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Article

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Energy Reports

Provided in Cooperation with:

Elsevier

Suggested Citation: Waheed, Rida; Sarwar, Sahar; Chen, Wei (2019) : The survey of economic growth, energy consumption and carbon emission, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 5, pp. 1103-1115,
<https://doi.org/10.1016/j.egyr.2019.07.006>

This Version is available at:

<https://hdl.handle.net/10419/243655>

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Research paper

The survey of economic growth, energy consumption and carbon emission

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ARTICLE INFO

Article history:

Received 24 April 2019

Received in revised form 25 June 2019

Accepted 5 July 2019

Available online xxxx

Keywords:

Literature survey

Economic growth

Economic consumption

Carbon emission

ABSTRACT

The study aims to examine the survey of earlier literature that deals with economic growth, energy consumption and carbon emission, both single country studies as well as multi-country studies that covers the period till 2019. The main focus of this survey is on the coverage of countries, modeling methodologies, periods as well as empirical conclusions. The literature survey in this research paper is based on the causality's direction between (i) economic growth and carbon emission; (ii) economic growth and energy consumption; (iii) energy consumption and carbon emissions. From reviewing these studies, general remark can be assumed that the literature which has been produced is paradoxical. Firstly, most of the earlier studies have reported that economic growth and energy consumption are significant sources of carbon emission, however, the role of economic growth in carbon emission is highly reported in highly developing countries. On contrary, in case of developed countries, carbon emission is not linked with economic development. Secondly, in case of developing countries, higher energy consumption leads to increase the economic growth. For developed countries, there are less evidence of dependence between energy consumption and economic growth. Lastly, in both developing and developed countries, higher energy consumption has reported the main culprit for carbon emission. Focusing on the implications, the governments and industries have to replace the non-renewable energy sources with renewable sources to generate electricity, run the industrial operations and for transportation purposes etc. Comprehending the literature survey has provided the basis to address the designing as well as implementing effective environmental as well as energy policies.

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1. Introduction

Increased carbon emissions and their relation to energy consumption and economic growth are among the most important areas of global warming debate. It can be realized that on the month of December, 1997, Kyoto protocol to the United Nations (UN) convention on the climate changes since the third millennium included that the crucial factor in order to determine or achieve sustainable development is environmental quality which would be quite consistent with what we call the Human rights' fifth generation. Along with that the summit of Johannesburg as well as Rio de Janeiro has also been organized in this regard. However, economic growth and energy consumption, being a great transmission channel, which are considered as main culprits of environmental degradation process. Therefore, the policies for economic growth need to be mold to reduce the environmental

degradation process that is considered to be a great challenge by policy makers as arbitrating between environment and growth.

The recent pace of higher economic growth is generally due to the industrialization, urbanization and transport infrastructure etc. which are mainly depend on energy consumption such as oil and coal. These oil and coal is consumed to generate electricity for industrial operations, electricity generation and for transport means. On one hand, higher energy consumption is considered as an important factor for rapid economic growth, industrialization and urbanization. On other side, the energy consumption induces the carbon emission.

The nexus among economic growth, energy consumption and carbon emission is important from all the perspectives i.e. economic policies, total and sectoral energy consumption and the environmental planning at national and global scale. Therefore, large number of studies have been conducted to examine the causal relationships among the increasing carbon emissions, energy consumption and economic growth, those considered different time periods, proxies, set of countries and econometric techniques etc. (Song et al., 2018; Rauf et al., 2018; Chaudhary and Bisai, 2018; Riti et al., 2017; Bildirici, 2017; Zhang et al., 2017;

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Zhao et al., 2017; Alam et al., 2016; Robaina-Alves et al., 2016; Ozcan, 2013; Jayanthakumaran et al., 2012; Ghosh, 2010; Apergis and Payne, 2010; Ang, 2008). The empirical results of these researches varies across studies, however, the multiple policy implications are driven that depends upon the causal relationship among studied variables. Therefore, the earlier literature that emphasizes on the interdependence among economic growth, energy consumption and carbon emission is not categorical to offer significant policy measures that can be adopted across countries.

