New insights on the long-run relationship between economic growth and environmental quality

by

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List of Abbreviations

CO_2	Carbon dioxide
CPI	Corruption Perception Index
EKC	Environmental Kuznets Curve
EPA	Environmental Protection Agency
FDI	Foreign Direct Investment
FEVDM	Forecast Error Variance Decomposition Method
FMOLS	Fully Modified Least Squares
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GSP	Generalized System of Preference
IAA	Innovative Accounting Approach
IRF	Impulse Response Function
NASA	National Aeronautics and Space Administration
NO_x	Nitrogen Oxide
OECD	Organization for Economic Co-operation and Development
SO_2	Sulfur dioxide
SPM	Suspended Particulate Matter
UNEP	United Nations Environment Program
VAR	Vector Auto-regression
VECM	Vector Error-correction Model

Abstract

One of the widespread debates in the field of environmental economics that started at the beginning of the 1990s concerns the relation between environmental pollution and economic growth. This research aims to investigate the most likely pattern of the long-run relationship between CO_2 emissions and economic growth, identify the factors that drive CO_2 emissions and propose policy recommendations for reducing CO_2 emissions. The study utilizes panel data on seven variables – per capita CO_2 emissions, GDP per capita, energy consumption, human population, trade openness, financial development and corruption in 65 countries over 51 years, from 1960 to 2010. Employing graphical tool and econometric techniques such as panel unit root test, panel cointegration test, FMOLS (Fully Modified Least Squares) estimates, Granger causality and IAA (Innovative Accounting Approach) analysis, the study finds that the most likely pattern of the relationship is a sigmoid curve showing that a country's per capita CO_2 emissions increase when the country transitions from a low-income status to a middle-income status to a high-income status. Also, the study documents that the potential factors driving global CO_2 emissions are economic growth, financial development, energy consumption and corruption. An appropriate combination of emissions standards, pollution tax on fossil fuel based energy sources, anti-corruption strategies, socio-environmental standards for global trade, mass education and awareness about the adverse effects of CO_2 emissions on the environment and human health are potential policy measures.

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Chapter 1

1.1 Introduction

Since the beginning of human civilization in the Early Stone Age or Paleolithic Era, humans started transforming inputs collected from nature into economic outputs, i.e. goods and services, using their indigenous knowledge and primitive technology. Later, the transformation process was accelerated for more economic outputs after developing and adopting modern science and technology. The scientific discoveries and the continuous effort towards achieving an increasing volume of economic outputs resulted in the Industrial Revolution in the 18^{th} century. The Revolution started not only a new era of rapid economic growth but also attenuated the environmental quality, and more importantly it started transforming the global economy from an organic economy based on labor power to an inorganic economy based on unexpansive fossil fuels (Kasman and Duman, 2015; Ahmed, et al, 2016 a). Burning fossil fuels releases greenhouse gases (GHG) which the scientific community undisputedly declared as the major cause of the global warming (*idem*). A recent study by the NASA confirms that atmospheric carbon dioxide (CO_2) - the major GHG, has significantly increased since the Industrial Revolution (NASA, 2017). The study further reports that atmospheric CO_2 for the last centuries had never exceeded the 1950s level. Enhancing economic growth was the main purpose of all innovations introduced during and after the Industrial Revolution regardless of their nature, such as sophisticated machineries, new economic policies or financial development. Consequently, the global community has seen a substantial progress in its economic development over the last few decades (Al-Mulali, et al, 2015d). Economic growth requires transforming an enormous volume of raw materials and increases the use of energy generated mostly from fossil fuels (Ahmed, et al, 2016 a). Excessive use of both raw materials and energy causes environmental pollution on one hand and reduces the natural resource base on the other hand (*idem*).

CO_2 emissions are considered one of the major pollutants contributing to climate change (C2ES, 2013; EPA, 2015; Lacheheb et al., 2015). Climate change in recent decades, has caused widespread impacts on natural and human systems (IPCC, 2014). The impacts include, but are not limited to, altering hydrological systems, affecting water resources in terms of quantity and quality, affecting biological activities of many species, and affecting crop yields (IPCC, 2014). It has been forecasted that there will be an increase in global temperatures - from 1.1° C to 6.4°C due to increases in CO_2 emissions and other greenhouse gases (GHG) emissions (IPCC, 2007; Lacheheb et al., 2015). As a result, sea levels are projected to rise from 16.5 cm to 53.8 cm by 2100, which will cause diverse socio-economic complications in many coastal areas (*idem*). Though CO_2 emissions originate from both anthropogenic and natural sources, it is believed that human activities are responsible for altering the carbon cycle – both by increasing the concentration of CO_2 in the atmosphere and by lowering the earth's capacity to absorb CO_2 from the atmosphere (Ballantyne et al., 2015; EPA, 2015). The level of anthropogenic CO_2 emissions of a country depends on various factors such as the intensity of its economic activity and the mode of production it uses for manufacturing output, the consumption level of the population, and the stringency of environmental regulations (Luptfáčik and Schubert, 1982).

Countries vary in the modes of production they choose to adopt, the level of output they produce, the level of consumption, as well as the level of CO_2 emissions. Economic growth is often accompanied by an increased demand for durable goods such as cars, refrigerators, air conditioners and heat pumps, which results in even more CO_2 emissions (EXEC, 2015); and logically it could be further extended that the relationship between consumption and CO_2 emissions implies that the more durable (and non-durable) goods a nation consumes, the higher the level of its CO_2 emissions. The consumption level of a country depends primarily on its own production and partially on its imports from the rest of the world (Chacholiades, 1990). When a country specializes in export-based growth, it will have a comparative advantage in producing pollution-intensive output if its level of environmental regulations is weaker than average (Cole and Elliott, 2003). Since there is a strong positive correlation between the per capita income level of a country and the stringency of its environmental regulations (*idem*), developing countries will specialize in pollution-intensive production whilst developed countries will specialize in clean production due to comparative advantage (*idem*).

Shahbaz et al. (2012) also support this conclusion, as they explain how environmental quality in Nigeria, a developing country, decreased significantly due to higher levels of pollution-intensive output production under the trade openness regime. Recent evidence, however, shows that many developing countries are addressing their pollution problems through formulating effective environmental policies, with or without the help of developed countries or international organization such as the United Nations Environment Program (UNEP) (Dasgupta et al., 2006). By adopting standards that exist in developed countries and by implementing them in society, these countries often times perform better than developed countries (Dasgupta et al., 2006; Stern, 2004). For example, Costa Rica, which is a developing country, received the 2010 Future Policy Award issued by the World Future Council for pioneering legal protection of biodiversity, which served as a model for other nations to follow (Theguardian, 2016). Therefore, it cannot be maintained that all developing countries are lagging in formulating effective environmental policies.

In formulating environmental policies, the main objective of policy makers varies by country. While reducing energy consumption as a means to reduce CO_2 emissions is important to policy makers in developed countries, it is unrealistic to expect all developing nations to have the same goal, as their primary objective is to raise the standard of living of their societies rather than environmental quality (Han and Chatterjee, 1997). However, environmental quality is also essential for human wellbeing. Therefore, sustainable development is the ultimate goal of all countries. In order to achieve sustainable development, better understanding of the relationship between the economy and the environment is necessary. Therefore, studying the relationship between economic growth and environment quality has become the focus of research works both in economics and environmental science over the latest decade (Sharma, 2011). The relationship is important in the domain of environmental policy, where it allows policy makers to judge the impacts of economic activities on the environment, thereby enabling them to formulate effective conservation policies for sustainable development (Narayan and Narayan, 2010).

Many research works on the issue have been carried out, and therefore, a wide range of literature on the same issue is now available (Al-Mulali, et al, 2015; Kasman and Duman, 2015; Ahmed, et al, 2016 a). However, the findings are mostly inconclusive because in these studies different indicators are used for environmental quality, along with different econometric techniques and different control variables (Rehman, et al, 2012; Ahmed, et al, 2016 a; Ahmed, et al, 2016 b). Most of the studies do not include most of the relevant control variables such as energy consumption, urbanization or human population growth, trade openness, financial development and so on; and therefore, they suffer from the omitted variable bias (Halicioglu, 2009; Sharma, 2011; Farhani, et al, 2013; Al-Mulali, et al, 2015; Farhani and Ozturk, 2015). Also, most of them were done using information from a single country or a region. Consequently, it is difficult to generalize the results of a country or region for the rest of the world (Rehman, et al, 2012). An inclusive global based research on the relationship, including important variables, is necessary for two reasons; it would reduce the omitted variable bias and its findings would be appropriate at the global level assisting policy makers working at global (e.g. IPCC) and regional levels (e.g. EU).

1.2 Research objectives

Studying the impact of economic activities on the environment is required in order to design sound policies aiming to achieve sustainable development. It is evident that the nature of a country's economy changes, for example from traditional to modern when it evolves from being a developing country to becoming a developed country. The transition implies a change in the pattern of the relationship between CO_2 emissions and economic growth of the country. Therefore, a dynamic analysis on the relationship is needed to understand how the pattern of the relationship between economic growth and CO_2 emissions of a country changes over time and what are the factors driving CO_2 emissions of the country. The objectives of the study are;

1) To examine what would be the most likely pattern of the long-run relationship between economic growth and CO_2 emissions of a country when it changes its mode of production from labor intensive to factor neutral and to capital intensive because of its economic progress.
2) To identify what are the factors that drive CO_2 emissions of a country.
3) To propose sound policy formulation for reducing CO_2 emissions based on the research findings.

Chapter 2

2.1 The pattern of the long-run relationship between economic growth and CO_2 emissions

Human economic activities appear to be the main reason for deteriorating environmental quality through emissions of GHGs such as CO_2. However, it is an interesting but unsettled debate in environmental economics whether economic growth is deteriorating or ameliorating the quality of the earth's environment (Grossman and Krueger, 1994). On one hand, researchers argue that environmental pollution comes in many shapes and forms (e.g. SO_2, CO_2 emissions) and that it is positively correlated with economic growth, meaning that higher levels of economic activity result in more emissions (Bertinelli and Strobl, 2005; Chen and Huang, 2013; Heil and Selden, 2001; Holtz-Eakin and Selden, 1995; Shafik, 1994). On the other hand, several researchers consider that economic growth is necessary to conserve the long-run sustainability of the natural environment, meaning that economic resources must be invested in research and development to discover pollution abatement technologies and in sustainability programs aimed at conserving the environment (Grossman and Krueger, 1994; Urheim, 2009). In order to understand the debate, proper specification and justification of the relationship between environmental pollution and economic growth is required (Azomahou et al., 2006; Kijima et al., 2010; Narayan and Narayan, 2010).

2.2 Literature review

Researchers all over the world have attempted to estimate the relationship between environmental pollution and economic growth, employing various techniques. Most of these attempts have used GDP, GDP per capita or per capita national income data and information on various pollutants such as emissions of CO_2, nitrogen oxide (NO_x), sulfur dioxide (SO_2) and suspended particulate matter (SPM) (Bo, 2011; Grossman and Krueger, 1994). The findings of most research works show no consistent relationship between CO_2 emissions and economic growth. However, in numerous studies the nexus is found as an inverted U-shaped curve also known as the Environmental Kuznets Curve (EKC). The curve shows that at the beginning of a country's economic development, environmental degradation rises and then it levels off and falls with continuous economic growth (Azomahou et al., 2006; Bradford et al., 2000; Canas et al., 2003; Galeotti et al., 2006; Grossman and Krueger, 1994; Kahn,1998; List and Gallet,1999; Millimet et al., 2003; Millimet and Stengos, 2000; Panayotou, 1993; Perman and Stern, 2003; Schmalensee et al., 1998; Selden and Song, 1994; Shafik and Bandyopadhyay,1992; Shukla and Parikh,1992; Taskin and Zaim, 2000). The findings imply that poorer nations, as they start their economic growth process, pollute more, while richer nations are cleaner due to their ongoing economic development. Some research studies (Bertinelli and Strobl, 2005; Chen & Huang, 2013; Heil & Selden, 2001; Holtz-Eakin & Selden, 1995; Shafik, 1994) describe the relationship as monotonically increasing or non-declining, implying that higher levels of economic activity require the use of more natural resources (e.g. coal, oil, gas, etc.) which results in more CO_2 emissions. Therefore, developed countries emit more CO_2

because of their numerous economic activities. Two other studies, conducted by Sengupta (1996); and De Bruyn and Opschoor (1997), found the relationship to be an N-shaped curve, meaning that environmental quality started falling again after an improvement to a certain level. Interestingly, Roy and van Kooten (2004) discovered the relationship as a U-shaped (not inverted) curve; however, Lacheheb et al. (2015) did not find the existence of any inverted U-shaped curve.

The relationship varies across countries, especially between developed and developing countries. Using different datasets for the OECD (Organization for Economic Co-operation and Development) and non-OECD countries, Galeotti et al. (2006) examined the relationship between CO_2 emissions and income level, and found it as an inverted U-shaped curve only for the OECD countries. Another study, by Lapinskienė et al. (2014), found the inverted U-shaped nexus for 29 European countries. The study also mentioned that an article by Huang et al. (2008) could not provide any evidence to support the same relationship for developed countries. In order to test the validity of the inverted U-shaped relationship for developing countries, Apergis and Ozturk (2015) conducted empirical tests for 14 Asian countries, using data from 1990 to 2010, and found the relationship across these countries to be valid. Narayan and Narayan (2010) tested the relationship for 43 developing countries and found an inverted U-shaped relationship for only a few Middle Eastern and South Asian countries. The pattern of the relationship between pollution and economic growth that is mostly reported in the literature is an inverted U-shape. According to the pattern, environmental degradation in a country starts to fall when its per capita GDP reaches a turning point such as US$ 3,137 (Panayotou, 1993) or a per capita income of less than US$ 8,000 (Grossman and Krueger, 1994). In recent years, the GDP per capita of developed or high-income countries has increased beyond the turning point. However, both real GDP per capita as well as per capita CO_2 emissions continue to increase (Ang, 2008), thus disproving the hypothesis of *pollution-income progression of agrarian communities (clean) to industrial economies (pollution intensive) and to service economies (cleaner)* (Arrow et al., 1996*)*. More importantly, the EKC or the inverted U-shape relationship does not describe CO_2 emissions in a meaningful way (Holtz-Eakin and Selden, 1995; Robers and Grimes, 1997), whereas these emissions, i.e. CO_2 emissions, have been commonly used as the proxy for the level of pollution in the existing literature (Ang, 2008). De Bruyn et al. (1998) and Dinda et al. (2000) argue that the EKC does not exist in the long-run. Therefore, an attempt is necessary to estimate the long-run relationship between CO_2 emissions and economic growth, which may enable policy makers to formulate policies facilitating long-run sustainable development.

2.3 Research methods

Following Törnros (2013), who used a scatterplot to see whether the inverted U-shaped relationship exists, a similar graphical method, a line chart, will be used in the paper to explore the long-run relationship between economic growth and CO_2 emissions. In the chart, economic growth is measured as GDP per capita and CO_2 emissions are measured as per capita CO_2 emissions. The two variables are denoted on the horizontal and the vertical axis respectively. All low-income countries are assumed to aspire to transition from a low-income status to a middle-income status and then a high-income status, by means of economic growth. Countries are classified as high, middle and low-income, following the most recent UN country classification list (UN, 2014). However, in the study, lower-middle and low-income countries defined on the list are combined as one low-income country category - LIC. One of the main reasons for classifying countries into broad three categories instead of four is to demonstrate more visibly how the pattern of the long-run relationship of a country changes when it changes its mode of production from labor intensive to factor neutral and to capital intensive because of its economic progress.

For exploring the pattern of the long-run relationship, data on both variables are required over a period long enough to cover an entire transitional phase. An entire transitional phase can be explained as a period when a previously low-income country which is currently a high-income country managed to transform its economy from a traditional economy based on labor power to a modern economy based on machineries, because of economic progress. What was the time frame for a developing low-income country to become a high-income country? Some countries took more than a hundred years and others needed less than a hundred years to become high-income countries from their initial low-income position. Currently, no database provides time series data on the per capita CO_2 emissions and GDP per capita for any country before 1960 (Törnros, 2013). This limitation may be overcome if an assumption is made following Rostow's theory on the stages of economic growth. The assumption is that every country – either low or middle-income or both - follows a growth path similar to what current developed countries had experienced prior to becoming high-income countries, since both low and middle-income countries desire to become high-income countries (Rostow,1959). In fact, developing economies, for becoming developed adopt the strategies pursued by current advanced economies in their earlier stages of development (Han and Chatterjee, 1997). The per capita CO_2 emissions data are plotted against the corresponding GDP per capita for all three categories of countries – low, middle and high-income countries in a same diagram, in such a way that the first segment of the chart represents the relationship between these two variables for a low-income country whose mode of production is labor intensive; the middle fragment is for a middle-income country which follows a factor neutral mode of production, and the last segment is for a high-income country whose mode of production is capital intensive, respectively. The resulting combined line chart will specify the most likely pattern of the long-run relationship between economic growth and CO_2 emissions of a country, when it improves its economic status from a low-income country to a middle-income country and then to a high-income country. However, before exploring the long-run relationship, an analysis of the recent per capita CO_2 emissions trends in the countries belonging to all three categories is necessary.

2.4 Data description

The study depends largely on secondary sources for data collection. Data on both GDP per capita and per capita CO_2 emissions were collected from the World Development Indicators of the World Bank on March 19, 2016. Data on both variables cover 51 years, from 1960 to 2010, and 63 countries comprising 25 low-income (LICs), 16 middle-income (MICs), and 22 high-income countries (HICs). Only 63 countries have been selected due to availability of full data sets for these countries over the period. Table 1 provides a list of the 63 countries classified over three categories. In order to plot the data on a graph, the panel data have been converted into time series data by taking the average of values of same category countries (e.g. LICs, MICs and HICs) across the 51-year period.

Table 1. List of 63 Countries Classified over Three Categories.

High-income countries - HICs (22) - Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Singapore, Spain, Sweden, UK and USA
Middle-income countries - MICs (16) - Algeria, Brazil, Chile, China, Costa Rica, Dominican Republic, Ecuador, Gabon, Jamaica, Mexico, Panama, Peru, South Africa, Suriname, Thailand and Turkey
Low-income countries – LICs (25) - Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Ghana, Guatemala, Honduras, Kenya, Liberia, Madagascar, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Papua New Guinea, Philippines, Rwanda, Sierra Leone, Sri Lanka, Togo and Uganda

2.5 Empirical findings and discussion

Trends in the per capita CO_2 emissions for all three categories of countries – LICs, MICs and HICs - over the last five decades are depicted in Figure 1. It is evident that the per capita CO_2 emissions in all categories of countries rose with the per capita GDP overtime. Unlike the rate of change of the per capita CO_2 emissions in HICs, the rate of the per capita CO_2 emissions in both MICs and LICs was much higher in 2010 compared to that in 1960. However, HICs emitted higher levels of per capita CO_2 emissions than MICs and LICs. The increase in per capita CO_2 emissions in all groups of countries occurred primarily due to expanding economic activities, since output is positively correlated with pollution in the long-run (Ang, 2008; Han and Chatterjee, 1997). These results indicate that emissions rise monotonically with output. This finding is consistent with other empirical findings (Shafik (1994) and Holtz-Eakin and Selden (1995).

Table 2. Summary statistics of GDP per capita and per capita CO_2 emissions (1960-2010)

Range of values				
For GDP per capita (in US$)				
Country	**1960**	**2010**	**Min**	**Max**
LICs	122.99	1208.13	122.99	1208.13
MICs	307.70	7381.72	300.88	7381.72
HICs	1262.91	47313.74	1262.91	51420.19
For per capita CO_2 emissions (in metric tons)				
Country	**1960**	**2010**	**Min**	**Max**
LICs	0.15	0.39	0.15	0.41
MICs	1.10	3.54	1.10	3.56
HICs	6.95	9.60	6.95	11.46

Source: The World DataBank, accessed on March 19, 2016

Among the three groups of countries, the per capita CO_2 emissions in HICs experienced significantly more fluctuations, especially a continuous rise until 1973 and then an overall decline with some modest fluctuations. The nature of the fluctuations in HICs' per capita CO_2 emissions raises the question what initiatives had been taken by developed countries before 1973 to reduce the overall per capita CO_2 emissions trend, or even to level it off in later periods? Developed countries began formulating and implementing environmental policies vigorously since the 1960s, and therefore the end of the1960s is marked as the beginning of the modern environmental policy-making era (Andrews, 2006). In the USA, the Environmental Protection Agency (EPA) was established in 1970 with the goal to protect all Americans from significant risk to human health and the natural environment (EPA, 2016). The U.S. president at the time, Richard Nixon, signed the Clean Air Act in 1970. This act marks a milestone for environmental conservation in the USA. In Europe, the EU Council of Environmental Ministers adopted the first Environmental Action Program in 1973 and since then the EU environmental policy has become a core area of European politics (Knill and Liefferink, 2013). Other developed countries, along with global organizations, have undertaken initiatives to conserve the natural environment, aiming to protect all living beings from significant risk**.** All of these initiatives contributed to the leveling off or the falling trend in per capita CO_2 emissions in HICs in the 1980s and onwards.

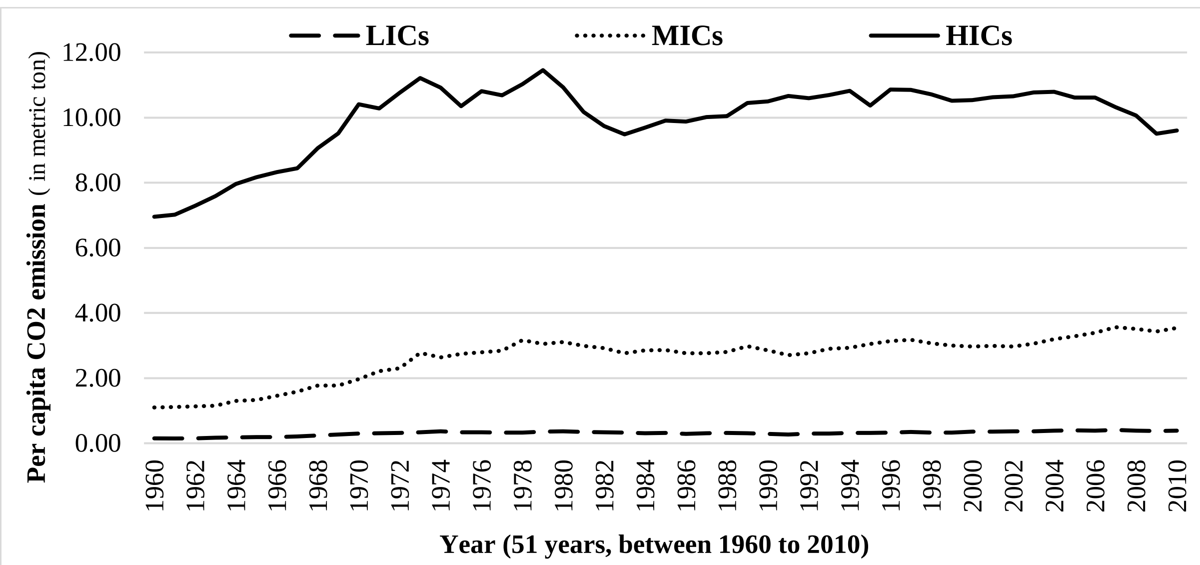

Figure 3. Trends in per capita CO_2 emissions of LICs, MICs and HICs over the last five decades

The line chart in Figure 2 is derived by plotting the per capita CO_2 emissions data against the corresponding GDP per capita. The trend line of the chart is a curve, similar to a sigmoid curve. The curve shows a monotonically increasing relationship between per capita CO_2 emissions and GDP per capita. This is compatible with the findings of Shafik (1994) and Holtz-Eakin and Selden (1995). However, the distinctive feature of the curve is its two wiggles, which split it into three segments. The first segment represents the per capita CO_2 emissions of the LICs, which was at a lower level with a gradual increase. The traditional economy of LICs was mostly dependent on agricultural activities and, employed more labor than capital (Han and Chatterjee, 1997). Less capital use in the production processes consumed less fossil fuel, which resulted in lower levels of per capita CO_2 emissions. Structural change is essential for these traditional economies, without which modern economic growth would not be possible (Kuznets, 1971). However, the structural shifts from a rural, and predominantly agricultural economic base, to a manufacturing one resulted in increasing energy demand (Han and Chatterjee, 1997), and therefore a gradually increasing rate of per capita CO_2 emissions. The middle segment shows a dramatic rise in the per capita CO_2 emissions of MICs. Industrialization was emphasized highly in developing countries to accelerate economic growth aiming to improve the standard of living of the societies in the region (*idem).* The ongoing industrialization required a continuous process of capital formation for higher economic growth. According to Solow's theory of economic growth, countries invest more resources in their physical capital aiming to realize their potential economic growth, since an increase in the stock of physical capital results in higher growth rate both in the short-run and in the long-run (Bond, Leblebicioğlu and Schiantarelli, 2010; Solow, 1956).

