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CARBON EMISSION, ENERGY CONSUMPTION AND ECONOMIC GROWTH NEXUS- A LITERATURE SURVEY

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Abstract

The current study aims to assess the worldwide literature available on the economic growth-energy consumption-carbon dioxide emissions nexus. The data from all around the globe has been assessed for this literature survey. The causality relationships studies were categorized within six major categories on the basis of different variables i.e. economic growth and carbon emission (single-country studies); economic growth and carbon emission (multi-countries studies); economic growth and energy consumption (single-country studies); economic growth and energy consumption (multi-countries studies); energy consumption and carbon emissions (single-country studies); and energy consumption and carbon emissions (multi-countries studies).

1. Introduction

Increased Carbon emissions and their relation to energy consumption and economic growth are among the most important areas of global warming debate. The interrelationship nexus among these three is important from all the perspectives i.e. economic policies, total and sectoral energy consumption and the environmental planning at national and global scale. Recently, many researches have been conducted to study the causal relationships among the increasing carbon emissions, energy consumption and economic growth in different countries of the world e.g. China, India, France and Middle eastern countries etc. (Ozcan, 2013; Ghosh, 2010; Jayanthakumaran, et. al. 2012).

There are several factors that govern this nexus. The main controlling factors include population base, the GDP, the total energy consumption and the total carbon emissions. In order to study this nexus, and to test the hypothesis that the three variables economic growth, energy consumption and carbon emissions are inter-reliant, different types of statistical techniques are applied e.g. ANOVA and Environmental Kuznets curve (Ozcan, 2013).

The existing literature on Carbon, energy and economy nexus has several variations depending upon the kind of statistical tools/methodologies, the regional differences (in political and social perspective), the information gaps concerning economic sectors' data and the different cultural and geographical differences. But most of the studies confirm the

existence of significant causal relationships among the three variables i.e. economic growth and carbon emissions, energy consumption and economic growth and the energy consumption and carbon emissions.

1.1 Carbon Emissions

Levels of atmospheric carbon dioxide have been rising ever since the beginning of the industrial revolution, indicating its relation to the economic growth as well as energy utilization. The first measurements of CO_2 concentrations in the atmosphere started in 1958 at an altitude of about 4,000 metres on the summit of Mauna Loa Mountain in Hawaii. The measurements were made here to be remote from local sources of pollution. These measurements revealed that atmospheric concentrations of CO_2 have increased every single year since 1958. The mean concentration of approximately 316ppmv (parts per million by volume) in 1958 rose to approximately 369ppmv in 1998. The annual variations in the Mauna Loa are mostly due to CO_2 uptake by growing plants. The uptake is highest in the northern hemisphere spring time; hence every spring there is a drop in atmospheric carbon dioxide which unfortunately does nothing to the overall trend towards ever higher values (Sundquist & Keeling, 2009). In 2013, the concentration of CO_2 (396ppmv) was approximately 40% higher than in mid-1800 (around 280 ppmv), with an average increase of 2 ppmv / year throughout the previous ten years. As per Garret, worldwide temperature will ascend by a normal of 2 ° C to 4ºC (critical situation) by the year 2100 compared to the average temperature of the Industrial Revolution era (Garrett., 1992). The rising levels of carbon can be associated with the rise in both economic growth and energy consumption parameters,

1.2 Energy Consumption

Because of growing environmental awareness over the last two decades, scholars have started to analyse the environment–economy nexus in the context of environmental economics. Researchers dealing with climate change, observed that concentrations of carbon dioxide in the atmosphere have increased considerably over the last century. In recent decades, global economic growth has caused various negative impacts including climate change due to global warming. Accordingly, international interest in carbon dioxide increases. Since the late 1970s there are a number of scientific publications concerning controlling of CO_2 emissions in the atmosphere and its relationship to that of economic growth and energy consumption (as carbon emissions are related to the fossil fuel consumption.

According to Dyson, fossil fuel combustion adds an annually of 5x109 tons of CO_2 of which approximately half remains in the atmosphere. As a way of resolving, he proposes, the implementation of afforestation programs and energy crops that are able to save carbon dioxide. The need for a shift from fossil fuels to other more environmentally friendly fuel forms is emphasized, with fuels including the nuclear energy (Ntanos, et al. 2015).

1.3 Economic Growth

Increasing population rate, energy consumption and economic development contribute to climate change. The possible solutions for mitigating these emissions are new carbon based technologies (gasification and liquefaction), nuclear energy, and solar energy and controlling the rate of energy use in combination with energy saving measures. Anthropogenic CO_2 emissions result from the combustion of fossil fuels as a result of energy production and fuel

consumption. The main areas where fossil fuels are used are Electricity, Industry, Transport, Agricultural sector, and the residential sector.

It must be noticed that carbon emissions data are approximations, as there is no way for real measurement to all emission sources. Total energy consumption is allocated to sectors and then carbon emissions are calculated indirectly by using the revised emission factors according to the Intergovernmental Panel Guidelines on Climate Change. Emission factors indicate carbon content per unit of energy produced or consumed. The International Energy Agency (IEA), records energy consumption on a global scale. The calculation of carbon emissions is done with two different approaches. The first approach (Reference method) refers to a uniform emission factor applied after the conversion of the total energy consumed in tonnes of oil equivalent. The second approach calculates CO_2 emissions per energy sector, using different emission factors. IEA provides calculated carbon emissions at a global and country level. For cross-countries energy comparisons, the index of total primary energy supply is used: TPES = energy production + imports - exports - international marine bunkers - International Aviation ± stock changes (Omri, 2013).

With the rapid development of global economy, CO_2 emissions have surged and environmental pollution has become increasingly serious, drawing broad attention globally. To improve the global environmental quality, series of ambitious goals to control carbon intensity and even cut total CO_2 emissions have been set. Global energy consumption structure relies heavily on coal. However, so far research on the relationship between energy consumption structure and CO_2 emissions is scarce. This paper investigates this topic for the first time and calculates the input-output and alternative elasticities and impacts the energy consumption structure on carbon emissions.