Kraft and Kraft (1978) used the granger causality test in order to test nexus between energy consumption and economic growth in various countries. Payne (2010) has confirmed the relationship between electricity and economic growth; similarly, between energy consumption and economic growth. Ozturk (2010) ratified the relationship between electricity consumption and economic growth, as well as energy consumption and growth. Bozoklu and Yilanci (2013) attempted to explore the relationship between economic growth and energy consumption. For full sample estimations, the findings have confirmed the unidirectional relationship from economic growth to energy consumption. In case of OECD countries, energy consumption has confirmed direct relationship economic growth. Sarwar et al. (2017) proved mix evidences about the relationship between energy consumption and economic growth; the findings vary across income groups, oil-importing and oil exporting group of countries, regions etc. Shahbaz et al. (2017) also validated parallel results in case of 157 countries. Sarwar et al. (2018) investigated the impact of energy consumption on economic growth, stock market, industrial stocks and firm level stocks. The results have reported significant impact of energy consumption on economic growth, but the impact varies across industries.

Ang (2007) validated the “Environmental Kuznets Curve” (EKC) hypothesis; the nexus between environment and economic development is Inverted U-Curve; The levels of environmental pollution are greatly increased with the increase in output, but it starts declining as rising incomes get passed beyond the turning point. Similar findings have endorsed by Saboori et al. (2012) and Arouri et al. (2012). Arouri et al. (2012) investigated the “Environmental Kuznets Curve (EKC)” hypothesis from the year 1980 to 2005. The results clearly depict that the Inverted-U shape relationship is exhibited by economic growth and carbon emissions.

Pao and Fu (2013) found unidirectional relationship from economic growth to energy consumption in Brazil over the period of 1980–2010. Chandran Govindaraju and Tang (2013) have also examined the nexus among economic growth, carbon emissions and coal consumption, in India and China. In case of China, granger causality test has greatly revealed a clear as well as strong evidence of unidirectional relationship that runs from carbon emission to economic growth. Moreover, the bidirectional causality between economic growth and coal consumption in the short run, as well as in long run. For the estimations of India, only short-run causality is detected among carbon emissions and energy consumption as well as carbon emission and coal consumption. Apergis and Payne (2014) employed vector error correction model and reported co-integration among energy consumption, carbon emissions and economic growth.

In general, all the previous studies have diverse findings. These varied findings are due to the given reasons: (i) heterogeneity among country characteristics such as economic condition, political stability, industrial infrastructure, energy sources etc. (ii) diverse results are mainly for the use of different data set, different econometric estimation techniques. (iii) reliability of data sources; in case of developing countries, the data sources are less reliable and measured inappropriately. Resultantly, the causality with this inappropriately measured factor produce wrong results.

The main contribution of this study is to have a survey of previous studied that researched the relationship between energy consumption, economic growth and carbon emission, that has missed by previous literature. Although, some of the survey studies available that attempted to examine the relationship between economic growth and energy consumption (e.g. Ozturk, 2010; Payne, 2010; Omri, 2013). Likewise, Mardani et al. (2019) surveyed the earlier literature that deals with economic growth and carbon emission. However, as far authors limited knowledge, this is the pioneer survey study which simultaneously uses the survey of earlier studies that deals with economic growth, energy consumption and carbon emission to both specific and multi-country studies. In summarizing all the literature, the main objective of the current study is to investigate the theoretic reasons for these diverse results across selected studies. We further attempt to explore the dynamics of developing and developed countries; which of the category have higher dependence among economic growth, carbon emission and energy consumption. Lastly, we conclude a meaningful recommendation that may helpful for continuous economic growth and sinking the carbon emission.

