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ABSTRACT

This study evaluates the link between disaggregate energy consumption (coal, petroleum, electricity, renewable energy consumption), economic growth and environment for Asian Developing countries. Cointegration tests verify long run relationship among energy consumption and growth, energy consumption and environment degradation along with trade openness and financial development as control variables. To find long run elasticities fully modified OLS is used, which confirms that all forms of disaggregate energy consumption explain positive and significant impact on economic growth. Results also show that all forms of disaggregate energy use more pollute environment (except coal consumption) and also validate the existence of Environmental Kuznets curve. Important policy implication is that government needs to promote renewable energy sector because its increase economic growth and its impact on environment degradation is low as compare to other sources. Investment in renewable energy sector is beneficial for private and public sector after conducting cost and benefit analysis.

Keywords: Disaggregate Energy Consumption, Economic Growth, CO_2 Emissions, Environmental Kuznets Curve

1. INTRODUCTION

The relationship between economic growth, consumption of energy and environment attracts economists, policy-makers, researchers, and analyst recently. Erbaykal (2008) suggests the petroleum emergency in 1970s shows that energy should be treated as a production factor. Previous studies [Sadorsky (2012); Apergis and Payne (2009)] paying attention on aggregate level of energy consumption. For the time being coil, petroleum, electricity, renewable energy consumption has become important component in Asian developing countries energy use. The significance of these components of energy consumption can be recognised by the huge amount of money spent to import these components and how an increase in petroleum price and LPG shortage affect the smooth operation of many businesses in the country [Kwakwa (2011)].

The link between economic growth and consumption of energy is mostly intentional area of energy policy and energy economics [Payne (2010); Ozturk (2010)]. The relationship between economic growth, disaggregated form of energy use and environment are also important for policy making. The relationship between these variables is very critical, but need is to evaluate it for developing new valuable energy and environmental policies. If causal link is found as of energy use (disaggregate forms) to output, then any shrinking in consumption of energy for energy conservative policies to reduce CO_2 emissions will reduce output. This is the main motivation to undertake this study.

Literature on energy economics has possible four hypotheses for evaluate the link between consumption of energy and economic growth. First, the growth hypothesis explains that energy plays a major role to determine growth and complement with labour and capital. According to growth hypothesis any conservation policy to reduce consumption of energy for environment protection will affect economic growth; it means by increasing consumption of energy will boost real GDP. But if increase in consumption of energy reduces real GDP then conservation policies will not affect growth. Second, the conservation hypothesis confirms that energy consumption rise in response to increase in real GDP. Third, the neutrality hypothesis exists if no causal association between consumption of energy and real GDP. Forth, the feedback hypothesis, bidirectional causal connection exists between consumption of energy and real GDP.

Previous empirical findings supports that in addition to traditional variable, other variables called, control variables effect growth [Sadorsky

(2012) and others]. This study includes financial development and trade openness as Hecksher Ohlin (H-O) theory supports that trade openness increase growth. These variables also have effect on carbon dioxide emissions. According to environmental Kuznets curve at earlier stage the impact of economic growth is higher on CO_2 emission but after a point its impact decreases. This effect can be examined by including nonlinear GDP. Theoretically and empirically evidence is found that consumption of energy effects growth and vice versa. However growth models do not treat consumption of energy as input factor.

In current scenario consumption of energy has great importance for economy because energy is a backbone for growth. On other scenario if with economic growth of a country, per capita income grows, end result is that demand for energy like oil, gas and electricity will also grow. According to Global Energy Survey 2007, the expected demand for energy is increased minimum 50 percent by 2030 and 70 percent for developing countries. Causality analysis is very important for policy making issues like energy conservation policy. When consumption of energy is treated as an input factor then conservation policy is very important for policy making. This leads to undertake the causality test of energy consumption and growth for developing Asia in this study.

The reasons of use disaggregate energy consumption are that, first, aggregate energy consumption data does not show which country is dominant against many sources of energy use. Second, aggregate consumption of energy does not capture which type of energy resource has higher effect on growth as Yang (2000). Third, the gain of disaggregate energy consumption is that comparison is possible between different sources of energy spending [Sari, *et al.* (2008)].

Renewable energy supply may play a key role for fulfillment of future energy demand. Now various kinds of new technologies can complete the space between energy order and supply by improving supply of renewable energy consumption [Economic Report of the President USA (2006)].

The main objective of study is to examine the impact of disaggregates energy consumption (coil, petroleum, electricity, renewable sector) on growth in developing Asian Economies. The present study examines the impact of disaggregated energy consumption including control variables financial development and trade openness on economic growth. The study also investigates the impact of disaggregated energy consumption including control variables financial development, trade openness on environment.

Economic growth, consumption of energy, financial development and trade openness all have a trend to progress together across every point in time in all the countries of the world. This study contributes to existing literature by explaining the impact of disaggregate energy consumption (coal, petroleum, electricity, renewable sector); also include control variables trade openness and financial development on economic growth and environment. One of the scholars has rightly put the crystal clear importance of the Asian countries in the following manner: *"twenty first century is going to be Asia centered economically"* this quote has motivated to examine the impact of disaggregate energy consumption on economic growth and environment in Asian developing economies. This study considers both, the impact of disaggregate energy consumption on growth, and then growth and energy consumption impact on environment.

After introduction section, the rest of study is planned as follows, Second section provides literature review. Third section lays down the methodology and data. Fourth section presents empirical results and discussion. Fifth section concludes the study and derives some policy implications.

2. LITERATURE REVIEW

A large body of research is undertaken to evaluate the association between energy use, growth and environment. This section reviews the most relevant literature in these two areas; literature review, energy consumption on growth and literature review about energy consumption on environment.

2.1. Literature Review on Effect of Energy Consumption on Growth

The relationship between energy consumption and economic growth is extensively researched issue. Salim, *et al*. (2008) examine the short run and as well as long run causal affiliation between energy consumption and output in six Non-OECD (Pakistan, Thailand, Bangladesh, China, India and Malaysia) developing countries from 1980–2005. The results show bidirectional causal link between energy consumption and income in Malaysia, unidirectional causal association runs from output to energy consumption in Thailand and China, however, Pakistan and India, Bangladesh are found as energy neutral economies. For South Africa, Ziramba (2009) shows that industrial production and employment are found long run variables forcing variables for consumption of electricity, whereas bidirectional causal affiliation exists between industrial production and consumption of oil. Neutrality hypothesis is accepted for other forms of energy consumption. The results also show causal association between employment and consumption of electricity and consumption of coal to employment.

The association between disaggregate energy consumption and industrial output and employment in United States is investigated by Sari, *et al.* (2008) by using ARDL technique from 2001:1–2005:6. The results of the study show that real output and employment are long run variables and key determinants of fossil fuel, solar, waste, and conventional hydroelectric power, and wind energy consumption. However, employment and real output are not significance determinants of natural gas and wood energy consumption. Lee and Chang (2008) discover long run association between energy consumption and real GDP and that unidirectional Granger causal association runs from energy consumption to energy growth in long run but not in the short run for 16 Asian countries from 1971–2002. Shrif, *et al.* (2012) show that the electricity consumption has positive impact on growth as compare to others energy sources, while oil consumption effect growth negatively due to higher imports volume in Pakistan from the time period 1972–2012. This study also suggests that gas or coal should be used for energy consumption for the purpose of reducing import burden.