2. Causality Literature Survey

The interrelationships between energy consumption, economic growth and carbon emissions have been the matter of thorough research during the most recent decades. There are three types of studies (for single-country as well as multi-country data) which are categorically highlighted within the current literature survey.

1) The first category of the study highlights the relationship between the economic growth and carbon emissions, discussing the different methodologies that are used to understand the relationship. The empirical findings of numerous authors depict different conclusions. Selden and Song (1994) and Galeotti et.al (2009) provided empirical evidences on the validity of EKC hypothesis. However Holtz-Eakin and Selden (1995) found a monotonic rising curve and Friedl and Getzner (2003) found an N-shaped curve. In addition Agras and Chapman (1999) and Richmond and Kaufman (2006) concluded that there is no significant relationship between economic growth and environmental pollutants.
2) The second category of research examines the relationships between energy consumption and economic growth. These studies have attempted to investigate the causal relationships between these three variables by combining the literature on economic growth symbols (GDP, per capita income etc.) with the energy consumption-growth literature (Richmond and Kaufman, 2006; Soytas et al., 2007; Ang, 2007; Soytas and Sari, 2009; Akbostanci et al., 2009; Acaravci and Ozturk,

2010; Apergis and James, 2010; Ozturk and Acaravci, 2010; Arouri et al., 2011 and Wang et al., 2011).

3) The third type focuses on the relationship between energy consumption and carbon emissions based on environmental data. The input-output and alternative elasticities and impacts of energy consumption structure on carbon emissions is addressed in this category (Hao, & Huang, 2017). Energy (Fossil fuel mainly) consumption has been, in most of the cases, accredited to economic growth. The Environmental Kuznets Curve (EKC) explains the relationship among the commercial activities and the emission of carbon and between the economic activity and the utilization of natural resources. The EKC hypothesis postulates that environmental degradation primarily expands when a country's economy is stumpy but, as the economy flourishes, environmental degradation drops, resulting in an inverted U shaped relationship among economic profits and the usage of natural resources and waste emissions.

Concerning the causal relationship among the three important variables i.e. energy consumption, economic growth and carbon emissions, the current literature consists of four types of hypothesis.

1. No causal relationship (neutrality hypothesis) which denies any kind of causal relationship between the variables under study.
2. Uni-directional causal relationship (conservational hypothesis) which exhibits the negative or inverse relations among the variables.
3. Uni-directional causal relationship (growth hypothesis) which confirms the existence of a direct or positive relationship between the variables.
4. Bi-directional causal relationship (feedback hypothesis) which shows the dependency of two variables on each other.

2.1 Literature survey on causal relationship between economic growth and carbon emissions (single country studies)

The country-specific studies on causal relationship between economic growth and carbon emissions are summarised within table 1. These studies include Lau, et al. (2014); Ahmad, et al. (2016); Begum, et al. (2015); Alshehry, & Belloumi, (2015); Mirza, & Kanwal, (2017); Ahmad, et al. (2017); Xu, & Lin, (2015); Bano, et al. 2018; Yeh, & Liao, (2017); Long, et al. (2015); Ben Jebli, & Ben Youssef, (2017); Abid, (2015); Mikayilov, et al. (2018); Liu, & Bae, (2018); Shabestari, (2018); Ang, (2007); Halicioglu, (2009); Akpan, & Akpan, (2012); Zhang, & Da, (2015); Saboori, et. al. (2012). A cumulative outcome of all these studies is a bidirectional or unidirectional causal relationship among the two variables namely economic growth and carbon dioxide emissions. Although few of the studies conclude no causality exist between the two but most of the studies confirms the existence of this causality. Few of the studies are discussed in detail below.

In 2014, Lau et al. examined the causal relationship between carbon emissions and the economic growth variables in Malaysia for the period 1984 to 2008. The methodology he employed comprised of bounds test and different conditioning information sets. The results of this study, confirmed a positive and significant interaction term between carbon dioxide emission and economic growth. (Lau, et al. 2014).

Ahmad, et al., (2017) investigated the existence of environmental Kuznets Curve in Croatia for the time period of 1992-2011. Autoregressive Distributed Lag (ARDL) and VECM method were employed. The study showed the existence of inverted U-shape relation between CO_2 emissions and economic growth in long term which validates the EKC. Granger causality based on VECM approach indicated a bi-directional causality between CO_2 emissions and economic growth in short run and uni-directional causality from economic growth to CO_2 emissions in long run (Ahmad, et. al., 2017).

Xu, & Lin, (2015) examined the impacts of industrialization and urbanization on CO_2 emissions in China using nonparametric additive regression models and provincial panel data from 1990 to 2011. This study also revealed the presence of a U-shaped relationship between industrialization and CO_2 emissions in the three regions in China. The second variable i.e. Urbanization showed an inverted U-shaped pattern with CO_2 emissions in the eastern region, and a positive U-shaped pattern in the central region. According to this study the two most important aspects of economic growth i.e. Industrialization and Urbanization significantly impacts the Carbon emissions (Xu, & Lin, 2015).

Bano, et al. (2018) studied the impacts of human capital on the carbon emissions both in the long-term and short-term scenario in Pakistan from 1971 to 2014. The methodology applied for the co-integration and the causality direction was an autoregressive distributed lag model and the vector error correction model. According to this study, there exists a long-term relationship between human capital and carbon emissions. Upgrading human capital will diminish carbon emissions without shrinking the overall economic growth. The results of Granger causality test confirmed the bidirectional causality that exists between the two variables in the long term, whereas no causality was found in the short term. Both the parameters have feedback impact on each other in the long run and no influence in the short run. The study suggests that development in the human capital through education will help carbon emissions mitigation in the long term (Bano, et. al., 2018).