The remaining of this research paper has been organized as follows: Section 2 reviews and analyze the literature that examine the relationship between (i) economic growth and carbon emission; (ii) economic growth and energy consumption; (iii) energy consumption and carbon emissions. Section 3 have all of the concluding remarks and recommendations for policy makers and future researchers.

2. Literature

The interrelationships between energy consumption, economic growth and carbon emissions have been the matter of thorough research during the most recent decades. Previous studies focus on single-country as well as multi-country data analysis 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 between these variables. However, the empirical findings of numerous authors depict different conclusions. Selden and Song (1994), Galeotti et al. (2009), Saboori et al. (2012), Fujii and Managi (2013), Wang and Liu (2017) and He et al. (2017) provided empirical evidences on the validity of EKC hypothesis. On contrary, Holtz-Eakin and Selden (1995), Azam (2016) and Antonakakis et al. (2017) found a monotonic rising curve, whereas, Friedl and Getzner (2003) found an N-shaped curve. In addition, Agrab and Chapman (1999) and Richmond and Kaufmann (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. A large number of studies have confirmed the significant relationship between energy consumption and economic growth (e.g. Richmond and Kaufmann, 2006; Soytaş et al., 2007; Apergis and Payne, 2010; Ozturk and Acaravci, 2010; Arouri et al., 2012; Wang et al., 2011; Shahbaz et al., 2011; Saidi and Mbarek, 2016; Adewuyi and Awodumi, 2017; Shahbaz et al., 2017; Sarwar et al., 2017; Tiba and Omri, 2017; Sarwar et al., 2018).
- (3) The third part focuses on the relationship between energy consumption and carbon emissions. The energy consumption is one of the major sources of carbon emission, through direct or indirect channel. The empirical relationship between energy consumption and carbon emission

has reported by numerous researchers (e.g. Ang, 2008; Jalil and Mahmud, 2009; Zhang and Cheng, 2009; Soytaş and Sari, 2009; Alkhatlan and Javid, 2015; Ahmad et al., 2016; Saidi and Mbarek, 2016; Tiba and Omri, 2017; Adewuyi and Awodumi, 2017), in case of single and multiple countries.

2.1. Economic growth and carbon emission

2.1.1. Single country studies

The country-specific studies on causal relationship between economic growth and carbon emissions are summarized in Table 1. These studies include Ang (2007), Halicioglu (2009), Akpan and Akpan (2012), Saboori et al. (2012), Lau et al. (2014), Zhang and Da (2015), Begum et al. (2015), Alshehry and Belloumi (2015), Abid (2015), Long et al. (2015), Xu and Lin (2015), Ahmad et al. (2016), Mirza and Kanwal (2017), Ahmad et al. (2017), Yeh and Liao (2017), Jebli and Youssef (2017), Mikayilov et al. (2018), Bano et al. (2018), Liu and Bae (2018) and Shabestari (2018). Most of these studies present bidirectional or unidirectional causal relationship between economic growth and carbon emissions. Although few of the studies conclude that no causality exists between economic growth and carbon emission. Few of the studies are discussed in detail, as given below.

Saboori et al. (2012) researched in order to assess the causal relationship between economic growth and carbon emissions for Malaysia, over the period 1980–2009. The results of the study suggest that there exists a long-run relationship between carbon emissions and economic growth. For both long term and short term scenarios, the study supported the EKC by depicting an inverted-U shape relationship between carbon emission and economic growth. The results of Vector Error Correction Model (VECM) and Granger Causality test showed the absence of causality between carbon emission and economic growth in the short-run. On contrary, a unidirectional causality has observed from economic growth to carbon emissions in the long-run.