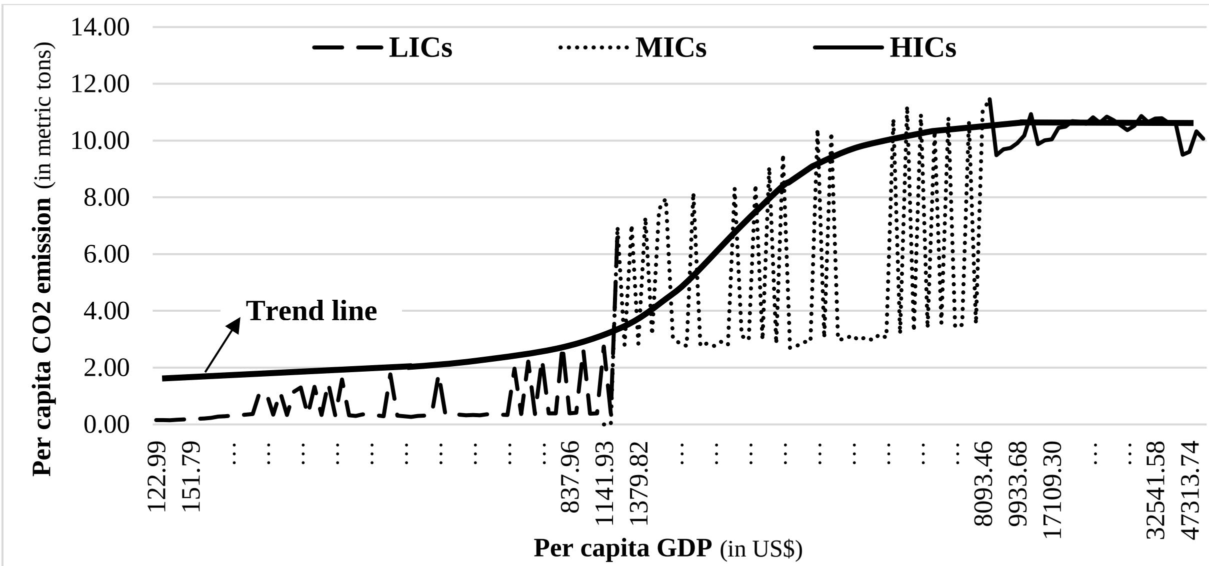

Figure 4. The long-run relationship between per capita CO_2 emissions and GDP per capita

Since industrialization in the MICs resulted in a substitution of labor by machines, the MICs were becoming even more energy intensive, and the corresponding per capita CO_2 emissions rate was continued rising. The last segment represents the higher level of per capita CO_2 emissions in HICs. Developed economies are highly industrialized. Industrialization in these countries transformed their economies from organic economies based on labor power to inorganic economies based on fossil fuels (Kasman and Duman, 2015). Developed countries use more physical capital or capital-intensive techniques in manufacturing output (Cole and Elliott, 2003). Capital-intensive techniques are more pollution-intensive, since more fossil fuels are necessary to operate machineries in the production process (Gradus and Smulders, 1993; UCSUSA, 2013). Therefore, the use of the capital-intensive techniques in HICs resulted in a higher level of per capita CO_2 emissions. Instead of pollution-intensive technologies, developed countries could use green technologies which consume less fossil fuels and use more renewable energy, and are more labor-intensive (UCSUSA, 2013).

In examining how the findings of this research compare with other findings available in the large body of literature about the relationship under consideration, I find not only similarities but also dissimilarities. The most reported shape of the relationship is an inverted U-shaped curve. The left segment of an inverted U-shaped curve before its turning point expresses a monotonically increasing relationship between environmental pollution and economic growth of a country when it was a developing country. The first and second segments of the sigmoid curve depict a similar increasing relationship in the case of developing countries. On the other side, the right segment of the inverted U-shaped curve after its turning point, which implies environmental degradation, is declining when a country becomes developed. However, the last segment of the sigmoid curve depicts a leveling off or slight falling in the pollution trend for developed countries. This is consistent with other empirical findings that showed that the per capita CO_2 emissions of developed countries were much higher, but the trend was either leveling off or slightly declining (Olivier, et al., 2015). As mentioned earlier, the findings of this research are compatible with the findings of Bertinelli and Strobl, 2005; Chen and Huang, 2013; Heil and Selden, 2001; Holtz-Eakin and Selden, 1995; Shafik, 1994. In comparison with the N shaped curve (Sengupta, 1996; De Bruyn and Opschoor, 1997), initially both findings provide a similar relationship that is increasing. After that, these findings vary with each other. In fact, the sigmoid curve shows a significantly unique relationship between the per capita CO_2 emissions and the GDP per capita in the long-run.

Chapter 3

3.1 The factors that drive the CO_2 emissions of a country

Better understanding of the relationship between the economy and the environment is one of the preconditions of achieving sustainable development which scientific community defines as "*development that meets the needs of the present without compromising the ability of future generation to meet their own needs*" (Bruntland Commission, 1987). While economic development enables a nation to meet its economic needs at any cost, sustainable development does not weaken the integrity and stability of the natural systems. The shift of global focus from mere economic development to sustainable development compels researchers in both economics and environmental studies to conduct research on the linkage between economic development and environmental pollution. There is a plethora of both theoretical and empirical studies which provide a better understanding about the relationship. However, recent studies are not limited to estimating the relationship, they rather attempt to explore the factors affecting the nexus. Many research works on the issue of finding factors affecting the relationship have been carried out and a wide range of multivariate econometric studies is now available (Al-Mulali and Ozturk, 2015; Kasman and Duman, 2015; Ahmed, et al, 2016 a). However, most of these studies suffer from the omitted variable bias due to avoiding important relevant control variables such as energy consumption, urbanization or human population growth, trade openness, financial development and so on; and from various complex econometric modeling which are criticized, in some cases as inappropriate (Halicioglu, 2009; Sharma, 2011; Farhani, et al, 2013; Al-Mulali and Ozturk, 2015; Farhani and Ozturk, 2015). A further study on the issue including all relevant variables and employing an appropriate econometric model is necessary to explore the factors affecting CO_2 emissions in a country.

3.2 Literature review

The existing multivariate econometric literature can be divided into five categories: the growth-environment nexus, the growth-energy-environment nexus, the growth-energy-trade-environment nexus, the growth-energy-trade-population (or urbanization)-environment nexus, and the growth-energy-trade-population (or urbanization)-financial development-environment nexus.

Growth and the Environment Nexus – Any manufacturing process produces simultaneously economic output on one hand and industrial waste (or pollutants) on the other hand, and contributes to human life differently with both outputs. While the former is the basis of economic development, the latter output pollutes the natural environment. Being interested in understanding the linkage between economic development and environmental pollution, several researchers studied the issue, and came up with different findings (Shafik and Bandyopadhyay,1992; Shukla and Parikh,1992; Panayotou, 1993; Grossman and Krueger, 1994; Selden and Song, 1994; Kahn,1998; Schmalensee et al., 1998; List and Gallet,1999; Bradford et al., 2000; Millimet and Stengos, 2000; Taskin and Zaim, 2000; Canas et al., 2003; Millimet et al., 2003; Azomahou et al., 2006; Galeotti et al., 2006). The most reported finding among the results of these research studies is the inverted U-shaped relationship between these variables, also known as the EKC

(Environmental Kuznets Curve) hypothesis showing that at the beginning of a country's economic development, environmental degradation rises and then it levels off and falls with continuous economic growth. However, these studies suffer from the omitted variable bias.

Growth, Energy and the Environment Nexus – Any transformation of raw materials into economic output requires energy, which is generated mostly from fossil fuels. An estimate shows that fossil fuels still represent 80 percent of total energy consumed globally (Al-Mulali and Ozturk, 2015). Numerous researchers analyze the causal relationship between energy use, income and environmental pollution, mostly for single countries or a small group of countries (Ang, 2007; Apergis and Payne, 2009, 2010; Soytas and Sari, 2009; Chang, 2010; Lean and Smyth, 2010; Marrero, 2010; Pao and Tsai, 2010; Alam et al. 2011; Wang et al. 2011; Hamit-Haggar, 2012; Jafari et al. 2012; Al-Mulali et al. 2013; Govindaraju and Tang, 2013; Ozcan, 2013; Saboori and Sulaiman, 2013a,b). Most of these studies find a statistically significant positive relationship between these variables. Some studies report a non-linear relationship between environmental pollution and economic growth, that is consistent with the EKC hypothesis (Apergis and Payne, 2009, 2010; Lean and Smyth, 2010; Marrero, 2010; Pao and Tsai, 2010; Hamit-Haggar, 2012; Saboori and Sulaiman, 2013a,b; Ozcan, 2013; Al-Mulali et al. 2015d). However, there is no conclusive direction for the causal relationship between these variables. Critics believe that the omitted variable bias is the major weakness of these studies.

Growth-Energy-Trade-the Environment Nexus – Trade openness affects industrial production both at home and abroad through the process of trade creation and trade diversion. Trade creation (or trade diversion) occurs when trade openness resulting from tariff agreements causes a shift in the imports from an inefficient (or an efficient) to an efficient (inefficient) producing country. As an accelerating factor of GDP growth, trade liberalization enables developing countries to increase their income per capita which, according to the EKC hypothesis, will eventually improve environmental quality. Grossman and Krueger (1994) and Ahmed et al. (2016a) argue that trade openness causes not only a movement of goods and services across borders but also dissemination of modern technologies and managerial philosophies to developing countries, that help these countries reduce environmental pollution when outputs are being produced using these technologies and philosophies. However, with trade openness and weaker environmental regulation/ standards in developing countries, they have comparative advantage in the production of pollution intensive output. Due to comparative advantage, there will be a shift in the production of pollution intensive output from developed countries to developing countries which results in higher environmental pollution in these developing countries; that is also known as the *pollution haven hypothesis*. For developed countries, trade openness impacts the economy and the environment in a similar fashion (for more, see Ahmed et al. 2016a). Having realized the significance of trade openness to economic growth, recent studies incorporate it into estimation of the linkage between environmental pollution and GDP growth. After developing a pollution function using as variables - per capita CO_2 emissions, income per capita, energy use per capita, and trade openness, Ang

(2009) estimates it utilizing time series data from China during 1953 and 2006 inclusive. The study finds that more energy consumption, higher income and greater trade openness leads to more CO_2 emissions. Halicioglu (2009) attempts to examine the long-run relationship between CO_2 emissions, income, energy use, and trade using time series data in the case of Turkey during 1960-2005. The result of the study is twofold: firstly, the level of CO_2 emissions is determined by income, energy use and trade in the long-run, and lastly the income is also determined by CO_2 emissions, energy use, as well as trade in the long-run. Furthermore, an Augmented Granger Causality (AGC) test is conducted and the corresponding results show that income is the most important variable in explaining the variation in CO_2 emissions in Turkey, followed by energy use and trade openness. With an objective to test whether the EKC hypothesis for the linkage between CO_2 emissions and real GDP holds in the long-run, Jalil and Mahmud (2009) use the Auto regressive distributed lag (ARDL) model, and find a nonlinear relationship between these variables which provides an evidence to the existence of the EKC hypothesis. However, their results also indicate a unidirectional causality from real GDP to CO_2 emissions, and no significant impact of trade liberalization on CO_2 emissions. These results are not conclusive though, since these studies suffer from the omitted variable bias.

Growth-Energy-Trade-Population-the Environment Nexus – Humans are the only beings for which most of the economic outputs are being produced. Any increase in human population requires more production of economic outputs necessary to feed the additional population, and eventually that leads to more CO_2 emissions. Murtaugh and Schlax (2009) state that an increase in human population adds more CO_2 in the atmosphere than the CO_2

amount one can reduce by changing lifestyle such as by adopting energy efficient appliances and light bulbs, or using high-mileage vehicles, and adopting recycling, etc. The study also finds that each child born in the US adds about 9, 441 metric tons of CO_2 to the carbon legacy of an average mother; that amount is 7 times higher and 168 times higher than the amount added by a child born in China and Bangladesh, respectively. Most of the human population currently live in the urban areas of a country, as these are the hub of all economic activities (SUF, 2015). This is the reason why urbanization in many studies is used as a proxy of population growth. In recent years, with an objective to reduce the omitted variable bias, researchers take human population or urbanization into account when they estimate the relationship between the economy and the environment. In order to investigate whether there is a dynamic causal relationship between CO_2 emissions and some other factors like - income, energy use, urbanization and trade liberalization for a panel including all newly industrialized countries, Hossain (2011) finds no long-run causal relationship but a short-run unidirectional causal relationship. This relationship is running from GDP growth and trade liberalization to CO_2 emissions, from trade liberalization and urbanization to economic growth, from economic growth to energy use and from trade liberalization to urbanization. Also, he finds that both economic growth and energy use has significant positive effect on CO_2 emissions in the long-run. Kasman and Duman (2014) find the existence of an inverted U-shaped curve or EKC in their study. They use unit root tests, cointegration tests and causality tests to examine the relationship between CO_2 emissions and other variables such as, GDP growth, energy use, urbanization and trade openness, for a panel including new EU members and candidate countries (*idem*). They also find a short-run, unidirectional causality from urbanization, energy use, and trade openness to CO_2 emissions, from GDP growth, energy use, urbanization to trade openness, from GDP growth to energy use and from urbanization to GDP growth, and a long-run, bidirectional causal relationship among these variables. Using information on CO_2 emissions as well as its potentially contributing factors – income, energy use, population and trade liberalization, from five selected South Asian economies, Ahmed et al. (2016a) examined the long-run relationship as well as the causal relationships among these variables. All the contributing factors, except income, have a statistically significant positive effect on CO_2 emissions. The study reveals a unidirectional causality running from energy use, population and trade openness to CO_2 emissions and a bidirectional causality between energy use and trade openness. In comparison with earlier studies, these multivariate studies explain the long-run causal relationship in a better way, but they fail to provide conclusive results. The perceived weakness of these studies may be due to omitting the necessary variables in the estimation.

Growth-Energy-Trade-Population-Financial Development-the Environment Nexus – Financial development (FD) facilitates economic growth through encouraging capital accumulation, mobilizing and pooling savings, attracting inflows of foreign capital, producing information about investment, facilitating international trade and optimizing the allocation of available capital (Ozturk and Acaravci, 2013; WB, 2015). Countries with well-developed financial systems tend to grow faster in terms of per capita income which, according to the EKC hypothesis, will eventually improve environmental quality (Grossman and Krueger, 1994; WB, 2015). However, financial intermediaries under well-developed financial systems tend to offer consumer loans to individuals; this makes it easier to buy items like cars, heaters, refrigerators, air conditioners, washing machines, etc. which then accelerate CO_2 emissions (Ozturk and Acaravci, 2013). Thus, the effect of FD on CO_2 emissions is ambiguous. Frankel and Romer (1999), Dasgupta et al. (2001), Sadorsky (2010) and Zhang (2011) find a positive effect of FD on CO_2 emissions. Nevertheless, Claessens and Feijen (2007), Tamazian et al. (2009) and Jalil and Feridun (2011) argue that FD either reduces or has no effect on CO_2 emissions. Recent studies document heterogeneous findings about the issue. In a study, Ozturk and Acaravci (2013) use a bounds F-test for investigating whether there is a long-run association between per capita CO_2 emissions, income per capita, energy use per capita, trade liberalization and FD in the case of Turkey, and they find an association in the long-run. The study also finds a positive impact of the trade-GDP ratio on CO_2 emissions but no effect of FD on the emissions variable in the long-run. Aiming to examine the casual relationship between CO_2 emissions, real income, energy use, trade liberalization, urbanization and FD, Farhani and Ozturk (2015) use the ARDL bounds testing approach in the case of Tunisia for the period between 1971 and 2012. Their analysis reports a positive effect of FD on CO_2 emissions, that is FD intensifies CO_2 emissions. They further mention that they did not find any proof of existence of the EKC hypothesis. However, using panel data from ninety-three countries classified as a different income group, Al-Mulali and Ozturk (2015) find the existence of the EKC hypothesis only for the high-income and upper middle-income countries. They argue that the inverted U-shaped relationship only exists at the beginning of economic development, when technologies for improving energy efficiency are available. Lower income countries have no access to advanced technologies, as they did not reach such a stage of development. The study also finds a significant contribution of FD in reducing environmental degradation. A survey of the relevant literature, does not provide any conclusive evidence whether FD increases environmental pollution or not. These inconclusive results urge researchers to conduct further study and to incorporate relevant variables, and to choose sound models as well as an appropriate methodology. Farhani and Ozturk (2015) believe that more research on the issue is still needed to estimate the relationship between the economy and the natural environment.

In recent years, the study of corruption has gained importance among environmental economists as they believe it is one of the dominant reasons of environmental degradation. Theoretically, it has a direct impact on the environment, in terms of lowering the stringency of environmental regulations, as well an indirect impact which operates through corruption's effect on income and then the resultant income's effect on pollution (Lopez and Mitra, 2000; Damania et al., 2003; Fredriksson et al., 2004; Welsch, 2004; Cole, 2007). Welsch (2004) attempted to quantify both the direct and indirect effects of corruption on the environment and found that the direct effect is always positive but the indirect effect is either positive or negative depending on the income level, and thus, the resulting total effect is ambiguous. The study found an overall monotonically increasing relationship between corruption and pollution and the relationship becomes relatively stronger for low-income countries. With a critical view of the study, Cole (2007) argued the study incorporates neither potential endogeneity of corruption in estimating the relationship nor enough data (more than one year) to explain unobserved heterogeneity across countries. Later, Cole conducted a study using data for a sample of 94 countries covering the period 1987–2000 with the objective to quantify both the direct and indirect impacts of corruption on environmental pollution, specifically air pollution emissions (Cole, 2007). The study found a positive direct effect of corruption on both sulfur dioxide and carbon dioxide emissions, but a negative indirect effect, with larger positive value, and therefore a negative total effect for all countries except high-income countries in the sample. Both studies found that the direct effect of corruption on the environment is positive. This result is consistent with Lopez and Mitra (2000) who stated that corruption causes pollution for a given per capita income to a level higher than the socially optimal level. The resulting higher level of pollution delays a nation to reach the turning point in its EKC curve (Lopez and Mitra, 2000 and Rehman, et al., 2012).

Fredriksson et al. (2004) developed a model to analyze the impact of corruption on environmental policy, and concluded that greater corruptibility weakens the stringency of environmental policy. Other researchers, for example Fredriksson and Svensson (2003), Damania et al. (2003), and Cole et al. (2006), examined how corruption can affect the relationship between political stability and the stringency of environmental policy (SEP), trade and SEP, and foreign direct investment (FDI) and SEP respectively. All the studies found similar results, namely that grater corruptibility, political stability, trade and FDI make environmental policy less stringent. Most of the previous studies on the effect of corruption on the environment are theoretical in nature and meaningful for ideal cases. The insufficiency of empirical research on the issue leads to uncertainty about the nature and magnitude of any such effect in real-life cases (Welsch, 2004). Rehman, et al. (2012)

mentioned the effect of corruption on environmental policy as one of the least researched issues that needs to be empirically tested for different regions. Welsch (2004) argued that the total effect of corruption on the environment is ambiguous a priori, due to a positive direct effect and a negative indirect effect. However, Welsch (2004) and Cole (2007) attempted to quantify these effects. Examples of other recent empirical studies are studies conducted by Damania et al. (2003), Pellegrini and Vujic (2003), Fredriksson et al. (2004), Fredriksson et al. (2005), Faiz-Ur-Rehman et al. (2007) and Rehman, et al. (2012). No multivariate research work involving corruption has yet been done. Any further multivariate studies involving corruption and the aforementioned control variables may be worthwhile by reducing the omitting variable bias and contributing to the existing empirical literature.

3.3 The model, econometric methodology and data description

3.3.1 The model

Following Hossain (2011), Farhani, et al (2013), Ozturk and Acaravci (2013), Al-Mulali et al. (2015d), Farhani and Ozturk (2015) and Kasman and Duman (2015), a dynamic model is developed to examine the long-run relationship between CO_2 emissions and its potentially contributing factors such as economic growth, energy consumption, population, trade openness, financial development and corruption. The model is specified as:

$$PCO_{2it} = A_0 PGDP_{it}^{\alpha_{1i}} PEC_{it}^{\alpha_{2i}} POP_{it}^{\alpha_{3i}} TROP_{it}^{\alpha_{4i}} FD_{it}^{\alpha_{5i}} CPI_{it}^{\alpha_{6i}} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (1)$$

Logarithmic transformation of the equation can be written as:

$$\ln(PCO_{2it}) = \alpha_0 + \alpha_{1i}\ln(PGDP_{it}) +$$
$$\alpha_{2i}\ln(PEC_{it})+\alpha_{3i}\ln(POP_{it})+\alpha_{4i}\ln(TROP_{it})+\alpha_{5i}\ln(FD_{it})+\alpha_{6i}\ln(CPI_{it}) + \varepsilon_{it} \ldots\ldots (2)$$

where PCO_{2it}, $PGDP_{it}$, PEC_{it}, POP_{it}, $TROP_{it}$, FD_{it} and CPI_{it} represent per capita CO_2 emissions, GDP per capita, per capital energy consumption, population, trade openness, financial development and corruption (measured by the corruption perception index-CPI) of i-th country at t time respectively. α_0 and ε_{it} represent $In(A_0)$ and error term respectively. Most importantly, α_1, α_2, α_3, α_4, α_5 and α_6 represent the long-run elasticities of CO_2 emissions with respect to PGDP, PEC, POP, TROP, FD and CPI respectively.

