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Abstract

This paper is aimed at investigating the non-linear relationship between foreign direct investment (FDI) and environmental degradation for high-, middle- and low-income countries in a multivariate framework using economic growth and energy consumption as additional variables. Employing recent panel data unit root tests and cointegration techniques, we find that all variables are non-stationary and cointegrated. Long-run results estimated by applying fully modified ordinary least squares (FMOLS) suggest that environmental Kuznets curve exists and foreign direct investment increases environmental degradation i.e. pollution heaven hypothesis (PHH) validate. Moreover, bidirectional causality between CO_2 emissions and FDI is observed in global panel. The findings are sensitive with different income groups and regional analysis. These empirical insights are of particular interest to policymakers as they help build sound economic policies to improve the environmental quality and sustain economic development.

Keywords: FDI, Economic Growth, Environment

1. Introduction

Foreign direct investment (FDI) essentially does three important things to host country economy; one it boosts country's development efforts (Alfaro, 2003), second, it is a source of external capital (Bustos, 2007) and third fills the gap between targeted investment and domestic savings (Bosworth et al., 1999). Furthermore, FDI help in reducing the gap between foreign exchange requirements and net exports earnings (Ndikumana and Verick, 2008). Indeed, FDI may provide direct capital financing, generate positive externalities, and consequently stimulate economic growth through technology transfer, spillover effects, productivity gains, and the introduction of new processes and managerial skills (Lee, 2013). Beside these important functions, FDI also helps in developing technical skills mix and process of learning in innovative ways. More importantly in the recipient country, FDI develops local enterprise opportunities and thus encourages employment opportunities for skilled and unskilled labor (Omri and Kahouli, 2014a). FDI promote growth activities in an economy but at a cost of impact the environment (Xing and Kolstad, 2002, He, 2006). This is due to the fact that the governments of developing countries have a tendency to undermine environmental concerns through relaxed or non-enforced regulation, which is termed as *pollution haven hypothesis* (Copeland and Taylor, 1994, Cole, 2004). Also, firms more likely to translocate their production in favor of those countries that are ignoring to environmental regulations and taking full advantage of reduced production costs which is called *industrial flight hypothesis* (Asghari, 2013). Either providing a relaxed regulatory environment or providing more production opportunities at the cost of environment lead to excessive pollution and degradation in environmental standard of the host countries. Contrary to this believe, foreign companies work under better management practices and up to date technologies that result in a relatively clean environment in the host countries (Zarsky, 1999). This is known as *pollution halo hypothesis*. The evidence from those studies that support *pollution haven hypothesis* does not support general industrial flight hypothesis rather claims that environmental regulations provide guidance to firms' locational decisions, especially in resource and severely polluted sectors (Lu et al. 2008). Empirical literature also provides evidence of *pollution halo hypothesis* in sectors that are energy intensive and having technological base (Blackman and Wu 1998, BIAC 1999)

Bourgeoning environmental concerns during the process of rapid industrialization has generated an intense debate on the links between economic growth and the environment. The linkage of environmental quality with economic growth induced much discussion in last decade or two. Empirical evidence (see inter-alia; Grossman and Krueger, 1991; Rothman, 1998; Selden and song, 1994) reinforced an inverted U-shaped relationship between environmental degradation and economic growth. All of these studies supported the hypothesis that environmental degradation curve moves upward initially, reaches to maximum point and start moving downward as economy develops further. This systematic inverted-U shaped relationship has been termed as Environmental Kuznets Curve (EKC). FDI affects economic growth and hence energy consumption (Sbia et al. 2014). Also, FDI lowers energy demand if foreigners adopt advanced technology for production process otherwise FDI increases host economy's demand for energy. Empirical literature also exists that linked increase in per capita income or energy demand due to FDI and its relation with CO_2 emissions (Shahbaz and Leitão, 2012; Shahbaz et al. 2013; and Omri and Kahouli, 2014b).

Due to the opening up of world economies in the late 1980s and due to economic and social reforms FDI inflows and the resultant economic growth, energy consumption and CO_2 emissions has moved erratically upward. For example, the amount of average annual global per capita FDI was US$ 7.74 in the early 1980s and this amount reached to US$ 126.37 during 1996-2000. This massive increase was due to acknowledgment of the benefits that effective outsourcing and international production strategies can possibly provide to host economy. However, the amount of average annual per capita FDI has been reduced and estimated at US$204.12, 23% less than the amount estimated for the period 2006-10because of global financial crisis (see Table-1). The average annual global per capita GDP has increased from US$1986.14 to US$8579.57 during the period between 1976-80 and 2006-10 respectively and further increased to US$10159.36 for the year 2010-11. This unprecedented growth in per capita income globally has increased the demand for energy consumption. The world average energy consumption was 1547.50 Kg of oil equivalent per capita in 1976-80 while the amount increased to 1917.98 Kg of oil equivalent per capita in year 2010-11. The enormous economic growth and demand for energy has increased the problem of environmental pollution. For example, the average annual per capita CO_2 emissions has increased from 4.36 metric tons in 1976-80 to 4.89 metric tons in 2010-11 (see Table-1). Recent numbers showed clearly that in the past two decades, FDI from developing countries has increased, especially in middle and low income countries. While FDI in high-income countries, is more likely to take advantage of assets such as technologies and intellectual property (Zeng and Eastin, 2012). The contemporary situation is a challenging one for global FDI. Particularly with political instability in the Middle East, global oil price crises, financial market crises in Europe and several natural disasters led many investors to hold their investments in Asia Pacific, Middle East and European regions. Foreign investments leading to sharp increase in environmental pollution North America, Latin America countries such and Brazil, Russia, India, China and South Africa.

Table 1

Trends in Global FDI, GDP, CO_2 Emissions and Energy Consumption.

Year	Per capita FDI (US $)	Per capita GDP (US $)	Per capita CO_2 emissions (metric tons)	Per capita energy consumption
1976-1980	7.74	1986.14	4.36	1547.50
1981-1985	12.03	2493.59	4.06	1399.25
1986-1990	29.28	3596.67	4.20	1496.09
1991-1995	38.61	4674.34	4.09	1622.66
1996-2000	126.37	5205.36	4.08	1632.43
2001-2005	126.96	6023.82	4.30	1704.22
2006-2010	265.76	8579.57	4.75	1826.33
2010-2011	204.12	10159.36	4.89	1917.98

Source: world development indicators (CD-ROM, 2012)

Therefore, this paper contributes to the empirical energy economics literature by investigating the non-linear relationship between FDI, economic growth, energy consumption and CO_2 emissions for a global panel consisting of 99 countries for the period of 1975-2012. This study covers the period of 1975-2012 of 99 high, middle and low income countries. We apply panel unit root tests and panel cointegration approaches for stationarity properties of the variables and long run relationship between the variables. The Fully Modified Ordinary Least squares (FMOLS) are applied and direction of causality between the variables is also investigated by applying the Dumitrescu and Hurlin (2012) causality tests. We also consider three homogeneous subpanels which are constructed based on the income level of sample countries (high-, middle-, and low-income subpanels).

Our results show that environmental Kuznets curve is validated, that is inverted U-shaped curve termed as *pollution heaven hypothesis* (PHH). Economic growth and energy consumption add in CO_2 emissions.

The algorithm of the article is as such: section 2 briefly reviews the related literature, followed by section 3 that is going to outline the model construction and the econometric methodology, section 4 depicts the empirical findings and the final section, being section 5, holds the concluding annotations and offers some policy implications.