In 2014, Taiwan was found to be among the top 20 carbon emitters in 2014. In order to study the nexus among the economic growth, carbon emissions and energy consumption, a study was conducted by Yeh & Liao, (2017). The study assessed the national data for the said variables from 1990-2014. The researchers employed an analytic tool of Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) was employed to analyse the relationship of the two variable with the carbon emissions. The results of the study suggested a significant impact of population and economic growth on carbon emission. This study also predicted the increase in this impact by the year 2025 in Taiwan (Yeh, & Liao, 2017).

Abid, (2015) studied the impact of the informal economy on Carbon emissions for Tunisia for the time period 1980-2009. He assessed the causal relationship between economic growth and CO_2 emissions by applying the Environmental Kuznets Curve hypothesis (EKC). The study established a monotonically growing relationship between total GDP (the sum of the formal and informal economy) and CO_2 emissions as well as between formal GDP and emissions. Thus there is no confirmation that supports the EKC hypothesis for greenhouse gas (GHG) emissions. The study applied a cointegrated VECM model and found the existence of co-integration relationships between the variables. Granger causality technique was also employed for both short and long-run. The results showed a unidirectional causality

from formal economic growth to CO_2 emissions, and bidirectional causality between CO_2 emissions and total GDP, implying that informal economy advances at the cost of the environment (Abid, 2015).

Mikayilov, et al. (2018) examined the relationship between the economic growth and CO_2 emissions in Azerbaijan. A co-integration analysis was conducted for the time period 1992-2013. The study also applied Johansen, ARDLBT, DOLS, FMOLS and CCR methods for validating the results. Cubic, quadratic and linear specifications were used and it was concluded that the linear specifications are more appropriate for depicting the impacts of economic growth on CO_2 emissions in Azerbaijan. The study inferred from the different co-integration approaches that the economic growth has a positive and statistically significant influence on the emissions in the long-run indicating that the EKC hypothesis does not hold for Azerbaijan. By means of different methods, it was found that the income elasticity of CO_2 emissions lie between 0.7 and 0.8. The study also suggested that the short-run imbalance can be attuned towards the long-run stability path within less than one year. The paper suggests that measures to upsurge energy efficiency, carbon pricing mechanisms in production and trade activities, and countrywide social awareness programs to educate the public about the negative costs of pollution should be considered as applicable environmental policies intended to mitigate carbon emissions (Mikayilov, et. al. 2018).

Saboori, et al. (2012) piloted a pertinent research in order to assess the long-run as well as causal relationship between economic growth and carbon emissions for Malaysia for the time period 1980-2009. For this study, Environmental Kuznets Curve (EKC) hypothesis was verified exploiting the Auto Regressive Distributed Lag (ARDL) approach. The results of the study suggest that there exists a long-run relationship between per capita carbon emissions and real per capita GDP. For both long term and short term scenarios, the study supported the EKC by depicting an inverted-U shape relationship between CO2 emissions and GDP. The results of Vector Error Correction Model for the Granger Causality test showed the absence of causality between CO_2 emissions and economic growth in the short-run. But a uni-directional causality was observed from economic growth to CO_2 emissions in the long-run (Saboori, et al., 2012).

Table: 1 Literature survey on causal relationship between economic growth and carbon emissions (single country studies)

Serial No.	Author	Time Period	Country	Methodology	Causal Relationship
1	Lau, et al. 2014	1984-2008	Malaysia	• bounds test • conditioning information sets	CE-EG
2	Ahmad, et al. 2016	1971–2014	India	• The ARDL for the co-integration analyses • vector error correction model for causality	EG-CE

3	Begum, et al. 2015	1970-2009	Malaysia	• ARDL bounds testing • DOLS	GDP-CE
4	Alshehry, & Belloumi, 2015.		Saudi Arabia	• Johansen multivariate cointegration	Bidirectional EG-EC
5	Mirza, & Kanwal, 2017			• Johansen-Julius co-integration • ARDL • Grangers' causalities in VECM	Bidirectional EG-EC
6	Ahmad, et al. 2017	1992-2011	Croatia	• EKC • ARDL • Grangers' causalities in VECM	Bidirectional EG-EC
7	Xu, & Lin, 2015	1990-2011		• nonparametric additive regression models	U-shaped nonlinear relationship
8	Bano, et al. 2018	1971-2014	Pakistan	• ARDL • VECM • Granger's causality	Bidirectional EG-EC
9	Yeh, & Liao, 2017	1990-2014	Taiwan	• Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT)	CE-EG
10	Long, et al. 2015	1952 to 2012	China	• unit root and co-integration analysis • Granger causality analysis	Bidirectional GDP-CE
11	Ben Jebli, & Ben Youssef, 2017.	1980–2011	Tunisia	• VECM • Granger causality tests • EKC	Bidirectional agricultural value added AVA-CE
12	Abid, 2015	1980–2009	Tunisia	• EKC • VECM	Unidirectional EG-CE

13	Mikayilov, et al. 2018	1992-2013	Azerbaijan	• Johansen, • ARDLBT • DOLS • FMOLS • CCR	EG-CE
14	Liu, & Bae, 2018	1970-2015	China	• ARDL • VECM (Granger causality)	CE-GDP
15	Shabestari, 2018	1970-2016	Sweden	• VECM • Granger causality test	Bidirectional EG-CE
16	Ang, 2007	1960-2000	France	• VECM	Unidirectional EG-CE
17	Halicioglu, 2009	1960-2005	Turkey	• Granger causality	CE-EG
18	Akpan, & Akpan, 2012	1970-2008	Nigeria	• VECM • EKC	Unidirectional EG-CE
19	Zhang, & Da, 2015	1996-2010	China	• LMDI	unidirectional EG-CE
20	Saboori, et al. 2012	1980-2009	Malaysia	• ARDL • EKC • Granger causality (VECM)	• No causality in short run CE-EG • Unidirectional causality in long run EG-CE

2.2 Literature survey on causal relationship between economic growth and carbon emissions (multi country studies)

The studies on the causal relationship between economic growth and carbon emissions (multi country) are shown in Table 2. Some of the selected studies are mentioned below.