Based on the discussion carried out in the literature review section, the nexus between CO_2 emissions, GDP per capita and per capita energy consumption may be either monotonically increasing or a positive nonlinear relationship implying the EKC hypothesis. The sign of the relevant elasticity coefficients is expected to be positive such as α_1, $\alpha_2>0$. Since an increase in human population adds CO_2 in the atmosphere more than the amount one can reduce by changing lifestyle (Murtaugh and Schlax, 2009), population is considered to have a positive effect on CO_2 emissions (Ahmed et al., 2016a). Thus, the sign of the long-run elasticity of CO_2 emissions with respect to population is assumed to be positive such as $\alpha_3>0$. Grossman and Krueger (1994) and Ahmed et al. (2016a) opined the trade openness has a negative effect on CO_2 emissions. However, Ang (2009) found a positive effect, and Jalil and Mahmud (2009) found no significant impact of trade openness on CO_2 emissions. The inconclusive results imply an ambiguity about the sign of the relevant elasticity coefficient. Financial development (FD) facilitates economic growth on the one hand, which according to the EKC hypothesis will eventually improve environmental quality (Grossman and Krueger, 1994; WB, 2015). On the other hand, FD offers more consumer loans to individuals, which makes it easier to buy items like cars, heaters, etc. and this accelerates CO_2 emissions (Ozturk and Acaravci, 2013). Some empirical studies find a positive effect of FD on CO_2 emissions (Frankel and Romer, 1999; Dasgupta et al., 2001; Sadorsky, 2010 and Zhang, 2011). However, others find no effect on CO_2 emissions (Claessens and Feijen, 2007; Tamazian et al., 2009 and Jalil and Feridun, 2011). Thus, the effect of FD on CO_2 emissions is ambiguous. Corruption affects environmental quality directly and indirectly. Welsch (2004) found a direct effect of corruption on CO_2 emissions is always positive but the indirect effect is either positive or negative depending on the income level; thus, the resulting total effect is ambiguous. Lastly, the sign of α_1, α_2 and α_3 is expected to be positive, but the sign of α_4, α_5 and α_6 is ambiguous.

3.3.2 Econometric methodology

Existing multivariate studies suffer from omitted variable bias due to avoiding important variable like corruption. At first it is important to test whether corruption is relevant control variable following omitted variable test. If the variable is found relevant, I may go forward to test whether any dynamic causal relationship exists between CO_2 emissions, economic growth, energy consumption, population, trade openness, financial development and corruption. To examine if any dynamic causal relationship exists, the testing procedure follows the following four steps. At first, all relevant variables are to be tested for stationarity properties using panel unit root test (Chang, 2010; Ozturk and Acaravci, 2013; Ahmed, et al., 2016a). If these variables are found as nonstationary, the next step employs a panel cointegration test to examine whether there is any long-run association between the series of these variables (Ahmed, et al., 2016a). If any long-run association is found between the series, the third step estimates the parameters of the long-run relationship between these variables, using the fully modified ordinary least square (FMOLS) method. Finally, the last step examines both the short-run and the long-run causal relationship between these variables, estimating vector error-correction model (VECM) (Chang, 2010; Hossain, 2011; Al-Mulali et al. 2013; Farhani, et al., 2013; Ozturk and Acaravci, 2013; Farhani and Ozturk, 2015; Kasman and Duman, 2015). Apart of specifying the direction of the causal relationship, the innovative accounting approach (IAA) is used to estimate the magnitude of the causal relationship between these variables (Alves and Moutinho, 2013; Ahmed, et al., 2016a; Lanne and Nyberg, 2016).

Step-1: The panel unit root test

Stationary variables or stationarizing non-stationary variables are necessary for a meaningful time series econometric analysis. Therefore, the use of unit root test for detecting unit root problems or testing stationarity properties of variables has become a widespread practice in time series econometric literature (Chang, 2010; Ozturk and Acaravci, 2013; Ahmed, et al., 2016a). The panel unit root test has higher power than the individual unit root test for maintaining persistence of individual time series regression errors across its cross sections (Al-Mulali et al. 2013; Kasman and Duman, 2015; Ahmed, et al., 2016a). There are several kinds of panel unit root tests available, however none of them are free from statistical deficiencies. In this study, three types of panel unit root tests are used to detect unit root problems properly.

Levine-Lin-Chu (LLC) test for panel unit root – the test is designed by Levin et al. (2002) and allows detection of individual regression errors, trend and intercept coefficient to move freely across the cross sections. Levin et al. (2002) consider the following regression equation:

$$\Delta X_{it} = \alpha_i + \beta_i X_{i,t-1} + \delta_i t + \sum_{j=1}^{k} \gamma_{ij} \Delta X_{i,t-j} + \epsilon_{it}$$

Where Δ and X_{it} stand for the first difference operator and the dependent variable, respectively. ε_{it} is a white-noise disturbance with a variance of σ_t^2, I = 1, 2,….., N indexes country, and t= 1, 2,…., T indexes time. The test proposes the following hypothesis:

Null hypothesis (H_0): unit root – each series contains a unit root, i.e. $\beta_i = 0$

Alternative hypothesis (H_1): stationary – each series does not contain a unit root, i.e. $\beta_i < 0$

Hossain (2011), Farhani, et al. (2013) and Ahmed, et al. (2016a) argued that the test is better than the common unit root test, and used it for detecting unit roots problems in their studies. For details about the test procedure, the reader should read Levin et al. (2002).

However, Hossain (2011), Farhani, et al. (2013) and Ahmed, et al. (2016a) provide a brief of the test procedure.

Breitung test for panel unit root – the test is developed based on detrending methods and provides an unbiased class of t- statistics. The test statistics is developed by Breitung (2001) who considered the following regression equation:

$$Y_{it} = \alpha_{it} + \sum_{k=1}^{p+1} \beta_{ik} \Delta X_{it-k} + \epsilon_{it}$$

The test statistics assumes the following hypothesis:

Null hypothesis (H_0): each series contains a unit root, i.e. $\sum_{k=1}^{p+1} \beta_{ik} -= 0$

Alternative hypothesis (H_1): each series does not contain a unit root,

i.e. $\sum_{k=1}^{p+1} \beta_{ik} -< 0$

Details of the test procedure are available in Breitung (2001). This unit root test is used by Farhani, et al. (2013), Kasman and Duman (2015) and Ahmed, et al. (2016a) to test stationarity properties of variables.

Im-Peasaran-Shin (IPS) test for panel unit root – Im et al. (2003) proposed a standardized t- bar test to detect unit roots in dynamic heterogenous panels. The test statistics is developed based on the mean of the individual Augmented Dickey Fuller (ADF) test statistics (Im et al., 2003). Unlike the LLC test, the test is relatively less restrictive (Farhani, et al., 2013). Several researchers have used the test statistics to test stationarity properties of variables in their studies (Hossain, 2011; Farhani, et al., 2013; Al-Mulali, et al., 2015d; Kasman and Duman, 2015 and Ahmed, et al., 2016a). The hypothesis of the test is given as:

Null hypothesis (H_0): each series assumes individual unit root process, i.e. $\beta_i = 0$

Alternative hypothesis (H_1): each series does not assume individual unit root process, i.e. $\beta_i < 0 \; for \; i = 1, \ldots., N_1$ and $\beta_i = 0 \; for \; i = N_1 + 1, \ldots., N$.

Step-2: The panel cointegration test

The cointegration test in time series literature is a recent practice to examine whether there is any long-run association between variables when they are nonstationary (Ahmed, et al., 2016a). Several testing procedures are available to examine cointegrating relationships, however, none of them are free from statistical deficiencies. Compared with other available testing procedures, Pedroni and Kao's residual cointegration tests are mostly used in recently available time series literature (Farhani, et al., 2013, Kasman and Duman, 2015, and Ahmed, et al., 2016a).

Pedroni residual cointegration test – Based on the residuals of the Engel and Granger (1987) cointegration regression, Pedroni (1999, 2004) developed seven different statistics to examine if any cointegration relationship is available in heterogeneous panels. To develop these seven statistics, Pedroni (1999, 2004) considered the following equation:

$$Y_{it} = \alpha_i + \beta_i t + \sum_{j=1}^{k} \gamma_{ij} \Delta X_{i,t-j} + \epsilon_{it}\,; t = 1, \ldots, T\; i = 1, \ldots, N$$

Where $Y_{i,t}$ and $X_{j,i,t}$ are integrated of order one in levels, I(1). The seven different statistics are classified into two groups, within dimension and between dimension groups. The first group of statistics, also referred as panel cointegration statistics, are mainly: panel *v*-statistic (Z_v), panel ρ -statistic (Z_ρ), panel *PP*-statistic (Z_{PP}), and panel *ADF*- statistic (Z_{ADF}). The second group of statistics are known as group mean panel cointegration statistics. These statistics are mainly; group ρ -statistic ($\widetilde{Z_\rho}$), group *PP*-statistic ($\widetilde{Z_{PP}}$), and group *ADF*-statistic ($\widetilde{Z_{ADF}}$). All statistics are used to test the following hypothesis:

Null hypothesis (H_0): No cointegration, i.e. $\rho_i = 0$

Alternative hypothesis (H_1): Cointegration, i.e. $\rho_i = \rho < 0$

Kao residual cointegration test – After studying a Dickey–Fuller (DF) and an augmented Dickey–Fuller (ADF) test to test the no cointegration hypothesis, Kao (1999) developed a residual-based test to examine if any cointegration relationship is available in heterogeneous panels. The basic construction of the test procedure is similar to the Pedroni test (Kasman and Duman, 2015). The hypothesis of the test is given as:

Null hypothesis (H_0): No cointegration, i.e. $\rho_i = 0$

Alternative hypothesis (H_1): Cointegration, i.e. $\rho_i = \rho < 0$

Step-3: The panel cointegration estimates

If any existence of cointegrating relationship between variables is found based on the outcomes of cointegration tests, the next task is to estimate the parameters of the long-run association. Various techniques such as OLS, fixed effect, random effect, GMM and the FMOLS method are available to estimate the parameters, however all methods are not equally efficient. Many researchers argued that estimating parameters using OLS, fixed effect, random effect, GMM methods is not always efficient, and resulting estimators are biased and inconsistent because of the presence of serial correlations in the panel data (Farhani, et al., 2013, Kasman and Duman, 2015, and Ahmed, et al., 2016a). Rather they used the FMOLS method of Pedroni (2000) in their studies for estimating the parameters. The main advantage of the FMOLS method is that it does not suffer from distortions in the presence of serial correlation, endogeneity, simultaneity bias and heterogeneous dynamics (Philips and Hansen, 1990; Farhani, et al., 2013, Kasman and Duman, 2015, and Ahmed, et al., 2016a). Following Pedroni (2000), the panel FMOLS estimator is defined as:

$$\hat{\beta}^{*}_{FMOLS} = \frac{1}{N}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(X_{it}-\bar{X}_i)^2\right)^{-1}\left(\sum_{t=1}^{T}(X_{it}-\bar{X}_i)Y^{*}_{it} - T\hat{\gamma}_i\right)$$

Where $Y^{*}_{it} = Y_{it} - \bar{Y}_i - \left({\hat{\Omega}_{2,1,i}}/{\hat{\Omega}_{2,2,i}}\right)\Delta X_{it}$, $\hat{\gamma}_i = \hat{\Gamma}_{2,1,i} + \hat{\Omega}^{0}_{2,1,i} - \left({\hat{\Omega}_{2,1,i}}/{\hat{\Omega}_{2,2,i}}\right)\left({\hat{\Gamma}_{2,2,i}}/{\hat{\Omega}_{2,2,i}}\right)$ and Ω_{it} is the long-run covariance matrix which can be further decomposed as; $\Omega_i = \Omega^{0}_i + \Gamma_i + \acute{\Gamma}_i$. The relevant t-statistics is specified as:

$$t_{\hat{\beta}^*_{FMOLS}} = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} t_{\hat{\beta}^*_{FMOLS},i}; \text{ where } t_{\hat{\beta}^*_{FMOLS},i} = \left(\hat{\beta}^*_i - \beta_0\right)\left[\hat{\Omega}^{-1}_{1,1,i} \sum_{t=1}^{T} (Y_{it} - \bar{Y})^2\right]^{1/2}$$

Step-4: The panel Granger causality analysis

The cointegrating relationship between variables indicates not only the existence of a long-run relationship but also the presence of a causal relationship between these variables, at least in one direction. However, the cointegration test results provide no clue about the direction of the causal relationship or the relative strength of the causal links.

To examine the direction of the causal relationship, a panel vector error-correction model (VECM) will be estimated. The direction of the short-run causal relationship is determined based on the F-statistics whereas the error correction term will provide information about the direction of the long-run causal relationship (Chang, 2010; Hossain, 2011; Al-Mulali et al. 2013; Farhani, et al., 2013; Ozturk and Acaravci, 2013; Farhani and Ozturk, 2015; Kasman and Duman, 2015). The panel VECM model is specified as:

$$\begin{pmatrix} \Delta lnPCO_{2it} \\ \Delta lnPGDP_{it} \\ \Delta lnPEC_{it} \\ \Delta lnPOP_{it} \\ \Delta lnTROP_{it} \\ \Delta lnFD_{it} \\ \Delta lnCPI_{it} \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \end{pmatrix} + \sum_{k=1}^{P} \begin{pmatrix} \beta_{11k} & \beta_{12k} & \beta_{13k} & \beta_{14k} & \beta_{15k} & \beta_{16k} & \beta_{17k} \\ \beta_{21k} & \beta_{22k} & \beta_{23k} & \beta_{24k} & \beta_{25k} & \beta_{26k} & \beta_{27k} \\ \beta_{31k} & \beta_{32k} & \beta_{33k} & \beta_{34k} & \beta_{35k} & \beta_{36k} & \beta_{37k} \\ \beta_{41k} & \beta_{42k} & \beta_{43k} & \beta_{44k} & \beta_{45k} & \beta_{46k} & \beta_{47k} \\ \beta_{51k} & \beta_{52k} & \beta_{53k} & \beta_{54k} & \beta_{55k} & \beta_{56k} & \beta_{57k} \\ \beta_{61k} & \beta_{62k} & \beta_{63k} & \beta_{64k} & \beta_{65k} & \beta_{66k} & \beta_{67k} \\ \beta_{71k} & \beta_{72k} & \beta_{73k} & \beta_{74k} & \beta_{75k} & \beta_{76k} & \beta_{77k} \end{pmatrix} \begin{pmatrix} \Delta lnPCO_{2it-k} \\ \Delta lnPGDP_{it-k} \\ \Delta lnPEC_{it-k} \\ \Delta lnPOP_{it-k} \\ \Delta lnTROP_{it-k} \\ \Delta lnFD_{it-k} \\ \Delta lnCPI_{it-k} \end{pmatrix}$$

$$+ \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \\ \omega_5 \\ \omega_6 \\ \omega_7 \end{pmatrix} ECM_{it-1} + \begin{pmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \\ \varepsilon_{5it} \\ \varepsilon_{6it} \\ \varepsilon_{7it} \end{pmatrix}$$

where i= 1, 2, … … …, n; t= P+1, P+2, P+3, … … …, T; Δ and ECM symbolize the first difference of the variable and the error-correction term respectively. K denotes the optimal lag length which is determined by the Schwarz Information Criterion (SIC). α's and β's are parameters of the model, and ω's are adjustment coefficients. These parameters are to be estimated.

To examine the relative strength of the causal links between variables, an Innovative Accounting Approach (IAA) will be employed. As an alternative technique for causality analysis, the IAA technique includes both the forecast error variance decomposition method (FEVDM) and the impulse response function (IRF) (Alves and Moutinho, 2013; Ahmed, et al., 2016a; Lanne and Nyberg, 2016). While the VECM model will be employed for detecting causal links between variables, the IAA will measure the relative strength of the causal links. Therefore, the IAA method will be used in this study as a complement to the traditional Granger causality test.

3.3.3 Data description

For this study, the sample is designed to include seven variables: CO_2 emissions, economic growth, energy consumption, population, trade openness, financial development and corruption; and as much countries as possible, with possibly the longest time length of observations. The CO_2 emissions in this study are those emitted mainly from the burning of fossil fuels as well as cement manufacturing plants, and measured in metric tons per capita. Economic growth is measured using GDP per capita which is originally computed as GDP divided by midyear population and in constant 2010 US$. Energy consumption represents the use of all primary energy before transformation to other types, the net import of energy and changes of existing stocks, and measured in kg of oil equivalent per capita. Population is the total human population, regardless of their legal status or citizenship. Trade openness in this study is measured using the percentage of GDP for total trade (i.e. total of exports and imports of goods and services). Similarly, financial development is measured using the percentage of GDP for domestic credit to private sector. Corruption in this study is measured using a widely-recognized index, the corruption perception index (CPI) which has a range of values from 0 (highly corrupt) to 100 (very clean) (TI, 2017).

Table 3. List of the 65 Countries Classified over Three Categories

High-income countries - HICs (26) - Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Trinidad and Tobago, UK, Uruguay and USA.
Middle-income countries - MICs (21) - Argentina, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Ecuador, Jamaica, Jordan, Malaysia, Mauritius, Mexico, Panama, Peru, South Africa, Thailand, Tunisia, Turkey and Venezuela.
Low-income countries – LICs (18) - Bolivia, Cameroon, Côte d´Ivoire, Egypt, El Salvador, Ghana, Guatemala, Honduras, India, Indonesia, Kenya, Morocco, Nicaragua, Nigeria, Pakistan, Philippines, Senegal and Zimbabwe.

Data on all variables except corruption, were collected from the World Development Indicators of the World Bank on January 03, 2017. Corruption data were obtained from CPI scores of Transparency International on the same date. Transparency International started estimating CPI scores based on a scale of 0 (highly corrupt) to 10 (very clean) since

1995, and later revised its scale with a range of 0 (highly corrupt) to 100 (very clean) in 2012 (TI, 2017). All CPI scores from 1995 to 2011 are multiplied by 10 to adjust the earlier scale with the recent one of 0 (highly corrupt) to 100 (very clean). The time length of observations starts from 1995, because of unavailability of CPI scores at any previous period, and ends in 2013, as energy consumption data after 2013 were not available on January 03, 2017. Within this time frame, only 65 countries data across the observations are available. Therefore, the sample data set contains annual data on these variables from 65 countries over nineteen years, from 1995 to 2013. These 65 countries are classified as high, middle and low-income countries following the most recent UN country classification list (UN, 2014). However, in the study, lower middle and low-income countries defined on the list are combined as one low-income country category. One of the main reasons for classifying countries into broad three categories instead of four is to demonstrate group specific differences more visibly. Table 3 provides a list of the 65 countries classified over three categories.

The summary statistics of the sample data set are reported in Table 4. For the first three variables, i.e. per capita CO_2 emissions, GDP per capita and per capita energy consumption, mean values range from lowest in LICs to highest in HICs. However, in realizing those variables, the global panel data (All) has the highest volatility, but sub-panel data (LICs) shows the lowest volatility. The average population ranges from 31.13 million in HICs to 110.02 million in LICs; however sub-panel data (MICs) has the highest volatility. As defined earlier, both the trade openness and financial development are expressed as the percentage of GDP for total trade and for domestic credit to private sector respectively; sub-panel (HICs) has the highest percentage of GDP for both variables, but LICs has the lowest percentage. The average score of the corruption perception index is highest in HICs but lowest in LICs; that implies that countries classified as HICs are less corrupted than countries of LICs. For individual countries, Appendix-A presents summary statistics of the sample data set.

Table 4. Summary Statistics of Time Series Variables over Four Categories of Countries

Panel Name	Statistics	PCO_2	PGDP	PEC	POP	TROP	FD	CPI
Global	Mean	5.52	19454.17	2598.84	73.51	81.28	67.88	51.30
	Stdev	5.37	22156.75	2637.27	211.63	55.8	45.52	24.28
HICs	Mean	10.25	42163.75	5015.62	31.13	93.57	103.92	76.03
	Stdev	5.36	18639.94	2622.27	60.61	77.22	38.29	15.95
MICs	Mean	3.61	6583.73	1370.7	94.68	79.21	56.09	40.85
	Stdev	1.99	2661.53	622.63	277.55	41.84	38.92	11.60
LICs	Mean	0.91	1666.94	540.76	110.02	65.95	29.58	27.8
	Stdev	0.48	716.43	154.6	260.52	20.20	12.34	5.67

Note: *Stdev stands for standard deviation. For panel (All), observation(O)= 1235, cross section (C)= 65, and time length(T)= 19; for HICs, O= 494, C= 26, T= 19; MICs, O= 399, C= 21, T= 19; for LICs, O= 342, C= 18, T=19*

3.4 Empirical findings and discussion

Corruption, based on omitted variable bias test, is found as an important relevant control variable which needs to be included in the study. Omitted variable bias test results are reported by Appendix-B in this study. All variables including corruption are tested whether they maintain stationary properties, using the widely used three panel unit root tests- LLC, Breitung, and IPS test for unit root. Table 5 reports the results of these unit root tests conducted over global (man or all) panel along with other three sub panels – HICs, MICs and LICs. Based on the tabulated results, the null hypothesis of the unit root tests under the global panel is accepted at level but significantly rejected at the first difference. It indicates that variables under the global panel are found as non-stationary at level but stationary at the first difference. As for the other three sub-panels, most of the variables are found as non-stationary at level, however all of them are stationary at the first difference, and these results are statistically significant at 1% level. Therefore, all variables under all four panels are characterized as integrated of order one, I(1). The I(1) variables may have utility in further econometric analysis, if these variables are cointegrated with each other.

Using the Pedroni and Kao Residual Cointegration Test, the I(1) variables are tested whether they have any long-run relationship. The results of these two tests are reported in Table 6. As for the Pedroni residual cointegration test, most of the statistics such as panel PP-stat, panel ADF-stat, group PP-stat and group ADF-stat are found statistically significant at 1% level for all four panels. The findings suggest that the I(1) variables are cointegrated, meaning that there is a long-run relationship between the variables. The result is also verified by another test, the Kao residual cointegration test. The findings of the test confirm that there is a long-run relationship between the I(1) variables. Since there is a long-run relationship, it should be estimated properly.