Shahbaz, *et al.* (2013) findings suggest that energy consumption, financial development; exports, capital, imports and international trade have positive impact on growth in China from 1971–2011. There is unidirectional causal linkfound from energy consumption to growth, bidirectional causal link found between financial development, trade, capital, financial development and energy consumption suggesting use of alternative energy sources. Shahbaz and Lean (2012) find long run association and causal relationship between energy consumption, economic growth, financial development, industrialisation and urbanisation in Tunisia from time period 1971–2008. Apergis and Payne (2009) find long run relationship and causality between energy consumption and growth in six Central American countries from 1980–2004. Narayan and Smyth (2009) confirm the causal affiliation between electricity consumption, exports and GDP for Middle Eastern countries. The study also suggests that these nations must focus on electricity infrastructure and promote exports especially non-oil exports.

Mahadevan and Asafu-Adjaye (2007) reinvestigate GDP growth and energy consumption nexus for 20 net importers and exporters countries from time period 1971–2002. The findings show bidirectional causal affiliation between growth and energy consumption exist in short and long run for developed countries, Tugcu (2013) finds the link between disaggregate energy consumption (nuclear, fossil, renewable) and total factor productivity growth in Turkey from 1970–2011. Lee (2005) observes causality runs from energy consumption to GDP both in long and short run but not vice versa for 18 developing countries from time period 1975–2001. Apergis and Payne (2010) confirm a long run equilibrium association between energy consumption, real GDP, labour force and capital with positive signs in nine South American nations. Sadorsky (2011) show positive impact of financial development on energy consumption for nine Central and Eastern European frontier economies from 1996 to 2006. Sadorsky (2012) also justifies that causal connection between international trade and energy consumption in long run for seven South American countries from 1980–2007.

2.2. Literature Review on the Impact of Energy Consumption on Environment

Many studies have been written to evaluate the impact of energy consumption on environment. Pao and Tsai (2011) look into the impact of foreign direct investment and growth on environment condition from 1980 to 2007. In long run energy consumption is found to be elastic and FDI inelastic. Unidirectional causal link is found from output to FDI and energy consumption to emissions. Bidirectional causal affiliation is found between emissions and FDI, output and energy consumption, output and emissions. Jalil and Feridun (2011) find negative relationship between financial development and environmental pollution, energy consumption and trade openness are main determinant of emissions in long run. Findings also verify the existence of Kuznets Curvein China.

Mehrara (2007) finds causal affiliation between per capita energy consumption and per capita GDP using panel data for eleven oil exporting countries from 1971–2002. The study suggests that these countries should adopt low domestic oil prices for the purpose of high exports, because any energy conservation policy like that any reduction in energy consumption will not harm growth. Sharma (2011) study the determinants of CO_2 emission for 69 countries, and high, low and middle income countries from 1985 to 2005. The results of the study show that total primary energy consumption and GDP per capita are main determinants of CO_2emission, while trade openness, urbanisation and electric power consumption negatively affect CO_2emission. Soytas and Sari (2009) finds surprising result that Granger causality runs from CO_2emission to energy consumption in Turkey from 1960 to 2000. No causal affiliation is found between emissions and income; it shows that Turkish government can shrink emissions without effecting growth.

Ozturk and Salahuddin (2012) observe that causal link is found from energy consumption to growth, growth to energy consumption, energy consumption to emissions in India from 1971 to 2007. The short term adjustment of ECM confirms that deviations will remove in long run, while emissions and energy consumption will converge to equilibrium. It shows that if Indian government wants to reduce CO_2emission then they will forgo growth. Suri and Chapman (1998) find the existence of Kuznets curve with time series and pooled cross country econometrically. The study also investigate that commercial energy consumption is a big cause of environment pollution. Soytas, *et al.* (2007) find the impact energy consumption and income on CO_2emission from1960 to 2004 in United States. This study finds energy consumption Granger causes carbon emissions while income does not Granger cause carbon emissions. This study concludes that growth in income of United States is not a way to reduce carbon emissions.

Hossain (2011) reveals the dynamic affiliation between emissions, growth, energy use, urbanisation and trade openness for newly industrial countries from the time period 1971 to 2007. The long run elasticity describe that energy consumption coefficient on CO_2emission is higher than short run which shows that as time pass CO_2 emission raise more due to energy use. Munir and Khan (2012) study the impact of energy use (fossil fuel) on CO_2emission from 1980 to 2010 in case of Pakistan. The results of the study confirm that inverted U shaped Kuznets curve exists in Pakistan. The results also show that trade and industry value added have positive effect on CO_2emission while development in financial sector has negative effect. Apergis and Payne (2010) confirm causal connection between CO_2emission, real GDP and energy consumption for eleven common wealth countries from 1992 to 2004. The results also shows that energy consumption impact carbon dioxide emissions positively while inverted U shaped Kuznets curve also exist. Bidirectional causality found between emissions and energy consumption, while unidirectional causal connection found from energy consumption to emissions and real output to emissions. Hilton and Levinson (1998) check the connection between national income and automotive lead emissions from the time period 1972 to 1992 for 48 countries. The results support the existence of inverted U shaped Kuznets curve when lead emissions treated as environmental pollution. According to this study automotive lead emission is divided between two categories, first consumption of gasoline known as pollution activity and second is for each gallon of gasoline known as pollution intensity. The interesting conclusion is that decreasing part of inverted U shaped environment Kuznets due to reducing pollution intensity not due to pollution activity.

Roca and Alcantara (2001) find no evidence that supporting the hypothesis of existence Kuznets curve in Spain. Kaufmann, *et al.* (1998) explore the impact of income on SO_2 (sulfur dioxide) and index of economic activity from time period 1974 to 1989 for 23 countries. The results of the study states that inverted U shaped Kuznets curve exist both cases for income as well as spatial intensity of economic activity. SO_2 reduced more in the case of economic activity index than income which provide new dimension for policy analyst. Jalil and Mahmud (2009) investigate long run link between energy consumption, foreign trade, income and emissions from 1975 to 2005 for china. The results support the existence of Kuznets curve when cubic term is added in the model. The energy consumption and income are key determinants of carbon dioxide emissions. Granger causality runs from growth to emissions.

Farhani and Rejeb (2012) verify the relationship exist between CO_2emission, GDP and energy consumption from 1973 to 2008 for fifteen Mena countries. Unidirectional causal affiliation is found from emissions to energy consumption and GDP to energy consumption. Liu (2005) investigate the impact of CO_2 including control variables on GDP and impact of GDP and energy consumption on CO_2emission. The surprising result of the study is that gross domestic product has negative sign on emissions when energy consumption is added in model. Stern and Common (2001) check the existence of Kuznets curve hypothesis for sulfur dioxide for world global panel, OECD countries and non-OECD countries from 1850 to 1990. They conclude that emissions reduction is due to time dependence rather than income dependence. Apergis and Payne (2009) prove the existence of Kuznets curve and causal connection between energy consumption, output and CO_2emission for six countries of Central America from1971 to 2004.

Most of the review describes the relation with aggregate energy consumption, only few studies consider disaggregate energy consumption using time series approach. It would be interesting to investigate the relationship in disaggregated form by using panel data. In literature, there is lack of literature that depict the impact of disaggregate energy consumption on environment, so it would be motivating to look at the connection between disaggregate energy consumption and environment.

3. METHODOLOGY AND DATA

The methodological framework, data and data sources are presented in this section. Section 3.1 describes theoretical framework, 3.2 model specifications, 3.3 methodological framework, 3.4 data, and 3.5 estimation techniques.

