0012	5	-8.4071	2.5588	1.0522	-0.3253	-3.9773***
$\ln E_t$	1	0.0020	5	-7.9513	4.2160	-3.8771	-1.8919	-5.9436***
$\ln FB_t$	1	0.0149	5	-5.9437	0.6807	-1.2201	-0.4934	-4.3500***
$\ln FS_t$	1	1.2107	5	-1.5491	4.3038	-2.7571	-1.9158	-3.1708***
$\ln F_t$	1	0.8542	5	-1.8979	4.1903	-2.7803	-1.9374	-4.2002***

Note: In nonlinear FADF unit root test, the optimal frequency ($\tilde{k}$) was selected by using the data-driven grid-search method. The optimal lag ($\hat{l}$) is the lag length that minimises the Akaike Information Criterion (AIC). The critical values are obtained from Table-1b in Enders and Lee (2012). For traditional ADF unit root test, critical values are based on MacKinnon (1996). All the variables assume intercept. *** indicates significance at 1% level.

After confirming that none of the variable is integrated at I(2), we apply NARDL approach to examine the impact of financial development, energy consumption and economic growth on CO_2 emissions. The results of model 1, 2 and 3 using banking, stock and overall financial development are reported in Table-4, 5 and 6, respectively. In long-run, we find that positive shocks in economic growth mainly increase CO_2 emissions. The positive shocks in economic growth add more in CO_2 emissions. The impact of negative shocks in economic growth on CO_2 emissions is positive but statistically insignificant[8]. This shows that domestic output is being enhanced without caring about the environmental rules and regulations that leads the deterioration in environment quality (Shahbaz, 2013). Energy consumption (positive and negative shocks) adds in CO_2 emissions. This empirical outcome is similar with Nasir and Rehamn (2011), Shahbaz et al. (2012), Ahmed et al. (2015), Javid and Sharif (2016) who noted that energy consumption is a major contributor to environmental degradation. The positive shocks in bank-based financial development positively and significantly impact CO_2 emissions at 10% level. The negative shocks in financial development (bank-based) have positive effect on CO_2 emissions but insignificant. This finding is consistent with Javid and Sharif, (2016) who reported that allocation of domestic credit to private sector (proxy for financial development) is impeding environmental quality by increasing CO_2 emissions. On contrary, Abbasi and Riaz (2016) documented that total credit, domestic credit to private sector and stock market capitalization has negative and positive but insignificant effect on CO_2 emissions. The impact of positive and negative shocks in stock market-based financial development on CO_2 emissions is

[8] Overall economic growth is positively linked with CO_2 emissions.

positive and negative but statistically insignificant (Table-5). Similarly, we used overall financial development (bank-based + stock market-based) in order to examine its impact on CO_2 emissions. The results show that financial development (overall index) has positive but insignificant effect on carbon emissions (see Table-6).

Table 4: Dynamic Asymmetric Model – Financial Development Banks

Dependent variable: ΔlnC_t

Variables	**Coefficients**		**S.E**
Constant	-0.9296***		(0.1184)
$\ln C_{t-1}$	-0.4461***		(0.0566)
$\ln Y^{+}_{t-1}$	0.1406*		(0.0811)
$\ln Y^{-}_{t-1}$	0.2306		(0.1918)
$\ln E^{+}_{t-1}$	0.4311***		(0.0914)
$\ln E^{-}_{t-1}$	0.3995***		(0.0932)
$\ln FB^{+}_{t-1}$	0.0665**		(0.0255)
$\ln FB^{-}_{t-1}$	0.0044		(0.0243)
$\Delta\ln C_{t-1}$	0.3708***		(0.0755)
$\Delta\ln C_{t-2}$	0.2652***		(0.0804)
$\Delta\ln Y^{+}_{t-2}$	-0.7387***		(0.2411)
$\Delta\ln Y^{-}_{t}$	1.4835***		(0.4455)
$\Delta\ln E^{+}_{t-1}$	-0.5253**		(0.2339)
$\Delta\ln E^{-}_{t}$	0.7156**		(0.3115)
$\Delta\ln FB^{+}_{t-1}$	0.4548***		(0.0772)
R^2	0.6371		
Adj. R^2	0.5852		
DW stats	2.0909		
χ^2_{SC}	0.9379		[0.1823]
χ^2_{FF}	0.0545		[0.8157]
χ^2_{HET}	1.8839		[0.0609]
χ^2_{NORM}	14.011		[0.0020]
L^{+}_{y}	0.3151*	L^{-}_{y}	0.2899
L^{+}_{E}	0.9664***	L^{-}_{E}	0.8955***
L^{+}_{FB}	0.1492***	L^{-}_{FB}	0.0099
$W_{LR,y}$	2.1274 [0.0918]	$W_{SR,y}$	16.558 [0.0001]
$W_{LR,E}$	0.0484 [0.8262]	$W_{SR,E}$	9.5393 [0.0026]
$W_{LR,FB}$	3.8239 [0.0613]	$W_{SR,FB}$	34.657 [0.0000]
F-Bound	9.15530***		
Asymmetry	-7.8799***		

Note: The superscript "+" and "-" denote positive and negative cumulative sums, respectively. L^+ and L^- are the estimated long-run coefficients associated with positive and negative changes, respectively, defined by $\hat{\beta} = -\hat{\theta}/\hat{\rho}$. χ^2_{SC}, χ^2_{FF}, χ^2_{HET}, and χ^2_{NORM} denote LM tests for serial correlation, normality, functional form and heteroscedasticity, respectively. W_{LR} and W_{SR} represents the Wald test for the null of long- and short-run symmetry for respective variable. Value in [] are p-values. S.E stands for standard errors.
***, ** & * indicate significance at 1%, 5% and 10% level, respectively.