Table 5. Panel Unit Root Test Results

Variable → / Test ↓		$LNPCO_2$	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
Panel: Global (All)								
LLC t*-Stat	At L	-2.72**	-22.45**	-2.35**	-6.18**	-5.77**	0.03	-2.24
Breitung t-Stat		4.87	4.42	2.80	12.49	-3.03	4.97	-0.19
IPS W-Stat		0.05	-0.98	0.65	-5.61	-3.18	0.31	-2.73**
LLC t*-Stat	At Δ	-19.82**	-17.08**	-19.76**	-4.02**	-21.98**	-16.41**	-18.45**
Breitung t-Stat		-10.61**	-10.32**	-5.97**	-0.05	-15.48**	-8.21**	-6.40**
IPS W-Stat		-18.77**	-11.69**	-17.33**	-6.93**	-17.78**	-13.02**	-19.39**
Decision		**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**
Panel: HICs								
LLC t*-Stat	At L	-1.51	-0.66	-2.59**	1.19	-5.16**	1.15	0.54
Breitung t-Stat		6.75	6.10	5.37	1.83	-4.02**	3.70	1.31
IPS W-Stat		1.23	5.17	1.05	2.78	-2.33	1.07	-0.94
LLC t*-Stat	At Δ	-11.40**	-9.69**	-14.43**	0.43	-14.71**	-8.43**	-6.89**
Breitung t-Stat		-6.62**	-8.99**	-2.10*	5.08*	-12.33**	-3.09**	-1.22
IPS W-Stat		-12.41**	-7.34**	-13.28**	-4.18**	-11.12**	-6.76**	-9.17**
Decision		**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**
Panel: MICs								
LLC t*-Stat	At L	-2.59**	-1.34	-1.57	-7.04**	-1.45	0.02	-2.46**
Breitung t-Stat		-3.17**	1.01	-1.93*	8.31	0.10	1.31	-1.16
IPS W-Stat		-1.94	-0.36	-0.84	-14.12**	-0.22	0.79	-1.73*
LLC t*-Stat	At Δ	-10.86**	-10.89**	-7.79**	-6.41**	-11.05**	-10.1**	-13.38**
Breitung t-Stat		-5.57**	-7.02**	-4.77**	2.12	-8.61**	-6.37**	-7.78**
IPS W-Stat		-9.67**	-7.06**	-7.25**	-6.81**	-9.67**	-7.94**	-12.47**
Decision		**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**
Panel: LICs								
LLC t*-Stat	At L	-0.61	-28.27**	0.12	3.90	-3.45**	-1.09	-3.72**
Breitung t-Stat		2.24	1.67	1.10	5.38	-2.01	3.88	-1.49
IPS W-Stat		0.75	-7.34**	0.95	1.34	-2.96**	-1.54	-2.23**
LLC t*-Stat	At Δ	-12.45**	-9.37**	-11.70**	-1.62**	-12.08**	-10.70**	-12.86**
Breitung t-Stat		-6.22**	-3.24**	-6.57**	-1.42**	-6.10**	-7.13**	-6.87**
IPS W-Stat		-10.29**	-5.80**	-9.20**	-0.95	-9.98**	-8.09**	-12.44**
Decision		**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**

Note: *L, Δ, ** and * stand for level, first difference, 1% level of significance and 5% level of significance respectively. All unit root tests have the same null hypothesis which examines the presence of unit root in the variables. Lag length is selected automatically based on Schwarz Information Criteria-SIC.*

Table 6. Cointegration Test Results

Test → / Panel ↓	Pedroni Residual Cointegration Test							Kao Residual Cointegration Test
	Within-dimension				Between-dimension			
	Panel v-stat	Panel rho-stat	Panel PP-stat	Panel ADF-stat	Group rho-stat	Group PP-stat	Group ADF-stat	
All	-3.69 (0.99)	6.38 (1.00)	-7.70** (0.00)	-8.92** (0.00)	9.66 (1.00)	-18.81** (0.00)	-11.37** (0.00)	-4.89** (0.00)
HICs	-0.03 (0.51)	2.21 (0.98)	-10.81** (0.00)	-9.82** (0.00)	5.29 (1.00)	-13.22** (0.00)	-8.97** (0.00)	-4.57** (0.00)
MICs	-1.46 (0.92)	3.37 (0.99)	-7.82** (0.00)	-6.51** (0.00)	5.63 (1.00)	-12.59** (0.00)	-5.84** (0.00)	-7.05** (0.00)
LICs	-2.87 (0.99)	4.01 (1.00)	-1.28** (0.01)	-2.89** (0.00)	5.91 (1.00)	-6.26** (0.00)	-4.51** (0.00)	-4.21** (0.00)

Note: *** stands for 1% level of significance. All cointegration tests have the same null hypothesis of not cointegration. Lag length is selected automatically based on Schwarz Information Criteria-SIC.*

To examine the long-run relationship between variables, the model of this study or equation 2 is estimated using the FMOLS estimation technique. Since all data are converted into natural logarithmic form, the parameters of the equation express long-run elasticities of the per capita CO_2 emissions with respect to the other six independent variables. The results of the estimation are presented in Table 7.

Table 7. Panel FMOLS Results (LNPCO$_2$ is the dependent variable)

Panel	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
All	0.348** (0.000)	0.606** (0.000)	-0.174 (0.026)	-0.072 (0.034)	-0.051** (0.006)	0.155** (0.000)
HICs	0.316** (0.006)	0.541** (0.000)	-0.893 (0.030)	-0.234** (0.000)	-0.080** (0.003)	0.014 (0.818)
MICs	0.231** (0.000)	0.859** (0.000)	-0.138 (0.046)	0.004 (0.878)	-0.055** (0.000)	0.001 (0.993)
LICs	0.589** (0.000)	0.196** (0.008)	-0.106 (0.381)	0.089 (0.156)	0.047 (0.279)	0.132** (0.004)

Note: *** stands for 1% level of significance. All cointegration tests have the same null hypothesis of not cointegration. Lag length is selected automatically based on Schwarz Information Criteria-SIC.*

Based on the tabulated results, there is a direct relationship between economic growth and CO_2 emissions. The long-run elasticity of CO_2 emissions for GDP is much higher for low-income countries (LICs) compared with the two other income group panels – HICs and MICs. In this study, the value of the elasticity is found as 0.589 for LICs. It indicates that 1% increase in GDP per capita requires producing more goods and services using existing technology that results in emitting an additional 0.59% of existing per capita CO_2 emissions. It is noticeable that an attempt to increase the per capita GDP in low-income countries will emit more per capita CO_2 emissions than the amount the middle-income or high-income countries emit for the same extra units of per capita GDP. One of the reasons is that low-income countries adopt cheaply available but inefficient technologies at their production plants because of scarcity of resources to adopt advanced technologies. These technologies are mainly inefficient in energy consumption, and are contributing to more emissions. The finding is statistically significant, and consistent with Hossain (2011), Farhani, et al (2013), Al-Mulali et al. (2015d) and Kasman and Duman (2015), but inconsistent with Ahmed et al. (2016a).

As for energy consumption, a significant and direct relationship with CO_2 emissions is found. The finding is consistent with Hossain (2011), Farhani, et al (2013), Al-Mulali et al. (2015d), Farhani and Ozturk, (2015), Kasman and Duman (2015) and Ahmed et al. (2016a). This study shows that the long-run elasticity of CO_2 emissions for energy consumption is 0.196, the lowest value found for low-income countries or the LICs panel. An increase in per capita energy consumption by 1% emits an additional per capita CO_2 emissions of 0.19% in low-income countries, but 0.86% and 0.54% in middle-income and high-income countries, respectively. Compared with the low-income countries, the consumption pattern in high-income countries consists of more durable goods like private cars, heaters, refrigerators, air conditioners, washing machines, etc. Consumption of such durable goods needs more energy and results in more emissions. In the middle-income countries, consumption of durable goods is also increasing. These countries are importing cheaper reconditioned cars and electronics goods from other countries. The available cheaper reconditioned cars are not usually made with modern technology, and as a result, need more fuel consumption. Therefore, HICs as well as MICs consume more energy, and have more emissions.

Table 7 shows an inverse relationship between CO_2 emissions and trade openness, and this relationship is found significant only for high-income countries. The long-run elasticity of CO_2 emissions for trade openness is -0.234 in HICs; that implies an increase in trade openness by 1% reduces per capita CO_2 emissions by 0.23%. However, for the other two groups – MICs and LICs, the relationship is direct but insignificant. These results confirm the existence of the *pollution haven hypothesis*, that means that there is a shift in the production of pollution intensive output from high-income countries to other countries. As for financial development, a significant but inverse relationship with CO_2 emissions is found for all panels except the LICs. The finding is consistent with Al-Mulali et al. (2015d). For the global panel, the long-run elasticity of CO_2 emissions for financial development is -0.05; this indicates that an increase in financial development by 1% reduces global per capita CO_2 emissions by 0.05%. The finding is consistent with Grossman and Krueger (1994) and the WB (2015) as they argued that countries with well-developed financial systems tend to grow faster in terms of per capita income which, according to the EKC hypothesis, will eventually improve environmental quality.

This study also shows another positive relationship between corruption and CO_2 emissions for all four panels; however, the relationship is found significant only for the LICs and global panels. For the global panel, the long-run elasticity of CO_2 emissions for corruption is 0.15. It indicates that 1% increase in global corruption results in 0.15% increase in global per capita CO_2 emissions. Similarly, for the LICs panel, 1% increase in corruption results in 0.13% increase in per capita CO_2 emissions. Greater corruption does not only weaken the stringency of environmental regulations, but also delays a nation in achieving the desired level of economic growth which, according to the EKC hypothesis, will not contribute to improving environmental quality (Fredriksson and Svensson, 2003; Damania et al., 2003; Fredriksson et al., 2004 and Cole et al., 2006). As for population, this study does not find any significant (at 1% level) long-run relationship with CO_2 emissions. The result is consistent in some cases, however inconsistent in other cases with previous studies. In conclusion, CO_2 emissions have a long-run relationship with economic growth, energy consumption, financial development and corruption at the global level. However, the relationship may vary at regional levels. For HICs, the long-run relationship is found between CO_2 emissions and other four variables - economic growth, energy consumption, trade openness and financial development. The long-run relationship, in the case of MICs is found between CO_2 emissions, economic growth, energy consumption and financial development. For LICs, this study shows a relationship between CO_2 emissions, economic growth, energy consumption and corruption.

The long-run relationship between variables in this study is found from the long-run estimates; however, these estimates do not provide information about causal relationships between these variables. The results of the panel Granger causality test, reported in Tables 8, 9, 10 and 11, provide information about the causal relationship. Moreover, the diagrams (Figures 3, 4, 5 and 6) drawn based on these tables (Tables 8, 9, 10 and 11) illustrate the direction of the causal links. As mentioned earlier in the methodology section, the statistical significance of coefficients on variables as well as on lagged error correction terms in the model present evidence of the existence of a short-run as well as a long-run causal relationship, respectively. Since there are four models/panels used in this study, it is wiser to analyze their causality test results separately. As for the global panel, Table 8 and Figure 3 indicate that there is a short-run bidirectional causal relationship between population and CO_2 emissions, which is consistent with the finding of Al-Mulali et al. (2013). Other short-run bidirectional causal relationships are found between economic growth and CO_2 emissions; between economic growth and financial development; between energy consumption and corruption; and between energy consumption and population. This study finds a short-run unidirectional causality running from economic growth to energy consumption, which is consistent with other studies (Zhang and Cheng, 2009; Hossain, 2011; Haggar, 2012; Ozcan, 2013; Hwang and Yoo, 2014 and Kasman and Duman, 2014). The study also shows another short-run causality running from energy consumption, financial development and corruption to CO_2 emissions and that finding is partially consistent with the findings of Farhani, et al. (2013), Kasman and Duman (2014) and Farhani and Ozturk (2015). Other short-run unidirectional causal relationships found in this study are running from population to financial development; from economic growth and trade openness to corruption; and from economic growth to population. Beside investigating the short-run causal relationship, there are two long-run unidirectional causal relationships found in this study. The first one is running from CO_2 emissions, economic growth, energy consumption, population, trade openness and corruption to financial development, and is consistent with Farhani and Ozturk (2015). The second one is running from CO_2 emissions, economic growth, energy consumption, trade openness, financial development and corruption to population.

Table 2. Panel Granger Causality Test Result for the Global Panel

Y↓ X→	ΔLNPCO₂	ΔLNPGDP	ΔLNPEC	ΔLNPOP	ΔLNTROP	ΔLNFD	ΔLNCPI	ETC
ΔLNPCO₂	------	33.143** (0.000)	11.544* (0.021)	14.797** (0.005)	3.095 (0.541)	13.472** (0.009)	8.686** (0.006)	[0.42] (0.67)
ΔLNPGDP	14.607** (0.005)	------	1.031 (0.904)	7.328 (0.119)	2.875 (0.579)	19.327** (0.000)	1.631 (0.803)	[-1.43] (0.15)
ΔLNPEC	4.871 (0.300)	30.603** (0.000)	------	35.837** (0.000)	8.431 (0.077)	11.824* (0.018)	9.800* (0.043)	[1.84] (0.06)
ΔLNPOP	18.095** (0.001)	28.377** (0.000)	28.580** (0.000)	------	0.597 (0.963)	4.128 (0.388)	0.877 (0.927)	[-2.38] (0.01)
ΔLNTROP	7.579 (0.108)	39.809** (0.000)	11.910* (0.018)	4.968 (0.290)	------	1.661 (0.797)	9.305 (0.053)	[2.36] (0.01)
ΔLNFD	8.247 (0.082)	35.642** (0.000)	8.259 (0.082)	11.208* (0.024)	8.327 (0.080)	------	6.009 (0.198)	[-5.54] (0.00)
ΔLNCPI	8.598 (0.071)	33.694** (0.000)	10.480* (0.033)	2.444 (0.654)	25.864** (0.000)	4.363 (0.359)	------	[1.34] (0.17)

*The p-values are presented in parentheses while t-statistics are in brackets. ** and * denote statistical significance at 1% and 5% level, respectively.*

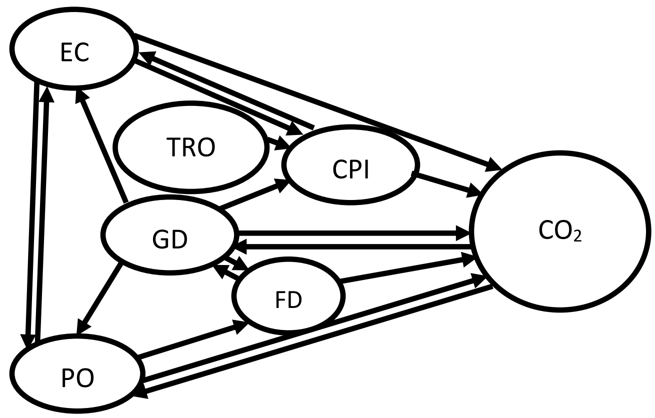

Figure 3. Direction of short-run causal links for the global panel

The Granger causality test results for the HICs panel is reported in Table 9. According to the table, a short-run bidirectional causal relationship is found between economic growth and CO_2 emissions; between economic growth and energy consumption, and between economic growth and trade openness. Beside the short-run bidirectional causal relationship, this study finds a short-run unidirectional causality running from energy consumption, population and financial development to CO_2 emissions, which is consistent with other studies (Kasman and Duman, 2014 and Farhani and Ozturk, 2015). Other short-run unidirectional causality, consistent with existing literature, is found running from CO_2 emissions to trade openness; and from economic growth and energy consumption to financial development (Farhani and Ozturk, 2015). This study also revels other short-run unidirectional causal relationships, running from population and trade openness to energy consumption; and from economic growth to population. Based on the statistical significance of the coefficients on lagged error correction terms in the model, two other long-run unidirectional causal relationships are identified; one is running from CO_2 emissions, energy consumption, population, trade openness, financial development and corruption to economic growth and the other is consistent with Farhani and Ozturk (2015) and is running from CO_2 emissions, economic growth, energy consumption, population, trade openness and corruption to financial development.

Table 9. Panel Granger Causality Test Result for the HICs Panel

Y ↓ X →	ΔLNPCO₂	ΔLNPGDP	ΔLNPEC	ΔLNPOP	ΔLNTROP	ΔLNFD	ΔLNCPI	ETC
ΔLNPCO₂	------	18.269** (0.001)	25.857** (0.000)	7.034* (0.013)	4.298 (0.367)	12.354* (0.014)	1.871 (0.759)	[-1.22] (0.22)
ΔLNPGDP	26.422** (0.000)	------	21.748** (0.000)	6.837 (0.144)	33.864** (0.000)	5.478 (0.241)	1.931 (0.748)	[-2.48] (0.01)
ΔLNPEC	6.462 (0.167)	23.412** (0.000)	------	30.246** (0.000)	13.265** (0.010)	7.654 (0.105)	2.321 (0.676)	[0.25] (0.79)
ΔLNPOP	24.859** (0.000)	45.492** (0.000)	29.870** (0.000)	------	5.223 (0.265)	2.311 (0.678)	0.406 (0.981)	[0.03] (0.97)
ΔLNTROP	10.185* (0.037)	18.407** (0.001)	3.082 (0.544)	3.791 (0.434)	------	0.757 (0.944)	6.769 (0.148)	[0.95] (0.34)
ΔLNFD	4.787 (0.309)	9.701* (0.045)	23.978** (0.001)	2.644 (0.619)	3.622 (0.459)	------	3.591 (0.464)	[-4.33] (0.00)
ΔLNCPI	2.374 (0.667)	0.929 (0.920)	1.232 (0.872)	2.374 (0.667)	4.931 (0.294)	1.217 (0.875)	------	[-0.21] (0.83)

*The p-values are presented in parentheses while t-statistics are in brackets. ** and * denote statistical significance at 1% and 5% level, respectively.*

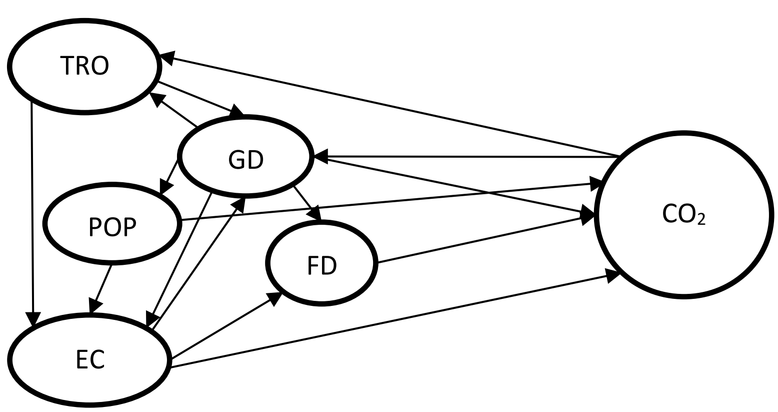

Figure 4. Direction of short-run causal links for the HICs panel

As for the MICs panel, Table 10 and Figure 5 indicate the causal relationship between variables. According to the tabulated information, there is a short-run bidirectional causality between economic growth and financial development, and the finding is partially consistent with Ozturk and Acaravci (2013) and Farhani and Ozturk (2015). This study reveals a short-run one directional causality running from economic growth to energy consumption which is mostly consistent with Zhang and Cheng (2009), Hossain (2011), Haggar (2012), Ozcan (2013), Hwang and Yoo (2014) and Kasman and Duman (2014).

Table 10. Panel Granger Causality Test Result for the MICs Panel

Y↓ X→	ΔLNPCO$_2$	ΔLNPGDP	ΔLNPEC	ΔLNPOP	ΔLNTROP	ΔLNFD	ΔLNCPI	ETC
ΔLNPCO$_2$	------	20.773** (0.000)	7.145 (0.128)	4.987 (0.288)	0.748 (0.945)	0.748 (0.208)	5.875* (0.040)	[-1.33] (0.18)
ΔLNPGDP	9.483 (0.051)	------	5.221 (0.265)	7.527 (0.110)	2.740 (0.602)	20.487** (0.000)	6.712 (0.151)	[-1.63] (0.10)
ΔLNPEC	8.916 (0.063)	10.859* (0.028)	------	2.698 (0.609)	1.487 (0.828)	5.312 (0.256)	5.966 (0.201)	[-0.95] (0.34)
ΔLNPOP	2.427 (0.657)	2.739 (0.602)	3.152 (0.532)	------	2.880 (0.578)	37.656** (0.000)	3.270 (0.513)	[0.00] (0.99)
ΔLNTROP	3.848 (0.427)	20.723** (0.000)	2.988 (0.559)	13.102** (0.010)	------	14.382** (0.006)	6.381 (0.172)	[-4.05] (0.00)
ΔLNFD	1.391 (0.845)	15.229** (0.004)	3.439 (0.487)	8.404 (0.077)	3.793 (0.434)	------	2.883 (0.577)	[3.93] (0.00)
ΔLNCPI	2.578 (0.630)	22.084** (0.000)	3.231 (0.519)	3.660 (0.453)	12.815* (0.012)	4.642 (0.326)	------	[-1.19] (0.23)

*The p-values are presented in parentheses while t-statistics are in brackets. ** and * denote statistical significance at 1% and 5% level, respectively.*

Other short-run unidirectional causal relationships partially consistent with the existing literature are running from economic growth and corruption to CO_2 emissions; and from economic growth, population and financial development to trade openness (Al-Mulali et al., 2013; Farhani, et al., 2013; Kasman and Duman, 2014; and Farhani and Ozturk, 2015). This study also shows some other short-run unidirectional causality running from financial development to population; and from economic growth and trade openness to corruption. Besides the short-run causality analysis, this study shows only one long-run unidirectional causality running from CO_2 emissions, economic growth, energy consumption, population, financial development and corruption to trade openness.

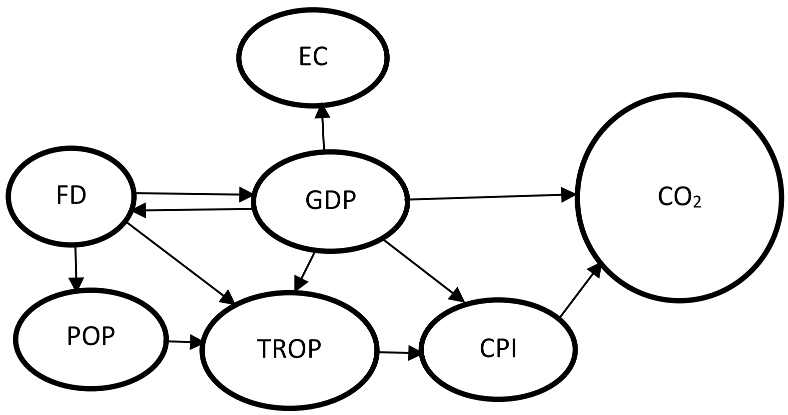

Figure 5. Direction of short-run causal links for the MICs panel

As for the last panel, the LICs, the Granger causality test is conducted and the test results are tabulated into Table 11 and depicted into Figure 6. According to the findings, a short-run bidirectional causality, consistent partially with other studies, is found between trade openness and CO_2 emissions, and between economic growth and financial development (Al-Mulali et al., 2013; Kasman and Duman, 2014; and Farhani and Ozturk, 2015). Other short-run bidirectional causality is found between economic growth and population; and between economic growth and corruption. The study finds a short-run unidirectional causality running from population to energy consumption which is consistent with the finding of Al-Mulali et al. (2013). The study also reveals another short-run unidirectional causality, consistent partially with Farhani, et al. (2013), and running from economic growth and corruption to CO_2 emissions. Moreover, other short-run unidirectional causal relationships found in this study is running from energy consumption to economic growth; and from population, trade openness and financial development to corruption. However, data does not support the existence of any long-run causal relationship between variables for the panel LICs. Finally, based on the Granger causality analysis, it is concluded that economic growth, energy consumption, population, financial development and corruption exert a causal influence on global CO_2 emissions. However, this conclusion may vary at regional levels. As for the HICs, the global emission factors, except corruption have noteworthy influence on CO_2 emissions. For the MICs' CO_2 emissions, only two factors, economic growth and corruption are found to have dominant influence on emissions. And for the LICs, economic growth, trade openness and corruption affects CO_2 emissions.