2. Literature Review

The role of FDI and economic growth on environment sustainability is debatable and remains contentious across globe with contradictory empirical results. Furthermore, number of studies provided theoretical rational of the impact of FDI on economic growth (for example, Lucas, 1988; Rebelo, 1991; Romer, 1986, 1993). For instance, Romer (1993) pointed out that FDI can be an important source for transferring technological and business knowledge to host countries and the transfer of technology may have substantial positive spillover effects. On the contrary, theoretical literature predicts that FDI in the presence of existing liberalization; deregulation and privatization policies hurt resource allocations and thus slow down the process of growth (Boyd and Smith, 1992). The theoretical line of inquiry in this regard also pin points about the success of countries in utilizing FDI for better and progressive economy at the cost of environmental degradation. For example, Grossman and Krueger (1995) have shown that environmental pollution increases with economic growth but start to decline when income growth reaches at certain threshold level. This phenomena is known as environmental Kuznets curve (EKC) hypothesis. The range of income level indicates the threshold point where the environmental pollution start to decline was formally said to be $4000-$8000 (Grossman and Krueger, 1995). In this context, there is a wide literature that explored the relationship between economic growth and CO_2 emissions employing environmental Kuznets curve (EKC) hypothesis. Stern (2004) provided the empirical support to EKC with the evidence that initially environmental degradation is increased and then falls with an increase in per capita income.

Several studies emphasized that foreign investors prefer to invest in countries where environmental regulations are compromised (Smarzynska and Wei, 2001; Copeland and Taylor 2003) and this helps in the deterioration of environmental quality. On contrary, Porter and van der Linde (1995) argued that environmental quality is a normal good, meaning as economic growth takes off with foreign inflows; countries tend to adopt more strict environmental regulations for cleaner and better environmental quality. Various studies investigated the following relationships: i) FDI and economic growth; ii) FDI and environment; iii) economic growth and environment and iv) FDI, economic growth and environment using country level and/or cross-country and time-series data. Various non-linear and linear parametric and semi parametric and non-parametric models have been employed for examining these relationships. However, empirical evidence is contrary. For instance, Alfaro (2003) examined the effect of FDI on economic growth of primary, manufacturing and services sector in a cross-country setting and remained unable to establish any clear relationship. Herzer et al. (2008) examined FDI–led growth hypothesis for 28 developing countries and neither long run nor short run relationship between FDI and economic growth in most of the countries analyzed. Moreover, causality analysis could not provide clear evidence on direction of causality.

Grimes and Kentor, (2003) argued that heavy dependence on FDI contributes to the growth of carbon dioxide emissions in less developed economies globally. However, domestic investment has no significant effect on CO_2 emissions. Furthermore, the study also suggested that FDI is more concentrated in energy intensive industries because of relaxed environmental laws. Haffmann et al. (2005) tested the direction of causality between FDI and environmental pollution in low, middle and high-income countries globally. The results of panel causality test indicated that unidirectional causality is running from FDI to energy emissions in middle-income countries while CO_2 emissions Granger cause FDI in low-income countries and no relationship exists between both the variables in high-income countries which imply the rejection of pollution haven hypothesis. Aliyu (2005) revisited the relationship between FDI and environment using panel data regression in case of OECD and non-OECD countries. Their results revealed that foreign outflows have positive effect on environmental policy (quality) while foreign inflows do not explain their role in explaining energy consumption and environmental pollution in non-OECD countries. In case of China, Zhang (2008) used regional data to analyze the impact of FDI and governance on environmental pollution (i.e. pollution haven hypothesis) and on CO_2 emissions across Chinese cities. The findings showed that intra-country pollution haven hypothesis (PHH) is validated in China and improvements in governance do effect on environment regulations while economic growth is positively linked with environmental degradation[1]. Bao et al. (2011) probed the relationship between FDI and energy emissions using data of 25 provinces of China. They decomposed the effect of FDI on both overall regional emersions into scale, technique and composite effects. Their results indicated that a rise in FDI is linked with a decline in energy emissions through technique effect but effect varies in different regions of China[2]. On contrary, Lan et al. (2012) reinvestigated the impact of FDI and human capital on environmental pollution and concluded that the effect of FDI on environment is highly sensitive to the level of human capital stock while FDI is inversely associated with emissions where human capital is highly qualified which validates pollution haven hypothesis (PHH). In case of Taiwan, Chang and Wang (2009) investigated the relationship between FDI, economic development and energy pollutants under various population intensity regimes using threshold effect approach. The results supported the threshold effect of FDI and economic development on CO_2 emissions and asymmetric nonlinear association between the variables. In addition, a rise in FDI is negatively linked with environmental degradation to certain urbanization level. Beak and Koo (2009) investigated the interrelationship between FDI, economic growth and energy emissions in China and India. They found a positive and significant impact of FDI on energy consumption in China. Whereas, in India, FDI deteriorates environment in the short-run while negative and insignificant effect of FDI on energy emissions are reported in long run. Moreover, empirical evidence showed positive impact of economic growth on CO_2 emissions indicating that

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[1] Liang (2006) also found inverse effect of foreign direct investment on air pollution in China.

[2] Cole et al. (2011) used data 112 cities of China to investigate the causal relation between economic growth and industrial pollution and concluded that economic growth is positively linked with industrial pollution.

economic growth worsens the environmental quality[3]. Beak et al. (2009) investigated the relationship between economic growth and environment by incorporating trade openness. Their results showed inverse impact of economic growth and trade openness on CO_2 emissions in developed countries and opposite in developing countries[4].

Lee (2010) investigated the link between economic growth, FDI and energy pollutants in case of Malaysia. The results indicated long run relationship between the variables when FDI is taken as dependent variable. The causality analysis showed unidirectional Granger causality running from FDI to economic growth, energy emissions to economic growth, FDI to energy pollutants in short run and economic growth Granger causes FDI in the long run. In case of transition economies[5], Tamazian and Rao (2010) used FDI as a financial variable to test its effect on CO_2 emissions[6] and the empirical evidence validated environmental Kuznets curve (EKC) and these findings are consistent with Tamazian et al. (2009) that FDI improves environmental quality due to the use of energy efficient technology. Mulatu et al. (2010) investigated the relationship between industry location and environmental degradation by incorporating agriculture, education and research and development characteristics of countries using data of European countries. Their empirical exercise validated the presence of pollution heaven hypothesis in 13 out of 16 countries.

Pao and Tsai (2011) investigated the effect of economic growth and FDI on environmental degradation using data of BRIC (Brazil, Russia, India and China) countries by applying panel cointegration. The estimated results confirmed the long run relationship between the variables and provided support for the existence of environmental Kuznets curve (EKC). Moreover, causality analysis indicated bidirectional causal relationship between FDI and energy pollutants, and economic growth Granger causes foreign direct investment. Hence, this confirmed the existence of pollution haven and both pollution haloes and scale effects. Kim and Beak (2011) tested the environmental consequences of economic growth using the ARDL bounds testing approach. Their results indicated that economic growth lowers the growth of CO_2 emissions in developed world whereas the environmental quality is deteriorated during economic growth process in developing economies. Moreover, a rising demand for energy is a major contributor to energy emissions and FDI has minimal effect on CO_2 emissions. Cole et al. (2011) used 112 Chinese cities data to investigate the relationship between economic growth, FDI and CO_2 emissions. Their empirical results support for the presence of inverted-U relationship between income per capita and CO_2 emissions per capita. Leiter et al. (2011) explored the relationship between environmental regulation and investment using the European industry data. Their analysis revealed that environmental regulations increase investment in European countries. Hsiao and Shen (2003) had reported the influence of economic growth as one of the important factors attracting FDI in developing countries. In long run, FDI from both private and

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[3] Acharyya (2009) reinvestigated the effects of economic growth and foreign direct investment on CO_2 emissions in India. The results of the study showed larger impact of foreign direct investment on energy emissions is larger in long run due to economic activities.