3.1. Theoretical Framework

3.1.1. *Conceptual Framework for Energy and Growth*

In literature of classical macroeconomic growth theories primary focusis on labour and capital and do not consider the role of energy resources, that are having significant role for economic growth and production [Stern and Cleveland (2004)]. Energy economists states that energy is an important factor as well as play a major role in production process; it can be used directly as a final product [Stern (1997)]. Production of output is determined by energy service, capital stock and labour [Pokrovski (2003)]. Energy input generates work that moves or transforms matter and physical capital and combines various energy inputs into an aggregate [Thompson (2006)]. Economic activities consider energy as a required input in the productive process and as the economy is driven by increasing energy demands, it is believed that excluding energy use from the production function would clearly be a sign of a lack of judgment [Lee and Chang (2008)].

Theoretically exports as an engine of growth by three ways. First by directly, an increase in demand of foreigners for domestic exportable products can promote output and overall growth of the economy that will increase income and employment in exportable sector [Awokuse (2008)]. Second, exports affect growth indirectly by many channels such as: efficient allocation of resources, exploitation of economies of scale, greater capacity utilisation and stimulation of technological improvement due to foreign market competition [Helpman and Krugman (1985)]. Third, by increasing exports foreign exchange reserves can be received that will be helpful for increasing the intermediate imports that in turn raises capital formation and growth [Balassa (1978); Esfahani (1991)].

The effect of imports on economic growth may be different from exports [Awokuse (2008)]. For developing economies, imports provide important factor of production that needed for exports sector. Transfer of technology from developed to underdeveloped nations could promote economic growth. Endogenous growth models also show that imports can be a channel of long run economic growth because it provides foreign technology and knowledge to domestic firms [Grossman and Helpman (1991); Coe and Helpman (1995)].

There are two channels through which financial development can lead to economic growth [Fung (2009)]. The first channel is factor productivity through which financial development may lead to economic growth. In this channel, financial innovations and technologies lesson informational asymmetries and this leads to better monitoring and selection of investment projects [Townsend (1979); King and Levine (1993); Baier, *et al*, (2004)]. Financial liberalisation increases risk diversification which should lower the cost of equity and investment will increase, thus through this channel ultimately final results increased economic growth [Bekaert and Harvey (2000); Bekaert, *et al.* (2001, 2002)]. The second channel is called factor accumulation, which states spread of organised financial systems over self-finance. Organised financial systems increase efficiency as previously unproductive resources are put to better use [Gurley and Shaw (1955); Bell and Rousseau (2001)].

3.1.2. *Conceptual Framework for Energy and Environment*

Energy plays a major role in residential, industrial needs, transportation, and electricity needs. The burning of fossil fuel is necessary in every region as it is used for the production of goods and services. While it is also true that burning of fossil fuel emits a high amount of CO_2 and pollutes the environment. It has been empirically and theoretically shown that an increase in energy consumption results in greater economic activity. Higher economic growth will have a positive effect. Boost in energy consumption results in higher GDP because, in addition to the undeviating effect of energy consumed for commercial use which stimulates higher rates of economic growth, higher energy consumption results in an increase in energy production. Through this channel, an increase in pollution emissions is expected due to fast economic growth and ensuing greater fossil fuel consumption [Hooi and Smyth (2010)].

Trade openness is expected to have a positive effect on CO_2 emissions. Hecksher Ohlin trade theory also supports positive effect on CO_2 emissions. H-O trade theory states that, under free trade, emergent countries would focus on production of goods in which they have a comparative advantage, such as labour and natural resources. Thus, the movement of goods and services produced in one country for either consumption or further processing is occurred as the result of trade. More consumption of goods and further processing of goods, which takes place due to greater trade openness, is a source of pollution. Hence, the H-O theory actually perceives that pollution is stimulated from further processing and manufacturing of goods, which results from greater trade openness.

Financial development can affect CO_2 emissions in many ways [Frankel and Romer (1999); Dasgupta, *et al.* (2001); Sadorsky (2010); and Zhang (2011)]. First, stock market development helps all listed companies to achieve lower cost of finance capital, increase finance channels, and diversify risk, so as to invest in new projects and buy new installations. Through this channel energy consumption and carbon emissions will increase. Second, financial development also attracts FDI through this channel boost economic growth and increase carbon emissions. Third, financial development making cheaper and easier for consumers to borrow money to buy houses, air conditioners, refrigerators, washing machines and automobiles and it will emit more carbon dioxide [Zhang (2011)]. However, financial development may increase energy efficiency and enterprises' performance and then reduce energy consumption and carbon emissions [Tamazian, *et al.* (2009); Claessens and Feijen (2007)].

3.2. Model Specifications

3.2.1. *Model Specification for Effect of Energy on Growth*

Cobb Douglas production function is extensively used to symbolise the connection between growth and energy consumption [Cobb and Douglas (1928)]. They represent a simplified outlook of economy in which production output is determined by the amount of labour involved and the amount of capital invested. While there are many other factors affecting economic performance, their model proved to be remarkably accurate. The following function is used.

$$P(K,L) = bK^{\alpha}L^{\beta}$$

Where P = total production, L = labour input, K = capital input, b = factor efficiency and α and β= output elasticity's of capital and labour respectively.

While in neo-classical production model and the traditional neo-classical growth model, treat energy inputs as intermediate factors but labour and capital as basic factors. By contrast, in the bio-physical and ecological view, energy economists consider that energy is a required input and an increasing demand in the production process, and that it plays a crucial role in output determination

[Ghali and El-Sakka (2004); Stern (2000)]. Numerous studies have attempted to highlight the importance of energy in the production process [Ghali and El-Sakka (2004); Oh and Lee (2004); Soytas and Sari (2003) and Sari and Soytas (2007); Stern (1993, 2000); Tsani (2010); Ayres and Warr (2010); Menyah and Rufael (2010); Yuan, *et al.* (2008)].

$$Y = f(K, L, E)$$

GDP depends on capital, labour and energy respectively. Latter this model is extended by including trade [Sadorsky (2012)] and trade and financial development [Shahbaz, *et al.* (2012)].

This study uses Cobb Douglas production function [1] to examine the relationship between disaggregates energy consumption and economic growth.

$$\ln G_t = \beta_1 + \beta_K \ln K_t + \beta_L \ln L_t + \beta_E \ln E_t + \beta_F \ln F_t + \beta_{TR} \ln T_t + \mu_t$$

GDP determine by capital, labour, energy, *F* (financial development) and *T* (trade openness) respectively.

3.2.2. *Model Specification for Impact of Energy Consumption on Environment*

To examine the impact of disaggregated energy consumption on environment the environment Kuznets curve is extended by including financial development and trade openness following Jalil and Feridun (2011):

$$\ln CO2_{it} = \nu_i + \alpha \ln E_{it} + \beta \ln Y_{it} + \gamma \ln Y_{it}^2 + \theta \ln F_{it} + \psi \ln T_{it} + \varepsilon_{it}$$

3.3. Methodological Framework

3.3.1. *Empirical Specification of Growth Model with Energy Consumption*

By extending the Cobb Douglas production function this study uses following empirical specification of the model as suggested by [Sadorsky (2012)]

$$Y = f(K, L, E, F, T) = K_{it}{}^{\alpha}\ L_{it}{}^{\beta}\ E_{it}{}^{\gamma}\ F_{it}{}^{\theta}\ T_{it}{}^{\psi} e^{\varepsilon_{it}}$$

---

[1] There are many reasons for using Cobb Douglas production function. First, the neo-classical marginal productivity theory describes that marginal productivity of labour is positive, because second derivative is firstly positive but after achieving maximum point it will be negative. Therefore, the graph of total output with regard to labour input describes an S-shaped curve. The second reason is that any production function that is used in the form of quantitative economics is basically near to reality. The third reason is that Cobb Douglas production function is mathematically tractable, simple and well-designed to first order conditions for derive factor demand or cost function. Finally, the Cobb-Douglas function can be used for any observed data [see Shaikh (1974) and Michl (1999)].