Table 11. Panel Granger Causality Test Result for the LICs Panel

Y ↓ X →	ΔLNPCO₂	ΔLNPGDP	ΔLNPEC	ΔLNPOP	ΔLNTROP	ΔLNFD	ΔLNCPI	ETC
ΔLNPCO₂	------	3.579* (0.046)	2.395 (0.663)	2.989 (0.559)	4.753* (0.031)	7.630 (0.106)	12.520* (0.013)	[2.35] (0.01)
ΔLNPGDP	9.096 (0.058)	------	9.528* (0.049)	20.546** (0.000)	7.495 (0.111)	27.199** (0.000)	21.609** (0.000)	[4.04] (0.00)
ΔLNPEC	4.963 (0.291)	2.936 (0.568)	------	9.542* (0.048)	6.298 (0.177)	7.195 (0.125)	19.627** (0.000)	[2.06] (0.04)
ΔLNPOP	1.563 (0.815)	14.054** (0.007)	8.721 (0.068)	------	4.832 (0.304)	22.159** (0.000)	0.473 (0.976)	[0.33] (0.73)
ΔLNTROP	10.457* (0.033)	7.712 (0.102)	5.306 (0.257)	3.674 (0.451)	------	8.571 (0.072)	4.484 (0.344)	[-1.27] (0.20)
ΔLNFD	5.480 (0.241)	9.683* (0.046)	3.366 (0.498)	4.348 (0.360)	2.594 (0.627)	------	5.299 (0.257)	[-0.36] (0.71)
ΔLNCPI	6.838 (0.144)	14.016** (0.007)	5.367 (0.251)	17.312** (0.001)	31.743** (0.000)	12.056* (0.016)	------	[5.39] (0.00)

*The p-values are presented in parentheses while t-statistics are in brackets. ** and * denote statistical significance at 1% and 5% level, respectively.*

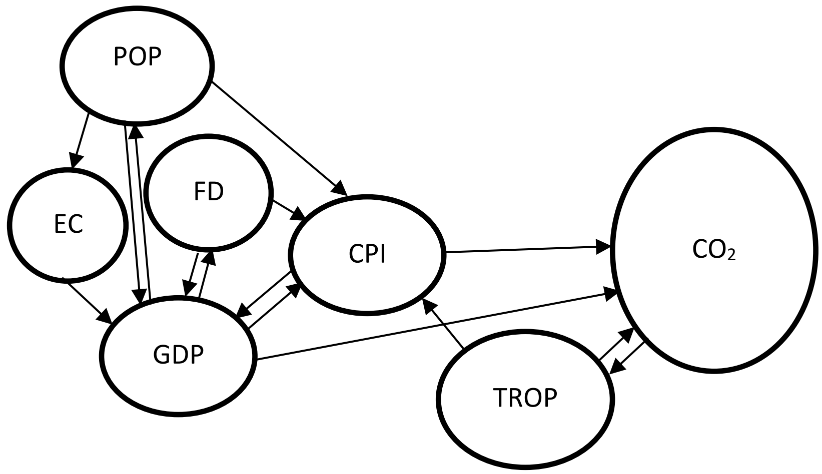

Figure 6. Direction of short-run causal links for the LICs panel

The traditional Granger causality test provides evidence for the existence of as well as the direction of causal links between variables. However, it does not examine the relative strength of the causal links. The innovative accounting approach (IAA), a set of FEVDM and IRFs, is used in this study to measure the relative strength of the causal links. Having intended to make IAA operational, the model of this study, i.e. equation 2, is simulated in a vector auto-regression (VAR) setting for causality analysis. The results of FEVDM for all four panels are reported in Tables 12, 13, 14 and 15, and the relevant IRFs are depicted in Figures 7, 8, 9 and 10. These tables show calculation in 10 different time horizons for the period 1995-2013 and each section in these tables describes how much variations in an endogenous variable contributed by its own innovative shock and other exogenous variables used in the model. As for the global panel, Table 12 shows the decomposition analysis of endogenous variables for the period 1995-2013. According to the table, 90.95% of the change in per capita CO_2 emissions is contributed endogenously due to its own innovative shock and 7.75%, 0.56%, 0.10%, 0.07% and 0.04% is contributed exogenously by GDP per capita, financial development, per capita energy consumption, corruption and population, respectively. It means that the global CO_2 emissions are mostly contributed by economic growth, financial development, energy consumption, corruption and population level.

Table 12. Variance Decomposition Analysis for the Global Panel

Period	S.E.	LNPCO₂	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
Variance Decomposition of $LNPCO_2$								
1	0.08	100.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.10	98.47	1.06	0.10	0.09	0.00	0.00	0.25
…..	……	……	……	……	……	……	……	……
10	0.24	90.95	7.75	0.10	0.04	0.48	0.56	0.07
Variance Decomposition of LNPGDP								
1	0.03	5.70	94.29	0.00	0.00	0.00	0.00	0.00
2	0.05	6.34	93.26	0.01	0.20	0.11	0.01	0.04
…..	……	……	……	……	……	……	……	……
10	0.16	12.26	82.12	0.54	0.67	1.61	1.43	1.32
Variance Decomposition of LNPEC								
1	0.05	26.79	4.17	69.02	0.00	0.00	0.00	0.00
2	0.07	23.15	7.46	67.32	1.74	0.01	0.02	0.26
…..	……	……	……	……	……	……	……	……
10	0.18	25.47	16.97	55.53	1.60	0.07	0.27	0.06
Variance Decomposition of LNPOP								
1	0.00	0.08	0.02	0.09	99.79	0.00	0.00	0.00
2	0.00	0.02	0.72	0.14	99.10	0.00	0.00	0.00
…..	……	……	……	……	……	……	……	……
10	0.04	0.05	3.23	0.19	96.17	0.15	0.12	0.04
Variance Decomposition of LNTROP								
1	0.08	0.67	2.41	0.84	0.04	96.02	0.00	0.00
2	0.11	1.02	3.49	0.58	0.05	94.66	0.06	0.09
…..	……	……	……	……	……	……	……	……
10	0.21	0.40	2.44	1.07	0.35	94.27	0.94	0.48
Variance Decomposition of LNFD								
1	0.12	0.52	0.00	0.00	0.01	0.99	98.44	0.00
2	0.19	0.23	1.52	0.43	0.00	0.43	97.17	0.18
…..	……	……	……	……	……	……	……	……
10	0.35	1.60	9.81	0.72	0.62	0.16	84.92	2.13
Variance Decomposition of LNCPI								
1	0.09	0.01	0.20	0.01	0.08	0.00	0.01	99.67
2	0.12	0.03	2.05	0.00	0.05	0.02	0.07	97.74
…..	……	……	……	……	……	……	……	……
10	0.18	0.40	9.89	0.18	0.34	0.64	0.09	88.42

Note: *complete table is provided in the appendix; Chowlesky ordering are defined as: LNPCO2, LNPGDP, LNPEC, LNPOP, LNTROP, LNFD AND LNCPI*

Figure 7. Impulse Response Function for the Global panel

According to the data, the major determinants of economic growth are CO_2 emissions, trade openness, financial development and corruption since any change in GDP per capita is exogenously contributed by per capita CO_2 emissions (12.26%), trade openness (1.61%), financial development (1.43%) and corruption (1.32%). Similarly, it is easy to find from the table that the major determinants of energy consumption, population, trade openness, financial development and corruption are CO_2 emissions, economic growth and population; economic growth; economic growth, energy consumption and financial development; economic growth, corruption and CO_2 emissions; economic growth and trade openness, respectively. Besides the tabular analysis, FEVDM results are verified graphically using IRF in Figure 7 which shows a binary relationship between the seven variables used in the study.

The FEVDM results for the HICs are reported in Table 13. According to the table, change in per capita CO_2 emissions is 85.21% self-contributed and 6.79%, 5.37% 1.30% and 0.22% is exogenously contributed by GDP per capita, financial development, per capita energy consumption and population, respectively. It indicates that CO_2 emissions in high-income countries is generally contributed by economic growth, financial development, energy consumption and population. Also, the table shows that the 67.78% change in GDP per capita is endogenously contributed due to the countries' own innovative shock and 15.61%, 7.71%, 4.92% and 2.46% is exogenously contributed by per capita CO_2 emissions, corruption, financial development and per capita energy consumption, respectively; that means economic growth in high-income countries is notably accompanied by CO_2 emissions, corruption, financial development and energy consumption. Similarly, the major determinants of energy consumption, population and trade openness are CO_2 emissions, economic growth, population and trade openness; economic growth and trade openness; and economic growth, population, CO_2 emissions and energy consumption, respectively. Moreover, the major determinants of financial development and corruption are energy consumption, trade openness, economic growth, corruption and CO_2 emissions; and financial development and economic growth, respectively. The findings from Table 13 are tested using IRF in Figure 8.

Table 13. Variance Decomposition Analysis for the HICs Panel

Period	**S.E.**	**LNPCO$_2$**	**LNPGDP**	**LNPEC**	**LNPOP**	**LNTROP**	**LNFD**	**LNCPI**
Variance Decomposition of LNPCO$_2$								
1	0.07	100.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.09	98.64	0.68	0.28	0.19	0.15	0.01	0.01
…..	……	……	……	……	……	……	……	……
10	0.22	85.21	6.79	1.30	0.22	1.02	5.37	0.05
Variance Decomposition of LNPGDP								
1	0.02	6.87	93.12	0.00	0.00	0.00	0.00	0.00
2	0.04	7.59	90.75	0.17	0.05	1.29	0.00	0.11
…..	……	……	……	……	……	……	……	……
10	0.12	15.61	67.78	2.46	0.50	0.99	4.92	7.71
Variance Decomposition of LNPEC								
1	0.04	35.21	1.91	62.87	0.00	0.00	0.00	0.00
2	0.06	27.93	5.64	60.83	4.20	1.36	0.00	0.00
…..	……	……	……	……	……	……	……	……
10	0.15	33.04	13.34	46.79	3.41	2.17	0.14	1.08
Variance Decomposition of LNPOP								
1	0.00	0.55	0.00	0.09	99.35	0.00	0.00	0.00
2	0.00	0.10	2.82	0.03	96.65	0.36	0.01	0.00
…..	……	……	……	……	……	……	……	……
10	0.04	0.03	17.16	0.10	80.97	1.29	0.14	0.27
Variance Decomposition of LNTROP								
1	0.06	1.78	14.70	0.39	0.42	82.69	0.00	0.00
2	0.09	1.03	20.08	0.39	1.01	77.42	0.00	0.03
…..	……	……	……	……	……	……	……	……
10	0.16	2.86	7.16	1.25	4.07	83.77	0.65	0.20
Variance Decomposition of LNFD								
1	0.11	2.78	2.57	0.00	0.02	0.23	94.37	0.00
2	0.16	4.36	1.37	2.18	0.01	0.11	91.92	001
…..	……	……	……	……	……	……	……	……
10	0.29	2.64	3.71	6.31	0.21	4.37	79.55	3.18
Variance Decomposition of LNCPI								
1	0.09	0.18	0.00	0.11	0.01	0.41	0.10	99.16
2	0.11	0.15	0.55	0.07	0.00	0.34	0.10	98.75
…..	……	……	……	……	……	……	……	……
10	0.17	0.43	0.57	0.06	0.04	0.27	1.07	97.53

Note: *complete table is provided in the appendix, Chowlesky orderings are defined as: LNPCO2, LNPGDP, LNPEC, LNPOP, LNTROP, LNFD AND LNCPI*

Figure 8. Impulse Response Function for the HICs panel

As for the MICs panel, Table 14 reports the FEVDM results for the period 1995-2013. According to the table, 88.04% of the change in per capita CO_2 emissions is contributed endogenously due to its own innovative shock and 6.15%, 3.71% and 1.14% is contributed by GDP per capita, trade openness and population respectively. The findings indicate that CO_2 emissions in middle-income countries are typically contributed by economic growth, trade openness and population. The table also reports that 81.55% of the change in GDP per capita, which is self-contributed and other exogenous contribution is found from per capita CO_2 emissions, trade openness and population by 10.42%, 6.91% and 0.84%, respectively. In the same way, it is easy to see from the table that the major determinants of energy consumption, population, trade openness, financial development and corruption are CO_2 emissions (52.16%), economic growth (12.93%) and trade openness (5.08%); CO_2 emissions (1.24%); economic growth (5.23%), CO_2 emissions (4.61%), population (2.52%), financial development (2.48%) and energy consumption (2.32%); economic growth (28.95%), population (2.66%), CO_2 emissions (1.82%) and corruption (1.04%); economic growth (4.98%), trade openness (3.07%) and energy consumption (1.21%), respectively. Apart from the tabular analysis, the FEVDM results are verified using IRF in Figure 9.

Table 14. Variance Decomposition Analysis for the MICs Panel

Period	S.E.	$LNPCO_2$	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
Variance Decomposition of $LNPCO_2$								
1	0.06	100.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.08	95.63	2.02	0.21	0.67	0.00	0.11	1.33
…..	……	……	……	……	……	……	……	……
10	0.17	88.04	6.15	0.15	1.14	3.71	0.10	0.66
Variance Decomposition of LNPGDP								
1	0.03	6.70	93.29	0.00	0.00	0.00	0.00	0.00
2	0.05	5.86	93.16	0.06	0.08	0.53	0.20	0.08
…..	……	……	……	……	……	……	……	……
10	0.13	10.42	81.55	0.07	0.84	6.91	0.06	0.12
Variance Decomposition of LNPEC								
1	0.04	48.35	6.89	44.74	0.00	0.00	0.00	0.00
2	0.06	50.01	8.61	40.35	0.34	0.10	0.19	0.36
…..	……	……	……	……	……	……	……	……
10	0.14	52.16	12.93	28.76	0.67	5.08	0.17	0.20
Variance Decomposition of LNPOP								
1	0.00	0.09	0.31	0.15	99.42	0.00	0.00	0.00
2	0.00	0.03	0.17	0.03	99.46	0.04	0.22	0.00
…..	……	……	……	……	……	……	……	……
10	0.03	1.24	0.09	0.01	98.25	0.04	0.34	0.00
Variance Decomposition of LNTROP								
1	0.08	3.30	1.80	0.60	0.15	94.13	0.00	0.00
2	0.11	5.24	1.29	0.77	0.45	91.22	0.96	0.04
…..	……	……	……	……	……	……	……	……
10	0.19	4.61	5.23	2.32	2.52	82.59	2.48	0.22
Variance Decomposition of LNFD								
1	0.09	0.14	5.33	0.00	0.01	0.02	94.48	0.00
2	0.15	0.12	11.32	0.00	0.02	0.20	88.27	0.03
…..	……	……	……	……	……	……	……	……
10	0.35	1.82	28.95	0.04	2.66	0.42	65.04	1.04
Variance Decomposition of LNCPI								
1	0.09	0.65	0.15	0.38	0.43	0.00	0.03	98.32
2	0.12	0.62	0.77	0.33	0.29	0.08	0.28	97.60
…..	……	……	……	……	……	……	……	……
10	0.18	1.09	4.98	1.21	0.42	3.07	0.40	88.79

Note: *complete table is provided in the appendix, Chowlesky orderings are defined as: LNPCO2, LNPGDP, LNPEC, LNPOP, LNTROP, LNFD AND LNCPI*

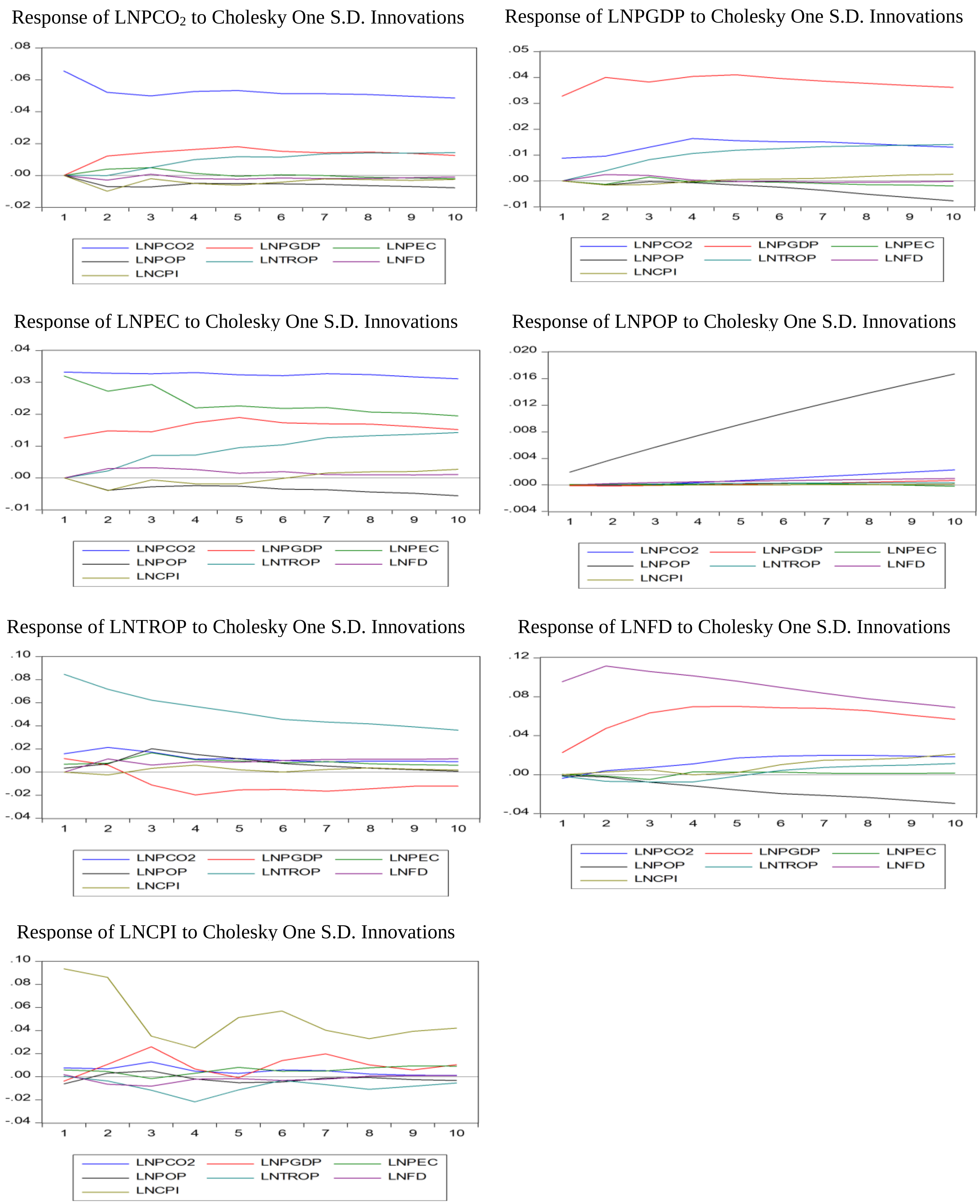

Figure 9. Impulse Response Function for the MICs panel

The decomposition analysis of endogenous variables for low-income countries during the period 1995-2013 is reported in Table 15. According to the table, 92.93% of the change in per capita CO_2 emissions is contributed by its own innovative shock and 2.62%, 1.82% and 0.87% is contributed exogenously by trade openness, GDP per capita and corruption respectively. It indicates that CO_2 emissions in low-income countries are mostly contributed by trade openness, economic growth and corruption. Similarly, economic growth is contributed by CO_2 emissions, trade openness, corruption and financial development. Other findings derived from the same table are that the major determinants of energy consumption, population, trade openness, financial development and corruption are economic growth, CO_2 emissions, trade openness and corruption; financial development and economic growth; economic growth, energy consumption and population; economic growth, trade openness, CO_2 emissions and energy consumption; economic growth, energy consumption, population, CO_2 emissions, trade openness and financial development respectively. The FEVDM results of $LNCO_2$, LNPGDP, LNPEC, LNPOP, LNTROP, LNFD and LNCPI are verified graphically using IRF in Figure 10.

In conclusion, the most important contributors to global CO_2 emissions are economic growth, financial development, energy consumption, corruption and population. However, the conclusion does not necessarily remain the same at regional level. CO_2 emissions in high-income countries are contributed by economic growth, financial development, energy consumption and population. In the case of middle-income countries, economic growth, trade openness and population affect CO_2 emissions notably. As for the low-income countries, the major contributors to CO_2 emissions are trade openness, economic growth and corruption. The findings of the IAA analysis (combination of FEVDM and IRF) are significantly consistent with the long-run estimates as well as the Granger causality test results at 1% level of significance, and the consistency indicates robustness of the overall findings of this study. This is a clear indication that the results of the study could be used for policy formulation.

Table 15. Variance Decomposition Analysis for the LICs Panel

Period	S.E.	$LNPCO_2$	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
Variance Decomposition of $LNPCO_2$								
1	0.10	100.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.13	98.35	0.53	0.23	0.07	0.19	0.00	0.60
…..	……	……	……	……	……	……	……	……
10	0.27	92.93	1.82	0.47	0.55	2.62	0.72	0.87
Variance Decomposition of LNPGDP								
1	0.03	4.14	95.85	0.00	0.00	0.00	0.00	0.00
2	0.05	5.54	93.44	0.07	0.04	0.73	0.10	0.03
…..	……	……	……	……	……	……	……	……
10	0.16	8.20	84.16	0.55	0.43	4.72	0.85	1.06
Variance Decomposition of LNPEC								
1	0.05	11.32	1.19	87.47	0.00	0.00	0.00	0.00
2	0.07	9.34	3.42	85.86	0.15	0.23	0.15	0.82
…..	……	……	……	……	……	……	……	……
10	0.14	7.29	7.54	80.77	0.30	2.14	0.65	1.29
Variance Decomposition of LNPOP								
1	0.00	0.02	0.00	1.08	98.88	0.00	0.00	0.00
2	0.00	0.00	0.00	1.00	98.95	0.01	0.01	0.00
…..	……	……	……	……	……	……	……	……
10	0.01	0.95	1.40	0.23	95.19	0.23	1.93	0.04
Variance Decomposition of LNTROP								
1	0.10	0.01	0.00	0.99	0.21	98.76	0.00	0.00
2	0.13	2.14	0.64	0.65	0.19	96.25	0.00	0.09
…..	……	……	……	……	……	……	……	……
10	0.23	0.88	3.34	1.50	1.30	92.01	0.63	0.32
Variance Decomposition of LNFD								
1	0.15	1.04	0.04	0.01	0.00	5.15	93.74	0.00
2	0.22	0.92	2.17	0.00	0.02	3.44	93.14	0.27
…..	……	……	……	……	……	……	……	……
10	0.32	5.10	7.20	1.14	0.12	5.49	80.65	0.26
Variance Decomposition of LNCPI								
1	0.08	0.31	2.13	0.06	0.59	0.74	1.21	94.92
2	0.11	0.19	5.43	0.12	0.86	0.53	0.78	92.05
…..	……	……	……	……	……	……	……	……
10	0.16	1.27	18.56	3.23	2.98	1.27	1.23	71.42

Note: *complete table is provided in the appendix, Chowlesky orderings are defined as: LNPCO2, LNPGDP, LNPEC, LNPOP, LNTROP, LNFD AND LNCPI*

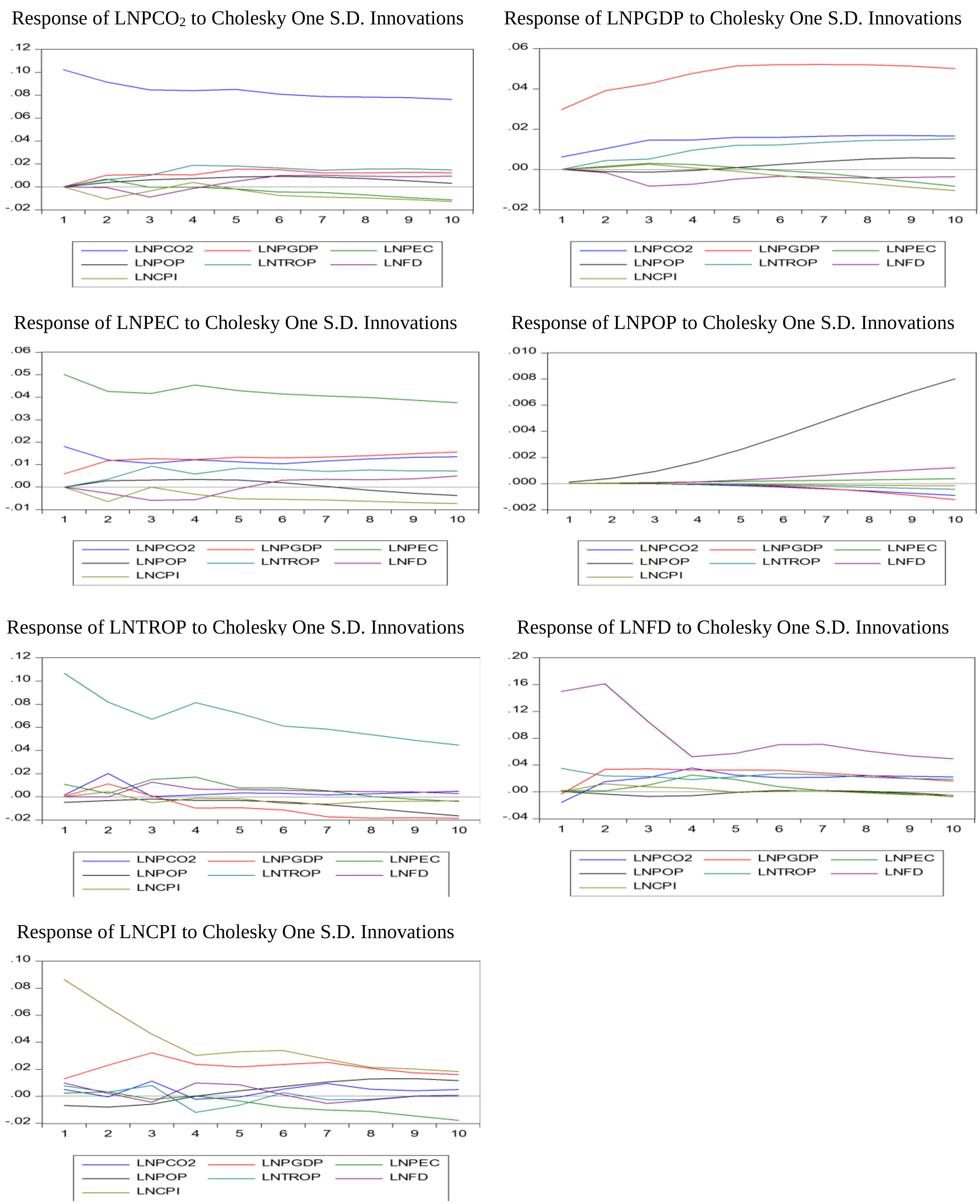

Figure 10. Impulse Response Function for the LICs panel

Chapter 4

4.1 Policy implications

The findings of this study have some policy implications. They indicate that formulating and implementing an appropriate combination of policy tools, such as regulation, economic, voluntary and educational/ informational instruments, a nation can address the root cause of CO_2 emissions and improve its environmental quality. In this study, the sigmoid curve found in section 2 indicates that all three categories of countries emitted increasing amounts of per capita CO_2 overtime, but that the relative emissions vary by category of a country's GDP per capita. This can be explained by the fact that different countries adopted different modes of production and produced various levels of output. They also produced different levels of CO_2 emissions. Limiting emissions while encouraging growth is necessary for sustainable development but it is challenging. Investment in green technologies and in human capital through education and training rather than in fossil fuel technologies may be a good policy towards sustainable development (Hartwick, 1977). Green technologies consume less fossil fuels and use more renewable energy, and are more labor-intensive (UCSUSA, 2013). Formulating and implementing a consistent environmental policy is another factor facilitating the process towards sustainable development by limiting pollution. Therefore, investment in green technologies and human capital along with proper environmental policy design and implementation may make the sigmoid curve flatter or change the direction of the curve and make it downward sloping, meaning that more output is being produced while limiting emissions. Section 3 of this study attempted to explore the factors determining CO_2 emissions. The long-run estimates, Granger causality and IAA analysis document that the potential factors driving global CO_2 emissions are economic growth, financial development, energy consumption and corruption. However, CO_2 emissions in high-income countries are caused by economic growth, energy consumption, population and financial development. As for the other two country categories, CO_2 emissions are determined by economic growth, trade openness and corruption only.