Lau et al. (2014) examined the causal relationship between carbon emissions and the economic growth in Malaysia for the period 1984 to 2008. The results confirmed a positive and significant interaction between carbon emission and economic growth. Xu and Lin (2015) examined the impacts of economic growth, industrialization and urbanization on carbon emission in China by using nonparametric additive regression models and provincial panel data from 1990 to 2011. The findings revealed the presence of a U-shaped relationship between industrialization and carbon emissions in three regions of China. The second variable i.e. Urbanization showed an inverted U-shaped pattern with carbon emissions in the eastern region, whereas 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 effects the carbon emissions.

Abid (2015) studied the impact of the economic growth on carbon emissions for the period 1980–2009, in case of Tunisia. The study used VECM and granger causality test, the findings have established a monotonically growing relationship between economic growth and carbon emission. In addition, the EKC hypothesis has rejected for the case of Tunisia. The results showed a unidirectional causality from formal economic growth to carbon emissions, and bidirectional causality between carbon emissions and economic growth, implying that informal economy advances at the cost of the environment.

Ahmad et al. (2017) investigated the existence of Environmental Kuznets Curve (EKC) in Croatia for the time period of 1992–2011. Autoregressive Distributed Lag (ARDL) and VECM methods have employed to examine the association between economic growth and carbon emission. The study showed the existence of inverted U-shape relation between carbon emissions

and economic growth in long term which validates the EKC hypothesis. Granger causality based on VECM approach indicated a bi-directional causality between carbon emissions and economic growth in short run. Whereas, unidirectional causality has reported from economic growth to carbon emissions in long run. In order to study the nexus among the economic growth, carbon emissions and energy consumption, a study was conducted by Yeh and Liao (2017). The study assessed the national data of Taiwan from 1990 to 2014. By employing the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT), the study suggested a significant impact of population and economic growth on carbon emission.

Bano et al. (2018) studied the impacts of human capital and economic growth on the carbon emissions both in the long-term and short-term scenario in Pakistan from 1971 to 2014. The autoregressive distributed lag model and the vector error correction model applied to examine the causality direction between economic growth and carbon emission. According to this study, there exists a long-term relationship between human capital and carbon emissions. Suggesting that 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 economic growth and carbon emission, in the long run, whereas, no causality has found in the short term. Mikayilov et al. (2018) examined the relationship between the economic growth and carbon emission in Azerbaijan. For econometric estimations, the study applied ARDL, DOLS and FMOLS methods and reported the significant impact of economic growth on carbon emissions. 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.

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.

2.1.2. 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.

By using parametric tools and panel data prediction models, Holtz-Eakin and Selden (1995) discovered nexus between emanations of carbon emission gas and economic growth, for the panel of 130 countries. The results presented mix findings; some cases presented U-shaped curve while remaining had confirmed N-shape curve. During the period 1955 to 1993, Cheng and Lai (1997) examined Taiwan and reported a significant causal relationship between energy consumption and economic growth. Glasure and Lee (1998) found the causality between economic growth and energy consumption for Singapore and South Korea's. Bruyn et al. (1998) analyzed the case of USA, Germany, Netherlands and UK by using the time period of 1933–1960. Empirical results have reported a positive influence of economic growth on the carbon emission. Other side, the emissions have negative impact of structural and technological changes.

Yang et al. (2015) determined the causal relationship for 67 countries over the period of 1971–2010. 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