GDP is a function of capital, labour, energy, financial development and trade openness respectively. Taking natural log on both sides the model becomes:

$$\ln Y_{it} = \alpha_0 + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln E_{it} + \theta \ln F_{it} + \psi \ln T_{it} + \varepsilon_{it} \quad \ldots \quad (1)$$

Where, Y = Gross Domestic Product, K= capital, L = labour, E = disaggregate energy consumption (coal, petroleum, electricity, renewable energy consumption) are included separately one by one for estimation in above equation. F = financial development, T = trade openness.

According to Equation (1) E is defined total energy consumption, electricity consumption, petroleum consumption, renewable energy consumption and coal consumption in model 1, 2,3,4,5 respectively and estimation is done for each category of energy separately.

3.3.2. *Empirical Specification of Environment Model with Energy Consumption*

The environment is captured by CO_2 emissions. To examine the impact of non-linear growth on environment following empirical specification of the model is used suggested by Jalil and Feridun (2011).

$$\ln CO2_{it} = \alpha_0 + \alpha \ln E_{it} + \beta \ln Y_{it} + \gamma \ln Y_{it}^2 + \theta \ln F_{it} + \psi \ln T_{it} + \varepsilon_{it} \quad \ldots \quad (2)$$

Where CO_2 = Carbon Dioxide Emissions, and all other variables are same as used by the above model. According to Equation (2) E is defined total energy consumption, and disaggregated consumption: electricity consumption, petroleum consumption, renewable energy consumption and coal consumption used separately for estimation one by one in model 1, 2,3,4,5 respectively.

3.4. Data and Variables Construction

The annual data is taken from WDI (World Development Indicators) and EIA (Energy Information Administration) for 8 Asian developing countries[2] (Bangladesh, Pakistan, Indonesia, China, Philippines, India, Sri Lanka, and Thailand). The data are taken from 1990 to 2010. Data are constructed by following manners

Coal consumption = (Thousand, Short Tons)
Petroleum consumption = (Thousand Barrels, Per Day)
Electricity consumption = (Billion, Kilowatt / hours)
Renewable electricity consumption = (Billion, Kilowatt / hours)
Total Energy consumption = (kt, of oil equivalent)

[2]The sample is selected based on the data availability for the period of 1990 to 2013.

Real GDP is calculated by (GDP, constant 2005 US$). Total labour force is used for labour, capital is calculated by gross, fixed capital formation, constant 2005 US$, domestic credit, to private sector, percent of GDP is used for financial development variable. Trade openness variable is constructed by (Imports + Exports /GDP). Total carbon dioxide emissions from the consumption of energy in million metric tons are used for CO_2 emissions.

3.5. Estimation Techniques

Panel co-integration; Pedroni (1997) and Kao (1999) tests are applied to verify the long run relationship between economic growth, disaggregated energy consumption, and environment. Fully modified OLS is applied to find long run elasticity. Short run dynamic relationship is estimated by vector error correction model (VECM). For this analysis first step is to verify the stationarity of data and panel based unit root tests are applied for this purpose.

3.5.1. *Panel Unit Root Tests*

DF (Dickey Fuller) and ADF (Augmented Dickey Fuller) tests are extended for panel data analysis, to check whether the data are stationary or not. The panel unit root tests are extension of ADF test because mostly test include it as a regression component. Five different types of panel unit root tests are applied.[3] First two tests, the Levin and Lin (LL) test and Breitung t-stat test are assumed common unit root process across cross sections. In these two tests null hypothesis is that data are non-stationary or have a unit root and alternative hypothesis is that data are stationary or have a no unit root. While the other three tests: ImPesaran and Shin W-stat test, ADF-Fisher Chi-square test and PP-Fisher Chi-square test assume individual unit root process across cross sections.

3.5.2. *Cointegration Tests*

The Kao Test

Kao has presented (1999) cointegration test that is similar as Augmented Dickey fuller and Dickey fuller type test. The model is given below

$$Y_{it} = \alpha_i + \beta X_{it} + \hat{u}_{it}$$

According to this equation residual based co-integration test could be apply.

$$\hat{u}_{it} = \rho \hat{u}_{it-1} + v_{it}$$

---

[3]The Levin and Lin (LL) test, Breitung t-stat test, ImPesaran and Shin W-stat test, ADF - Fisher Chi-square test and PP - Fisher Chi-square test.

$\hat{u}_{it}$ = estimated residuals from first equation. OLS estimate for ρ is given below

$$\hat{\rho} = \frac{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{u}_{it}\,\hat{u}_{it-1}}{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{u}_{it}^{2}}$$

$$t_{\rho} = \frac{(\hat{\rho}-1)\sqrt{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{u}_{it}^{2}}}{1/(NT)\sum_{i=1}^{N}\sum_{t=2}^{T}(\hat{u}_{it}-\hat{\rho}\,\hat{u}_{it-1})^{2}}$$

The above equation is t statistic.

Four different kinds of Dickey Fuller tests are proposed by Kao which are given below

$$DF \quad \rho = \frac{\sqrt{NT}\,(\hat{\rho}-1)+3\sqrt{N}}{\sqrt{10.2}}$$

$$DF \quad t = \sqrt{1.25 t_{\rho}} + \sqrt{1.875\,N}$$

$$DF \quad \dot{\rho} = \frac{\sqrt{NT}\,(\hat{\rho}-1)+3\sqrt{N}\,\sigma_{v}^{2}/\sigma_{0v}^{2}}{\sqrt{3+36\hat{\sigma}_{v}^{4}/(5\sigma_{0v}^{4})}}$$

$$DF \quad \dot{t} = \frac{t_{\rho}+\sqrt{6N}\,\hat{\sigma}_{v}/(2\hat{\sigma}_{0v})}{\sqrt{\hat{\sigma}_{0v}^{2}/(2\hat{\sigma}_{v}^{2})+3\hat{\sigma}_{v}^{2}/(10\sigma_{0v}^{2})}}$$

In first two types the association between errors and regressors is strongly exogenous, whereas in last two types the relationship between errors and regressors is endogenous. Kao (1999) has also proposed Augmented Dickey Fuller test, given below regression can be run under

$$u_{i,t} = \rho u_{i,t-1} + \sum_{j=1}^{n}\phi_{j}\Delta u_{i,t-j} + v_{it}$$

The null hypothesis is that no cointegration, same as Dickey Fuller test and Augmented Dickey Fuller statistic calculated as

$$ADF = \frac{t_{ADF}+\sqrt{6N}\hat{\sigma}_{v}/(2\hat{\sigma}_{0v})}{\sqrt{\hat{\sigma}_{0v}^{2}/(2\hat{\sigma}_{v}^{2})+3\hat{\sigma}_{v}^{2}/(10\hat{\sigma}_{0v}^{2})}}$$

All statistics follow standard normal distribution.