This shows that an increase in bank-based financial development has incremental effect on environmental degradation and decrease in financial development also increases CO_2 emissions but insignificantly. We note that in case of Pakistan, banks mostly involve in allocating financial resources to firms or investors at cheaper cost as well as households to purchase household items via consumer financing. Furthermore, car financing is more lucrative product of consumer financing for selling to emerging middle class in Pakistan. Due to lax of environmental regulations, firms or investors employ technology to enhance their production that consumes more energy and increases environmental degradation. For example, the auto-industry of Pakistan has been utilizing 85% inefficient technology for manufacturing vehicles which consumes 85% more energy compared to vehicle industry of developed countries. Similarly, machines and electrical appliances are used by factories and offices even at household level consume 14% more energy compared to India[9]. This shows that financial sector is contributing to environmental degradation by allocating financial resources to firms, investors and households abruptly without monitoring firms as well as investors (Shahbaz, 2013).

Table 5: Dynamic Asymmetric Model – Financial Development Stock

Dependent variable: $\Delta \ln C_t$

Variables	Coefficients	S.E
Constant	-0.6262***	(0.1117)
$\ln C_{t-1}$	-0.3029***	(0.0535)
$\ln Y^+_{t-1}$	0.2170***	(0.0680)
$\ln Y^-_{t-1}$	-0.0605	(0.2105)
$\ln E^+_{t-1}$	0.2062***	(0.0828)
$\ln E^-_{t-1}$	0.4140***	(0.1557)
$\ln FS^+_{t-1}$	0.0008	(0.0032)
$\ln FS^-_{t-1}$	-0.0034	(0.0045)
$\Delta \ln C_{t-1}$	0.4860***	(0.0798)
$\Delta \ln Y^+_t$	1.2834***	(0.3220)
$\Delta \ln Y^+_{t-1}$	-1.0487***	(0.3349)
$\Delta \ln FS^+_t$	0.9509***	(0.3403)
R^2	0.5266	
Adj. R^2	0.4771	

[9] Pakistan uses 60% and 37% energy inefficient technology compared to the US and UK.

DW stats	2.2556			
χ^2_{SC}	0.8376		[0.3283]	
χ^2_{FF}	0.7364		[0.3928]	
χ^2_{HET}	1.2671		[0.2494]	
χ^2_{NORM}	14.776		[0.0000]	
L_y^+	0.7166***	L_y^-		0.1997
L_E^+	0.6807***	L_E^-		1.3668***
L_{FS}^+	0.0028	L_{FS}^-		-0.0113
$W_{LR,y}$	1.9164 [0.0872]	$W_{SR,y}$		12.762 [0.0023]
$W_{LR,E}$	1.6860 [0.0877]	$W_{SR,E}$		-
$W_{LR,FS}$	0.0142 [0.3491]	$W_{SR,FS}$		14.657 [0.0000]
F-Bound	5.1605***			
Asymmetry	-5.6605***			

Note: see notes to Table-4.

In short-run, lagged terms CO_2 emissions (lagged 1 and 2) are contributing to environmental degradation in future. The positive shock in economic growth (lagged 2) is reducing CO_2 emissions but negative shock in economic growth adds in CO_2 emissions. A positive shock in energy consumption is decreasing CO_2 emissions but negative shock in energy consumption is increasing CO_2 emissions. The relationship between positive shocks in bank-based financial development and CO_2 emissions is positive and significant at 1% level. The positive shock of stock market-based financial positively associated with CO_2 emissions at 1% level. Moreover, empirical results indicate the asymmetric impact of economic growth, energy consumption and financial development (bank-based) on environmental degradation. A 63.71%, 52.66% and 54.69% of CO_2 emissions is explained by economic growth, energy consumption and financial development as we used bank-based index, stock market-based index and overall index of financial development in model-1, 2 and 3. The empirical evidence favors the absence of serial correlation, misspecification of model and heteroskedisticity but non-normally distributed is present in residual terms. There is no problem of autocorrelation in the empirical models. The F-bound test shows the presence of cointegration between economic growth, energy consumption, financial development (bank-based, stock market-based and overall index) and

CO_2 emissions. This fining is confirmed by the results of asymmetric cointegration (see lower panel of Table 4, 5 and 6). We find that economic growth, energy consumption, financial development (bank-based, stock market-based and overall index) and CO_2 emissions have cointegration in the presence of asymmetries.

Table 6: Dynamic Asymmetric Model – Financial Development Overall

Dependent variable: ΔlnC_t

Variables	Coefficients		S.E
Constant	-0.7825***		(0.1143)
lnC_{t-1}	-0.3766***		(0.0546)
lnY^{+}_{t-1}	0.2291***		(0.0690)
lnY^{-}_{t-1}	0.0883		(0.2053)
lnE^{+}_{t-1}	0.3742***		(0.0820)
lnE^{-}_{t-1}	0.2776*		(0.1562)
lnF^{+}_{t-1}	0.0039		(0.0037)
lnF^{-}_{t-1}	0.0024		(0.0050)
ΔlnC_{t-1}	0.4205***		(0.0805)
ΔlnC_{t-2}	0.3111***		(0.0888)
ΔlnY^{+}_{t}	0.7461**		(0.3015)
ΔlnY^{+}_{t-1}	-0.9559***		(0.3137)
ΔlnY^{-}_{t}	1.1528**		(0.4718)
ΔlnE^{+}_{t}	0.7301***		(0.2440)
ΔlnE^{+}_{t-1}	-0.5666**		(0.2500)
R^2	0.5469		
Adj. R^2	0.4947		
DW stats	2.1523		
χ^2_{SC}	1.6402		[0.1023]
χ^2_{FF}	0.0104		[0.9188]
χ^2_{HET}	2.3050		[0.0797]
χ^2_{NORM}	7.9381		[0.0080]
L^{+}_{y}	0.6084***	L^{-}_{y}	-0.0954
L^{+}_{E}	0.7546***	L^{-}_{E}	0.7638*
L^{+}_{F}	0.0104	L^{-}_{F}	0.0063
$W_{LR,y}$	2.7039 [0.0969]	$W_{SR,y}$	4.4556 [0.0373]
$W_{LR,E}$	0.2391 [0.9857]	$W_{SR,E}$	9.6380 [0.0025]
$W_{LR,F}$	0.0717 [0.7242]	$W_{SR,F}$	-
F-Bound	7.4371***		
Asymmetry	-6.8857***		