Jardón, et al. (2017) assessed the empirical relationship between carbon emissions per-capita and economic growth for 20 Latin American and Caribbean countries spanning the time period of 1971-2011. According to the results of Environmental Kuznets Curve (EKC) hypothesis tests, there exists an inverse U-shape relationship among the variables in the long run (Jardón, et. al. 2017).

Narayan, et al. (2016) examined the dynamic relationship between economic growth variable (income) and carbon emissions for 181 countries. The outcomes of the study suggest that 12% of the countries data support EKC. Another important inference of this study is that 49 out of 181 countries' (27%) results show that the income growth will decrease carbon emissions in the future (Narayan, et al., 2016).

Yang, et al. (2015) determined the EKC using a novel symbolic regression method in order to assess causal relationship for 67 countries from 1971 to 2010. From the empirical results, it can be concluded that there is no universal model for every country, and symbolic regression can provide specific models for a specific country or region. The relationship among the variables is dynamic due to the change of regions and economic development pattern, where developed countries mostly follow the inverted N-shaped and M-shaped models to describe the relationship, while developing countries refer to the inverted N-shaped, inverted U-shaped and monotonically aggregate models (Yang, et al., 2015).

Zhu, et al. (2016) examined the impact of foreign direct investment (FDI) and economic growth on carbon emissions in five ASEAN countries (ASEAN-5), including Indonesia, Malaysia, the Philippines, Singapore and Thailand. The researchers employed a panel quantile regression model. The empirical results indicate that the influence of the independent variables on carbon emissions is heterogeneous through the quantiles. Particularly, the impact of FDI on carbon emissions is negative. Energy consumption escalates carbon emissions. For the high-emissions countries, greater economic growth and population size seems to decrease emissions. The results of the research also validates the halo effect hypothesis for higher-emissions countries. (Zhu, et al. 2016).

Table 2: Literature survey on causal relationship between economic growth and carbon emissions (multi country studies)

Serial No.	Author	Time Period	Countries	Methodology	Causal Relationship
1	Kais, & Sami, 2016	1990 to 2012	58	Panel data model	GDP-CE U-shaped curve between CE-GDP per capita
2	Pao & Chen, 2019	1991-2016	G20	• CKC • clean/fossil fuels energy consumption (CE/FF) • panel co-integration	Long run relationship between CE-FF-real GDP
3	Jardón, et. al. 2017	1971-2011	20 Latin American and Caribbean countries	EKC	No causality
4	Narayan, et. al., 2016		181	EKC	
5	Antonakakis, et. al., 2017	1971 – 2011	106	PVAR	Bidirectional EG-CE Feedback
6	Esso &	1971-	12 Sub-	Granger causality	

	Keho (2016)	2010.	Sahara African countries		EG-CE
7	Le & Quah, 2018	1984-2012	14	• Panel Co-integration • OLS estimator	CE-EG
8	Chen et al. 2016	1993-2010	188	VECM	EG-CE
9	Yang et al. 2015	1971-2010	67	• Symbolic Regression Model • EKC	Diversified relationship No causality
10	Cai et al. 2018		G7	ARDL	• Germany CE-Real GDP
11	Saidi & Mbarek, 2016	1990-2018	9 (developed countries)	Dynamic Panel	No causality
12	Zhu et al. 2016		5 (ASEAN Countries)	Panel Quantile Regression Model	• FDI-EC • EC-CE • FDI-CE (negative impact on CE)
13	Wan et al. 2018	1996-2015	BRICS	Partial Least Square Regression Model	EG-CE (negative impact of corruption on EG and CE)
14	Li & Lin, 2015	1971-2010	73	• STIRPAT • Threshold Regression Model	• Urbanization-EC (low income countries) • Urbanization-CE (low income countries) • Industrialization-CE (Middle/low income countries/high income countries) • Middle/ High income (urbanization has no effect on EC & Urbanization decreases CE)
15	Alom, 2014		5 (South Asian Countries)	• Panel Unit Root Test • Panel Co-integration	In short run • EC-CE • CE-GDP In long run

				• Panel Causality	• No Causality GDP-CE, CE-EC
16	Vidhyarthi, 2014		5 (South Asian Countries)	• Panel Unit Root Test • Panel Co-integration • Panel Causality	In short run • EC-CE • CE-GDP In long run • No Causality GDP-CE, CE-EC
17	Oganesyan, 2017	1980-2013	BRICS	• EKC • Panel Co-integration	Elasticity CE-EC 0.60% EG-EC 1.74%
18	Obradović, & Lojanica, 2017	1980-2010	South Eastern Europe	VECM	In long run CE-EG In short run EC-EG
19	Omri, 2013	1990-2011	14 (MENA)		Bidirectional EC-EG Unidirectional EC-CE Bidirectional EG-CE
20	Arouri, et al. 2012	1981-2005	12 (MENA)	Panel unit root test	Long run • EC-CE (positive) • Real GDP-CE (Quadratic) • EG-CE (negative)
21	Lean & Smyth, 2010	1980-2006	5 (Asian Countries)	EKC Granger Causality	Long run • CE-EC (Positive) • Unidirectional-Electricity consumpion-EG Short run Unidirectional CE-El.C
22	Ouyang, & Lin, 2017		2 (China & Japan)	Co-inegration Model	Long run CE-GDP CE-Urbanization CE-Energy intensity Income Growth-CE (Quadratic)

2.3 Literature survey on causal relationship between economic growth and energy consumption (Single country studies)

The studies on economic growth and energy consumption relationship (single-country) are enlisted in Table 3. Some of them are described in detail below.