[4] Shahbaz et al. (2012) reported the negative impact of trade openness on CO_2 emissions in Pakistan.

[5] Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Macedonia FYR, Moldova, Poland, Romania, Russian Federation, Slovak Republic, Slovenia, Tajikistan, Ukraine, Uzbekistan.

[6] Although, focus of Tamazian and Rao (2010) was to investigate the effect of institutional and financial development on environmental degradation in case of transitional economies.

business investors provides access to financial market and expands demand for energy which reflects on environmental sustainability (Lee and Brahmasrene, 2013).

Al-mulali and Tang (2013) investigated the validity of pollution heaven hypothesis using data of Gulf Corporation countries (GCC) applying panel cointegration and causality approaches. Their results indicated that FDI lowers CO_2 emissions but energy consumption and economic growth increase it. The causality results exposed the neutral effect between FDI and CO_2 emissions. Wang et al. (2013) noted the role of local institutions in FDI-environment relationship using data of 287 cities of China. They reported that FDI increases domestic production via increase in labor productivity and innovation but also increases unemployment as well as CO_2 emissions in China. Khan et al. (2014) using panel estimation techniques has explored the dynamic linkages between energy consumption, economic growth and FDI, relative price and financial development for low, middle, high income non OECD, high income OECD, South Africa and Middle East and North Africa (MENA) countries using seemingly unrelated regression (SUR). The findings indicated that, FDI plays an important role in increasing energy demand for middle-income, high- income OECD and non-OECD countries. This is not a surprising result, because FDI is the key stimulating factor for continuous economic growth for most middle and low income countries worldwide (Cole et al. 2011; Pao and Tsai, 2011). The existing literature shows that there is no comprehensive study that has analyzed the relationship between FDI and economic growth and, FDI and CO_2 emissions using global level data. Table-2 reports the summary of literature review. Omri et al. (2014) investigated the interrelationships between environmental degradation, FDI and economic for three regional sub-panels (Europe and Central Asia, Latin America and the Caribbean, and the Middle East, North Africa, and sub-Saharan Africa) and their empirical findings provide evidence of bidirectional causality between FDI and economic growth for all the panels and between FDI and CO_2 for all the panels, except Europe and North Asia. They also indicate the existence of unidirectional causality running from CO_2 emissions to economic growth, with the exception of the Middle East, North Africa, and sub-Sahara panel, for which bidirectional causality between these variables cannot be rejected.

Table 2
Summary of Literature Review.

Authors	Time Period	Methodology	Countries	Result
Economic Growth and CO_2 Emissions				
Grossman and Krueger (1995)	1977,82,88	Reduced from regression	32 countries	Inverse U-shaped relationship between economic growth and environment
Holtz-Eakin and Selden (1995)	1951-1986	Quadratic and Cubic polynomial functional forms	130 countries	Linear relationship between economic growth and environment
de Bruyn, van den Bergh and Opschoor (1998)	1960-1993	Linear logarithmic model	Netherlands, United Kingdom, United States and west Germany	Linear relationship between economic growth and environment
Panayotou, Sachs, and Peterson (1999)	1960-1992	Spline regression	150 countries	Inverse U-shaped relationship between economic growth and environment

Martinez-Zarzoso and Bengochea-Maranco (2004)	1975-1998	Pooled mean group estimation	22 OECD countries	N-shaped relationship between economic growth and environment
Galeotti, Manera and Lanza (2006)	1960-2002	Panel Cointegration	24 countries	Inverse U-shaped relationship between economic growth and environment
Economic Growth and FDI				
Borensztein et al. (1998)	1970-89	Cross-country regression analysis	69 developing countries	Positive effect of FDI on economic growth
Alfaro (2003)	1985-99	OLS with White's correction of heteroskedasticity	47 countries	No clear evidence between FDI and economic growth
Grimes and Kentor, (2003)	1980-96	Panel data regression analysis	66 less developed countries	Positive effect of FDI on CO_2 emissions
Bengoa et al. (2003)	1970-99	Panel data regression analysis	18 Latin American countries	Positive effect of FDI on economic growth
Choe (2003)	1971-95	Panel VAR model	80 countries	Bidirectional causality between economic growth and FDI
Li and Liu (2005)	1970-99	single equation and simultaneous equation system techniques	84 countries	Positive effect of FDI on economic growth
Omri (2013)	1990-11	Simultaneous-equation models	14 MENA countries	Bidirectional causality between CO_2 emissions and economic growth
Economic Growth, FDI and CO_2 Emissions				
Haffmann et al. (2005)	1990-2001	Hurlin and Venet panel causality test	112 countries	Unidirectional causality running from FDI to CO_2 emissions
Aliyu (2005)	1990-00	Panel data regression analysis	11 OECD countries and 14 Non-OECD countries	Positive effect of FDI on CO_2 emissions in OECD countries
Zhang (2008)	1998-02	GMM and FGLS regression	30 Chinese regions	Positive effect of FDI on economic growth and support the existence of intra-country pollution haven hypothesis
Beak and Koo (2009)	1978-07	ARDL	China and India	Positive effect of economic growth and FDI on CO_2 emissions
Lee (2010)	1970-00	ARDL, Granger causality	Malaysia	Unidirectional causality running from FDI and CO_2 emissions to economic growth
Bao et al. (2011)	1992-04	simultaneous equations technique	29 Chinese provinces	Inverted U-shaped relationship between FDI and pollutants emissions have mixed effect on income growth
Pao and Tsai (2011)	1992-07	Granger causality test	BRIC countries	Bidirectional causality between FDI and CO_2 emissions, and

				unidirectional causality from economic growth FDI
Asghari (2013)	1980-11	Random effect and Fixed effect model	MENA region	Positive effect economic growth on CO_2 emissions and negative effect of FDI on CO_2 emissions
Lee (2013)	1971-09	Panel cointegration	G20 countries	Unidirectional causality from FDI to economic growth and FDI to CO_2 emissions
Omri et al., (2014)	1990-11	Simultaneous-equation models	54 countries	economic growth and FDI has positive impact on CO2 emissions
Economic Growth, FDI, Energy Consumption and CO_2 Emissions				
Tamazian and Rao (2010)	1993-04	GMM estimation technique	24 transition economies	Positive effect of economic growth and energy consumption on CO_2 emissions while negative effect of FDI on CO_2 emissions
He et al. (2012)	1985-10	Multivariate VAR model	China	unidirectional Granger causality from GDP to energy use and foreign direct investment, and a unidirectional Granger causality from energy consumption to FDI
Linh and Lin (2012)	1980-10	Cointegration and Granger causality test	Vietnam	Positive effect of economic growth and energy consumption on CO_2 emissions while negative effect of FDI on CO_2 emissions, Unidirectional causality from CO_2 emissions to FDI
Khan et al. (2014)	1975-11	Non-OECD, OECD, South African and MENA countries	Panel Cointegration and SUR Method	Positive effect of FDI and economic growth on energy consumption