Note: see notes to Table-4.

Next, to learn the asymmetric adjustments from an initial long-run equilibrium to a new long-run equilibrium after a negative or positive unitary shock, we plot the dynamic multipliers for three models (a-c) in Figure 2, 3 and 4, respectively. In these figures, the predicted dynamic multipliers for the adjustment of CO_2 emissions under the three NARDL specifications are shown. The asymmetry curves depict the linear combination of the dynamic multipliers associated with positive and negative shocks. The positive and negative change curves provide the information about the asymmetric adjustment to positive and negative shocks at a given forecasting horizon, respectively. Lower band and upper band (dotted red lines) for asymmetry indicate the 95% confidence interval.

The overall impression is that negative economic growth shocks (Figure-2) have a more profound impact on CO_2 emissions in short-run while there is a positive asymmetry in long-run. The long-run equilibrium is achieved in two years time period (eight quarters). The CO_2 emissions response to positive and negative energy consumption shocks (both short-and-long run) is somewhat symmetric except for model-2. As the gap in magnitude between positive and negative shocks in energy consumption is negligible especially in short-run. The response of CO_2 emissions to bank-based financial development is asymmetric (positive asymmetry) in both short-and-long run. The long-run equilibrium in response to bank-based financial development shocks are again achieved within two years time span. The response of CO_2 emissions to stock market and overall financial development is within -0.05 and +0.05 range and hence is negligible.