Alshehry, & Belloumi, (2015) assessed the dynamic causal relationships between energy consumption, and economic growth in Saudi Arabia based. They used Johansen multivariate co-integration approach and integrated carbon emissions as a control variable. The results of this study indicated that in the long-run there exists a relationship among the variables. The unidirectional causality runs from energy consumption to economic growth and carbon emissions, bidirectional causality runs among the carbon emissions and economic growth, and a long-run unidirectional causality exists from energy price to economic growth and carbon emissions. In the short-term, there is a unidirectional causality that runs from carbon emissions to energy consumption and also to the economic output and from energy price to carbon emissions (Alshehry, & Belloumi, 2015).

Mirza, & Kanwal, (2017) investigated the presence of causality between economic growth, energy consumption and carbon emissions for Pakistan. The bi-variate long term relationships between the variables were analysed by Johansen-Julius co-integration test. The results were verified using ARDL approach to co-integration. Grangers' long run and short run causalities were assessed by Vector Error Correction Model (VECM) framework. According to the results of the study bidirectional causalities between energy consumption, the economic growth and the carbon emissions exist both in the short run as well as long run (Mirza, & Kanwal, 2017).

Long, et al. (2015) This paper mainly examined the relationship among economic growth and energy consumption China from 1952 to 2012. Unit root, co-integration analysis and Granger causality analysis were carried out. The results indicate that coal has dominant effect on economic growth and bidirectional causality runs from GDP (Gross Domestic Product) to CO_2 emission, gas, coal and electricity consumption (Long, et al., 2015).

Ben Jebli, & Ben Youssef, (2017) analysed the economy-energy relationship in Tunisia from 1980-2011. Vector error correction model (VECM), Johansen-Juselius test and Granger causality tests were employed to examine the short and long-run relationships between per capita carbon emissions, real GDP, renewable energy consumption and non-renewable energy consumption, the trade openness ratio and the agricultural value added (AVA). According to the results of the study Short-run, bidirectional causalities exist between AVA and CO_2 emissions, and between AVA and the trade openness ratio. Unidirectional causalities running from non-renewable energy and GDP to AVA and to renewable energy. Long run bidirectional causalities were found between all considered variables (Ben Jebli, & Ben Youssef, 2017).

Another similar study was conducted by Ang (2008). The study was focused on assessing the relationship between energy consumption and economic growth in Malaysia during the period 1971-1999. Co-integrating analysis was carried out to serve this purpose. The results showed that pollution and energy use are significantly positively related to output in the long-run. A significant causality running from economic growth to energy consumption growth, both in the short-run and long-run was also observed in this study (Ang, 2008).

Table 3: Literature survey on causal relationship between economic growth and energy consumption (Single country studies)					
1	Alshehry, & Belloumi, 2015.		Saudi Arabia	• Johansen multivariate cointegration	Bidirectional EG-EC
2	Mirza, & Kanwal, 2017			• Johansen-Julius co-integration • ARDL • Grangers' causalities in VECM	Bidirectional EG-EC
3	Long, et. al., 2015	1952 to 2012	China	• unit root and cointegration analysis • Granger causality analysis	Bidirectional GDP-CE
4	Ben Jebli, & Ben Youssef, 2017.	1980–2011	Tunisia	• VECM • Granger causality tests • EKC	• Bidirectional agricultural value added AVA-CE
5	Liu, & Bae, 2018	1970-2015	China	• ARDL • VECM (Granger causality)	CE-GDP
6	Shabestari, 2018	1970 to 2016	Sweden	• VECM • Granger causality test	Bidirectional EG-CE
7	Ang, 2007	1960–2000	France	• VECM	Unidirectional EG-CE
8	Halicioglu, 2009	1960-2005	Turkey	• Granger causality	CE-EG
9	Akpan, & Akpan, 2012	1970 to 2008	Nigeria	• VECM • EKC	Unidirectional EG-CE
10	Ang, 2008	1971-1999	Malaysia	• Co-integration Analysis	Long run Pollution-EC Long & Short run EG-EC

2.4 Literature survey on causal relationship between economic growth and energy consumption (multi country studies)

The studies on economic growth and energy consumption relationship (multi-country) are enlisted in Table 4.

Pao & Chen (2019) conducted a study to assess the causal relationship between economic growth and energy consumption taking into account the carbon emissions as well for the developed economies around the world i.e. Group of Twenty (G20). The study was conducted within a panel Emissions-Energy-Output (EEO) framework over the period 1991-2016 in order to estimate the Carbon Kuznets Curve (CKC), the clean/fossil fuels energy consumption (CE/FF) elasticity of demand for carbon emissions and the causalities between emissions, energy, and economy. The panel co-integration test results revealed that there is a long-run balanced relationship between carbon emissions, FF, real GDP, and various types of CE (i.e., new renewable (Ren), hydropower (Hydro) and nuclear (Nuc). According to the results of the study, there exists CKC and the carbon emissions are positively related to FF and negatively to Ren/Hydro/Nuc. The study confirmed the feedback hypothesis amid economic growth and clean energy consumption (Pao, & Chen, 2019).

Antonakakis, et al. (2017) investigated the causal relationships among output-energy-environment nexus by employing panel vector auto regression (PVAR) and impulse response function analysis. The study covered 106 countries for the time period 1971-2011. Results of the study suggest that bidirectional (feedback hypothesis) causality exists between the economic growth and energy consumption. Our results reveal that the effects of the various types of energy consumption on economic growth and emissions are heterogeneous on the various groups of countries. Moreover, causality between total economic growth and energy consumption is bidirectional, thus making a case for the feedback hypothesis (Antonakakis, et al. 2017).