3. Model Construction and Econometric Methodology

The review of relevant literature allows constructing an algebraic model given below for empirical investigation:

$$\ln C_{it} = \alpha_1 + \alpha_2 \ln F_{it} + \alpha_3 \ln Y_{it} + \alpha_4 \ln E_{it} + \mu_i \qquad (1)$$

$\alpha's$ are regression coefficients. We have used per capita carbon dioxide emissions (in metric tons) to measure environmental degradation (C_{it}) and per capita FDI inflow ($ USD) to measure FDI. The level of country's economic growth (Y_{it}) is measured by per capita GDP ($ USD) while the use of energy (E_{it}) is measured by per capita energy consumption (kt of oil equivalent). To investigate the monotonic effect of FDI on carbon emissions, the following model will be used for empirical investigation:

$$\ln C_{it} = \beta_1 + \beta_2 \ln F_{it} + \beta_3 \ln F_{it}^2 + \beta_4 \ln Y_{it} + \beta_5 \ln E_{it} + \mu_{iT} \qquad (2)$$

$\beta's$ are regression coefficients. The linear and non-linear terms of per capita FDI (F_{it} & F_{it}^2) have been included in the model to validate the existence of Environmental Kuznets curve (EKC). The EKC implies that the flow of FDI initially deteriorates environmental quality but later on environmental quality start to improve when FDI reached at a certain level. The expected signs are $\beta_2 > 0$ and $\beta_3 < 0$. On contrary, the signs would be $\beta_2 > 0$ and $\beta_3 > 0$, if foreign investors find relax regarding environmental laws, then they enhance their production at the cost of environment. The other explanatory variables are economic growth (Y_{it}) and energy consumption (E_{it}) and the justification for the inclusion of these variables are that rise in economic growth leads energy consumption which increases environmental pollution. We expect $\beta_4 > 0$ and $\beta_5 > 0$.

The above mentioned model is investigated using panel data set consisting of 99 heterogonous (high, middle and low income) economies of the globe over the period 1975-2012[7]. We have collected data on CO_2 emissions (metric tons), energy consumption (kt of oil equivalent), FDI ($ USD) and GDP ($ USD) from "World Development Indicators" (CD-ROM, 2013) by World Bank. The population series is used to transform variables into per capita units.

3.1. Panel Unit Root Tests

Two panel unit root tests: Im, Pesaran and Shin (IPS, 2003) and Pesaran (2007) are employed to check the stationary properties of the variables. The IPS test assumes cross-sectional independence. However, this assumption is likely to be violated for FDI and GDP variables[8]. Pesaran (2007) panel unit root test relaxes this assumption and is applicable in the presence of cross-sectional dependence. The procedure involved in computing both these tests are provided in Appendix-A1.

3.2. Panel Cointegration Tests

Advance panel cointegration tests can be expected to have high power than the traditional tests. The tests applied for long-run examination are developed by Pedroni (1997, 1999, 2004) and Maddala and Wu (1999). Pedroni (1999) uses the following cointegration equation:

$$x_{i,t} = \alpha_i + \rho_i t + \beta_{1i} Z_{1i,t} \ldots\ldots\ldots\ldots\ldots \beta_{mi} Z_{mi,t} + \mu_{i,t} \qquad (3)$$

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[7] See Table-7 for selected sample countries.

[8] Countries depends upon each other to enhance economic growth and to get benefit of FDI

where x and Z are assumed to be integrated of order one. The specific intercept term α_i and slope coefficients $\beta_{1i}, \beta_{2i}, ..., \beta_{mi}$ vary across individual member of the panel. Pedroni (1999, 2004) proposed seven different statistics to test for cointegration relationship in heterogeneous panels. In the presence of cross-sectional dependence, Pedroni suggests to include common time dummies to eliminate this effect. The seven test statistics of Pedroni are classified into within dimension and between dimensions statistics. Within dimension statistics are referred to as panel cointegration statistics, while between dimension statistics are called group mean panel cointegration statistics. The procedure involved in computing these seven statistics are provided in Appendix-A2. All statistics test the null hypothesis of no cointegration as: $H_0 : \rho_i = 1 \quad for\ all\ i = 1, 2, ..., N$. Alternative hypothesis for between dimension and within dimension for panel cointegration is different. The alternative hypothesis for between dimension statistics is $H_a : \rho_i < 1 \quad for\ all\ i = 1, 2, ..., N$, where a common value for $\rho_i = \rho$ is not required. The alternative hypothesis for within dimension based statistics is $H_a : \rho_i = \rho < 1 \quad for\ all\ i = 1, 2, ..., N$.

Maddala and Wu (1999) proposed a Fisher cointegration test based on the multivariate framework of Johansen (1988). Johansen (1988) proposed two different approaches, one of them is the likelihood ratio trace statistics and the other one is the maximum eigenvalue statistics, to determine the presence of cointegrating vectors in the non-stationary time-series. The trace statistics and maximum eigenvalue statistics are following:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \tag{4}$$

$$\lambda_{trace}(r, r+1) = -T \ln(1 - \hat{\lambda}_i) \tag{5}$$

Here T= sample size, n = 4 variables CO$_2$ emissions, FDI, economic growth and energy consumption. Trace test statistics tests the null hypothesis of at most r cointegrating vector against the alternative hypothesis of full rank r = n cointegrating vector. The null and alternative hypothesis of maximum eigenvalue statistics is to check the *r* cointegrating vectors against the alternative hypothesis of *r + 1* of cointegrating vectors. Maddala and Wu (1999) proposed an alternative test to the previous two tests of Johansen for testing cointegration in the full panel by combining individuals' cross-section tests for cointegration. If π_i is the P-value from an individual cointegration test for cross-section *i*, under the null hypothesis, the test statistics for whole panel is given as following:

$$-2\sum_{i=1}^{n} \log(\pi) \chi^2_{2n} \tag{6}$$

The advantage of this test is that it can be applicable for both balanced and unbalanced panels.

3.3. Estimation of Panel Cointegration Regression

The OLS estimators do not give efficient estimates in the presence of unique order of integration of the variables. To solve this problem, FMOLS developed by Pedroni (2000, 2001) is applied to calculate the values of long-run estimates. The FMOLS technique generates consistent estimates in small samples and does not suffer from large size distortions in the presence of endogeneity and heterogeneous dynamics. The panel FMOLS estimate equation (1) and $y_{it} = y_{i,t-1} + e_{it}$. The innovating vector $\omega_{it} = (\mu_{it}, e_{it})'$ is I(0) with asymptotic long-run covariance vector $\Omega_i = \begin{bmatrix} \Omega_{11i} & \Omega_{12i} \\ \Omega_{21i} & \Omega_{22i} \end{bmatrix}$ and auto covariances Γ_i, and $x_{it} = (y_{it}, z_{it})$ is I(1) and y_{it}, z_{it} are cointegrated. The panel FMOLS estimators for the coefficient β is defined as:

$$\hat{\beta} = N^{-1} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} y_{it} - \bar{y} \right)^{-1} \left(\sum_{t=1}^{T} y_{it} - \bar{y} \right) z_{it}^{*} - T\hat{\eta}_i \tag{7}$$

Where $z_{it}^{*} = (z_{it} - \bar{z}) - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \Delta y_{it}$, $\hat{\eta}_i \equiv \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} (\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^{0})$ and $\hat{L}_i$ is a lower triangular decomposition of $\hat{\Omega}_i$.[9]