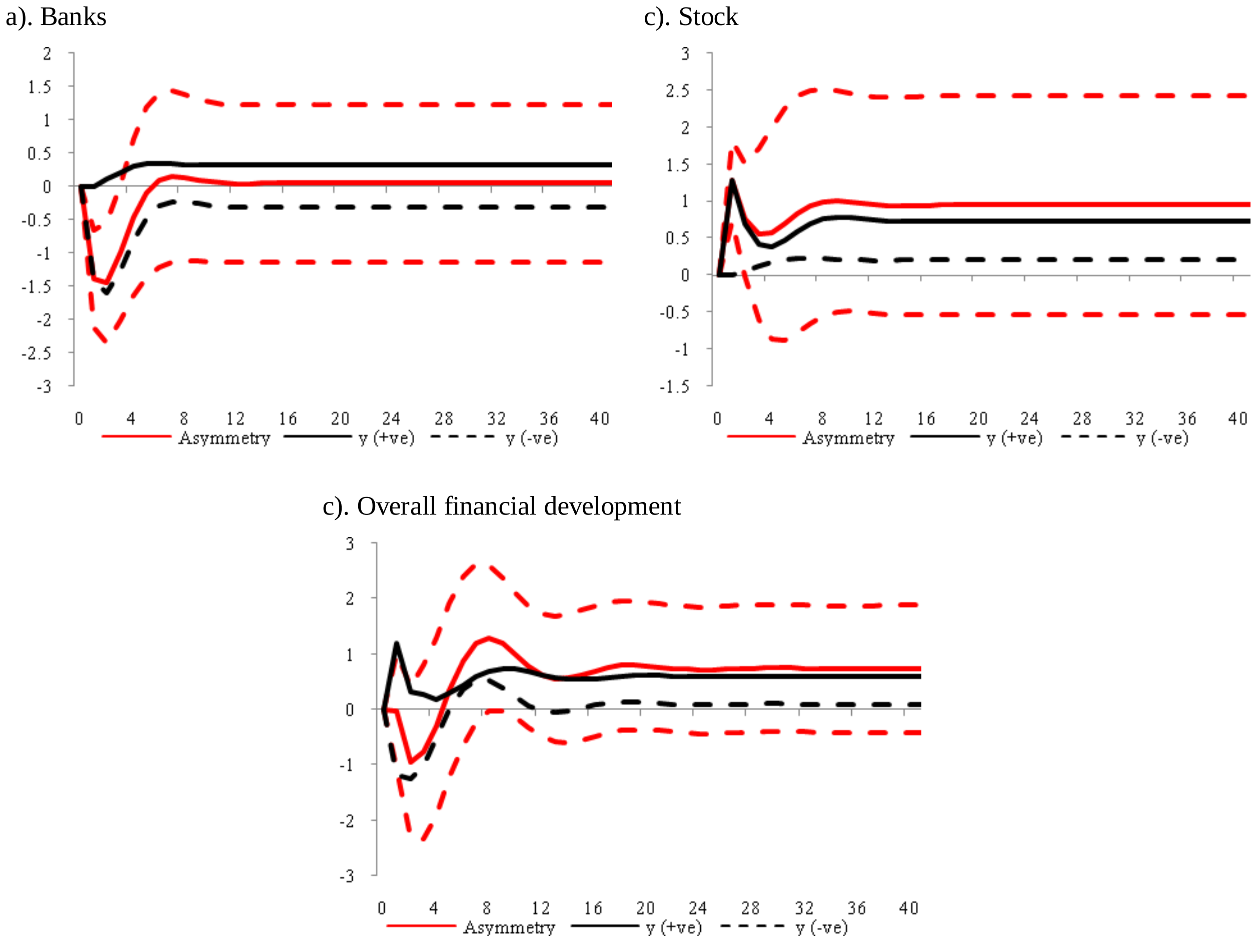


Figure 2: CO_2 Emissions–Economic Growth Dynamic Multipliers

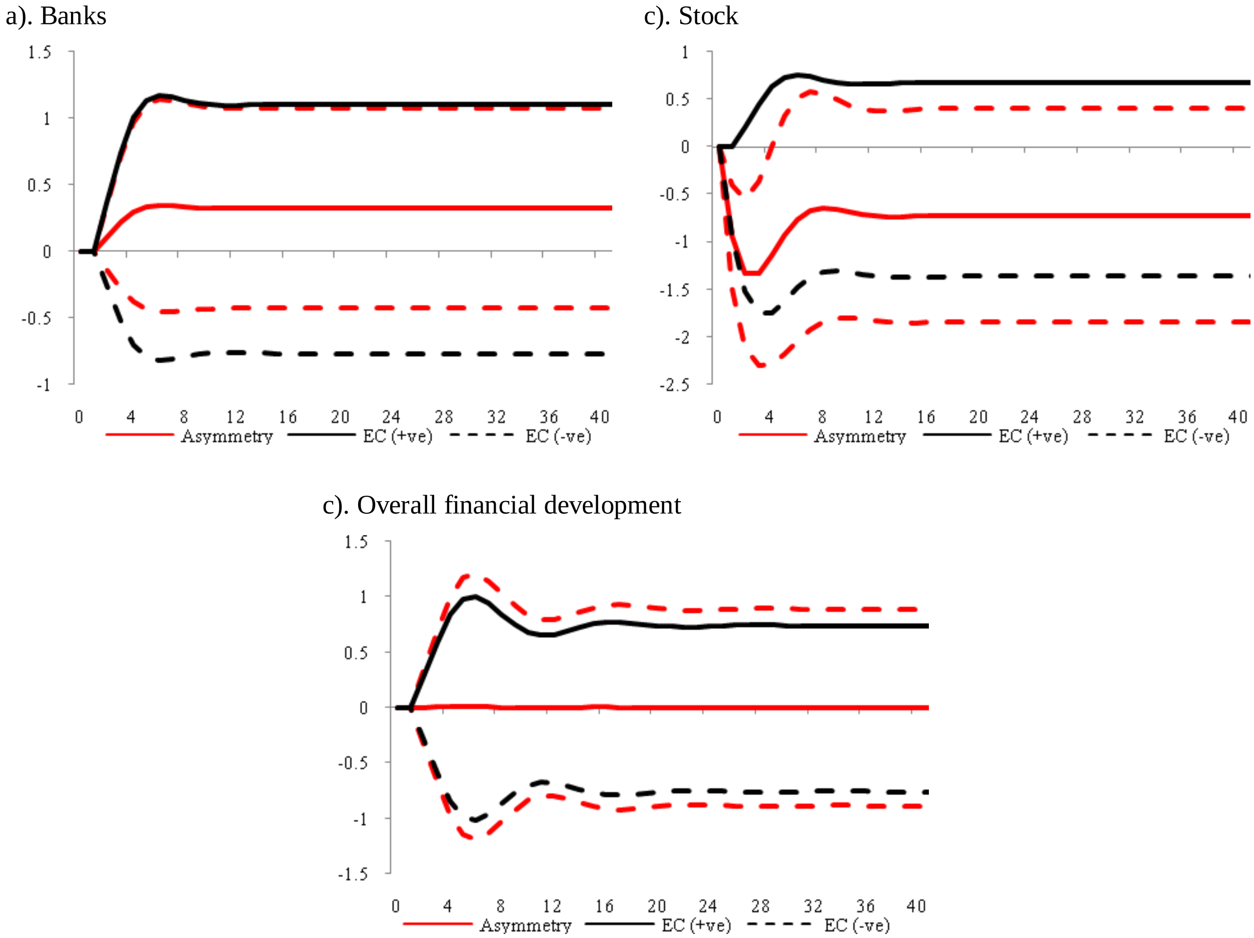


Figure 3: CO_2 Emissions–Energy Consumption Dynamic Multipliers

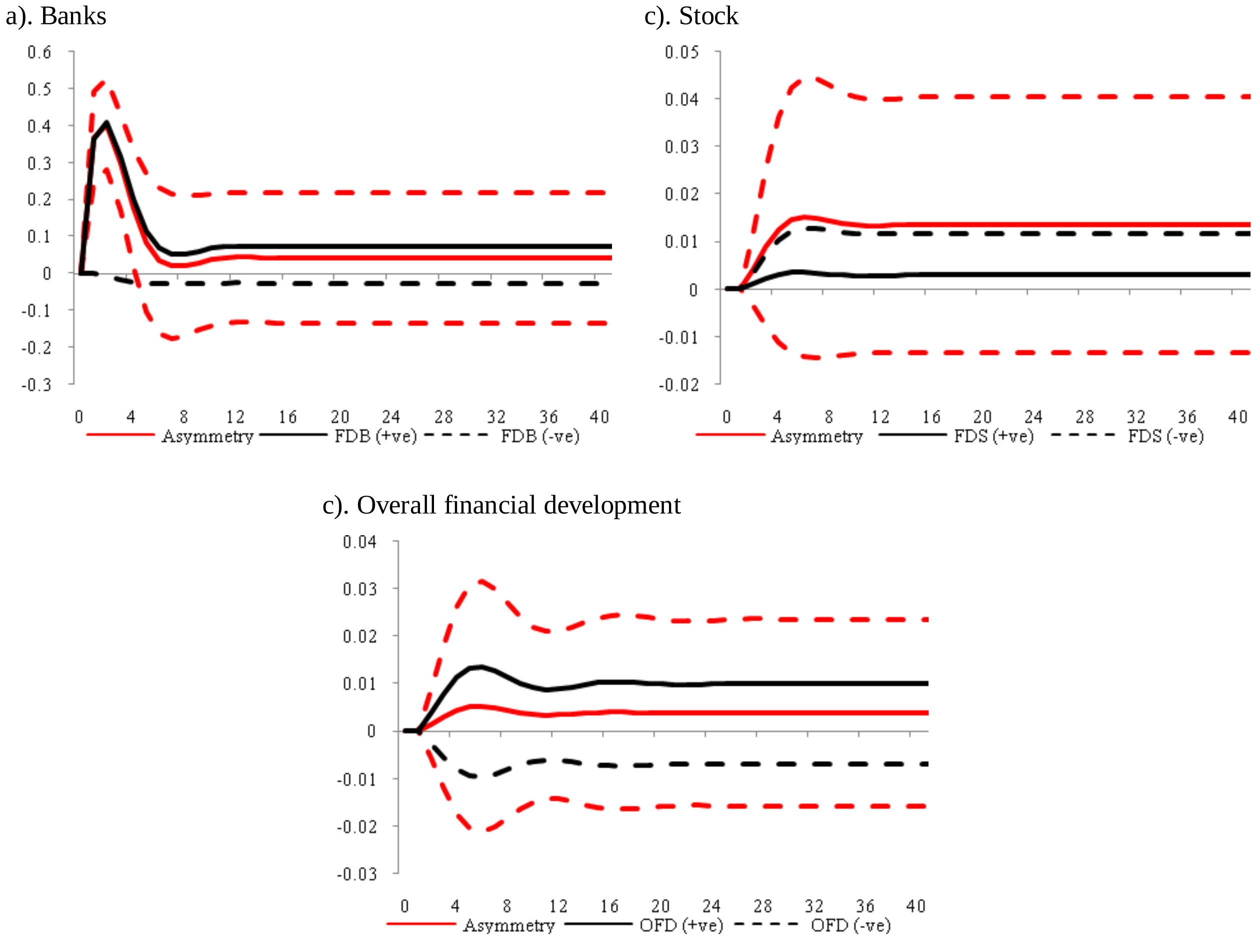


Figure 4: CO_2 Emissions–Financial Development Dynamic Multipliers

The results of asymmetric and non-asymmetric causality are reported in Table-7. We find that economic growth causes CO_2 emissions and in result, CO_2 emissions cause economic growth in Granger sense. This confirms the presence of feedback effect between economic growth and CO_2 emissions. This reveals that Pakistan is growing at cost of environment and for better environment Pakistan has to compensate economic growth. This finding is in consistent with Nasir and Rehman (2011), and later on, Shahbaz et al. (2012) reported that economic growth Granger causes CO_2 emissions not only in long-run but also in short-run. The causality between energy consumption and CO_2 emissions is bidirectional. This empirical outcome is similar with Javid and Sharif, (2016) who confirmed the feedback effect between energy consumption and environmental degradation. This empirical results is similar with Tiwari et al. (2013) who reported that energy consumption and CO_2 emissions for Indian economy. This shows that energy consumption causes CO_2 emissions and in resulting, CO_2 emissions cause energy consumption in Granger sense for India.