The Pedroni Tests

Pedroni (1997, 1999 and 2000) has proposed a number of tests for cointegration that allow considerable heterogeneity in panel data models. Pedroni tests are better than previous panel cointegration tests because they allow multiple regressors for heterogeneity in errors across cross sectional units and for cointegration vector to vary across different sections of the panel. Pedroni panel regression model is given below:

$$Y_{i,t} = \alpha_i + \delta_t + \sum_{m=1}^{M} \beta_{mi} X_{mi,t} + u_{i,t}$$

Pedroni proposed seven different kinds of cointegration statistics to capture the between and within effects in his panel. Pedroni tests are classified in two categories. Four tests are incorporated in first category (based on pooling, along the within dimension). These four tests are much similar as previous cointegration tests; these tests have the following test statistics. The panel, v-statistic

$$T^2 N^{3/2} Z_{\hat{v}NT} = \frac{T^2 N^{3/2}}{\left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{u}_{it}^2\right)}$$

The panel, ρ statistic

$$T\sqrt{N} Z_{\hat{\rho}NT} = \frac{T\sqrt{N}\left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} (\hat{u}_{it-1}^2 \Delta \hat{u}_{it}^2 - \hat{\lambda}_i\right)}{\left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{u}_{it}^2\right)}$$

The panel, *t*-statistic (non-parametric)

$$Z_{tNT} = \sqrt{\tilde{\sigma}_{NT}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{u}_{it-1}^2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{u}_{it-1}^2 \Delta \hat{u}_{it}^2 - \hat{\lambda}_i \right) \right)$$

The panel, *t*-statistic (parametric)

$$Z_{tNT} = \sqrt{\tilde{\sigma}_{NT}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{u}_{it-1}^{*2}} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{u}_{it-1}^{*2} \Delta \hat{u}_{it}^{*2} - \hat{\lambda}_i \right) \right)$$

Three tests are incorporate in second category, pooling between dimensions. Test statistics of these three tests are given below

The group, ρ statistic (parametric)

$$T\sqrt{N}\tilde{Z}_{\tilde{\rho}NT} = T\sqrt{N}\,\frac{\sum_{t=1}^{T}\left(\hat{u}_{it-1}^{2}\Delta\hat{u}_{it}^{2} - \hat{\lambda}_{i}\right)}{\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{u}_{it-1}^{2}\right)}$$

The group, *t*-statistic (non parametric)

$$\sqrt{N}\tilde{Z}_{tNT-1} = \sqrt{N}\sum_{i=1}^{N}\left(\sqrt{\tilde{\sigma}_{i}^{2}\sum_{t=1}^{T}\hat{u}_{it-1}^{2}}\right)\sum_{t=1}^{T}\left(\hat{u}_{it-1}^{2}\Delta\hat{u}_{it}^{2} - \hat{\lambda}_{i}\right)$$

The group, *t*-statistic (parametric)

$$\sqrt{N}\tilde{Z}^{*}{}_{tNT-1} = \sqrt{N}\sum_{i=1}^{N}\left(\sqrt{\tilde{s}_{i}^{*2}\sum_{t=1}^{T}\hat{u}_{it-1}^{*2}}\right)\sum_{t=1}^{T}\left(\hat{u}_{it-1}^{*2}\Delta\hat{u}_{it}^{*2}\right)$$

3.5.3. *Fully Modified OLS*

This study uses more developed panel estimation technique known as fully modified OLS (FMOLS) is testing hypothesis and estimating for cointegrating vectors in dynamic panels through a way in which also consistent with the degree of cross sectional heterogeneity. One advantage of fully modified OLS is that it allows to selectively pooling long run information and also allows short run dynamics and fixed effects to be heterogeneous among different member of the panels. Other advantage is that it produces asymptotically unbiased estimators and nuisance parameter free standard normal distribution [Pedroni (1999)].

3.5.4. *Panel Causality*

Cointegration tests confirm that causal relation exist between two variables but does not tell us direction of relationship. For find direction of relationship two steps Granger Causality test is applied. The procedure of this test is that, first estimate equation and find residuals and incorporates residuals as independent variable, then following dynamic vector error correction model is applied.

$$\Delta Y_{it} = \alpha_{1j} + \sum_{k=1}^{q}\theta_{11ik}\Delta Y_{it-k} + \sum_{k=1}^{q}\theta_{12ik}\Delta E_{it-k} + \sum_{k=1}^{q}\theta_{13ik}\Delta K_{it-k}$$
$$+ \sum_{k=1}^{q}\theta_{14ik}\Delta L_{it-k} + \sum_{k=1}^{q}\theta_{15ik}\Delta F_{it-k} + \sum_{k=1}^{q}\theta_{16ik}\Delta T_{it-k} + \lambda_{1i}\varepsilon_{it-1} + \mu_{1it}$$
$$\Delta E_{it} = \alpha_{2j} + \sum_{k=1}^{q}\theta_{21ik}\Delta Y_{it-k} + \sum_{k=1}^{q}\theta_{22ik}\Delta E_{it-k} + \sum_{k=1}^{q}\theta_{23ik}\Delta K_{it-k}$$
$$+ \sum_{k=1}^{q}\theta_{24ik}\Delta L_{it-k} + \sum_{k=1}^{q}\theta_{25ik}\Delta F_{it-k} + \sum_{k=1}^{q}\theta_{26ik}\Delta T_{it-k} + \lambda_{2i}\varepsilon_{it-1} + \mu_{2it}$$

$$\Delta CO2_{it} = \gamma_{1j} + \sum_{k=1}^{q} \theta_{11ik} \Delta CO2_{it-k} + \sum_{k=1}^{q} \theta_{12ik} \Delta E_{it-k} + \sum_{k=1}^{q} \theta_{13ik} \Delta Y_{it-k}$$
$$+ \sum_{k=1}^{q} \theta_{14ik} \Delta Y^2{}_{it-k} + \sum_{k=1}^{q} \theta_{15ik} \Delta F_{it-k} + \sum_{k=1}^{q} \theta_{16ik} \Delta T_{it-k} + \lambda_{1i} \varepsilon_{it-1} + \mu_{1it}$$
$$\Delta E_{it} = \gamma_{2j} + \sum_{k=1}^{q} \theta_{21ik} \Delta CO2_{it-k} + \sum_{k=1}^{q} \theta_{22ik} \Delta E_{it-k} + \sum_{k=1}^{q} \theta_{23ik} \Delta Y_{it-k}$$
$$+ \sum_{k=1}^{q} \theta_{24ik} \Delta Y^2{}_{it-k} + \sum_{k=1}^{q} \theta_{25ik} \Delta F_{it-k} + \sum_{k=1}^{q} \theta_{26ik} \Delta T_{it-k} + \lambda_{2i} \varepsilon_{it-1} + \mu_{2it}$$

4. EMPIRICAL RESULTS AND DISCUSSION

The empirical outcomes and explanations are reported in this section. Unit root tests, cointegration tests, FMOLS and VECM are given in Sections 4.1, 4.2, 4.3 and 4.4 respectively.

4.1. Panel Unit Root Tests

Five dissimilar types of panel unit root tests are applied. First two tests the Levin and Lin (LL) test and Breitung t-stat test are assumed common unit root process, across cross sections. In these two tests null hypothesis is that data are non-stationary or have a unit root and alternative hypothesis is that data are stationary or have a no unit root. While the other three tests such as ImPesaran and Shin W-stat test, ADF-Fisher Chi-square test and PP-Fisher Chi-square test are assumes individual unit root process, across cross sections. The results are reported in Table 1, all variables are non-stationary at level and stationary at first difference.