3.4. Panel Causality Test

To test causality, we employ the panel causality test developed by Dumitrescu and Hurlin (2012). This test is a simplified version of Granger (1969) non-causality test for heterogeneous panel data models with fixed coefficients. Also it take into account the two dimensions of heterogeneity: the heterogeneity of regression model used to test the Granger causality and the heterogeneity of the causality relationships. We consider the following linear model:

$$z_{it} = \alpha_i + \sum_{m=1}^{M} \gamma_i^{(m)} z_{i,t-m} + \sum_{m=1}^{M} \beta_i^{(m)} y_{i,t-k} + \varepsilon_{it} \tag{8}$$

In above equation, y and z are two stationary variables observed for N individuals in T periods. $\beta_i = (\beta_i^{(1)}, \ldots\ldots, \beta_i^{(m)})'$ and the intercept term α_i are assumed to be fixed in the time dimension. We allow the autoregressive parameter $\gamma_i^{(m)}$ and the regression coefficients $\beta_i^{(m)}$ to be varied across cross-sections. Under the null hypothesis, we assume that there is no causality relationship for any of the cross-section of the panel. This assumption is called the Homogenous Non-Causality (HNC) hypothesis, which is defined as:

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[9] The associated t-statistics gives: $t_{\hat{\beta}^*} = N^{-1/2} \sum_{i=1}^{N} t_{\hat{\beta}^*,i}$ Where $t_{\hat{\beta}^*,i} = \left(\hat{\beta}_i^{*} - \beta_0 \right) \left[\hat{\Omega}_{11i}^{-1} \sum_{t=1}^{T} (y_{it} - \bar{y})^2 \right]^{1/2}$

$H_0 : \beta_i = 0 \qquad \forall_i = 1, 2, ..., N$

The alternative hypothesis is called as Heterogeneous Non-Causality (HENC) hypothesis. Two sub-group of cross-section units are specified under this hypothesis. There is causality relationship from *y* to *z* for the first one, but it is not necessarily based on the same regression model. For the second sub-group, there is no causality relationship from *y* to *z*. We consider a heterogeneous panel data model with fixed coefficient in this group. The alternative hypothesis is as follows:

$H_a : \beta_i = 0 \qquad \forall_i = 1, 2, ..., N_1$
$\beta_i \neq 0 \qquad \forall_i = N_1 + 1, ..., N$

We assume that β_i may vary across cross sections and there are N_1< N individuals processes with no causality from y to z. N_1 is unknown but it provides the condition $0 \le N_1 / N < 1$. We propose the average statistics $W_{N,T}^{HNC}$, which is related with the Homogenous Non-Causality (HNC) hypothesis, as follows:

$$W_{N.T}^{HNC} = \frac{1}{N} \sum_{i=1}^{N} W_{i,T} \qquad (9)$$

Under the null hypothesis of non-causality, each individual Wald statistic converges to chi-squared distribution with M degree of freedom for $T \to \infty$. The standardized test statistics $Z_{N,T}^{HNC}$ for $T, N \to \infty$ is as follows:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2M}} (W_{N,T}^{HNC} - M) \to N(0,1) \qquad (10)$$

In (10) $W_{N,T}^{HNC} = (1/N) \sum_{1=1}^{N} W_{i,T}$. Further information about these statistics can be found in the study of Dumitrescu and Hurlin (2012).

IV. Empirical Results

Primarily, two panel unit root tests tests such as IPS and CADF are applied at level and first difference form to check the integrated properties of the variables. Estimated results reported in Table (3-6) show that each selected series is non-stationary in its level form and stationary in its first difference form with only intercept and with both intercept and trend in high, medium and low income panels as well as global panel. On the basis of these result, we may conclude that all selected variables ($(\ln C_{it}, \ln F_{it}, \ln F_{it}^2, \ln Y_{it}, \ln EN_{it})$ are stationary at first difference.

Table 3
Panel Unit Root Analysis for Global Panel.

Variables	**At level**				**At 1^{st} Difference**			
	Drift & No Trend	P-value	Drift & Trend	P-value	Drift & No Trend	P-value	Drift & Trend	P-value
IPS Unit Root Test								
$\ln C_{it}$	3.193	0.999	3.838	0.999	-16.528	0.000	-13.183	0.000
$\ln F_{it}$	1.417	0.921	0.204	0.581	-29.700	0.000	-24.869	0.000
$\ln F_{it}^{2}$	2.051	0.979	0.542	0.706	-28.873	0.000	-24.257	0.000
$\ln Y_{it}$	8.012	1.000	1.325	0.907	-18.523	0.000	-14.122	0.000
$\ln EN_{it}$	3.539	0.999	3.770	0.999	-17.387	0.000	-14.797	0.000
CADF Unit Root Test								
$\ln C_{it}$	-1.679	0.832	-1.941	1.000	-3.046	0.000	-3.288	0.000
$\ln F_{it}$	-1.500	0.998	-1.669	1.000	-4.115	0.000	-4.138	0.000
$\ln F_{it}^{2}$	-1.870	0.146	-2.081	0.998	-3.905	0.000	-3.958	0.000
$\ln Y_{it}$	-1.661	0.876	-2.169	0.966	-3.012	0.000	-3.100	0.000
$\ln EN_{it}$	-1.606	0.959	-1.717	1.000	-2.835	0.000	-3.158	0.000

Table 4
Panel Unit Root Analysis for High Income Panel.

Variables	**At level**				**At 1^{st} Difference**			
	Drift & no Trend	P-value	Drift & Trend	P-value	Drift & no Trend	P-value	Drift & Trend	P-value
IPS Unit Root Test								
$\ln C_{it}$	2.946	0.998	6.653	1.000	-11.339	0.000	-10.044	0.000
$\ln F_{it}$	-0.977	0.164	-0.176	0.430	-16.914	0.000	-14.034	0.000
$\ln F_{it}^{2}$	1.573	0.942	-0.244	0.403	-16.491	0.000	-13.848	0.000
$\ln Y_{it}$	2.093	0.982	-0.940	0.173	-10.579	0.000	-7.645	0.000
$\ln EN_{it}$	-0.582	0.280	3.185	0.999	-14.028	0.000	-11.996	0.000
CADF Unit Root Test								
$\ln C_{it}$	-1.598	0.860	-2.124	0.927	-4.181	0.000	-4.441	0.000
$\ln F_{it}$	-1.869	0.266	-1.956	0.995	-5.343	0.000	-5.430	0.000
$\ln F_{it}^{2}$	-1.962	0.114	-2.116	0.934	-5.223	0.000	-5.311	0.000
$\ln Y_{it}$	-1.831	0.351	-1.773	1.000	-3.620	0.000	-3.918	0.000
$\ln EN_{it}$	-1.592	0.917	-2.039	0.992	-3.834	0.000	-4.026	0.000

Table 5
Panel Unit Root Analysis for Middle-income Panel.

Variables	**At level**				**At 1^{st} Difference**			
	Drift & no	P-value	Drift &	P-value	Drift & no	P-value	Drift &	P-value

	Trend		Trend		Trend		Trend	
IPS Unit Root Test								
$\ln C_{it}$	3.488	0.999	5.636	1.000	-9.895	0.000	-6.351	0.000
$\ln F_{it}$	-0.655	0.256	1.531	0.937	-14.813	0.000	-11.176	0.000
$\ln F_{it}^2$	-0.492	0.311	-0.605	0.272	-17.049	0.000	-13.372	0.000
$\ln Y_{it}$	-0.842	0.199	1.753	0.960	-11.290	0.000	-7.613	0.000
$\ln EN_{it}$	5.745	1.000	4.563	1.000	-9.109	0.000	-6.540	0.000
CADF Unit Root Test								
$\ln C_{it}$	-1.821	0.346	-2.306	0.580	-4.212	0.000	-4.386	0.000
$\ln F_{it}$	-1.772	0.494	-2.144	0.938	-2.759	0.000	-4.047	0.000
$\ln F_{it}^2$	-1.775	0.483	-2.156	0.925	-4.041	0.000	-4.073	0.000
$\ln Y_{it}$	-1.829	0.324	-2.431	0.202	-3.017	0.000	-3.299	0.000
$\ln EN_{it}$	-1.800	0.408	-2.214	0.831	-3.914	0.000	-4.253	0.000

Table 6

Panel Unit Root Analysis for Low-income Panel.