Economic growth is the dominant factor that leads to more CO_2 emissions in high-income countries followed by middle-income and low-income countries, since the factor contributes to changes in CO_2 emissions in all sub-panels - HICs, MICs and LICs respectively. It indicates that different countries produce various levels of output employing different modes of production, and as a consequence, emit various levels of CO_2 emissions. The primary objective of economic growth is to ensure well-being for societies. However, unlimited economic growth or increase in wealth which disregards the objective limits of the earth ecosystem does not entirely bring well-being, as John Stuart Mill stated in his book, Principles of Political Economy: "*If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger, but not a better or a happier population, I sincerely hope, for the sake of posterity, that they will be content to be stationary, long before necessity compels them to it*" (Mill,1848, p. 192). Moreover, recent studies find that GDP fails to measure well-being accurately as it misses to count other important dimensions of wellbeing such as unemployment, poverty, health, suicide rates, crime, environmental health and so on (OECD, 2017). The other dimensions to wellbeing are required to be considered while measuring economic growth, and countries should count their Gross Sustainable Development Product (GSDP) rather than conventional GDP. It may be worthwhile to mention GSDP includes economic growth as well as it's resulting Scio-environmental costs while GDP measures only economic growth.

Energy consumption is another key factor of CO_2 emissions. In this study, energy consumption is mostly pollution intensive since it represents the use of all primary energy before transformation to other types. Nevertheless, currently more than 80% of the global energy supply is based on fossil fuels that continually adds more emissions to the existing global CO_2 stock (Hossain, 2011). The presence of Granger causality running from GDP to energy consumption indicates that an increase in GDP enables people to buy more items like cars, heaters, refrigerators, air conditioners, washing machines, etc. which need energy to be operated, and thus accelerate CO_2 emissions (Ozturk and Acaravci, 2013). Since the ongoing economic progress increases the demand for energy, countries should enhance their energy saving strategies through increasing energy efficiency of consumption and decreasing energy intensity of production, and focus on the utilization of renewable energy sources. The absence of Granger causality running from energy consumption to GDP found for all panels, except the HICs, recommends that policy measures may be taken to improve energy efficiency, without risking economic progress. With the aim to deter misuses or overuse of pollution intensive energy sources e.g. fossil fuels, countries may impose an excise tax, in the name of pollution or emission tax on fossil fuels, and invest a portion of the tax revenue on research and development for more energy efficient technologies and alternative energy sources. Moreover, they can encourage people subsidizing energy saving technologies, alternative cleaner fuels and other renewable energy equipment. Part of the fund could be used to educate people and make them well informed about the consequences of excessive energy uses.

Corruption has widespread but mostly indirect effects on CO_2 emissions. Greater corruption does not only weaken the stringency of environmental policy measures, but also drags economic progress down. The lower level of economic progress delays a nation to reach the turning point in its EKC curve. In this study, the presence of Granger causality running from corruption to energy consumption in low-income countries indicates that the energy sector in these countries is less transparent, causing misuses or over-consumption of energy. For example, the loss in distribution system, locally called ‘system loss’ in the energy sector of Bangladesh was 28% in the fiscal year 2001- 2002 which is considered the result of corruption and other inefficiencies in the sector (Ahmed, 2011). To reduce CO_2 emissions by promoting stringent environmental policy regulations, economic progress and an efficient energy sector, countries should develop anti-corruption strategies. Good governance structures should be in place to curve corruption.

Trade openness affects CO_2 emissions through allowing the exchange of output produced in a country where environmental regulation or standards are less stringent. The long-run estimates in this study find a positive relationship between CO_2 emissions and trade openness which indicates the existence of the *pollution haven hypothesis*. The governments of these countries may develop their own socio-environmental standards and/or promote existing global standards like the UN Global Compact, Carbon Trust Product Footprint Certification, the Associacao Brasileira de Normas Tecnicas (ABNT) Ecolabel and so on. Compliance with these standards might not significantly affect the GDP growth of these countries, as this study did not find any Granger causality running from trade openness to GDP.

Population growth is another factor of CO_2 emissions which indicates that an increase in human population results in increased economic output and energy consumption and leads to more CO_2 emissions. In this study, a Granger causality running from population to energy consumption was found. This finding likely indicates that a rise in existing human population requires more energy consumption which eventually leads to higher CO_2 emissions. Governments of these countries should take immediate policy response to the curve of population growth.

4.2 Conclusion

Economic activities have significant adverse effects on the natural environment. Studying the relationship between economic growth and CO_2 emissions is required in order to inform sound policies aiming to achieve sustainable development. With the objectives to examine the most likely pattern of the relationship, and to identify the factors that affect the relationship or drive CO_2 emissions and finally to design sound policy for reducing CO_2 emissions, this study has employed several quantitative methods, mostly econometric dynamic models, and has utilized data from widely recognized sources concerning three categories of countries undergoing various levels of economic growth. The most likely pattern of the long run relationship between per capita CO_2 emissions and GDP per capita is found as a sigmoid curve. The curve shows that per capita CO_2 emissions begin rising gradually from an initial low level and then reach a higher level following a dramatic increase. According to the curve, all three categories of countries emit per capita CO_2 increasingly overtime, but their relative emissions vary. The variation in relative emissions is due to heterogeneity in both the structure of their economies as well as the mode of production used in their manufacturing processes. The findings of the paper are significantly unique; however, they are consistent, in varying degrees, with other findings of previous studies. After performing the long-run estimates, Granger causality and IAA analysis, this study documents that the potential factors driving global CO_2 emissions are economic growth, financial development, energy consumption and corruption. However, this conclusion may vary at regional levels. CO_2 emissions in high-income countries are caused by economic growth, energy consumption, population and financial development. As for the other two country categories, CO_2 emissions are determined by economic growth, trade openness and corruption. It is recommended that countries develop their own policies combining an appropriate policy mix of tools, such as regulation, economic, voluntary and educational/ informational instruments to address their environmental pollution. Effective environmental policy implementation, along with investment in green technologies and human capital may change the direction of the sigmoid curve and make it downward sloping. Countries could consider other dimensions of wellbeing when they measure their economic growth. Imposing pollution taxes on energy supplies based on fossil fuels, developing emissions standards, strengthening anti-corruption strategies, adopting socio-environmental standards for the global trade and educating people about the adverse effects of CO_2 emissions on the natural environment and human health are potential policy measures.

4.3 Limitations of the study

The panel data in this study have been converted into time series data by using the average of values for same category countries. The average measure is convenient to provide a general view; however, it cannot provide an in-depth view of all countries under consideration. Development strategies vary by countries. For various reasons, developing countries may not require fulfilling all of the five stages of Rostow's economic growth model to improve their economic status. Australia, Canada and the U.S. are good examples, because they did not pass through the five stages of the growth model. More research is needed for filling these gaps in knowledge. Another limitation of this study is that it does not mention details about the possible presence of structural breaks in the data.

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Appendix-A: Summary Statistics of Time Series Variables

Country Name	PCO_2		PGDP		PEC		POP		TROP		FD		CPI	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
HICs														
Australia	17.0	0.6	47029.4	4919.2	5599.2	178.2	20.3	1.5	40.5	2.1	101.9	20.2	86.5	1.8
Austria	8.1	0.5	43524.9	3694.3	3824.8	221.0	8.2	0.2	89.5	11.5	93.9	3.6	77.9	4.8
Belgium	10.3	1.0	41458.1	3125.4	5472.9	226.9	10.5	0.3	140.3	15.0	64.3	6.2	68.6	7.6
Canada	16.1	1.2	44886.3	3788.0	7883.0	353.0	32.1	1.7	69.7	6.9	135.8	32.4	87.8	3.0
Denmark	9.5	1.7	56286.1	3282.7	3560.4	249.6	5.4	0.1	86.5	11.9	132.1	64.7	94.8	2.7
Finland	11.1	1.2	42503.9	5136.6	6490.3	384.6	5.3	0.1	73.6	6.5	68.8	15.7	94.2	3.4
France	5.8	0.4	39080.2	2393.3	4099.1	147.8	62.7	2.1	52.5	4.5	84.7	8.2	69.3	2.8
Greece	8.1	0.7	24949.9	3183.0	2501.7	203.0	10.9	0.2	51.1	7.8	68.5	31.8	43.4	5.3
Iceland	7.1	0.7	38830.1	4820.3	12671.7	3509.7	0.3	0.0	80.2	13.4	136.4	73.9	90.5	5.1
Ireland	9.8	1.1	45004.0	7268.7	3311.0	274.4	4.1	0.4	162.8	18.5	106.7	33.9	76.5	4.7
Israel	9.1	0.4	27704.0	2675.1	2900.8	110.7	6.8	0.8	69.8	7.0	70.4	5.2	66.6	6.9
Italy	7.5	0.7	35776.6	1572.4	2931.4	158.3	58.0	1.1	49.7	4.3	71.7	15.6	45.6	6.4
Japan	9.5	0.3	41500.4	1681.9	3921.3	175.6	127.2	0.8	25.4	6.0	188.5	16.1	70.9	5.7
Luxembourg	20.9	2.1	93612.7	11885.6	8121.9	690.9	0.5	0.0	286.0	48.8	83.8	11.4	83.4	8.3
Netherlands	10.6	0.3	46963.1	3951.9	4712.3	122.3	16.2	0.4	125.5	13.7	109.3	8.9	88.0	2.0
New Zealand	8.0	0.5	31797.0	2839.7	4213.1	127.7	4.1	0.2	59.3	3.8	119.1	18.9	94.0	1.6
Norway	9.5	1.3	84212.3	5801.9	5913.3	439.6	4.6	0.2	70.4	2.6	97.3	26.4	87.3	2.6
Portugal	5.5	0.6	21321.6	1308.7	2280.0	164.3	10.4	0.2	66.0	5.3	120.5	31.0	63.3	3.2
Singapore	10.1	3.5	38317.6	7032.9	5199.6	663.9	4.4	0.6	370.9	34.2	100.4	10.9	91.3	2.5
Spain	6.8	0.9	29146.9	2493.8	2898.4	251.0	43.1	2.9	54.3	4.5	122.8	38.8	63.2	7.9
Sweden	5.6	0.5	47303.8	5282.3	5528.9	254.6	9.1	0.2	81.3	6.9	86.9	38.3	92.0	1.9
Switzerland	5.4	0.4	69326.1	4794.1	3466.2	123.1	7.5	0.3	101.7	15.2	152.7	8.0	88.0	2.2
Trini. & Tob.	25.9	8.2	12785.4	3705.9	10776.4	3604.2	1.3	0.0	98.0	8.5	37.3	6.3	44.7	8.0
UK	8.6	0.8	36931.7	3166.6	3529.1	303.5	60.5	2.0	53.8	4.5	142.0	32.9	82.0	5.5
USA	18.8	1.2	46140.0	3502.3	7596.5	379.1	292.6	15.2	25.6	3.1	173.9	20.6	69.6	15.5
Uruguay	1.9	0.4	9865.5	1693.5	1002.7	201.8	3.3	0.0	48.4	10.3	32.3	13.5	57.4	11.2
MICs														
Argentina	4.1	0.4	8901.0	1204.9	1731.3	143.2	38.7	2.3	31.7	8.2	16.3	5.1	31.3	5.8
Botswana	2.1	0.2	5505.2	833.0	1004.2	54.6	1.9	0.2	96.1	9.4	20.3	7.1	59.8	2.8
Brazil	1.9	0.2	9658.0	1129.9	1168.5	129.6	184.9	12.8	23.5	4.3	40.5	11.9	37.2	4.0
Bulgaria	6.1	0.5	5391.9	1323.5	2495.5	149.4	7.8	0.4	99.8	17.4	40.9	23.6	36.7	3.9
Chile	4.0	0.5	11176.5	1672.8	1733.1	212.8	15.9	1.0	65.2	7.3	78.6	18.7	71.9	3.0

China	4.4	1.8	2921.1	1414.8	1335.5	452.0	1290.8	45.1	46.9	10.7	112.3	13.3	33.4	4.4
Colombia	1.5	0.2	5487.8	756.8	663.3	41.6	42.6	3.0	35.9	1.7	34.8	8.3	34.2	5.2
Costa Rica	1.6	0.2	7048.9	1062.2	855.2	156.3	4.2	0.4	81.4	8.4	33.2	12.9	51.0	5.9
Ecuador	2.1	0.4	4260.2	489.6	790.6	98.8	13.5	1.3	54.2	7.4	22.5	2.7	25.1	3.9
Jamaica	3.6	0.5	4980.5	161.8	1323.0	172.3	2.6	0.1	92.8	9.2	23.6	4.8	36.2	3.0
Jordan	3.4	0.3	3477.4	493.7	1088.6	96.0	5.5	0.9	123.3	13.3	75.5	7.3	48.1	3.3
Malaysia	6.4	1.0	7862.6	1201.0	2368.2	375.4	25.3	2.6	187.2	23.2	122.0	18.7	49.6	2.8
Mauritius	2.5	0.5	6431.5	1356.9	912.3	129.5	1.2	0.0	120.5	7.9	70.0	17.5	49.0	4.3
Mexico	3.8	0.2	8553.3	552.3	1474.9	62.8	108.8	8.7	54.9	5.6	19.9	4.5	33.5	2.4
Panama	2.1	0.4	6539.4	1565.8	895.1	106.6	3.3	0.3	139.9	13.6	82.0	9.4	34.5	2.0
Peru	1.3	0.3	4031.3	852.9	521.8	94.6	27.3	1.9	43.1	9.4	24.0	4.3	39.1	4.3
St. Africa	9.1	0.6	6715.4	643.1	2668.7	137.3	46.5	4.1	55.1	7.3	133.7	15.7	47.7	4.2
Thailand	3.6	0.6	4250.9	736.4	1436.5	282.5	64.4	2.6	119.4	17.1	118.2	23.8	33.5	2.4
Tunisia	2.2	0.3	3440.1	571.6	824.9	96.8	9.9	0.6	93.0	10.9	63.6	6.6	47.1	4.0
Turkey	3.6	0.5	8868.1	1317.2	1281.4	160.3	67.0	5.2	49.3	5.1	29.5	16.6	35.9	8.8
Venezuela	6.4	0.6	12757.2	1345.0	2212.2	121.3	26.3	2.5	50.2	5.8	16.4	6.1	23.0	3.1
LICs														
Bolivia	1.4	0.2	1766.8	206.5	589.0	84.8	9.0	0.9	62.6	14.6	47.6	9.1	27.1	4.0
Cameroon	0.3	0.1	1106.5	63.7	368.9	30.9	17.8	2.5	42.8	3.9	10.0	2.4	21.1	3.4
Cote d'Ivoire	0.4	0.1	1288.0	75.8	469.0	79.9	17.9	2.1	83.3	7.8	14.6	2.7	23.8	3.0
Egypt	2.1	0.4	2202.4	330.2	753.1	133.7	74.0	7.5	49.4	9.9	43.2	9.9	31.2	2.3
El Salvador	1.0	0.1	3272.7	318.0	697.8	56.5	5.9	0.1	67.8	5.5	41.4	2.4	37.8	2.4
Ghana	0.4	0.1	1135.7	221.1	329.5	47.7	21.1	2.9	84.5	15.5	12.7	3.4	36.9	3.8
Guatemala	0.8	0.1	2644.5	172.7	612.4	68.4	12.9	1.6	58.1	9.9	24.2	4.2	29.0	3.3
Honduras	1.0	0.2	1884.9	215.5	571.8	63.9	6.7	0.7	116.0	14.8	40.9	8.8	23.1	3.7
India	1.1	0.2	996.5	289.2	469.3	71.3	1124.1	97.6	37.4	12.7	37.1	11.7	30.5	3.3
Indonesia	1.6	0.4	2615.6	457.7	768.3	65.3	223.6	16.4	58.4	11.3	32.2	13.2	23.6	4.8
Kenya	0.3	0.0	910.9	73.0	459.0	17.1	34.9	4.9	55.9	5.3	26.0	2.5	21.9	2.2
Morocco	1.4	0.3	2369.5	429.2	445.9	74.6	30.2	1.8	65.7	12.3	49.6	13.8	36.7	3.9
Nicaragua	0.8	0.1	1406.1	166.7	517.6	24.6	5.3	0.4	73.4	19.7	23.0	6.3	27.1	2.1
Nigeria	0.6	0.2	1748.4	461.1	730.3	32.9	137.8	19.6	59.7	12.4	15.9	7.9	18.7	5.8
Pakistan	0.8	0.1	940.6	100.3	476.6	23.8	150.9	17.5	33.3	2.5	23.7	3.8	23.3	3.7
Philippines	0.9	0.1	1838.5	273.2	464.9	28.4	84.1	8.4	87.8	15.3	35.5	7.4	27.9	4.0
Senegal	0.5	0.1	920.5	68.2	252.7	26.8	11.1	1.7	68.0	5.3	20.2	5.5	32.9	2.9
Zimbabwe	0.9	0.2	956.9	249.5	757.5	55.8	13.1	0.9	83.0	14.7	34.6	18.8	27.9	7.8

Appendix-B: Omitted Variable Bias (for Global/All panel)

Null hypothesis: LNCPI is jointly significant
Omitted variable: LNCPI

Statistics	Value	df	Probability
t - statistics	1.544	1228	0.122
F - statistics	2.384	(1, 1228)	0.122
Likelihood ratio	2.395	1	0.121

Conclusion: null hypothesis is accepted, that means LNCPI (or corruption) is important variable that needs to be included into the model.