Table 1

Panel Unit Root Test

Variables	The Levin and Lin (LL) Test	Breitung t-stat Test	Im Pesaran and Shin, W-stat Test	ADF - Fisher Chi-square Test	PP - Fisher Chi-square Test
ΔGDP	–4.607***	–3.913***	–3.201***	35.760***	47.040***
ΔGDP^2	–4.629***	–3.871***	–3.174***	35.531***	46.617***
ΔLabour	–3.627***	0.497	–3.252***	43.266***	54.762***
ΔCapital	–5.263***	–3.542***	–3.932***	42.175***	46.381***
ΔOpenness	–10.427***	–3.936***	–8.936***	88.435***	96.241***
ΔCO_2Emision	–4.713***	–1.386	–5.637***	59.384***	89.247***
ΔTotal Energy	–5.513***	–3.608***	–6.218***	63.682***	91.777***
ΔPetrol	–3.544***	–2.150**	–4.197***	45.676***	94.565***
ΔRe	–5.054***	–3.948***	–5.420***	60.258***	98.390***
ΔElectricity	–3.087***	–3.192***	–3.240***	40.323***	86.302***
ΔCoal	–7.073***	–2.783***	–5.369***	60.741***	85.840***
ΔFD	–4.597***	–4.207***	–3.303***	41.452***	58.216***

Note: The statistics values (at 1st difference) are reported. *** Indicates significance at 1 percent, ** at 5 percent and * at 10 percent.

4.2. Panel Cointegration Tests

Pedroni and Kao cointegration, tests are applied to verify long run relationship between variables. Pedroni presents two set of cointegration tests. First set is known as within dimension (four, statistics) and the second one set known as between dimension (three, statistics). Kao cointegration test is based on ADF t-statistic. The results of cointegration are presented in Tables 2(a) and 2(b) According to Pedroni test four out of seven (two, within dimension and two, between dimensions) statistics verify long run relationship between variables: GDP growth, labour, capital, financial development, trade openness and energy consumption. [4] Findings of Kao test also confirm long run relationship between variables.

Table 2(a)

Cointegration Results for Effect of Disaggregate Energy on Growth

	Pedroni Test				Kao Test (ADF)
Model1 Within Dimension	Statistics (Probability)	Weighted Statistics	Between Dimension	Statistics (Probability)	Statistics (Probability)
Panel, PP- Statistic	–1.080 (0.140)	–1.774 (0.038)	Group, PP- Statistic	–1.855 (0.031)	3.851 (0.0001)
Panel, ADF- Statistic	–2.676 (0.004)	–3.211 (0.007)	Group, ADF- Statistic	–3.669 (0.001)	
Model 2					
Panel, PP- Statistic	–2.248 (0.012)	–2.207 (0.013)	Group, PP- Statistic	–2.691 0.003()	–3.375 (0.0004)
Panel, ADF- Statistic	–2.996 (0.001)	–2.977 (0.001	Group, ADF- Statistic	–3.569 (0.0002)	
Model 3					
Panel, PP- Statistic	–2.405 (0.008)	–1.774 (0.038)	Group, PP- Statistic	–2.321 (–.010)	–2.978 (0.001)
Panel, ADF- Statistic	–3.974 (0.000)	–3.860 (0.0001)	Group, ADF- Statistic	–4.460 (0.000)	
Model 4					
Panel, PP- Statistic	–2.802 (0.002)	–2.656 (0.003)	Group, PP- Statistic	–3.248 (0.0006)	–3.939 (0.000)
Panel, ADF- Statistic	–2.580 (0.004)	–1.855 (0.031)	Group, ADF- Statistic	–2.875 (0.002)	
Model 5					
Panel, PP- Statistic	–0.818 (0.206)	–0.528 (0.298)	Group, PP- Statistic	–1.598 (0.005)	–3.324 (0.004)
Panel, ADF- Statistic	–2.825 (0.002)	–2.662 (0.003)	Group, ADF- Statistic	–2.967 (0.001)	

Note: Statistics in brackets are p-values.

[4] In Table 2 only four statistics (out of seven) of Pedroni test are shown that confirm cointegration exists.

Table 2(b)

Cointegration Results for Effect of Disaggregate Energy on Environment

	Pedroni Test				Kao Test (ADF)
Model1 Within Dimension	Statistics (Probability)	Weighted Statistics	Between Dimension	Statistics (Probability)	Statistics (Probability)
Panel, PP-Statistic	–2.367 (0.000)	–2.612 (0.004)	Group, PP-Statistic	–2.908 (0.001)	–5.038 (0.000)
Panel, ADF-Statistic	–2.401 (0.008)	–2.490 (0.006)	Group, ADF-Statistic	–3.191 (0.0007)	
Model 2					
Panel, PP-Statistic	–2.038 (0.020)	–2.210 (0.013)	Group, PP-Statistic	–2.122 (0.016)	–4.133 (0.000)
Panel, ADF-Statistic	–2.756 (0.002)	–2.750 (0.003)	Group, ADF-Statistic	–2.724 (0.003)	
Model 3					
Panel, PP–Statistic	–1.694 (o.045)	–2.768 (0.002)	Group, PP-Statistic	–2.827 (0.002)	–2.551 (0.005)
Panel, ADF-Statistic	–2.660 (0.003)	–4.031 (0.000)	Group, ADF-Statistic	–4.519 (0.000)	
Model 4					
Panel, PP-Statistic	0.011 (0.504)	–0.792 (0.213)	Group, PP-Statistic	–0.679 (0.248)	–2.619 (0.004)
Panel, ADF-Statistic	–1.405 (0.080)	–2.124 (0.016)	Group, ADF-Statistic	–2.549 (0.005)	
Model 5					
Panel, PP-Statistic	–2.762 (0.002)	–2.832 (0.002)	Group, PP-Statistic	–2.662 (0.003)	–1.860 (0.031)
Panel, ADF-Statistic	–3.329 (0.0004)	–2.732 (0.003)	Group, ADF-Statistic	–2.819 (0.002)	

Note: Statistics in brackets are p-values.

4.3. Fully Modified OLS

The results reported in Table 3(a) model 1, real gross domestic product rise 0.389 percent owing to1 percent growth in capital, RGDP rise 0.329 percent owing to 1 percent growth in labour, RGDP rise 0.552 percent owing to 1 percent growth in total energy consumption, RGDP decline 0.093 percent owing to 1 percent growth in financial development, RGDP rise 0.123 percent owing to 1 percent growth in trade openness. As far disaggregated energy consumption according to Table 3(a) model 2 results, real gross domestic product rise 0.313 percent owing to 1 percent grow in electricity consumption, The result of model 3 shows real gross domestic product rise 0.288 percent owing to 1 percent grow in petroleum consumption. In model 4, real gross domestic product rise 0.265 percent owing to 1 percent grows in renewable energy consumption. The results of model 5 indicates real gross domestic product rise 0.035 percent owing to 1 percent grow in coal consumption.

Table 3(a)

Fully Modified OLS Results for Effect of Disaggregate Energy on Growth

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Capital	0.389***	0.323***	0.390***	0.378***	0.404***
	(10.101)	(7.101)	(8.138)	(7.891)	(7.851)
Labour	0.329***	0.331**	0.630***	0.655***	0.792***
	(3.004)	(2.585)	(5.688)	(6.363)	(7.098)
T Energy	0.552***				
	(7.371)				
Electricity		0.313***			
		(5.792)			
Petrol			0.288***		
			(3.971)		
Renew				0.265***	
				(5.033)	
Coal					0.035**
					(2.149)
FD	–0.093***	–0.093***	–0.134***	–0.029	–0.113***
	(–3.150)	(–2.897)	(–3.707)	(–0.781)	(–2.943)
TO	0.123**	0.232***	0.203***	0.195***	0.350***
	(2.239)	(4.090)	(3.096)	(3.094)	(5.121)

Note: The t-values are reported below the coefficient in parenthesis, The *** indicates significance at 1 percent, ** at 5 percent and * at 10 percent.