Esso, & Keho, (2016) assessed the long-term and causal relationships among three variables i.e. energy consumption, carbon dioxide emissions and economic growth. The study was carried out for 12 selected countries (Sub-Saharan African) and it spanned over the time period of 1971-2010. The bounds test and Granger causality test were employed to assess the data. The experimental results reveal that in the long-run, energy consumption and economic growth are linked. Results from the Granger causality tests indicated that economic growth causes CO_2 emissions in the short-run in most of the countries under study. Besides that, bidirectional causality exists between economic growth and carbon emissions in short run. And in the long-term, energy consumption and economic growth causes carbon dioxide in most of the Sub-Saharan African countries under study (Esso, & Keho, 2016).

Le, & Quah, (2018) investigated the causal relationships between carbon emissions, energy consumption, and economic growth for 14 Asian countries in Asia for the time period 1984-2012 by applying panel co-integration test. According to the results of this study, there exists a long-run relationship between carbon emissions, energy consumption, and economic growth. The Fully Modified OLS estimators of the panel, as well as the sub-panel of lower-to-upper-middle-income countries, provide proof against the Environmental Kuznets Curve (EKC) hypothesis. But data from the panel of high income countries show a uniformity with the EKC hypothesis. The overall results of the causality tests propose that carbon emissions in the region could be decreased through energy conservation policy measures without damaging the economic growth (Le, & Quah, 2018).

Saidi, & Hammami, (2015) presented a research on the energy-economy nexus covering 58 countries from 1992-2012. The research employed Generalized Method of Moments (GMM) dynamic data penal model to achieve the goal for three regional panels i.e. from Europe and North Asia, Latin America and Caribbean, and Sub- Saharan, North African and Middle Eastern. The experimental results revealed a significant positive impact of carbon emissions on energy consumption for four global panels. The study also demonstrated that Economic growth has a positive influence on energy consumption (Saidi, K., & Hammami, S. 2015).

Table 4: Literature survey on causal relationship between economic growth and energy consumption (Multi country studies)

1	Pao & Chen, 2019	1991-2016	G20	• CKC • clean/fossil fuels energy consumption (CE/FF) • panel co-integration	Long run relationship between CE-FF-real GDP
2	Antonakakis, et. al., 2017	1971 – 2011	106	PVAR	Bidirectional EG-CE feedback
3	Esso & Kaho (2016)	1971-2010.	12 Sub-Sahara African countries	Granger causality	EG-CE CE-EG
4	Le & Quah, 2018	1984-2012	14	• Panel Co-integration • OLS estimator	CE-EG
5	Chen et al. 2016	1993-2010	188	VECM	EG-CE
6	Cai et al. 2018		G7	ARDL	• Germany CE-Real GDP
7	Saidi & Mbarek, 2016	1990-2018	9 (developed countries)	Dynamic Panel	No causality
8	Li & Lin, 2015	1971-2010	73	• STIRPAT • Threshold Regression	• Urbanization-EC (low income countries)

				Model	• Urbanization-CE (low income countries) • Industrialization-CE (Middle/low income countries/high income countries) • Middle/ High income (urbanization has no effect on EC & Urbanization decreases CE)
9	Saidi & Hammadi, 2015	1990-2012	58	• Generalized Methods of Moments (GMM)	CE-EC EG-EC
10	Alom, 2014		5 (South Asian Countries)	• Panel Unit Root Test • Panel Co-integration • Panel Causality	In short run • EC-CE • CE-GDP In long run • No Causality GDP-CE, CE-EC
11	Vidhyarthi, 2014		5 (South Asian Countries)	• Panel Unit Root Test • Panel Co-integration • Panel Causality	In short run • EC-CE • CE-GDP In long run • No Causality GDP-CE, CE-EC
12	Oganesyan, 2017	1980-2013	BRICS	• EKC • Panel Co-integration	Elasticity CE-EC 0.60% EG-EC 1.74%
13	Obradović, & Lojanica, 2017	1980-2010	South Eastern Europe	VECM	In long run CE-EG In short run EC-EG
14	Omri, 2013	1990-2011	14 (MENA)		Bidirectional EC-EG Unidirectional EC-CE Bidirectional EG-CE
15	Arouri, et al. 2012	1981-2005	12 (MENA)	Panel unit root test	Long run • EC-CE (positive) • Real GDP-CE (Quadratic) • EG-CE (negative)

16	Lean & Smyth, 2010	1980-2006	5 (Asian Countries)	EKC Granger Causality	Long run • CE-EC (Positive) • Unidirectional-El.C-EG Short run Unidirectional CE-El.C

2.5 Literature survey on causal relationship between energy consumption and carbon emissions (single country studies)

The studies on energy consumption and carbon emissions relationship (single-country) are enlisted in Table 5.

Begum, et al. (2015) investigated the dynamic impacts of energy consumption on CO_2 emissions in Malaysia for the time period 1970-1980. ARDL bounds testing approach, dynamic ordinary least squared (DOLS) and the Sasabuchi–Lind–Mehlum U (SLM U test) tests were employed to achieve this objective. The results of the study suggest that EKC was not valid in Malaysia for that specific study period. The results also revealed that both per capita energy consumption and per capita GDP has a long term positive relationship with per capita carbon emissions, but the other variable i.e. population growth rate has no significant impacts on per capita CO_2 emission. Still, the study suggests that, economic growth may have an adverse effect on the CO_2 emissions in in the long run in Malaysia (Begum, et.al. 2015).

Liu, & Bae, (2018) assessed the causal relationships among CO_2 emissions per capita, the energy intensity, the real GDP and the share of renewable energy consumption in China spanning the period from 1970 to 2015. Autoregressive distributed lag (ARDL) technology, and vector error correction model (VECM) were applied to test the co-integration in short run and long run and the directional causality respectively. The approximations of long-run parameters specify that 1% expansion of energy intensity, real GDP, industrialization, and urbanization proliferates CO_2 emissions by 1.1%, 0.6%, 0.3%, and 1.0%, respectively. The study also exhibits that there exit the Long-run feedback Granger causalities among emissions, real GDP, and industrialization (Liu, & Bae, 2018).