Appendix-C: Variance Decomposition Analysis

Panel: All

Variance Decomposition of LNPCO2:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.082840	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.109186	98.47548	1.065217	0.106325	0.094405	0.000195	0.007821	0.250556
3	0.130440	96.67215	2.481660	0.276915	0.109130	0.041731	0.203840	0.214576
4	0.150588	94.97531	3.978854	0.214971	0.085609	0.205581	0.357986	0.181687
5	0.169617	93.60492	5.230939	0.175771	0.087290	0.312296	0.438405	0.150384
6	0.186576	92.65926	6.143456	0.156011	0.078398	0.346214	0.490412	0.126245
7	0.202002	92.04444	6.727392	0.139444	0.068199	0.391146	0.521458	0.107920
8	0.216465	91.58213	7.164937	0.126482	0.059955	0.431014	0.541471	0.094011
9	0.230083	91.21241	7.515525	0.116111	0.053169	0.463788	0.555655	0.083338
10	0.242857	90.95887	7.756749	0.107183	0.047750	0.489033	0.564671	0.075745

Variance Decomposition of LNPGDP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.030456	5.700289	94.29971	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.050970	6.346651	93.26475	0.014665	0.201632	0.114485	0.012367	0.045450
3	0.067744	8.846426	89.86352	0.148288	0.267363	0.292088	0.317385	0.264930
4	0.084793	9.960553	87.78055	0.308682	0.277294	0.533904	0.645387	0.493631
5	0.100995	10.43781	86.58782	0.400547	0.324308	0.751965	0.855194	0.642348
6	0.115630	10.91490	85.51218	0.451403	0.386915	0.940324	1.017719	0.776553
7	0.129093	11.32658	84.54347	0.496319	0.448299	1.115975	1.152265	0.917096
8	0.141633	11.65998	83.68752	0.526320	0.518582	1.286892	1.263428	1.057281
9	0.153301	11.97020	82.88585	0.541858	0.596379	1.454149	1.357867	1.193694
10	0.164186	12.26858	82.12446	0.549805	0.677069	1.615370	1.439480	1.325234

Variance Decomposition of LNPEC:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.050853	26.79624	4.177836	69.02592	0.000000	0.000000	0.000000	0.000000
2	0.071427	23.15932	7.464320	67.32684	1.744145	0.016062	0.021870	0.267447
3	0.089477	23.42446	8.911494	65.57314	1.660603	0.126548	0.125876	0.177885
4	0.105877	23.79309	11.15904	63.13876	1.442217	0.096905	0.207829	0.162153
5	0.121071	23.89323	13.08642	61.17404	1.365209	0.088612	0.252462	0.140030
6	0.134794	24.17548	14.32923	59.62342	1.394056	0.087398	0.275993	0.114427
7	0.147697	24.53074	15.28795	58.28512	1.425486	0.087526	0.287778	0.095407
8	0.159745	24.83429	16.04856	57.19051	1.471178	0.084675	0.289057	0.081728
9	0.170989	25.14943	16.58834	56.29186	1.533634	0.080523	0.284252	0.071960
10	0.181563	25.47212	16.97143	55.53359	1.605644	0.076001	0.275444	0.065764

Variance Decomposition of LNPOP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.002514	0.089373	0.020056	0.096654	99.79392	0.000000	0.000000	0.000000
2	0.005848	0.022808	0.725464	0.142718	99.10798	0.000681	0.000252	9.99E-05
3	0.009466	0.030594	1.652838	0.080193	98.22182	0.008673	0.005426	0.000453
4	0.013315	0.024080	2.164829	0.058581	97.70328	0.028123	0.014998	0.006107
5	0.017422	0.019886	2.466387	0.066495	97.35826	0.046876	0.028996	0.013102
6	0.021750	0.021385	2.710948	0.085409	97.04854	0.067938	0.045800	0.019974
7	0.026246	0.026480	2.904392	0.107005	96.78083	0.090299	0.064311	0.026687
8	0.030873	0.033873	3.049109	0.132693	96.55453	0.112351	0.084468	0.032976
9	0.035601	0.044060	3.157393	0.162981	96.35619	0.134379	0.106030	0.038966
10	0.040405	0.057209	3.237950	0.197054	96.17747	0.156762	0.128698	0.044858

Variance Decomposition of LNTROP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.089335	0.671899	2.410937	0.847236	0.044759	96.02517	0.000000	0.000000
2	0.117216	1.027137	3.497333	0.587268	0.058349	94.66779	0.064445	0.097683
3	0.134412	0.799901	2.706334	1.346229	0.059674	94.84291	0.130004	0.114946
4	0.151502	0.664649	2.286991	1.492523	0.099216	94.99514	0.174686	0.286791
5	0.165603	0.566801	2.031859	1.416745	0.125951	95.19781	0.273042	0.387789
6	0.177056	0.512854	1.960392	1.366909	0.154658	95.21072	0.416123	0.378340
7	0.187325	0.484149	2.093191	1.302299	0.200432	94.98280	0.557855	0.379277
8	0.196728	0.457236	2.238733	1.222723	0.251376	94.72167	0.690879	0.417385
9	0.205213	0.431394	2.341381	1.145073	0.303782	94.50025	0.820244	0.457875
10	0.212874	0.408238	2.447088	1.073857	0.359908	94.27626	0.946941	0.487709

Variance Decomposition of LNFD:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.126811	0.529953	0.008821	0.001431	0.010730	0.999391	98.44968	0.000000
2	0.192978	0.232325	1.529200	0.437318	0.004871	0.432473	97.17988	0.183932
3	0.232439	0.260764	2.972057	0.649445	0.004277	0.301486	95.58304	0.228926
4	0.258900	0.564377	4.086300	0.721793	0.032603	0.267082	94.09165	0.236199
5	0.280621	0.811328	5.225544	0.728688	0.094639	0.232759	92.54441	0.362632
6	0.299846	1.002223	6.370361	0.722966	0.175765	0.204871	90.85107	0.672744
7	0.316927	1.190001	7.465795	0.726787	0.266733	0.188469	89.12528	1.036934
8	0.331928	1.356772	8.409504	0.726919	0.367800	0.175789	87.58852	1.374693
9	0.345200	1.492992	9.175397	0.725376	0.486695	0.166188	86.22430	1.729047
10	0.357175	1.608593	9.818296	0.726266	0.621582	0.161062	84.92757	2.136628

Variance Decomposition of LNCPI:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.093244	0.013677	0.201847	0.012355	0.084907	0.003721	0.012329	99.67116
2	0.122852	0.038238	2.053749	0.009381	0.056437	0.023679	0.073689	97.74483
3	0.134562	0.447489	5.350298	0.172493	0.047334	0.024340	0.130009	93.82804
4	0.141096	0.437347	6.091447	0.197451	0.045274	0.768685	0.131544	92.32825
5	0.149901	0.396303	6.180119	0.179128	0.072908	0.894851	0.128969	92.14772
6	0.160240	0.387494	6.957231	0.192628	0.124735	0.785627	0.114373	91.43791
7	0.168431	0.429269	8.114016	0.200759	0.163295	0.721508	0.103728	90.26743
8	0.174658	0.433979	8.878082	0.197012	0.210293	0.708660	0.098294	89.47368
9	0.180550	0.418553	9.377770	0.191348	0.274427	0.680584	0.097056	88.96026
10	0.186415	0.403066	9.894313	0.188636	0.349334	0.640571	0.097669	88.42641

Cholesky Ordering: LNPCO2 LNPGDP LNPEC LNPOP LNTROP LNFD LNCPI

Panel: HICs

Variance Decomposition of LNPCO2:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.076186	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.097415	98.64362	0.684922	0.289553	0.192716	0.156945	0.012418	0.019823
3	0.114985	96.29904	2.065379	0.207890	0.232213	0.121722	0.962962	0.110794
4	0.134648	90.30209	4.639472	2.334665	0.170235	0.684245	1.787408	0.081889
5	0.153422	88.87709	5.471184	2.267864	0.396186	0.721418	2.202988	0.063269
6	0.168723	87.78119	6.146516	1.977609	0.371180	0.808897	2.862119	0.052486
7	0.183884	86.70426	6.550266	1.739800	0.312495	0.907799	3.737983	0.047400
8	0.197971	86.05048	6.687307	1.597175	0.273737	0.979155	4.363677	0.048473
9	0.211234	85.65502	6.736268	1.432585	0.254634	0.990942	4.876743	0.053805
10	0.223662	85.21995	6.790742	1.305436	0.228718	1.026272	5.373854	0.055024

Variance Decomposition of LNPGDP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.023795	6.877485	93.12252	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.040986	7.594420	90.75369	0.175393	0.055146	1.299802	0.002926	0.118625
3	0.053077	11.88158	85.92010	0.290939	0.211022	1.221758	0.136977	0.337622
4	0.064185	12.99339	83.18084	0.838263	0.199390	1.248777	0.757161	0.782176
5	0.075674	13.21651	80.41492	1.654984	0.263253	1.387040	1.578087	1.485202
6	0.086552	13.94547	77.68127	1.775785	0.369836	1.409130	2.267382	2.551121
7	0.096512	14.81457	74.96393	1.982733	0.360793	1.277980	2.878887	3.721112
8	0.105919	15.15102	72.56474	2.262975	0.382194	1.173017	3.547404	4.918646
9	0.114887	15.37413	70.18901	2.396940	0.453141	1.089553	4.267681	6.229551
10	0.123346	15.61039	67.78552	2.464932	0.501202	0.994547	4.925809	7.717598

Variance Decomposition of LNPEC:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.047220	35.21472	1.914691	62.87059	0.000000	0.000000	0.000000	0.000000
2	0.066056	27.93599	5.644944	60.83642	4.206924	1.363572	0.003342	0.008817
3	0.081261	31.20700	6.518540	57.07048	4.152384	1.006346	0.039194	0.006055
4	0.093049	32.41051	9.137239	53.69339	3.489262	1.134318	0.036923	0.098359
5	0.105916	32.32845	11.37186	51.80905	3.017289	1.316603	0.028722	0.128018
6	0.117044	32.43378	12.80196	49.63598	3.198442	1.644851	0.037344	0.247650
7	0.127803	32.95268	13.20638	48.44304	3.181640	1.767003	0.058013	0.391247
8	0.138145	32.90962	13.41757	47.89659	3.195728	1.912907	0.081803	0.585788
9	0.148038	32.91726	13.46368	47.34012	3.306541	2.053885	0.118214	0.800309
10	0.157187	33.04179	13.34733	46.79365	3.412055	2.172828	0.147539	1.084802

Variance Decomposition of LNPOP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.003170	0.553597	0.000418	0.093044	99.35294	0.000000	0.000000	0.000000
2	0.007282	0.108328	2.822978	0.037500	96.65932	0.360422	0.011164	0.000289
3	0.011648	0.114832	7.241844	0.226339	91.55495	0.846276	0.008520	0.007238
4	0.016163	0.100277	9.980490	0.420424	88.40890	1.033067	0.006968	0.049876
5	0.020759	0.088194	11.63686	0.338003	86.76207	1.094374	0.004235	0.076265
6	0.025306	0.086030	13.08866	0.234259	85.29362	1.197143	0.012739	0.087549
7	0.029797	0.074815	14.33942	0.169202	83.98220	1.284395	0.036231	0.113736
8	0.034282	0.060009	15.36676	0.129379	82.90855	1.308539	0.064464	0.162294
9	0.038725	0.047922	16.30059	0.111501	81.91971	1.303346	0.099801	0.217136
10	0.043072	0.038793	17.16188	0.107313	80.97736	1.293357	0.146529	0.274770

Variance Decomposition of LNTROP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.067297	1.789368	14.70352	0.390703	0.425111	82.69130	0.000000	0.000000
2	0.090702	1.039999	20.08019	0.393532	1.017206	77.42804	0.005369	0.035661
3	0.103844	0.891650	16.89303	1.066687	2.261254	78.83877	0.011743	0.036868
4	0.115162	1.665046	13.97355	1.119768	3.100838	79.87036	0.036018	0.234421
5	0.126229	1.890957	11.92886	1.664448	3.229331	81.03026	0.031572	0.224569
6	0.135951	2.081372	10.61993	1.655275	3.572599	81.78246	0.094658	0.193702
7	0.145277	2.169543	9.414407	1.563891	3.699986	82.76335	0.211320	0.177501
8	0.153976	2.445212	8.467141	1.462631	3.801862	83.31351	0.346536	0.163105
9	0.161991	2.687981	7.752290	1.365562	3.950474	83.58753	0.484415	0.171747
10	0.169476	2.865219	7.165908	1.257507	4.077197	83.77286	0.655894	0.205411

Variance Decomposition of LNFD:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.115368	2.786291	2.572351	0.001826	0.024338	0.235590	94.37960	0.000000
2	0.167066	4.363463	1.377622	2.186292	0.016956	0.118613	91.92116	0.015892
3	0.200809	4.544608	0.955213	3.503471	0.017598	0.465495	90.48006	0.033554
4	0.228875	4.105755	0.842968	5.091045	0.022455	1.174583	88.71027	0.052928
5	0.248331	3.648231	0.955935	5.712646	0.040414	1.706980	87.81149	0.124302
6	0.262610	3.324930	1.333909	5.984965	0.053462	2.286655	86.66989	0.346184
7	0.273777	3.064035	1.891096	6.209493	0.067519	2.878250	85.14825	0.741356
8	0.282852	2.872216	2.481258	6.340062	0.109615	3.413567	83.42101	1.362273
9	0.290308	2.737972	3.096871	6.349628	0.165043	3.905182	81.57335	2.171953
10	0.296782	2.642340	3.713667	6.317008	0.210259	4.379618	79.55641	3.180700

Variance Decomposition of LNCPI:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.090401	0.182482	0.005986	0.116160	0.012331	0.411230	0.109124	99.16269
2	0.117641	0.159022	0.550024	0.072681	0.007285	0.348800	0.107638	98.75455
3	0.123375	0.221939	0.855272	0.066413	0.011215	0.318093	0.148668	98.37840
4	0.127932	0.207919	0.803324	0.084582	0.019358	0.425580	0.387132	98.07211
5	0.138181	0.264822	0.689273	0.084197	0.017825	0.416733	0.666898	97.86025
6	0.148515	0.253404	0.695175	0.074543	0.016997	0.360781	0.773695	97.82540
7	0.154942	0.236057	0.700087	0.070153	0.021955	0.333051	0.823376	97.81532
8	0.159991	0.254945	0.656691	0.067507	0.024414	0.312383	0.908330	97.77573
9	0.165737	0.350090	0.612030	0.066211	0.029826	0.291745	1.012220	97.63788
10	0.171590	0.439268	0.576325	0.064142	0.041216	0.272352	1.075453	97.53124

Cholesky Ordering: LNPCO2 LNPGDP LNPEC LNPOP LNTROP LNFD LNCPI

Panel: MICs

Variance Decomposition of LNPCO2:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.065553	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.085675	95.63005	2.028295	0.211185	0.674522	5.63E-05	0.118168	1.337722
3	0.100747	93.72733	3.544788	0.386648	1.004067	0.237147	0.090616	1.009401
4	0.115536	92.07124	4.682985	0.307581	0.954705	0.919294	0.100597	0.963595
5	0.129309	90.48753	5.683436	0.247056	0.915509	1.562477	0.112687	0.991306
6	0.140603	89.88485	5.964193	0.209662	0.917191	1.986341	0.108442	0.929320
7	0.151073	89.37780	6.050089	0.181626	0.932054	2.521603	0.110943	0.825890
8	0.160859	88.81887	6.171707	0.166125	0.981472	2.996393	0.111658	0.753781
9	0.169680	88.39044	6.211606	0.158558	1.051287	3.368832	0.107570	0.711708
10	0.177727	88.04614	6.157583	0.158663	1.148406	3.719980	0.101167	0.668066

Variance Decomposition of LNPGDP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.033900	6.701186	93.29881	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.053546	5.860861	93.16201	0.060987	0.084150	0.534169	0.209115	0.088707
3	0.067602	7.370841	90.36024	0.085368	0.054927	1.801708	0.227726	0.099193
4	0.081107	9.192716	87.50987	0.062396	0.044484	2.961254	0.159798	0.069483
5	0.092969	9.790052	86.04697	0.048195	0.063425	3.871882	0.122465	0.057008
6	0.102953	10.13857	84.94404	0.042007	0.106357	4.616512	0.100223	0.052298
7	0.111819	10.41206	83.89524	0.043247	0.194928	5.314310	0.087454	0.052769
8	0.119771	10.51426	83.03168	0.052231	0.354098	5.903334	0.077783	0.066618
9	0.126997	10.50248	82.27051	0.062385	0.569888	6.432109	0.069979	0.092652
10	0.133676	10.42739	81.55581	0.078169	0.844389	6.910457	0.063402	0.120382

Variance Decomposition of LNPEC:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.047794	48.35914	6.899292	44.74157	0.000000	0.000000	0.000000	0.000000
2	0.066100	50.01350	8.614379	40.35845	0.346155	0.108125	0.196748	0.362638
3	0.081085	49.48099	8.909048	39.90345	0.347482	0.825900	0.286666	0.246463
4	0.092311	51.02683	10.40635	36.45970	0.337019	1.236818	0.302473	0.230807
5	0.102677	51.18096	11.82481	34.31733	0.336164	1.856584	0.264316	0.219840
6	0.111677	51.51934	12.40023	32.82371	0.383738	2.432165	0.254757	0.186056
7	0.120395	51.71919	12.65892	31.60732	0.425105	3.186898	0.226366	0.176196
8	0.128289	51.93573	12.88099	30.43622	0.493404	3.870608	0.205575	0.177473
9	0.135472	52.05617	12.96060	29.55151	0.570373	4.491279	0.189078	0.180992
10	0.142032	52.16211	12.93142	28.76401	0.674987	5.089539	0.177396	0.200531

Variance Decomposition of LNPOP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.001923	0.095461	0.317770	0.158646	99.42812	0.000000	0.000000	0.000000
2	0.004308	0.038950	0.179314	0.038728	99.46911	0.045364	0.228357	0.000177
3	0.007135	0.028919	0.075852	0.014353	99.46702	0.061150	0.350305	0.002403
4	0.010319	0.138390	0.036360	0.020322	99.37083	0.059215	0.373417	0.001468
5	0.013799	0.304905	0.023471	0.033050	99.20364	0.057559	0.376548	0.000822
6	0.017534	0.499735	0.024505	0.035733	99.00915	0.058023	0.372294	0.000558
7	0.021486	0.694797	0.034639	0.029336	98.81820	0.056190	0.366404	0.000431
8	0.025623	0.881562	0.049922	0.021422	98.63310	0.053306	0.360145	0.000547
9	0.029921	1.063893	0.069178	0.016024	98.44554	0.050278	0.353991	0.001093
10	0.034359	1.243499	0.092127	0.015928	98.25141	0.047124	0.347896	0.002017

Variance Decomposition of LNTROP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.087226	3.303318	1.808987	0.605262	0.150334	94.13210	0.000000	0.000000
2	0.116132	5.243618	1.293470	0.777367	0.457820	91.22257	0.961690	0.043465
3	0.136034	5.415647	1.623681	2.071482	2.533027	87.37041	0.899160	0.086598
4	0.150710	4.963947	3.042184	2.192106	3.089926	85.39147	1.090727	0.229642
5	0.161359	4.858658	3.565313	2.265361	3.208905	84.65637	1.230785	0.214608
6	0.169305	4.767339	4.031429	2.276978	3.113629	84.14857	1.467122	0.194938
7	0.176427	4.638987	4.593657	2.359589	2.954038	83.52307	1.734604	0.196060
8	0.182665	4.601744	4.911415	2.355724	2.789221	83.13071	1.988719	0.222470
9	0.187918	4.603241	5.062770	2.342026	2.647168	82.88763	2.229675	0.227492
10	0.192439	4.610647	5.230237	2.329361	2.525749	82.59222	2.487191	0.224593

Variance Decomposition of LNFD:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.098113	0.148436	5.332766	0.000522	0.011157	0.024654	94.48246	0.000000
2	0.156126	0.124809	11.32780	0.009568	0.026585	0.202648	88.27781	0.030781
3	0.199512	0.206866	17.00953	0.067704	0.169490	0.264171	82.20375	0.078492
4	0.235085	0.368721	21.05112	0.062714	0.365447	0.291108	77.80423	0.056667
5	0.264428	0.709562	23.64911	0.058980	0.643719	0.234105	74.65348	0.051044
6	0.289014	1.027804	25.43385	0.057657	0.993192	0.217104	72.10450	0.165899
7	0.310265	1.299111	26.88130	0.052386	1.338207	0.245077	69.81074	0.373183
8	0.328494	1.521539	27.97602	0.047948	1.705478	0.294037	67.89996	0.555018
9	0.344178	1.692149	28.61677	0.044980	2.145612	0.350331	66.39333	0.756833
10	0.358081	1.823197	28.95361	0.043775	2.662616	0.424547	65.04749	1.044768

Variance Decomposition of LNCPI:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.094332	0.657053	0.158670	0.389502	0.437512	0.001391	0.035768	98.32010
2	0.128717	0.628757	0.776325	0.332705	0.291337	0.084052	0.280001	97.60682
3	0.137385	1.417294	4.240255	0.305536	0.390385	0.804214	0.600343	92.24197
4	0.141627	1.448834	4.216437	0.331867	0.386007	3.132490	0.587580	89.89679
5	0.151411	1.304013	3.692624	0.576610	0.457006	3.316367	0.526465	90.12692
6	0.162677	1.258908	3.936342	0.587345	0.473422	2.911802	0.494034	90.33815
7	0.169056	1.259218	5.011372	0.629464	0.442838	2.861810	0.472721	89.32258
8	0.173075	1.218935	5.136842	0.798637	0.424045	3.129492	0.451666	88.84038
9	0.178055	1.156852	4.963246	1.029724	0.421381	3.174946	0.429796	88.82405
10	0.183610	1.092473	4.988207	1.216014	0.428869	3.074384	0.406525	88.79353

Cholesky Ordering: LNPCO2 LNPGDP LNPEC LNPOP LNTROP LNFD LNCPI

Panel: LICs

Variance Decomposition of LNPCO2:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.102174	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.138281	98.35767	0.532387	0.233206	0.073815	0.195405	0.001852	0.605669
3	0.163212	97.51103	0.820079	0.167973	0.194493	0.517584	0.301540	0.487304
4	0.184973	96.51565	0.951366	0.131024	0.301597	1.437224	0.240697	0.422438
5	0.205228	95.58029	1.337783	0.114515	0.417261	1.947180	0.249616	0.353355
6	0.222271	94.71068	1.592731	0.139984	0.524062	2.209991	0.406541	0.416012
7	0.237174	94.21646	1.664792	0.165083	0.590936	2.314374	0.540719	0.507636
8	0.251098	93.77887	1.718163	0.226730	0.609873	2.444884	0.618526	0.602954
9	0.264270	93.34632	1.781948	0.332254	0.590730	2.559791	0.668585	0.720373
10	0.276436	92.93426	1.823358	0.472170	0.551871	2.622276	0.723999	0.872068

Variance Decomposition of LNPGDP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.030352	4.144322	95.85568	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.050822	5.545638	93.44826	0.079777	0.047324	0.735337	0.105598	0.038070
3	0.068730	7.527700	89.52060	0.232674	0.070944	0.952010	1.538436	0.157637
4	0.085857	7.722123	88.30706	0.228077	0.049828	1.851469	1.733704	0.107736
5	0.102167	7.881378	87.70917	0.168376	0.041952	2.666834	1.446754	0.085540
6	0.116567	7.924307	87.38573	0.132484	0.077097	3.141249	1.200014	0.139116
7	0.129706	8.016085	86.76086	0.129612	0.154436	3.611355	1.065008	0.262644
8	0.141869	8.108505	85.95770	0.186148	0.259884	4.042874	0.980448	0.464440
9	0.153057	8.171551	85.09966	0.323136	0.364241	4.391031	0.910971	0.739409
10	0.163317	8.204468	84.16968	0.550022	0.436230	4.721326	0.850563	1.067714

Variance Decomposition of LNPEC:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.053623	11.32869	1.197464	87.47385	0.000000	0.000000	0.000000	0.000000
2	0.071015	9.340215	3.421341	85.86677	0.158474	0.233198	0.152918	0.827085
3	0.084755	8.100319	4.624254	84.48692	0.245094	1.362764	0.599930	0.580722
4	0.098149	7.571562	4.995851	84.44515	0.302864	1.366153	0.777271	0.541152
5	0.109019	7.193314	5.534395	83.94468	0.325537	1.697978	0.635254	0.668842
6	0.118255	6.880811	5.913243	83.62001	0.303140	1.891730	0.607826	0.783239
7	0.126628	6.839235	6.268448	83.18296	0.264852	1.950260	0.603903	0.890342
8	0.134485	6.928190	6.639694	82.53145	0.245925	2.047966	0.593738	1.013033
9	0.141781	7.105358	7.072642	81.71005	0.259690	2.099239	0.600905	1.152113
10	0.148597	7.290323	7.542411	80.77430	0.301362	2.142204	0.656456	1.292947

Variance Decomposition of LNPOP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.000109	0.023641	2.81E-05	1.089063	98.88727	0.000000	0.000000	0.000000
2	0.000420	0.001612	0.000838	1.004858	98.95462	0.015936	0.012183	0.009956
3	0.001019	0.044498	0.003030	0.810414	98.90887	0.048510	0.158314	0.026363
4	0.001966	0.151897	0.025171	0.629689	98.61820	0.076595	0.462972	0.035473
5	0.003286	0.285544	0.091397	0.490348	98.16720	0.103117	0.822987	0.039404
6	0.004969	0.425236	0.215645	0.390809	97.63349	0.130186	1.162589	0.042050
7	0.006980	0.563852	0.406547	0.322384	97.05671	0.158095	1.448289	0.044119
8	0.009261	0.699209	0.669079	0.276818	96.45294	0.185740	1.671152	0.045065
9	0.011744	0.829443	1.003695	0.248592	95.83010	0.211607	1.832146	0.044414
10	0.014361	0.952919	1.407301	0.234590	95.19223	0.234749	1.936098	0.042109

Variance Decomposition of LNTROP:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.107280	0.019217	0.001048	0.999167	0.216399	98.76417	0.000000	0.000000
2	0.136954	2.147694	0.647225	0.655027	0.194561	96.25804	5.10E-05	0.097403
3	0.153749	1.704148	0.515832	1.468393	0.171218	95.28191	0.666123	0.192373
4	0.175172	1.319635	0.717144	2.058973	0.164984	94.93551	0.649527	0.154229
5	0.189938	1.151638	0.864136	1.906138	0.170338	95.11284	0.655952	0.138960
6	0.200220	1.056615	1.102802	1.858820	0.205300	94.89513	0.669985	0.211346
7	0.209602	0.969366	1.691694	1.755498	0.300554	94.33794	0.661012	0.283936
8	0.217483	0.912990	2.297451	1.630649	0.493912	93.70769	0.655821	0.301491
9	0.224134	0.885188	2.825755	1.545850	0.823811	92.95301	0.651998	0.314387
10	0.230030	0.881638	3.346835	1.500407	1.303277	92.01080	0.633196	0.323845