Variables	**At level**				**At 1^{st} Difference**			
	Drift & no Trend	P-value	Drift & Trend	P-value	Drift & no Trend	P-value	Drift & Trend	P-value
IPS Unit Root Test								
$\ln C_{it}$	0.981	0.837	-0.706	0.240	-11.114	0.000	-9.834	0.000
$\ln F_{it}$	-0.549	0.291	-0.276	0.391	-16.874	0.000	-15.790	0.000
$\ln F_{it}^2$	0.549	0.708	1.214	0.887	-16.237	0.000	-14.923	0.000
$\ln Y_{it}$	0.600	0.726	1.271	0.898	-8.688	0.000	-7.558	0.000
$\ln EN_{it}$	3.333	0.999	3.907	1.000	-7.782	0.000	-8.372	0.000
CADF Unit Root Test								
$\ln C_{it}$	-1.775	0.493	-2.419	0.382	-3.009	0.000	-4.579	0.000
$\ln F_{it}$	-2.046	0.165	-2.672	0.106	-3.440	0.000	-3.516	0.000
$\ln F_{it}^2$	-1.446	0.873	-1.798	0.979	-3.871	0.000	-3.926	0.000
$\ln Y_{it}$	-1.902	0.321	-2.655	0.118	-3.045	0.000	-3.385	0.000
$\ln EN_{it}$	-1.080	0.993	-1.955	0.926	-3.540	0.000	-3.978	0.000

The results of Pedroni (1999, 2004) cointegration tests are displayed in Table-7. The results of within dimensions statistics and between dimensions statistics show that the null hypothesis of no cointegration can be rejected in most cases. Therefore, carbon emissions, FDI, economic growth and energy consumption are cointegrated in our panels of high, middle and low income countries as well as global panel for the period of 1975-2012. Johansen Fisher panel cointegration test results provide additional support for the presence of cointegration between variables by rejecting null of no cointegration in all panels at 5% level of significance (see Table-8).

Table 7
Pedroni Panel Cointegration Test Results.

Models	**Global Panel**		**High-income Panel**	
	Statistics	P-value	Statistics	P-value
Panel υ-statistic	4.697	0.000	1.753	0.039
Panel σ-statistic	-1.778	0.037	-1.790	0.036
Panel ρρ-statistic	-4.203	0.000	-3.314	0.000
Panel adf-statistic	-4.909	0.000	-3.367	0.000
Group σ-statistic	1.852	0.968	1.876	0.969
Group ρρ-statistic	-2.088	0.018	1.020	0.846
Group adf-statistic	-3.581	0.000	-2.100	0.015
Models	**Middle-income Panel**		**Low-income Panel**	
	Statistics	P-value	Statistics	P-value
Panel υ-statistic	3.189	0.000	0.677	0.249
Panel σ-statistic	-1.816	0.034	-1.283	0.099
Panel ρρ-statistic	-3.955	0.000	-4.492	0.000
Panel adf-statistic	-3.392	0.000	-4.679	0.000
Group σ-statistic	-0.003	0.498	0.485	0.686
Group ρρ-statistic	-5.100	0.000	-5.699	0.000
Group adf-statistic	-3.665	0.000	-3.788	0.000

Note: An intercept and trend is included in the cointegrating equations.

Table 8
Johansen Fisher Panel Cointegration Test results.

No. of CE(s)	**Global Panel**		**High-income Panel**		**Middle-income Panel**		**Low-income Panel**	
	Statistics	P-Value	Statistics	P-Value	Statistics	P-Value	Statistics	P-Value
Trace statistics								
None	777.9	0.000	249.3	0.000	387.6	0.000	94.82	0.000
At most 1	267.8	0.000	81.50	0.163	167.1	0.000	41.70	0.007
At most 2	164.0	0.963	54.06	0.920	118.0	0.200	28.43	0.162
At most 3	231.5	0.051	76.70	0.272	170.2	0.000	39.05	0.014
Max Eigen Statistics								
None	640.9	0.000	186.2	0.000	306.8	0.000	76.47	0.000
At most 1	224.9	0.092	66.65	0.591	121.2	0.148	27.39	0.197
At most 2	138.7	0.999	47.99	0.979	87.57	0.903	19.10	0.639
At most 3	231.5	0.051	76.70	0.272	170.2	0.000	39.05	0.014

Note: Intercept (no trend) is included in the cointegrating equations and VAR.

The results of FMOLS reported in Table-9 show that by taking CO_2 emissions as dependent variable, all coefficients are statistically significant. In global panel, economic growth and energy consumption positively and significantly affect CO_2 emissions which imply that 1 percent increase in economic growth and energy consumption increases environmental pollution by 0.07 percent and 0.65 percent respectively. The sign of FDI coefficient is negative and statistically significant at 1% level. Thus shows that CO_2 emissions decline by 0.02 percent in global for every 1% increase in FDI. The quadratic term of FDI has negative effect on CO_2 emissions in global panel which reveals that environmental quality start to improve when FDI reaches at certain maximum level.

In high income panel, the linear and non-linear terms of FDI are negatively linked with CO_2 emissions which supported the *pollution haloes hypothesis* (PHH). This implies that foreign investors use better management practices and advanced technology that result is clean environment in host countries. In middle income countries' panel, the linear and non-linear terms of FDI has opposite sign and statistically significant at 5% and 10% level respectively, thus indicating that initial effect of FDI on environmental degradation is positive but after certain level of FDI, environmental quality starts to improve i.e. inverted U-shaped relationship between FDI and CO_2 emissions is found. In low income panel, positive relationship is found between FDI and environmental degradation as represented by both linear and non-linear terms of FDI. These results support the findings of Peter and Jeffrey (2003) who reported that FDI increases environmental pollution in less developed countries. Further, economic growth and energy consumption are important contributors of environmental pollution in high, middle and low income countries' panels.

Table 9
FMOLS Results.