Hao, & Huang, (2017) assessed the input-output and alternative elasticities as well as the impacts of the energy consumption on per capita carbon emissions. This study utilized the trans-log production function as the theoretical framework. The experimental results propose that replacing coal with oil or gas may drop CO_2 emissions considerably (Hao, & Huang, 2017).

Soytas, et al. (2007) examined the effect of energy consumption and output on carbon emissions in the United States. The study focused to assess the Granger causality relationship between income, energy consumption, and carbon emissions, including the labour and gross fixed capital. According to this study the no causality was found between the carbon emissions in the long run, but significant causal relationship exist between carbon emissions and energy consumption (Soytas, et. al., 2007).

Shabestari, (2018) conducted a study in order to ainvestigate the causal relationship between Carbon emissions and energy consumption in Sweden from 1970-2016. Vector Error Correction model was applied for this purpose. The results indicate that in the long-run, bidirectional Granger causality relationship exists between energy consumption and CO_2 emissions. This result is consistent with the Feedback Hypothesis (Shabestari, 2018).

Another research was conducted by Ang, (2007). This research examines the dynamic causal relationships between pollutant emissions and energy consumption for France over the time period 1960-2000. The methodology included co-integration and vector error-correction modelling techniques. The results suggest that the variables are significantly inter-related and therefore their relationship must be examined using an integrated framework. The results also indicate a uni-directional causality running from energy consumption to output growth in the short run (Ang, 2007).

Another related study was conducted by Halicioglu, (2009) to assess the causal relationship between carbon emissions and energy consumption in Turkey from1960-2005. This research investigated the said interrelationship between the variables using the bounds testing co-integration procedure. The bounds test results show that there exist two forms of long-run relationships between the variables (Halicioglu, 2009).

Table 5: Literature survey on causal relationship between Energy Consumption and Carbon Emissions (single country studies)

Serial No.	Author	Time Period	Country	Methodology	Causal Relationship
1	Ahmad, et. al., 2016	1971–2014	India	• The ARDL for the cointegration analyses • vector error correction model to determine the direction of causality	EG-CE
2	Begum, et.al, 2015	1970 to 2009	Malaysia	• ARDL bounds testing • DOLS	GDP-CE
3	Dong et al. 2018	1965-2016	China	• EKC	In long and short run EC-CE
4	Alshehry, & Belloumi, 2015.		Saudi Arabia	• Johansen multivariate cointegration	Bidirectional EG-EC
5	Mirza, & Kanwal, 2017			• Johansen-Julius co-integration	Bidirectional EG-EC

				• ARDL • Grangers' causalities in VECM	
6	Long, et. al., 2015	1952 to 2012	China	• unit root and cointegration analysis • Granger causality analysis	Bidirectional GDP-CE
7	Ben Jebli, & Ben Youssef, 2017.	1980–2011	Tunisia	• VECM • Granger causality tests • EKC	• Bidirectional agricultural value added AVA-CE
8	Liu, & Bae, 2018	1970-2015	China	• ARDL • VECM (Granger causality)	CE-GDP
9	Hao & Huang, 2017			•	EC-CE per capita
10	Soytas et al. 2007		USA	• EKC • Granger	No Causality Income-CE Long run EC-CE (negative)
11	Shabestari, 2018	1970 to 2016	Sweden	• VECM • Granger causality test	Bidirectional EG-CE
12	Ang, 2007	1960–2000	France	• VECM	Unidirectional EG-CE
13	Halicioglu, 2009	1960-2005	Turkey	• Granger causality	CE-EG
14	Akpan, & Akpan, 2012	1970 to 2008	Nigeria	• VECM • EKC	Unidirectional EG-CE
15	Zhang, & Da, 2015	1996 to 2010	China	• LMDI	unidirectional EG-CE
16	Ang, 2008	1971-1999	Malaysia	• Co-integration Analysis	Long run Pollution-EC Long & Short run EG-EC

2.6 Literature survey on causal relationship between energy consumption and carbon emissions (multi country studies)

The studies on energy consumption and carbon emissions relationship (multi-country) are enlisted in Table 6.

Chen, et al. (2016) investigated the relationships among, energy consumption carbon emissions and economic. The study was conducted for 188 countries over the time period of 1993-2010. Panel co-integration and vector error-correction model were applied for the assessment. The experimental results showed the existence of long-run relationships among economic growth, energy consumption and carbon dioxide emissions. Unidirectional causality was observed from energy consumption to carbon dioxide emissions for both developing and developed countries. (Chen, et al. 2016).

Cai, et al. (2018) examined the energy-economy-emissions nexus for the G7 countries. The bootstrap ARDL bounds test with structural breaks was applied to assess the co-integration and causality for these countries. According to the results of the study, no co-integration was found among the real GDP per capita, the clean energy consumption and carbon dioxide emissions in France, USA, Italy, UK and Canada. But, in Germany and Japan, co-integration was found between real GDP per capita and carbon emissions. Concerning the results of causality test, unidirectional causality run from clean energy consumption to real GDP per capita for USA Canada, and Germany and from carbon emissions to clean energy consumption for Germany. Moreover, feedbacks exists between clean energy consumption and carbon emissions for Germany, and unidirectional causality runs from clean energy consumption to carbon emissions for the USA (Cai, et al. 2018).