Table 1

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

Author	Time	Country	Methodology	Relationship
Ang (2007)	1960–2000	France	VECM	EG → CO
Halicioglu (2009)	1960–2005	Turkey	Granger causality	EG ← CO
Akpan and Akpan (2012)	1970–2008	Nigeria	VECM	EG → CO
Saboori et al. (2012)	1980–2009	Malaysia	ARDL–VECM	Short run EG ≠ CO Long run EG → CO
Lau et al. (2014)	1984–2008	Malaysia	Bound test	EG ← CO
Begum et al. (2015)	1970–2009	Malaysia	ARDL–DOLS	EG → CO
Xu and Lin (2015)	1990–2011	China	Nonparametric additive regression models	EG → CO
Long et al. (2015)	1952–2012	China	Co-integration analysis	EG ↔ CO
Abid (2015)	1980–2009	Tunisia	VECM	EG → CO
Zhang and Da (2015)	1996–2010	China	LMDI	EG → CO
Ahmad et al. (2016)	1971–2014	India	ARDL–VECM	EG → CO
Wang et al. (2016)	1990–2012	China	Granger causality	EG ↔ CO
Shahbaz et al. (2016)	1970–2012	Australia	VECM	EG → CO
Mirza and Kanwal (2017)	1971–2009	Pakistan	ARDL–VECM	EG ↔ CO
Ahmad et al. (2017)	1992–2011	Croatia	ARDL–VECM	EG ↔ CO
Yeh and Liao (2017)	1990–2014	Taiwan	STIRPAT	EG ← CO
Jebli and Youssef (2017)	1980–2011	Tunisia	VECM	EG ↔ CO
Riti et al. (2017)	1970–2015	China	ARDL–VECM	EG ↔ CO
Bano et al. (2018)	1971–2014	Pakistan	ARDL–VECM	EG ↔ CO
Mikayilov et al. (2018)	1992–2013	Azerbaijan	ARDL–DOLS–FMOLS	EG → CO
Liu and Bae (2018)	1970–2015	China	ARDL–VECM	EG ← CO
Shabestari (2018)	1970–2016	Sweden	ARDL–VECM	EG ↔ CO
Han et al. (2018)	1996–2014	China	Granger causality	EG ↔ CO
Bekun et al. (2019)	1960–2016	South Africa	Pesaran et al. (2001) bounds test	EG ← CO

Note: ←, → represents unidirectional, ↔ is bidirectional, whereas, ≠ presents no relationship.

Table 2

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

Author	Time	Countries	Methodology	Relationship
Lean and Smyth (2014)	1980–2006	5 (Asian countries)	Granger causality	EG ← CO
Arouri et al. (2012)	1981–2005	12 (MENA)	Panel test	EG → CO (Quadratic)
Omri et al. (2014)	1990–2011	14 (MENA)	Panel test	EG ↔ CO
Yang et al. (2015)	1971–2010	67	Symbolic regression model	EG ≠ CO
Kasman and Duman (2015)	1992–2010	New EU member	Panel cointegration	EG ↔ CO
Kais and Sami (2016)	1990–2012	58	Panel data model	EG → CO (U-shaped curve)
Narayan et al. (2016)	1960–2008	181	EKC	EG → CO
Esso and Kehoe (2016)	1971–2010	12 Sub-Sahara African countries	Granger causality	Short run: EG → CO (Benin, Democratic Republic of Congo and Senegal) EG ↔ CO (Nigeria and Ghana) long run: EG → CO (Benin, Cote d'Ivoire, Nigeria, Senegal, South Africa and Togo) EG ↔ CO (Congo and Gabon)
Chen et al. (2016)	1993–2010	188	VECM	EG → CO
Saidi and Mbarek (2016)	1990–2018	9 (developed countries)	Dynamic panel	EG ≠ CO
Zhu et al. (2016)	1981–2011	5 (ASEAN countries)	Panel quantile regression model	EG → CO
Jardón et al. (2017)	1971–2011	20 Latin American and Caribbean countries	GM–FMOLS–GM–DOLS	EG ≠ CO
Antonakakis et al. (2017)	1971–2011	106	PVAR	EG ↔ CO (U-shaped curve)
Obradović and Lojanica (2017)	1980–2010	South Eastern Europe	VECM	Long run EG ← CO
Wolde-Rufael and Idowu (2017)	1971–2010	China–India	ARDL	EG ↔ CO
Rahman (2017)	1960–2014	11 Asian populous countries	FMOLS–DOLS	EG ↔ CO
Bekhet et al. (2017)	1990–2011	GCC countries	VECM	EG ↔ CO
Le and Quah (2018)	1984–2012	14	Panel Co-integration–OLS	EG ← CO
Cai et al. (2018)		G7	ARDL	EG ← CO
Wang et al. (2018)	1996–2015	BRICS	Partial least square regression model	EG → CO
Pao and Chen (2019)	1991–2016	G20	VECM	EG → CO