Variables	**Coefficients**	**P-value**	**Coefficients**	**P-value**
Global Panel				
$\ln F_{it}$	-0.019	0.000	0.013	0.000
$\ln F_{it}^2$	-	-	-0.0007	0.000
$\ln Y_{it}$	0.070	0.000	0.004	0.052
$\ln EN_{it}$	0.647	0.000	0.788	0.000
High-income Countries				
$\ln F_{it}$	-0.035	0.000	-0.013	0.017
$\ln F_{it}^2$	-	-	-0.002	0.000
$\ln Y_{it}$	0.046	0.054	0.0431	0.000
$\ln EN_{it}$	0.528	0.000	0.541	0.000
Middle Income Countries				
$\ln F_{it}$	0.011	0.050	0.013	0.020
$\ln F_{it}^2$	-	-	-0.002	0.065
$\ln Y_{it}$	0.038	0.055	0.051	0.015
$\ln EN_{it}$	1.170	0.000	1.175	0.000
Low Income countries				
$\ln F_{it}$	0.033	0.004	0.038	0.020
$\ln F_{it}^2$	-	-	0.0003	0.562
$\ln Y_{it}$	0.393	0.000	0.389	0.000
$\ln EN_{it}$	0.622	0.032	0.618	0.033

After finding the marginal impacts of FDI, economic growth and energy consumption on carbon emissions, we apply the Dumitrescu and Hurlin (DH) causality tests to examine the direction of causality between the variables[10]. The results of DH causality test for global panel are reported in Table-10. The results of DH causality reveal the feedback hypothesis between carbon emissions and energy consumption. The relationship between FDI and carbon emissions is bidirectional. Economic growth causes energy consumption and in resulting, energy consumption causes economic growth. The results further support unidirectional causality running from economic growth to energy consumption in global panel. The neutral effect exists between economic growth and CO_2 emissions and same is true for energy consumption and FDI as no causality is found between these variables in the full sample of 99 high, middle and low income countries.

The results of high income countries' panel reported in Table-9 supported the bidirectional causality between energy consumption and CO_2 emissions. The unidirectional causality is found running from CO_2 emissions to economic growth. FDI causes CO_2 emissions and energy consumption is cause of economic growth. However, null of HNC cannot be rejected between FDI, economic growth and energy consumption in the sample of high income countries' panel. In middle income countries' panel, we find the feedback relationship between energy consumption and CO_2 emissions. The relationship between FDI and energy consumption is bidirectional. The unidirectional causality is also observed running from economic growth to carbon emissions. Economic growth causes energy consumption and FDI is cause of CO_2 emissions and economic growth because HNC hypothesis in opposite direction cannot be rejected (see Table-9).

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[10] All the variables are stationary at first difference i.e. I(1). The DH test of causality is applied on first differenced series.

Table 10
The Result of DH Panel Causality Test.

	Global Panel			**High-income Countries**			**Middle-income Countries**			**Low-income Countries**		
Direction of Causality	$W_{N,T}^{HNC}$	$Z_{N,T}^{HNC}$	**P-Value**	$W_{N,T}^{HNC}$	$Z_{N,T}^{HNC}$	**P-Value**	$W_{N,T}^{HNC}$	$Z_{N,T}^{HNC}$	**P-Value**	$W_{N,T}^{HNC}$	$Z_{N,T}^{HNC}$	**P-Value**
$\ln Y_{it} \rightarrow \ln C_{it}$	2.259	0.503	0.614	2.369	0.582	0.560	3.864	5.437	0.000	1.594	1.111	0.266
$\ln C_{it} \rightarrow \ln Y_{it}$	2.261	0.511	0.608	2.869	1.865	0.062	2.127	-0.051	0.959	0.846	-0.457	0.647
$\ln EN_{it} \rightarrow \ln C_{it}$	3.365	5.286	0.000	3.602	3.749	0.000	4.487	7.406	0.000	1.328	0.554	0.579
$\ln C_{it} \rightarrow \ln EN_{it}$	2.894	3.248	0.001	3.338	3.070	0.002	4.014	5.909	0.000	2.490	2.990	0.003
$\ln F_{it} \rightarrow \ln C_{it}$	2.784	2.773	0.005	2.987	2.170	0.030	2.314	0.540	0.589	0.669	-0.828	0.407
$\ln C_{it} \rightarrow \ln F_{it}$	2.660	2.236	0.025	2.016	-0.325	0.745	4.030	5.960	0.000	0.832	-0.486	0.626
$\ln EN_{it} \rightarrow \ln Y_{it}$	2.267	0.537	0.590	2.679	1.377	0.168	1.641	-1.585	0.113	0.679	-0.806	0.419
$\ln Y_{it} \rightarrow \ln EN_{it}$	2.794	2.817	0.004	2.879	1.893	0.058	1.593	-1.738	0.082	1.026	-0.080	0.936
$\ln F_{it} \rightarrow \ln Y_{it}$	3.667	6.589	0.000	2.455	0.801	0.423	2.402	0.819	0.413	2.562	3.138	0.002
$\ln Y_{it} \rightarrow \ln F_{it}$	2.600	1.979	0.047	1.841	-0.776	0.437	2.927	2.479	0.013	1.078	0.028	0.977
$\ln F_{it} \rightarrow \ln EN_{it}$	2.090	-0.226	0.820	2.508	0.939	0.347	1.600	-1.715	0.086	0.906	-0.331	0.740
$\ln EN_{it} \rightarrow \ln F_{it}$	2.287	0.624	0.532	1.877	-0.682	0.494	3.217	3.395	0.000	0.666	-0.834	0.404

In low income countries' panel, results (reported in Table-9) support only unidirectional causality running from CO_2 emissions to energy consumption and FDI to economic growth. However, the neutral hypothesis is supported in all other cases.

5. Concluding Remarks and Policy Implications

The objective of present study is to examine the causal relationship between FDI, economic growth, energy consumption and CO_2 emissions using data of 99 countries by applying recent panel cointegration and causality analysis techniques for the period of 1975-2012. The results are also estimated by three heterogeneous panels' i.e. high-, middle- and low-income countries' panels.

Our results indicated that all variables are integrated at I(1) confirmed by panel unit root tests. Panel cointegration tests confirmed the long-run relationship between, CO_2 emissions, FDI, economic growth and energy consumption. The FMOLS estimation analysis reveals an inverted-U shaped relationship between FDI and CO_2 emissions in global and middle-income panels. FDI is reducing CO_2 emissions at every stage in high-income countries but it is not true for low-income countries. The causality analysis confirms the existence of feedback effect between CO_2 emission and energy consumption in global as well as high- and middle-income countries' panels. This implies that FDI policies in low-income countries promote environment pollutions which lower the environment quality. Over time, this will cause major environmental unsustainability for low-income countries, where rise in FDI mainly in industrial and production sectors will pollute environment. Memon et al. (2011) revealed that FDI is increasing in the Asian region while financial markets are in the stable position; otherwise GDP growth which proxy to economic activities will be negatively affected by FDI. The feedback effect is found between FDI and CO_2 emissions in global panel while unidirectional causality running from FDI to CO_2 emissions is observed in high-income countries and inverse is true for middle-income countries. Causality from CO_2 emissions to economic growth is found only in high-income countries and from economic growth to CO_2 emissions in middle-income countries while neutral effect is observed in low-income countries and global panel.

In order to sustain a clean environment for future generation, the usage of renewable energy such as biomass can be used in future to overcome CO_2 emissions. It been suggested by Demirbas et al. (2009) and Dincer and Rosen (2002) that biomass is the high potential renewable energy source that able to contribute to energy needs in a modern society for both developed and developing nations worldwide. Indeed, renewable energy technologies and efficient energy utilization are some of potential solution for current environment issues. In term of long term direction of energy generation, green renewable energy can be introduced to overcome CO_2 emissions from natural energy consumption such as oil, natural gas and coal. Wind, geothermal heat and sunlight are part of the green renewable energy components. This finding is consistent with Xing and Kolstad (2002), Chang and Wang (2009), Beak and Koo (2009), Lee (2010), Pao and Tsai (2011) and Zhang (2011). However, this contrasts with Tamazian eta al. (2009), Tamazian and Rao (2010), who find that increase in FDI declines CO_2 emissions. In some circumstance, FDI and economic growth promote technological innovation, which will increase energy efficiency with low CO_2 emissions (List and Co, 2000; Tamazian et al. 2009). Therefore, emerging and transitional economies must enthusiastically encourage environmental protection by technological transmission and know-how from developed countries to save the environmental quality and natural resources consumption.