Saidi, & Mbarek, (2016) assessed the causality among energy consumption, carbon dioxide emissions, renewable energy and real GDP per capita by applying dynamic panel for nine countries for the period of 1990-2013. Capital and labour were also incorporated as additional variables. According to the results of the study, a unidirectional causality runs from energy consumption to real GDP per capita in the short term which suggests that policies for decreasing energy consumption may not hinder the economic growth as well as income. The study revealed no causality between energy consumption and real GDP per capita, but there exists a unidirectional causality from energy consumption to the labour. The results also revealed, a bidirectional causality amid the labour and the capital, and the CO_2 emissions and capital. There is also a unidirectional causal relationship running labour to CO_2 emissions. In the long run, a bidirectional causality runs from energy consumption to real GDP per capita. Moreover, the results also showed a unidirectional causality from GDP to CO_2 emissions. (Saidi, & Mbarek, 2016).

Li, & Lin, (2015) studied the causal relationships among the carbon dioxide, energy consumption by including Urbanization and industrialization variables into the data set of 73 countries for a time period from 1971-2010. The study employed have the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework as an initial point and re-estimated the relationship using various panel date models. According to the results of the study, within the low-income group, urbanization reduces the energy consumption but escalates CO_2 emissions; secondly, within the middle-/low-income and high-income groups, industrialization minimizes energy consumption but escalates CO_2 emissions, while urbanization prominently upsurges both energy consumption and CO_2 emissions; thirdly, for the middle-/high-income group, urbanization does not impact the energy consumption, but it impedes the growth of emissions; whereas industrialization

insignificantly influences the energy consumption and CO_2 emissions; and fourthly from the population angle, it yields positive impacts on energy consumption, and also escalates emissions (excluding the high-income group) (Li, & Lin, 2015).

Alom, (2014) carried out a similar research by utilizing the panel unit root tests, panel co-integration methods and panel causality test to examine the relationship between GDP, CO_2 emissions and the energy consumption for 5 South Asian countries for the time period 1972-2010. The outcome of this study revealed that there are causal relationships between Energy consumption and CO_2 emissions and also between the CO_2 emissions and GDP in the short term. But, in the long run, no causality exists between the CO_2 emissions and the energy consumption. (Alom, 2014).

Table 6: Literature survey on causal relationship between Energy Consumption and Carbon Emissions (multi country studies)

Serial No.	Author	Time Period	Countries	Methodology	Causal Relationship
1	Kais, & Sami, 2016	1990 to 2012	58	Panel data model	Positive relationship CE-EC
2	Adewuyi, & Awodumi, 2017	1980-2010		Three staged Least Square Model (3SLS)	Feedback EC-CE
3	Pao & Chen, 2019	1991-2016	G20	• CKC • clean/fossil fuels energy consumption (CE/FF) • panel co-integration	Long run relationship between CE-FF
4	Antonakakis, et. al., 2017	1971 – 2011	106	PVAR	No causality
5	Esso & Kaho (2016)	1971-2010.	12 Sub-Sahara African countries	Granger causality	Unidirectional (Negative impact) EC-CE
6	Le & Quah, 2018	1984-2012	14	• Panel Co-integration • OLS estimator	Unidirectional (Negative impact) EC-CE
7	Chen et al. 2016	1993-2010	188	VECM	Unidirectional EC-CE
8	Cai et al. 2018		G7	ARDL	• Germany feedback EC-CE • USA Unidirectional EC-CE

9	Saidi & Mbarek, 2016	1990-2018	9 (developed countries)	Dynamic Panel	• Unidirectional EC-Real GDP • Unidirectional nuclear EC-Labour • Bidirectional Renewable EC-Real GDP
10	Li & Lin, 2015	1971-2010	73	• STIRPAT • Threshold Regression Model	• Urbanization-EC (low income countries) • Urbanization-CE (low income countries) • Industrialization-CE (Middle/low income countries/high income countries) • Middle/ High income (urbanization has no effect on EC & Urbanization decreases CE)
11	Saidi & Hammadi, 2015	1990-2012	58	• Generalized Methods of Moments (GMM)	CE-EC EG-EC
12	Alom, 2014		5 (South Asian Countries)	• Panel Unit Root Test • Panel Co-integration • Panel Causality	In short run • EC-CE • CE-GDP In long run • No Causality GDP-CE, CE-EC
13	Vidhyarthi, 2014		5 (South Asian Countries)	• Panel Unit Root Test • Panel Co-integration • Panel Causality	In short run • EC-CE • CE-GDP In long run • No Causality GDP-CE, CE-EC
14	Oganesyan, 2017	1980-2013	BRICS	• EKC • Panel Co-integration	Elasticity CE-EC 0.60% EG-EC 1.74%
15	Obradović, & Lojanica, 2017	1980-2010	South Eastern Europe	VECM	In long run CE-EG In short run

					EC-EG
16	Omri, 2013	1990-2011	14 (MENA)		Bidirectional EC-EG Unidirectional EC-CE Bidirectional EG-CE
17	Arouri, et al. 2012	1981-2005	12 (MENA)	Panel unit root test	Long run • EC-CE (positive) • Real GDP-CE (Quadratic) • EG-CE (negative)
18	Lean & Smyth, 2010	1980-2006	5 (Asian Countries)	EKC Granger Causality	Long run • CE-EC (Positive) • Unidirectional-El.C-EG Short run Unidirectional CE-El.C

Conclusion

The literature survey for this nexus bears a significant place for the policy makers. The results highlighted within this literature survey imply that, in most of the scenarios, for developed as well as develop countries, there exists either a unidirectional or a bidirectional causality among the variables under study. In a negligible number of studies, no causality was found among the variables. The variation in the results may corresponds to the variation in the applied methodologies, the different regions, varied economic systems and the countries' social, industrial, cultural and political setups. The methodologies in most of the studies for this nexus include ARDL, VECM, PVAR, STIRPAT and unit root test. For assessing the kind of relationships among the variables, the Grangers Causalities were integrated. Environmental Kuznets Curve were observed within most of the literature.

The relevant studies can present more uniformity regarding the literature if the methodologies are assessed comparatively for validation among each other.

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