The unidirectional causality is found running from positive shocks in bank-based financial development to positive shocks in CO_2 emissions. Our empirical evidence is contradictory with Javid and Shahrif (2016) as well as Abbasi and Riaz (2016). Javid and Sharif, (2016) employed augmented carbon emissions function by incorporating trade openness and financial development as additional determinants of economic growth, energy consumption and hence CO_2 emissions. Their empirical exercise reported that financial development causes CO_2 emissions and CO_2 emissions cause financial development in Granger sense i.e. bidirectional causality. Similarly, Abbasi and Riaz, (2016) used total credit, domestic credit and stock market capitalization as proxies of financial development in order to determine the relationship between financial development and CO_2 emissions. They noted the neutral effect between financial development and CO_2 emissions in full sample (1971-2011) but in reduced sample (1988-2011), domestic credit to private sector Granger causes CO_2 emissions. There is no causal relationship between positive (negative) shocks in stock market-based financial development to positive (negative) shocks in CO_2 emissions. This shows that stock market-based financial development and CO_2 emissions are independent. This empirical finding corroborated by Abbais and Riaz (2016) who found neither stock market capitalization causes CO_2 emissions nor CO_2 emissions cause stock market capitalization in Granger sense. On similar lines, causality between positive (negative) shocks in energy consumption and positive (negative) CO_2 emissions is neutral. This shows that there is no asymmetric causality between energy consumption and stock market-based (overall financial development) financial development. Furthermore, the neutral effect exists between stock market-based (overall financial development) financial development and CO_2 emissions.