Note: ←, → represents unidirectional, ↔ is bidirectional, whereas, ≠ presents no relationship.

the inverted N-shaped and M-shaped models to describe the relationship, while developing countries refer to the inverted U-shaped and monotonically aggregate models. Narayan et al. (2016) examined the dynamic relationship between economic growth and carbon emissions for 181 countries. The outcomes

of the study suggest that 12% of the countries support EKC hypothesis. Another important inference of this study is that 49 out of 181 countries (around 27%) show that the income growth will decrease carbon emissions in the future.

Zhu et al. (2016) examined the impact of foreign direct investment and economic growth on carbon emissions in five ASEAN

countries; Indonesia, Malaysia, Philippines, Singapore and Thailand. By employing 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 foreign direct investment on carbon emissions is negative. For the high-emissions countries, greater economic growth and population size seems to decrease emissions. The results of the research also validate the halo effect hypothesis for higher-emissions countries. On contrary, energy consumption escalates carbon emissions. [Jardón et al. \(2017\)](#) assessed the empirical relationship between carbon emissions and economic growth for 20 Latin American and Caribbean countries, over the period of 1971–2011. According to the results of Environmental Kuznets Curve (EKC) hypothesis, there exists an inverse U-shape relationship among the economic growth and carbon emission in the long run.

2.2. Economic growth and energy consumption

2.2.1. 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. [Wolde-Rufael \(2004\)](#) used Toda and Yamamoto causality test and confirmed a unidirectional relationship from energy consumption to economic growth, in case of Shanghai. [Ang \(2008\)](#) focused on assessing the relationship between energy consumption and economic growth in Malaysia during the period 1971–1999. The co-integrating analysis have presented that pollution and energy use are significantly positively related to economic growth in the long-run. A significant causality running from economic growth to energy consumption, both in the short-run and long-run. [Jobert and Karanfil \(2007\)](#) mentioned that there is no causality between energy consumption and economic growth in Turkey. Similar findings have confirmed by [Karanfil \(2008\)](#), [Soytas and Sari \(2009\)](#) and [Halicioglu \(2009\)](#) in Turkey and [Payne \(2009\)](#) in case of USA. [Erdal et al. \(2008\)](#) reported bidirectional relationship between economic growth and energy consumption in Turkey. In Tunisia, [Belloumi \(2009\)](#) confirmed bidirectional relationship between energy consumption and economic growth, in long run analysis. [Zhang and Cheng \(2009\)](#) studied China and confirmed unidirectional relationship from economic growth to energy consumption.

[Alshehry and Belloumi \(2015\)](#) assessed the dynamic causal relationships between energy consumption and economic growth in Saudi Arabia. By using the Johansen multivariate co-integration approach, the findings have indicated that in the long-run there exists a relationship energy consumption and economic growth. The unidirectional causality runs from energy consumption to economic growth and carbon emissions, bidirectional causality runs among the carbon emissions and economic growth. In the short-term, there is a unidirectional causality that runs from carbon emissions to energy consumption and economic growth. [Long et al. \(2015\)](#) examined the relationship between economic growth and energy consumption, in case of China from 1952 to 2012. Estimations have indicated that coal has dominant effect on economic growth and bidirectional causality runs from economic growth to carbon emission, gas consumption, coal consumption and electricity consumption.