According to the impact of energy consumption on environment, the results reported in Table 3(b) model 1 reveal that CO_2emission rise 1.649 percent owing to 1 percent grow in RGDP, CO_2 emissions decrease 0.030 percent owing to 1 percent grow in RGDP square,CO_2 emissions rise 1.091 percent owing to 1 percent grow in total energy consumption, CO_2 emissions rise 0.061 percent owing to 1 percent grow in financial development, CO_2 emissions rise 0.079 percent owing to 1 percent grow in trade openness.

The disaggregated results reported in Table 3(b) model 2 show, CO_2emission rise 0.479 percent owing to 1 percent grow in electricity consumption, in model 3 CO_2emission rise 0.596 percent owing to 1 percent grow in petroleum consumption, in model 4, CO_2emission rise 0.224 percent owing to 1 percent grow in renewable energy consumption, in model 5, CO_2emission rise 0.017 percent (insignificant) owing to 1 percent grow in renewable energy consumption.

All the results of this study are empirically and theoretically acceptable. The sign of energy consumption on economic growth and CO_2 emissions is expected to be positive, results also support positive relationship. Financial development can be positive or negative depends on investment decisions, if investment decisions have asymmetric information then sign of financial development would be negative on economic growth. Findings also confirm that financial development negatively impact on economic growth, empirically [Loaayza and Ranciere (2004)] also verify that financial development negatively impact on economic growth.

Table 3(b)

Fully Modified OLS Results for Effect of Disaggregate Energy on Environment

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
GDP	1.649***	1.814***	2.540***	4.140***	4.271***
	(4.506)	(7.222)	(5.990)	(7.428)	(4.617)
GDPS	–0.030***	–0.021***	–0.041***	–0.068***	–0.065***
	(–4.456)	(–4.580)	(–5.357)	(–6.311)	(–3.763)
T Energy	1.091***				
	(15.817)				
Electricity		0.479***			
		(12.301)			
Petrol			0.596***		
			(8.621)		
Renew				0.224***	
				(3.177)	
Coal					0.017
					(0.694)
FD	0.061***	0.103***	–0.001*	0.001	0.005
	(2.633)	(3.979)	(–1.761)	(0.924)	(0.104)
TO	0.079*	–0.136***	0.404***	0.589***	0.137
	(1.731)	(–5.216)	(3.935)	(4.196)	(1.346)

Note: The t values are reported below the coefficient in parenthesis, The *** indicates significance at 1 percent, ** at 5 percent and * at 10 percent respectively.

Theoretical and empirical verification express that coefficient of financial development can be positive or negative on CO_2 emissions. Development of financial sector can provide higher level of financing at a very low level of costs, this facility also provide for environmental projects. These kinds of projects have much importance for government in both private and public sector. Government also encourage private sector to invest in environmental projects for reduce CO_2emissions. Development in financial sector can increase environment performance as said by Claessens and Feijen (2007). In developing nations laws and regulatory authority forces firms to decrease CO_2emissions or improve environment performance [Dasgupta, *et al.* (2001)]. Some other writers such as [List and Co (2000)] also conclude that relationship between financial development and CO_2emissions is negative. Zhang (2011) finds a positive relationship due to the reason of inefficient distribution of financial resources to enterprises. Some other writers such as Cole and Elliot (2005) and Feridun (2006) also find positive impact of financial development on CO_2emissions.

The impact of trade openness on CO_2emissions may also be positive or negative as Hecksher Ohlin theory postulates that under free trade, developing countries (mostly middle and low income countries) would focus on the production of goods that are rigorous in factors in which they have a comparative advantage, such as labour and natural resources. Thus, trade causes the movement of goods produced in one country for either consumption or further processing due to greater trade openness, is a source of pollution. Jalil and Feridun (2011) conclude that trade openness has positive impact on emissions; Grossman and Krueger (1985) also conclude that dirty industry in developing nations is a cause of pollution. The indication of trade openness on emissions (CO_2) can be negative; the reason behind this is that due to trade openness any nation can reach international market which enhances the market share among countries [Shahbaz, *et al.* (2012)]. The competition among nations will use scarce resources for efficiency and import cleaning technology for lower CO_2emissions [Runge (1994); Helpman (1998)].

4.4. Panel Causality

The results reported in Table 4(a) indicate short run dynamics that there exists bidirectional causal relationship between electricity consumption and economic growth, petroleum use and economic growth. Unidirectional causal connection is found between renewable energy consumption to economic growth, coal consumption to economic growth and total energy consumption to economic growth. Error, correction term shows adjustment speed and it is significant that also confirms long run relationship holds.

According to Table 4(b) bidirectional causal relationship is established between total energy consumption and CO_2 emission and petroleum use and CO_2emission. Unidirectional causal connection is found between electricity consumption to CO_2emission, renewable energy consumption to CO_2emission and coal consumption to emissions. The negative and significant error adjustment term also confirms long run causal relationship.

Table 4(a)

Panel Causality Results for Effect of Disaggregate Energy on Growth

	Short Run						Long Run
Dependent Variables	Δ GDP	Δ TEnergy	Δ Capital	Δ Labour	ΔFD	ΔTO	ΔECT
Model 1							
Δ GDP	–	0.57***	0.17**	0.18*	–0.15*	0.22**	–0.03***
Δ TEnergy	1.727	–	0.30*	0.31	0.26**	0.38*	–0.01***
Model 2			Short Run				Long Run
Δ GDP	–	0.31***	0.51***	0.09*	–0.53***	0.45***	–0.03***
Δ Elec	3.15***	–	–1.62*	–0.29	1.67***	–1.44***	–0.01***
Model 3							
Δ GDP	–	0.24*	0.81***	0.02*	–0.20***	0.20***	–0.08*
Δ Petrol	12.30***	–	10.05***	0.36	2.54***	2.46***	–0.01*
Model 4			Short Run				Long Run
Δ GDP	–	0.32***	0.30	0.35**	–0.06*	0.01*	–0.04***
Δ Renew	16.02	–	22.29**	7.52	1.38	2.19*	–0.01***
Model 5			Short Run				Long Run
Δ GDP	–	0.01*	0.93***	–0.07*	–0.19***	0.06	–0.03**
Δ Coal	7.53		1.49*	5.51	1.94	2.72*	–0.01***

Note: ECT represents error correction term, The* significant at 10 percent, ** at 5 percent and *** at 10 percent respectively.