Table 7: The Asymmetric and Non-asymmetric Causality Analysis

Null hypothesis	**Test value**	**Bootstrap CV at 1%**	**Bootstrap CV at 5%**	**Bootstrap CV at 10%**
$lnY_t \neq> lnC_t$	90.047***	42.127	28.993	23.958
$lnY_t^+ \neq> CO_{2,t}^+$	0.057	13.397	7.281	5.352
$lnY_t^- \neq> CO_{2,t}^-$	0.048	17.069	5.348	1.955
$lnC_t \neq> lnY_t$	26.761**	35.572	25.038	20.833
$lnC_t^+ \neq> lnY_t^+$	0.951	15.534	7.686	5.631
$lnC_t^- \neq> lnY_t^-$	0.000	29.440	7.859	3.022
$lnE_t \neq> lnC_t$	29.668**	32.584	23.399	19.782
$lnE_t^+ \neq> lnC_t^+$	1.708	14.309	7.350	5.354
$lnE_t^- \neq> lnC_t^-$	0.075	14.752	4.711	2.422
$lnC_t \neq> lnE_t$	42.553***	39.315	25.357	20.869
$lnCO_t^+ \neq> lnE_t^+$	0.287	13.046	7.638	5.032
$lnC_t^- \neq> lnE_t^-$	0.000	16.032	6.199	3.149
$lnFB_t \neq> lnC_t$	8.722	20.321	14.774	12.499
$lnFB_t^+ \neq> lnC_t^+$	9. 345**	12.301	7.286	5.342
$lnFB_t^- \neq> lnC_t^-$	0.062	16.400	7.553	5.287
$lnC_t \neq> lnFB_t$	4.456	22.672	15.854	13.594
$lnC_t^+ \neq> lnFB_t^+$	2.360	20.114	9.657	5.581
$lnC_t^- \neq> lnFB_t^-$	4.647	14.499	7.672	5.074
$lnFS_t \neq> lnC_t$	4.449	37.854	25.121	20.343
$lnFS_t^+ \neq> lnC_t^+$	0.801	13.036	7.393	5.361
$lnFS_t^- \neq> lnC_t^-$	0.010	16.238	4.965	2.395
$lnC_t \neq> lnFS_t$	16.851	40.338	26.640	21.906
$lnC_t^+ \neq> lnFS_t^+$	0.640	14.370	7.532	5.222
$lnC_t^- \neq> lnFS_t^-$	0.016	20.294	6.417	2.821
$lnF_t \neq> lnC_t$	7.007	38.349	25.226	20.854
$lnF_t^+ \neq> lnC_t^+$	0.805	12.713	7.548	5.492
$lnF_t^- \neq> lnC_t^-$	0.016	16.349	4.780	2.311
$lnC_t \neq> lnF_t$	18.940	41.133	25.191	21.703
$lnC_t^+ \neq> lnF_t^+$	0.263	14.652	7.847	5.170

$lnC_t^- \neq> lnF_t^-$	0.001	19.782	6.918	3.096

Note: The denotation CV is an abbreviation for the critical value. An extra unrestricted lag was included in the VAR model in order to account for the effect of a unit root as suggested by Toda and Yamamoto (1995).

5. Conclusion and policy implications

This paper re-examines the relationship between financial development and CO_2 emissions by incorporating energy consumption and economic growth as additional factors in carbon emissions function. The study has covered the period of 1985-2014 using quarterly frequency data. For empirical purpose, we applied the ADF and FADF in order to determine the integrating properties of the variables to accommodate multiple structural breaks and nonlinearities in the time series. The asymmetric ARDL cointegration approach is applied to test the impact of positive and negative shocks in financial development, energy consumption and economic growth on CO_2 emissions. The symmetric and asymmetric causality association between the variables is examined by applying the asymmetric Granger causality.

On the basis of our empirical findings, we conclude that strong asymmetric cointegration exits between the variables i.e. financial development, energy consumption, economic growth and CO_2 emissions. Economic growth via positive shock affects CO_2 emissions positively. Energy consumption has positive asymmetric effect on CO_2 emissions through positive and negative shocks. Financial development in banking sector is also responsible for adding CO_2 emissions via positive shocks. The asymmetric causality explores the bidirectional symmetric causality between economic growth and CO_2 emissions. Energy consumption causes CO_2 emissions and in resulting, CO_2 emissions cause energy consumption in Granger sense. The unidirectional causality exists running from positive shock in bank-based financial development to CO_2 emissions.

Energy consumption is a dire need for any economy to grow and reduction in energy consumption is accompanied with decline in economic growth. To keep economy on development path, exploration of renewable energy sources should be on priority. The development of renewable energy sources may secure a country from foreign reliance to meet domestic energy needs, increase energy efficiency and secure the country form energy crisis, improve environmental quality (Halkos and Tzeremes, 2013). Furthermore, economic growth is positive linked with CO_2 emissions via positive shocks. This shows the negative consequence of economic growth in terms of environmental degradation. This environmental degradation may affect human health which decline productivity in long-run and hence affect pace of economic growth. This suggests adoption of energy efficient technology not only at production level but also at transportation level as well as at households level. The adoption of environment friendly technology would be helpful in improving the environmental quality that improves the productivity in long-run but also saves energy for the usage of future generations. Furthermore, for long-run economic development, plantation for trees instead of deforestation must be implemented on propriety basis which is also a great source of renewable energy sources like wind, hydro, solar can be used for the mitigation of emissions. A strong legislation should also be proposed for the imposition of carbon tax and for the use of minimum fuel efficient standard for vehicles.