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Appendix-A1

Panel Unit Root Tests

IPS (2003) test is estimated using the following model:

$$\Delta y_{i,t} = \alpha_i + \vartheta_i t + \theta_t + \rho_i y_{i,t-1} + \sum_{j=1}^{p} \varphi_{i,j} y_{i,t-j} + \upsilon_{i,t} \qquad (1)$$

The IPS test is the adjusted average of ADF individual unit root test statistics. The IPS statistics is asymptotically normally distributed, as T and N goes to infinity. The null hypothesis of IPS test assumes that each series in the panel has unit root for all cross sectional units against the alternative that at least one of the series is stationary.

$$\begin{aligned} &H_0 : \rho_i = 0 \quad \textit{for all } i \\ &H_A : \rho_i < 0 \quad i = 1, 2, \ldots\ldots, N \\ &\quad\ \rho_i = 0 \quad i = N_1 + 1, N_1 + 2, \ldots\ldots\ldots\ldots, N \end{aligned}$$

The estimable equation of IPS unit root test is modeled as following:

$$\bar{t}_T = \frac{1}{N} \sum_{i=1}^{N} t_{i,t}(P_i) \qquad (2)$$

Where $t_{i,t}$ is the ADF t-statistics for the unit root tests of each country and P_i is the lag order in the ADF regression and test statistic can be calculated as following:

$$A_T = \frac{\sqrt{N(T)[\bar{t}_T - E(t_T)}}{\sqrt{\operatorname{var}(t_T)}} \qquad (3)$$

As $\bar{t}_T$ is explained above and values for $E[t_{iT}(P_i, 0)]$ can be obtained from the results of Monte Carlo simulation carried out by IPS. The IPS simulation indicated that in the presence of no serial correlation, the $\bar{t}_T$ statistics is more powerful even for small sample size. Another important feature of IPS test is that the power of this test is relatively more affected by rise in T then rise in N. Pesaran (2007) augmented the standard ADF regressions with the cross-section averages of the lagged level and first differences of the individual series. In the presence of N cross-sectional and *t* time series observation, Pesaran uses the following simple dynamic linear heterogeneous model:

$$\Delta x_{i,t} = \alpha_i + \rho_i x_{i,t-1} + c_i \bar{x}_{t-1} + d_i \Delta \bar{x} + \varepsilon_{i,t} \qquad (4)$$

Where $\bar{x}_{t-1} = (1/N) \sum_{i=1}^{N} x_{i,t-1}$ *and* $\Delta \bar{x}_t = (1/N) \sum_{i=1}^{N} \Delta x_{i,t}$

The presence of cross-sectional averages of lagged levels $\bar{x}_{t-1}$ and first differences $\Delta \bar{x}_t$ of individual series capture the cross-sectional dependence through a factor structure. Pesaran suggests to modify equation-6 with appropriate lags in the presence of serially correlated error term. Pesaran (2007) obtains the modified IPS statistics based on the average of individual CADF, which is denoted as cross-sectional augmented IPS (CIPS). This is estimated from:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \tag{5}$$

Where $CADF_i$ is the cross-sectional augmented Dickey-Fuller statistic for the ith cross-sectional unit given by the t-ratio of ρ_i in the CADF regression-6. The distribution of the CIPS statistic is found to be non-standard even for large N.

Appendix-A2

Pedroni Cointegration Test

Pedroni's seven test statistics are given below:

1. Panel v-Statistic: $Z_v \equiv T^2 N^{3/2}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\kappa}_{11,i}^{-2}\hat{\mu}_{it-1}^{2}\right)^{-1}$
2. Panel ρ -statistic: $Z_p \equiv T\sqrt{N}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\kappa}_{11,i}^{-2}\hat{\mu}_{it-1}^{2}\right)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\kappa}_{11,i}^{-2}\left(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it}-\hat{\lambda}_i\right)$
3. Panel t-statistic (non-parametric): $Z_t \equiv \left(\tilde{\sigma}^2\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\kappa}_{11,i}^{-2}\hat{\mu}_{it-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\kappa}_{11,i}^{-2}\left(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it}-\hat{\lambda}_i\right)$
4. Panel t-statistic (parametric): $Z^{*}{}_{t} \equiv \left(\tilde{s}_{N,T}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\kappa}_{11,i}^{-2}\hat{\mu}_{it-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{\kappa}_{11,i}^{-2}\hat{\mu}_{it-1}^{*}\Delta\hat{\mu}_{it}^{*}$
5. Group ρ-statistic: $\tilde{Z}_p \equiv TN^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2}\right)^{-1}\sum_{t=1}^{T}\left(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it}-\hat{\lambda}_i\right)$
6. Group t-statistic (non-parametric): $\tilde{Z}_t \equiv N^{-1/2}\sum_{i=1}^{N}\left(\hat{\sigma}_i^2\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it}-\hat{\lambda}_i\right)$
7. Group t-statistic (parametric): $\tilde{Z}_t^{*} \equiv N^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\tilde{s}^{*2}\hat{\mu}_{it-1}^{2*}\right)^{-1/2}\sum_{t=1}^{N}\hat{\mu}_{it-1}^{*}\Delta\hat{\mu}_{it}{}^{*}$

Where $\hat{\lambda}_i = \frac{1}{2}(\hat{\sigma}_i^2 - \hat{s}_i^2)$ and $\tilde{s}_{N,T}^{*2} = \frac{1}{N}\sum_{i=1}^{N}\hat{s}^{*2}$

The first four statistics are within dimension based statistics and the rest are between dimension statistics. Pedroni (2004) examined the small sample power properties of his seven test statistics. He found that the size distortion is small and the power is high for T > 100. For smaller T, he shows that the group ADF test has the best power properties followed by the panel ADF test; the panel variance test and group rho test perform poorly.

Appendix A-3

High Income Panel	Australia	Bahrain	Canada	Chile
	Cyprus	Denmark	Finland	France
	Germany	Greece	Iceland	Ireland
	Israel	Italy	Japan	Korea, Rep.
	Kuwait	Malta	Netherlands	New Zealand
	Norway	Oman	Portugal	Qatar
	Saudi Arabia	Singapore	Spain	Sweden
	Trinidad and Tobago	United Arab Emirates	United Kingdom	United Kingdom
	Uruguay	Poland	Switzerland	
Middle Income Panel	Albania	Algeria	Angola	Argentina
	Bolivia	Botswana	Brazil	Bulgaria
	Cameroon	China	Colombia	Congo, Rep.
	Costa Rica	Cote d'Ivoire	Cuba	Dominican Rep.
	Ecuador	Egypt, Arab Rep.	El Salvador	Gabon
	Ghana	Guatemala	Honduras	Hungary
	India	Indonesia	Iran, Islamic Rep.	Syrian Arab Rep.
	Jamaica	Jordan	Libya	Malaysia
	Mexico	Morocco	Nicaragua	Nigeria
	Pakistan	Panama	Paraguay	Peru
	Philippines	Romania	Senegal	South Africa
	Sri Lanka	Sudan	Thailand	Iraq
	Tunisia	Turkey	Venezuela, RB	Vietnam
	Zambia			
Low Income Countries	Bangladesh	Benin	Kenya	Congo, Dem. Rep.
	Mozambique	Nepal	Togo	Zimbabwe
	Tanzania	Haiti	Ethiopia	