Table 4(b)

Panel Causality Results for Effect of Disaggregate Energy on Environment

	Short Run						Long Run
Dependent Variables	Δ CO2	Δ TEnergy	Δ GDP	Δ GDPS	Δ FD	Δ TO	ΔECT
Model 1							
Δ CO2	–	0.96***	3.02***	–0.06***	0.22***	0.03	–0.08**
Δ TEnergy	0.74**		2.82**	–0.06*	0.08	0.35*	–0.03***
Model 2			Short Run				Long Run
Δ CO2	–	1.49*	18.22**	–0.31**	1.91**	–1.91**	–0.01***
Δ Elec	1.42		24.6***	–0.46***	1.095*	1.41**	–0.01***
Model 3							
Δ CO2	–	0.84***	7.19***	–0.13**The*	–0.32***	0.33**	–0.04***
Δ Petrol	2.26***		–16.29***	0.30***	0.72***	0.76***	–0.02***
Model 4			Short Run				Long Run
Δ CO2	–	0.50***	11.8***	–0.20***	0.75***	0.32*	–0.02***
Δ Renew	2.46		12.20*	–0.28**	0.85*	0.19	–0.01***
Model 5			Short Run				Long Run
Δ CO2		0.33*	3.94***	–0.07**	0.07*	0.62	–0.01***
Δ Coal	3.02		11.92**	–0.22**	0.22	1.89*	–0.01**

Note: ECT represents error correction term. The *is significant at 10 percent, ** at 5 percent and *** at 10 percent respectively.

5. CONCLUSION, AND POLICY IMPLICATIONS

An extensive literature has been done on energy consumption and economic growth, energy consumption and environment. Previous studies mostly use total energy consumption. This study uses disaggregated data of energy consumption to find relationship between various types of energy sources, economic growth and environment.

Results of panel cointegration show that long run relationship exists between energy consumption, economic growth, and control variables: financial development and trade openness. Fully modified OLS confirms that all forms of disaggregate energy consumption have positive and significant impact on economic growth. Results of impact of energy consumption on environment also explain that all forms of disaggregate energy consumption have positive and significant impact on CO_2emission except coal consumption. Environment Kuznets curve hypothesis exist in all models, which shows that economic growth is a solution for environment rather than a problem.

Panel causality through VECM elaborate that bidirectional causal connection is found between electricity consumption and economic growth, petroleum consumption and economic growth, total energy consumption and CO_2, and petroleum consumption and CO_2emission. Unidirectional causal association is found renewable energy consumption to economic growth, coal consumption to economic growth, total energy consumption to economic growth, electricity consumption to CO_2emission, renewable energy consumption to CO_2emission and coal consumption to CO_2emission.The negative and significant error correction term shows that deviations will remove with specific speed of adjustment and this confirms the existence of long run relationship between components of energy consumption with growth and environment.

Bidirectional causal link between electricity consumption and economic growth, petroleum consumption and economic growth, unidirectional causal connection renewable energy consumption to economic growth, coal consumption to economic growth, total energy consumption to economic growth indicates that any energy conservation policy (for, environment safety) may dangerous for economic growth. On other hand, bidirectional causal relationship among total energy consumption and CO_2emission, and petroleum consumption and CO_2emission, unidirectional causal relation electricity consumption toCO_2emission, renewable energy consumption to CO_2emission and coal consumption to CO_2emission explains that consumption of energy increase economic growth but also pollute environment. There is need to adopt sustainable development policy according to empirical results which increase economic growth and keep environment level at sustainable level.

According to empirical results government needs to promote renewable energy sector because its increase economic growth and its impact on environment degradation is low as compare to other sectors. Investment in renewable energy sector is beneficial for private and public sector. For this purpose cost and benefit analysis, of various forms of energy sector considered to be adopted.

APPENDIX

THE LEVIN AND LIN (LL) TEST

Levin and Lin was developed panel unit root test in 1992 and published in 2002 with Chu (co-author). This test is extension of DF (Dickey Fuller) test, model is given below:

$$\Delta Y_{i,t} = \alpha_i + \rho Y_{i,t-1} + \sum_{k=1}^{n} \phi_k \Delta Y_{i,t-k} + \delta_i t + \theta_t + \mu_{it}$$

α_i and θ_t shows that two way fixed effect allows by the model. Time effects (Unit specific) and fixed effects (Unit specific) both are included.

Two hypothesis null and alternative are given below:

$$H_O : \rho = 0$$
$$H_a : \rho < 0$$

The main assumption of LL test is that individual processes and cross sectionals independent. According to this assumption under null hypothesis ρ will follow standard normal distribution.

The Im, Pesaran and Shin (IPS) Test

This test is extension of LL test by introduce heterogeneity on the coefficient of the $Y_{i,t-1}$ variable and proposed as a fundamental testing method one based (on the average, of the individual unit root test statistics). The model of this test is given below:

$$\Delta Y_{i,t} = \alpha_i + \rho_i Y_{i,t-1} + \sum_{k=1}^{n} \phi_{ik} \Delta Y_{i,t-k} + \delta_i t + \mu_{it}$$

And both null and alternative hypothesis are given below:

$H_O : \rho = 0$ (For all i)

$H_a : \rho < 0$ (For, at least one i)

Null hypothesis= series are non-stationary

Alternative hypothesis= at least (one fraction) from series is stationary.

The Maddala and Wu (MW) Test

Maddala and Wu (1999) discuss some drawbacks of previous tests and proposed a model that can also be estimate unbalanced panels. The basis assumption of MW test is that, a heterogeneous alternative is preferable. Assuming that, if *N* unit root tests are there then MW is given below:

$$\pi = -2\sum_{i=1}^{N} \ln \pi_i$$

Breitung Unit Root Test

There is slight difference between LLC and Breitung test. The difference lies in two ways. Only auto regression portion is removed when constructing standardise proxies. That is:

$$\tilde{e}_{it} = \Delta\tilde{Y}_{it} = \frac{\Delta Y_{it} - \sum_{j=1}^{P_i} \beta_{ij} \Delta Y_{i,t-j}}{\sigma_i}$$

$$\tilde{v}_{i,t-1} = \tilde{Y}_{it-1} = (Y_{it-1} - \sum_{j=1}^{P_i} \beta_{ij} \Delta Y_{i,t-j})/\sigma_i$$

Running the following regression:

$$e^*_{it} = \rho v^*_{i,t-1} + \mu_{it}$$

Where

$$e^*_{it} = \sqrt{\frac{T-t}{T-t+1}} \left(\tilde{e}_{it} . \frac{\tilde{e}_{it} + \cdots + \tilde{e}_{it+T}}{T-t} \right) \ and$$

$$v^*_{i,t-1} = \tilde{v}_{i,t-1} - C_{it}$$

Fisher ADF Test

Consider the following regression model.

$$\Delta Y_{it} = \rho Y_{it-1} + \sum_{i=2}^{P} \theta_i \Delta Y_{t-i+2} + \varepsilon_{it}$$

Null and Alternative Hypothesis:

$H_0: \rho = 0$ (Series is non-stationary)
$H_A: \rho < 0$ (Series is stationary)

We use ADF (for the presence, of unit root) test as:

$$t_{\hat{r}} = \frac{\hat{\rho}-1}{SE(\hat{\rho})}$$

This $t_{\hat{r}}$ does not follow standard student t-value but the critical values are calculated by DF and depend on whether there is an intercept, trend, or intercept and trend.

Fisher-PP Test

Fisher-PP (Fisher-Phillips and Parron) proposed non parametric transformation of the t-stat from original DF regression such that under the unit roots null. The transformed statistic (Z-statistic) has DF distribution. To test regression for PP we specify the following model:

$$\Delta Y_t = \beta' D_t + \pi Y_{t-1} + u_t$$

Where u_t is I(0) may be heteroscedastic. Serial correlation correction, and hetroskedasticity (in the error term u_t) are settlement of PP test.

Null and Alternative Hypothesis

$H_0: \pi = 0$ (Series is non-stationary)
$H_A: \pi < 0$(Series is stationary)

We use ADF test (for the presence of unit root) as:

$$t_{\hat{r}} = \frac{\hat{\pi}-1}{SE(\hat{\pi})}$$

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