We may note that efficient technology plays its dual role i.e. increase productivity for long-run economic growth and reduction in emissions to improve environmental quality. Financial development (bank-based) may help in purchasing such advanced and energy efficient technologies by the provision of financial resources at cheaper cost. Although, our empirical evidence suggests that bank-based financial development impedes environmental quality via positive shocks occurring in bank-based financial sector development. In this regard, financial system can also be developed with new instruments and regulations because it is concomitant for economic growth. For example, government should direct central bank of Pakistan for monitoring banking sector financial resource allocation mechanism. The banking sector should monitor the firms after the allocation of financial resources to ensure that credit is not allocated at the cost of environmental quality. If any firm is involved in increasing environmental degradation then it should be punished via reduction in tax holidays or increase in interest rate allocated loans. The government should encourage banking sector to investment in energy sector generally and renewable energy sector particularly. Banking sector should allocate financial resources for R&D for inventing energy efficient technologies and get patents for these technologies in obtaining life time profits rather than to waste financial resources in consumer financing i.e. car leasing or household items etc.

Reference

Abbasi, F. and Riaz, K. (2016). CO_2 emissions and financial development in an emerging economy: an augmented VAR approach. Energy Policy 90, 102-114.

Acaravci, A. and Ozturk, I. (2010). On the relationship between energy consumption, CO2 emissions and economic growth in Europe. Energy 35, 5412–5420.

Ahmed, K., Shahbaz, M., Qasim, A. and Long, W. (2015). The linkages between deforestation, energy and growth for environmental degradation in Pakistan. Ecological Indicators 49, 95-103.

Akbostanci, E., Asık, S.T., Tunc, G.I., 2009. The relationship between income and envi-ronment in Turkey: is there an environmental Kuznets curve? Energy Policy 37,861–867.

Aldy, J. E. (2005). An environmental Kuznets curve analysis of US state-level carbon dioxide emissions. Journal of Environment and Development 14, 48–72.

Al-Mulali, U., Ozturk, I. and Lean, H. H. (2016). The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. Natural Hazards, DOI 10.1007/s11069-015-1865-9

Apergis, N. and Ozturk, I. (2015). Testing the environmental Kuznets hypothesis in Asian countries. Ecological Indicators 52, 16–22.

Banerjee, A., Dolado, J. and Mestre, R. (1998). Error-correction mechanism tests for cointegration in a single-equation framework. Journal of Time Series Analysis 19, 267-283.

Bello, A, K. and Abimola, Q, M. (2010). Does the level of Economic Growth influence Environmental Quality in Nigeria: A test of environmental Kuznets curve (EKC) Hypothesis. Pakistan. Journal of Social Science 7, 325-329.

Boutabba, M.A. (2014). The impact of financial development, income, energy and trade on carbon emissions: Evidence from the Indian economy. Economic Modelling 40, 33-41.

Carson, R.T., 2010. The environmental Kuznets curve: seeking empirical regularity and theoretical structure. Review of Environmental and Economic Policy 4, 3–23.

Chang, S-C. (2015). Effects of financial developments and income on energy consumption. International Review of Economics & Finance 35, 28-44.

Charfeddine, L. and KhediriK, B. (2016). Financial development and environmental quality in UAE: Cointegration with structural breaks. Renewable and Sustainable Energy Reviews 55, 1322-1335.

Diwan, I. and Shafik, N. (1992). Investment, technology and the global environment: towards international agreement in a world of disparities. In: Low, P. (Ed.), International Trade and the Environment. World Bank, Washington, DC.

Dogan, E. and Turkekul, B. (2016). CO2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA. Environmental Science and Pollution Research, DOI 10.1007/s11356-015-5323-8

Enders, W. and Lee, J. (2012). A unit root test using a Fourier series to approximate smooth breaks. Oxford Bulletin of Economics and Statistics 74, 574-599.

Frankel, J. and Romer, D. (1999). Does trade cause growth? The American Economic Review 89, 379–399.

Gantman, E. R. and Dabós, M. P. (2012). A Fragile Link? A New Empirical Analysis of the Relationship between Financial Development and Economic Growth. Oxford Development Studies, 40 (4), 517-532.

Grossman, G. and Krueger, A. (1995). Economic environment and the economic growth. Quarterly Journal of Economics 110, 353–377.

Halkos, G. E. and Tzeremes, N. G. (2014). The effect of electricity consumption from renewable sources on countries′ economic growth levels: Evidence from advanced, emerging and developing economies. Renewable and Sustainable Energy Reviews 39, 166-173.

Hatemi-J, A. (2003). A new method to choose optimal lag order in stable and unstable VAR models. Applied Economics Letters 10, 135–137.

Hatemi-J, A. (2008) Forecasting properties of a new method to choose optimal lag order in stable and unstable VAR models. Applied Economics Letters 15, 239–243.

Hatemi-J, A. (2012). Asymmetric causality tests with an application. Empirical Economics 43, 447-456.

Iwata, H., Okada, K. and Samreth, S. (2010). Empirical study on the environmental Kuznets curve for CO2 in France: the role of nuclear energy. Energy Policy 38, 4057–4063.

Jalil, A. and Feridun, M. (2011). The impact of growth, energy and financial development on the environment in China: a cointegration analysis. Energy Economics 33, 284–291.

Javid, M. and Sharif, F. (2016). Environmental Kuznets curve and financial development in Pakistan. Renewable and Sustainable Energy Reviews 54, 406-414.

Jebli, M. B., Youssef, S. B. and Ozturk, I. (2016). Testing the environmental Kuznets curve hypothesis: the role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators 60, 824–831.

Karima, S. and Ken, H. (2008). Evidence on growth and financial development using principal components. Applied Financial Economics, 18 (19), 1549-1560.