Variance Decomposition of LNFD:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.154698	1.043753	0.040675	0.013811	0.001733	5.159086	93.74094	0.000000
2	0.227949	0.925791	2.171589	0.009566	0.021668	3.445846	93.14962	0.275916
3	0.255335	1.425484	3.539914	0.163572	0.090774	3.539187	90.93787	0.303194
4	0.267006	3.077710	4.728053	1.034776	0.130886	3.711756	87.00044	0.316382
5	0.277709	3.648751	5.767780	1.396024	0.122032	4.076760	84.69603	0.292625
6	0.290456	3.870060	6.505697	1.344239	0.114811	4.603179	83.28765	0.274363
7	0.302109	4.082059	6.878938	1.245312	0.109996	4.956656	82.47065	0.256388
8	0.310889	4.448544	7.113900	1.176065	0.104261	5.179549	81.73287	0.244814
9	0.317637	4.793169	7.210182	1.135667	0.102628	5.351342	81.15298	0.254031
10	0.323308	5.101449	7.206004	1.146623	0.125445	5.496502	80.65597	0.268008

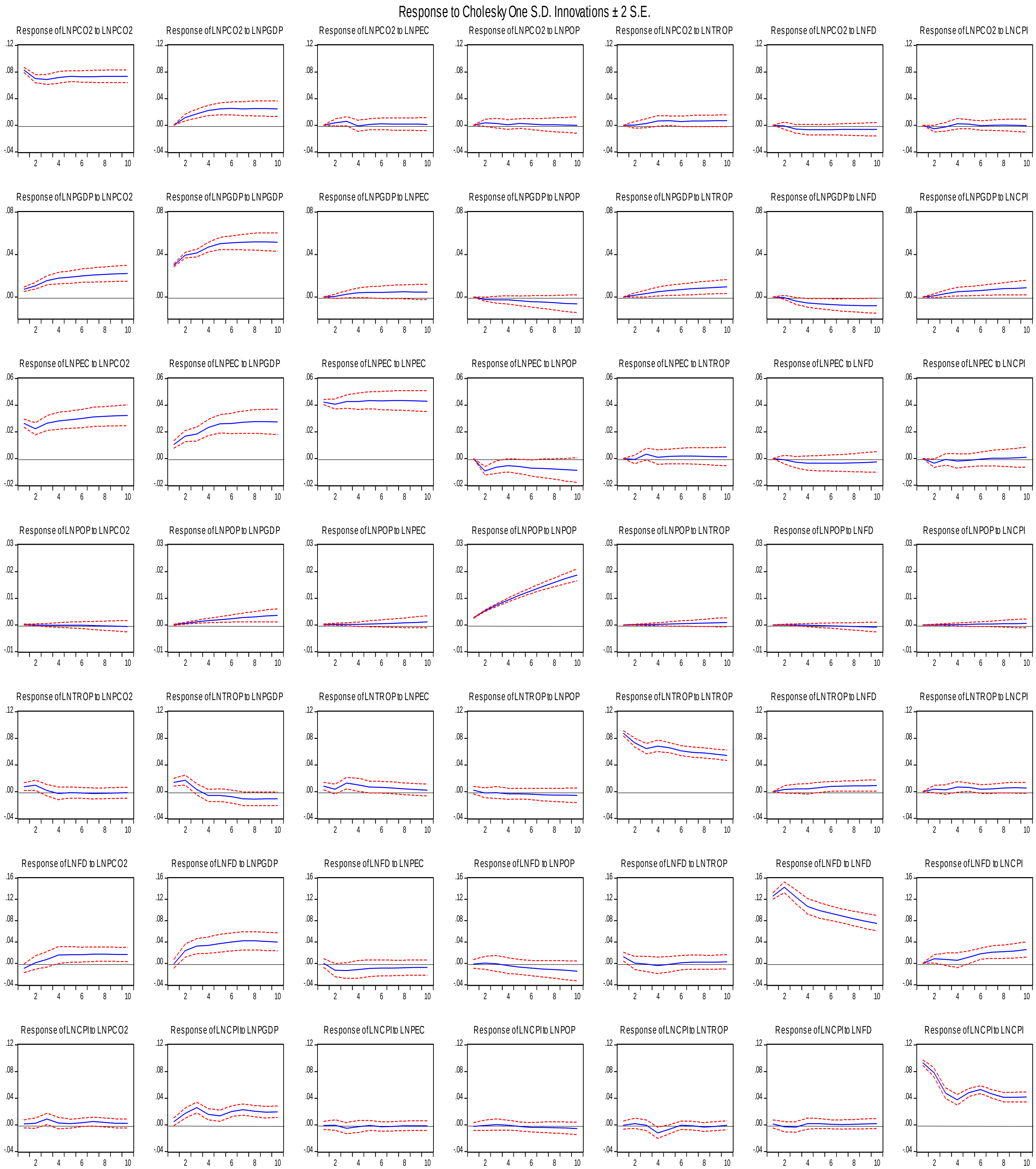
Variance Decomposition of LNCPI:

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPOP	LNTROP	LNFD	LNCPI
1	0.088600	0.318613	2.130449	0.069925	0.593614	0.747581	1.215812	94.92401
2	0.113056	0.197320	5.432205	0.126605	0.866856	0.536134	0.783333	92.05755
3	0.127208	0.928653	10.69106	0.131837	0.900594	0.815533	0.743456	85.78887
4	0.133806	0.867525	12.79866	0.119508	0.813978	1.539542	1.212345	82.64844
5	0.140030	0.793430	14.09205	0.172403	0.826703	1.628494	1.480480	81.00644
6	0.146509	0.852311	15.44751	0.471157	0.994116	1.520412	1.358318	79.35618
7	0.152267	1.172571	17.02730	0.882313	1.401396	1.437305	1.378351	76.70077
8	0.156211	1.223615	17.93562	1.350786	2.004002	1.388207	1.340084	74.75769
9	0.159719	1.237270	18.32869	2.131273	2.586219	1.328135	1.281878	73.10654
10	0.163031	1.279847	18.56380	3.237011	2.988773	1.277594	1.230327	71.42265

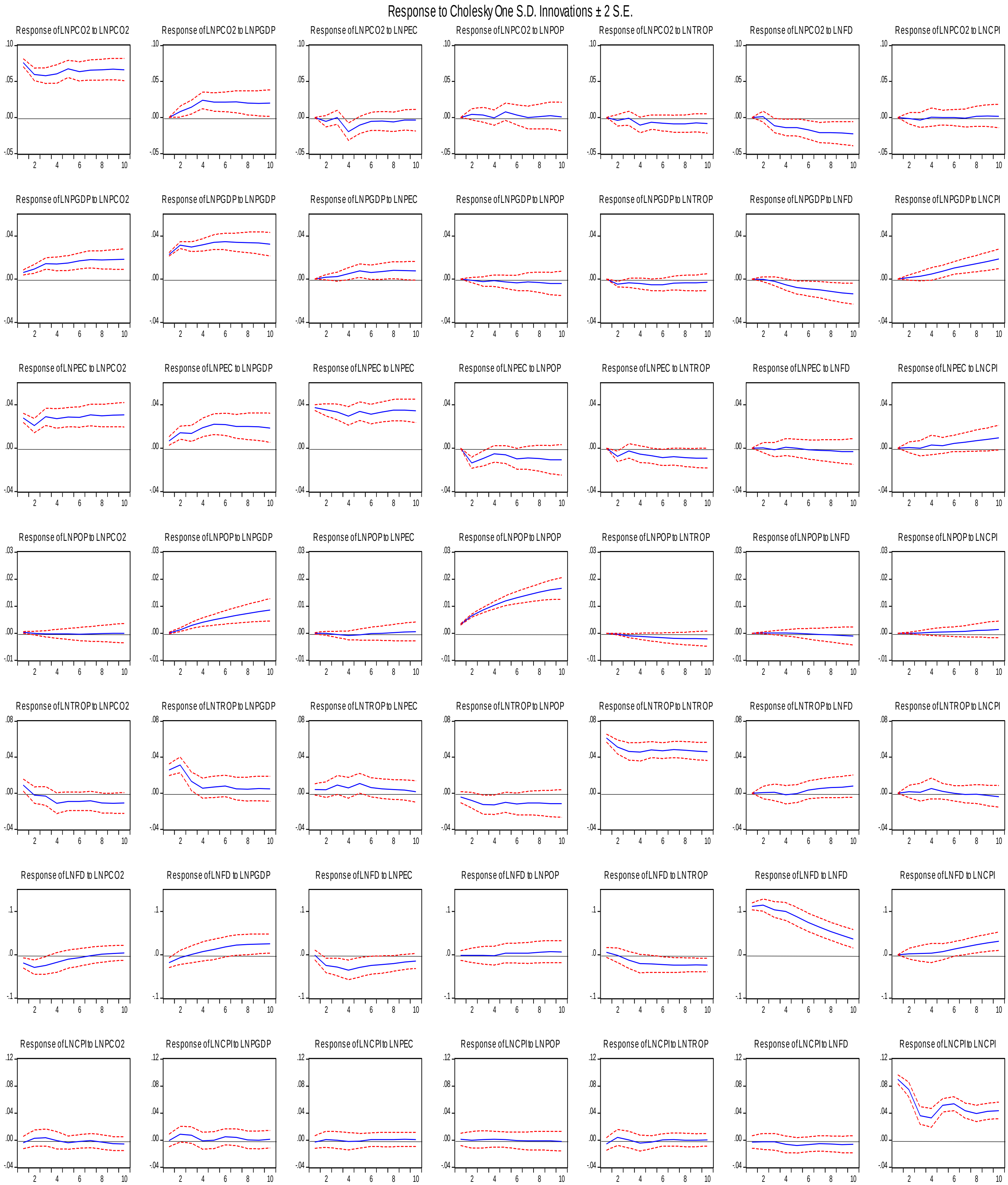
Cholesky Ordering: LNPCO2 LNPGDP LNPEC LNPOP LNTROP LNFD LNCPI

Appendix-D: Impulse Response Function

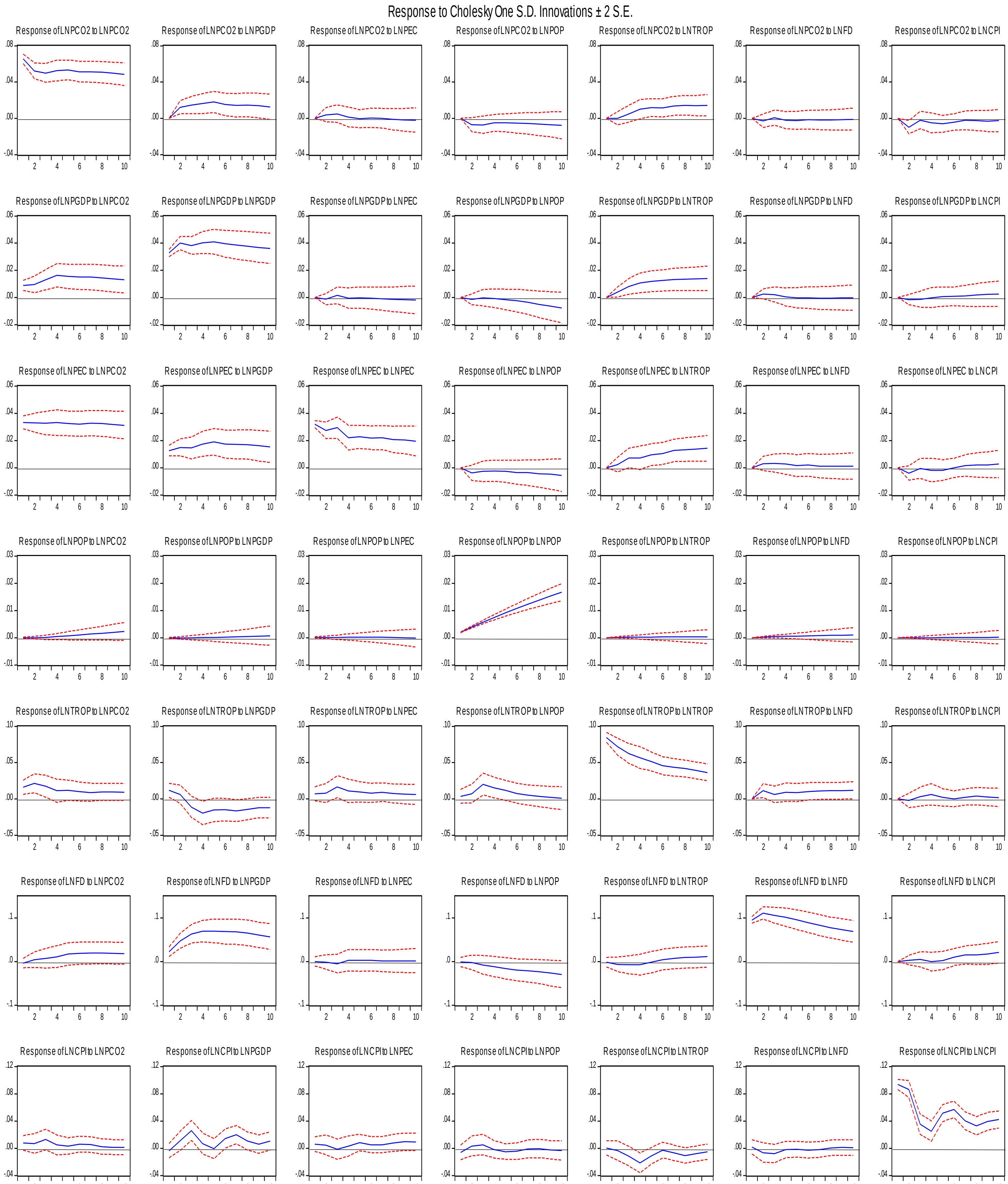
Panel: All



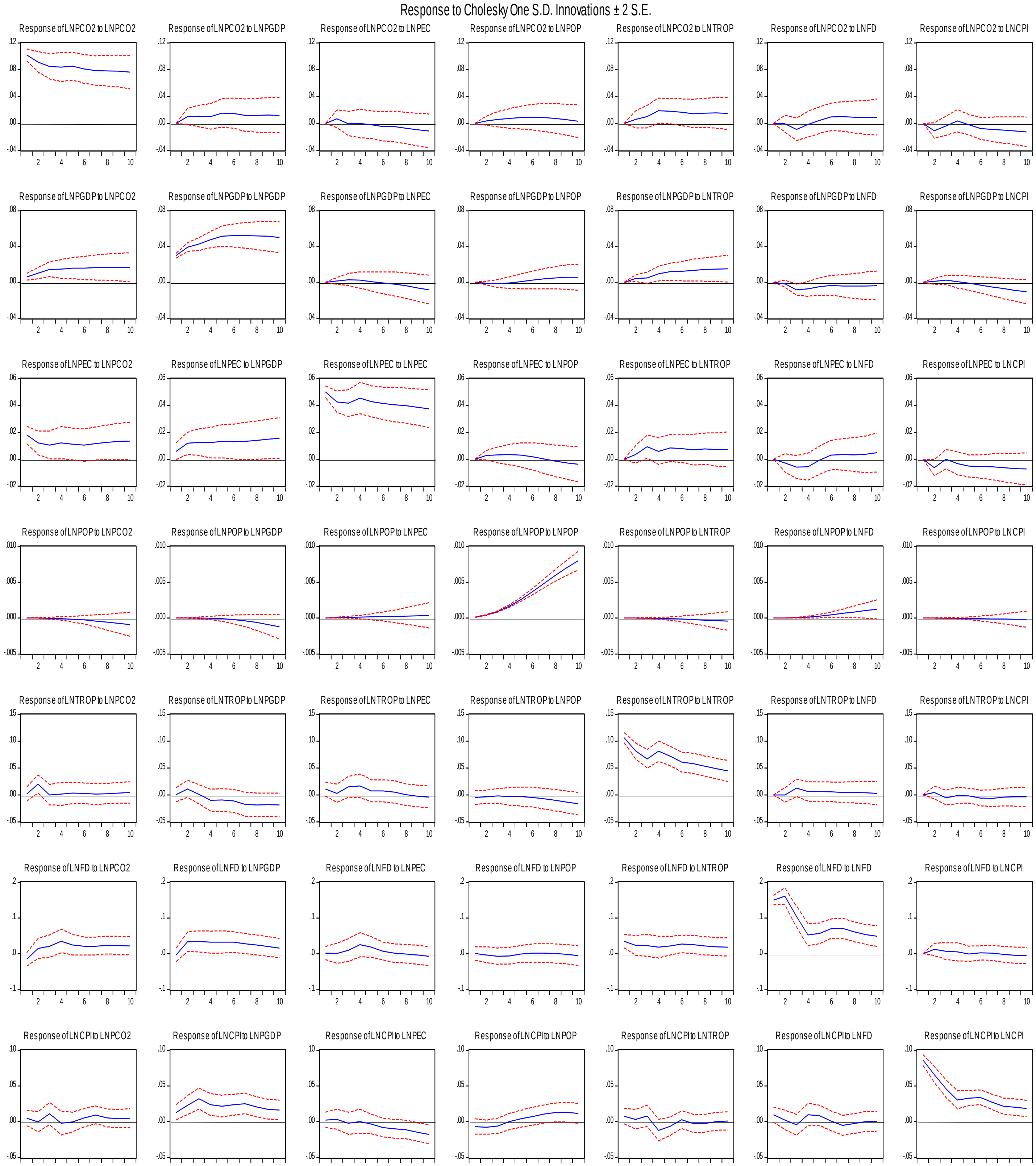
Panel: HICs


Response to Cholesky One S.D. Innovations ± 2 S.E.
Response of LNPCO2 to LNPCO2
Response of LNPCO2 to LNPGDP
Response of LNPCO2 to LNPEC
Response of LNPCO2 to LNPOP
Response of LNPCO2 to LNTROP
Response of LNPCO2 to LNFD
Response of LNPCO2 to LNCPI
Response of LNPGDP to LNPCO2
Response of LNPGDP to LNPGDP
Response of LNPGDP to LNPEC
Response of LNPGDP to LNPOP
Response of LNPGDP to LNTROP
Response of LNPGDP to LNFD
Response of LNPGDP to LNCPI
Response of LNPEC to LNPCO2
Response of LNPEC to LNPGDP
Response of LNPEC to LNPEC
Response of LNPEC to LNPOP
Response of LNPEC to LNTROP
Response of LNPEC to LNFD
Response of LNPEC to LNCPI
Response of LNPOP to LNPCO2
Response of LNPOP to LNPGDP
Response of LNPOP to LNPEC
Response of LNPOP to LNPOP
Response of LNPOP to LNTROP
Response of LNPOP to LNFD
Response of LNPOP to LNCPI
Response of LNTROP to LNPCO2
Response of LNTROP to LNPGDP
Response of LNTROP to LNPEC
Response of LNTROP to LNPOP
Response of LNTROP to LNTROP
Response of LNTROP to LNFD
Response of LNTROP to LNCPI
Response of LNFD to LNPCO2
Response of LNFD to LNPGDP
Response of LNFD to LNPEC
Response of LNFD to LNPOP
Response of LNFD to LNTROP
Response of LNFD to LNFD
Response of LNFD to LNCPI
Response of LNCPI to LNPCO2
Response of LNCPI to LNPGDP
Response of LNCPI to LNPEC
Response of LNCPI to LNPOP
Response of LNCPI to LNTROP
Response of LNCPI to LNFD
Response of LNCPI to LNCPI

Panel: MICs


Response to Cholesky One S.D. Innovations ± 2 S.E.
Response of LNPCO2 to LNPCO2
Response of LNPCO2 to LNPGDP
Response of LNPCO2 to LNPEC
Response of LNPCO2 to LNPOP
Response of LNPCO2 to LNTROP
Response of LNPCO2 to LNFD
Response of LNPCO2 to LNCPI
Response of LNPGDP to LNPCO2
Response of LNPGDP to LNPGDP
Response of LNPGDP to LNPEC
Response of LNPGDP to LNPOP
Response of LNPGDP to LNTROP
Response of LNPGDP to LNFD
Response of LNPGDP to LNCPI
Response of LNPEC to LNPCO2
Response of LNPEC to LNPGDP
Response of LNPEC to LNPEC
Response of LNPEC to LNPOP
Response of LNPEC to LNTROP
Response of LNPEC to LNFD
Response of LNPEC to LNCPI
Response of LNPOP to LNPCO2
Response of LNPOP to LNPGDP
Response of LNPOP to LNPEC
Response of LNPOP to LNPOP
Response of LNPOP to LNTROP
Response of LNPOP to LNFD
Response of LNPOP to LNCPI
Response of LNTROP to LNPCO2
Response of LNTROP to LNPGDP
Response of LNTROP to LNPEC
Response of LNTROP to LNPOP
Response of LNTROP to LNTROP
Response of LNTROP to LNFD
Response of LNTROP to LNCPI
Response of LNFD to LNPCO2
Response of LNFD to LNPGDP
Response of LNFD to LNPEC
Response of LNFD to LNPOP
Response of LNFD to LNTROP
Response of LNFD to LNFD
Response of LNFD to LNCPI
Response of LNCPI to LNPCO2
Response of LNCPI to LNPGDP
Response of LNCPI to LNPEC
Response of LNCPI to LNPOP
Response of LNCPI to LNTROP
Response of LNCPI to LNFD
Response of LNCPI to LNCPI

Panel: LICs


Response to Cholesky One S.D. Innovations ± 2 S.E.
Response of LNPCO2 to LNPCO2
Response of LNPCO2 to LNPGDP
Response of LNPCO2 to LNPEC
Response of LNPCO2 to LNPOP
Response of LNPCO2 to LNTROP
Response of LNPCO2 to LNFD
Response of LNPCO2 to LNCPI
Response of LNPGDP to LNPCO2
Response of LNPGDP to LNPGDP
Response of LNPGDP to LNPEC
Response of LNPGDP to LNPOP
Response of LNPGDP to LNTROP
Response of LNPGDP to LNFD
Response of LNPGDP to LNCPI
Response of LNPEC to LNPCO2
Response of LNPEC to LNPGDP
Response of LNPEC to LNPEC
Response of LNPEC to LNPOP
Response of LNPEC to LNTROP
Response of LNPEC to LNFD
Response of LNPEC to LNCPI
Response of LNPOP to LNPCO2
Response of LNPOP to LNPGDP
Response of LNPOP to LNPEC
Response of LNPOP to LNPOP
Response of LNPOP to LNTROP
Response of LNPOP to LNFD
Response of LNPOP to LNCPI
Response of LNTROP to LNPCO2
Response of LNTROP to LNPGDP
Response of LNTROP to LNPEC
Response of LNTROP to LNPOP
Response of LNTROP to LNTROP
Response of LNTROP to LNFD
Response of LNTROP to LNCPI
Response of LNFD to LNPCO2
Response of LNFD to LNPGDP
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Response of LNFD to LNFD
Response of LNFD to LNCPI
Response of LNCPI to LNPCO2
Response of LNCPI to LNPGDP
Response of LNCPI to LNPEC
Response of LNCPI to LNPOP
Response of LNCPI to LNTROP
Response of LNCPI to LNFD
Response of LNCPI to LNCPI