Khan, M. A., Khan, M. Z., Zaman, K. and Arif, M. (2014). Global estimates of energy-growth nexus: Application of seemingly unrelated regressions. Renewable and Sustainable Energy Reviews 29, 63-71.

Lau, L-S., Choong, C-K. and Eng, Y-K. (2014). Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: Do foreign direct investment and trade matter? Energy Policy 68, 490-497.

Lee, J-M., Chen, K-H. and Cho, C-H. (2015). The relationship between CO_2 emissions and financial development: evidence from OECD countries. The Singapore Economic Review, Vol. 60, No. 5 1550117.

Liang, Q. and Jian-Zhou, T. (2010). Financial development and economic growth: Evidence from China. China Economic Review, 17 (4), 395-411.

MacKinnon, J. G. (1996). Numerical distribution functions for unit root and cointegration tests. Journal of Applied Econometrics 11, 601-18.

Masih, M., Al-Alg, A., Madani, H. (2009). Causality between financial development and economic growth: an application of vector error correction and variance decomposition methods to Saudi Arabia. Applied Economics, 41 (1), 1691-1699.

Meadows, D.H., Meadows, D.L., Randers, J. and Behrens, W. (1992). The limits to growth. Universe Books, New York.

Moomaw, W. R. and Unruh, G. C. (1997). Are environmental Kuznets curves misleading us? The case of CO2 emissions. Environment and Development Economics 2, 451–463.

Narayan, P. K. and Narayan, S. (2013). The short run relationship between the financial systems and economic growth: new evidence from regional panels. International Review of Financial Analysis 29, 70-78.

Nasir, M. and Rehman, F. U. (2011). Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. Energy Policy 39, 1857-64.

Omri, A., Daly, S., Rault, C. and Chaibi, A. (2015). Financial development, environmental quality, trade and economic growth: What causes what in MENA countries. Energy Economics 48, 242-252.

Ozturk, I. and Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Economics 36, 262-7.

Ozturk, I. and Al-Mulali. U. (2015). Investigating the validity of the environmental Kuznets curve hypothesis in Cambodia. Ecological Indicators 57, 324-330.

Pesaran, M. H., Shin, Y. and Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics 16, 289-326.

Polat, A., Shahbaz, M., Rehman, I. and Satti, S. L. (2015). Revisiting linkages between financial development, trade openness and economic growth in South Africa: fresh evidence from combined cointegration test. Quality and Quantity, 49 (2), 785-803.

Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies, Energy Policy, 38, 2528-2535

Salahuddin, M., Gow, J. and Ozturk, I. (2015). Is the long-run relationship between economic growth, electricity consumption, carbon dioxide emissions and financial development in Gulf Cooperation Council Countries robust? Renewable and Sustainable Energy Reviews, 51, 317–326.

Shahbaz, M. (2013). Does financial instability increase environmental degradation? fresh evidence from Pakistan. Economic Modelling 33, 537-544.

Shahbaz, M., Jam, F. A., Bibi, S. and Loganathan, N. (2016). Multivariate granger causality between CO2 emissions, energy intensity and economic growth in Portugal: evidence from cointegration and causality analysis. Technological and Economic Development of Economy, DOI: 10.3846/20294913.2014.989932

Shahbaz, M., Lean, H. H. and Shabbir, M. S. (2012). Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality. Renewable and Sustainable Energy Reviews 16, 2947–53.

Shahbaz, M., Solarin, S. A., Mahmood, H. and Arouri, M. (2013a). Does financial development reduce CO2 emissions in Malaysian economy? A time series analysis. Economic Modeling 35, 145-152.

Shahbaz, M., Tiwari, A. K. and Nasir, M. (2013b). The effects of financial development, economic growth, coal consumption and trade openness on CO2 emissions in South Africa. Energy Policy 61:1452-9.

Shin, Y., Yu, B. and Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in an ARDL framework. In: Horrace, W.C., Sickles, R.C. (Eds.), Festschrift in Honor of Peter Schmidt. Springer Science & Business Media, New York(NY).

Stern, D. I. (2004). The rise and fall of the Environmental Kuznets Curve. World Development 32, 1419–1438.

Tamazian, A. and Rao, B. B. (2010). Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. Energy Economics 32, 137–145.

Tamazian, A., Chousa, J. P. and Vadlamannati, C. (2009). Does higher economic and financial development lead to environmental degradation: evidence from the BRIC countries. Energy Policy 37, 246–253.

Tiwari, A.K., Shahbaz, M. and Hye, Q.M.A. (2013). The environmental Kuznets curve and the role of coal consumption in India: cointegration and causality analysis in an open economy. Renewable Sustainable and Energy Reviews 18, 519–527.

Toda, H. Y. and Yamamatoo, T. (1995). Statistical inference in vector autoregression with possibly integrated process. Journal of Econometrics 66, 225-250.

Tyavambiza, T. and Nyangara, D. (2015). Financial and Monetary Reforms and the Finance-Growth Relationship in Zimbabwe. International Journal of Economics and Financial Issues, 5 (2), 590-602.

Wang, H. and Jin, Y. (2007). Industrial ownership and environmental performance: evidence from China. Environmental and Resource Economics 36, 255–273.

Zhang, C. and Lin, Y. (2011). Panel estimation for urbanization, energy consumption and CO2 emissions: a regional analysis in China. Energy Policy 49, 488-98.

Zhang, Y.-J. (2011). The impact of financial development on carbon emissions: an empirical analysis in China. Energy Policy 39, 2197–2203.

Ziaei, S. M. (2015). Effects of financial development indicators on energy consumption and CO2 emissions of European, East Asian and Oceania countries. Renewable and Sustainable Energy Reviews 42, 752-759.