[Mirza and 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 have analyzed by Johansen-Julius co-integration, ARDL and VECM test. The findings have verified bidirectional causalities between energy consumption, economic growth and carbon emissions, both in the short run as well as

long run. [Jebli and Youssef \(2017\)](#) analyzed the economy-energy relationship in Tunisia from 1980–2011. The vector error correction model (VECM), Johansen-Juselius test and Granger causality tests were employed to examine the short and long-run relationships between carbon emissions, economic growth, renewable energy consumption, non-renewable energy consumption, trade openness ratio and the agricultural value added. According to the short-run, bidirectional causalities exist between agricultural value added and carbon emission, and between agricultural value added and the trade openness. Unidirectional causalities running from non-renewable energy and economic growth to agricultural value added and to renewable energy.

2.2.2. Multi country studies

The studies on economic growth and energy consumption relationship (multi-country) are enlisted in [Table 4](#). [Lee \(2005\)](#) used panel VECM to examine the relationship between energy consumption and economic growth by using the data of 18 developing countries. The empirical estimations have confirmed a unidirectional relationship from energy consumption to economic growth. Later, [Narayan and Smyth \(2008\)](#) and [Apergis and Payne \(2009\)](#) have confirmed unidirectional causality from energy consumption to economic growth, in G-7 countries and 6 countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama) respectively.

[Wolde-Rufael \(2006\)](#) analyzed 17 African economies by using Toda–Yamamoto test; the results have confirmed unidirectional causality from economic growth to energy consumption in Algeria, Congo DR, Egypt, Ghana, Ivory Coast. Whereas, a unidirectional causality run from energy consumption to economic growth in Cameroon, Morocco, Nigeria. Gabon and Zambia have reported bidirectional causality. While, there is no causality in Benin, Congo RP, Kenya, Senegal, South Africa, Sudan, Togo, Tunisia, Zimbabwe. Similarly, mix findings have reported by forthcoming researchers (e.g. [Lee, 2006](#); [Soytas and Sari, 2006](#); [Francis et al., 2007](#); [Mahadevan and Asafu-Adjaye, 2007](#); [Akinlo, 2008](#); [Chiou-Wei et al., 2008](#); [Lee and Chang, 2008](#); [Sahbaz et al. \(2017\)](#); [Sarwar et al., 2017](#)).

[Kais and Sami \(2015\)](#) used the data of 58 countries from 1992 to 2012 to examine the nexus among economic growth, energy consumption and carbon emission. The findings revealed a significant positive impact of carbon emissions on energy consumption. The study also demonstrated that economic growth has a positive influence on energy consumption. [Esso and 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 Sub-Saharan African countries over the time period of 1971–2010. In the long-run, the empirical results revealed that energy consumption and economic growth are linked, whereas, energy consumption and economic growth causes carbon dioxide in most of the Sub-Saharan African countries. In the short-run, the granger causality tests indicated that economic growth causes carbon emissions and bidirectional causality exists between economic growth and carbon emissions.

[Antonakakis et al. \(2017\)](#) investigated the causal relationships among output-energy-environment nexus by employing panel vector auto regression 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.

Table 3

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

Author	Time	Countries	Methodology	Relationship
Ghosh (2002)	1950–1997	India	Granger causality	EG → EC
Hondroyannis et al. (2002)	1960–1996	Greece	ECM	EG ↔ EC
Oh and Lee (2004)	1970–1999	South Korea	VECM	EG ↔ EC
Altinay and Karagol (2004)	1950–2000	Turkey	Granger causality	EG ≠ EC
Ghali and El-Sakka (2004)	1961–1997	Canada	Granger causality	EG ≠ EC
Jumbe (2004)	1970–1999	Malawi	Granger causality–ECM.	EG ↔ EC
Paul and Bhattacharya (2004)	1950–1996	India	ECM	EG ← EC
Shiu and Lam (2004)	1971–2000	China	ECM	EG → EC
Wolde-Rufael (2004)	1952–1999	Shanghai	Granger causality	EG ← EC
Lee and Chang (2005)	1954–2003	Taiwan	Granger Causality–VECM	EG ← EC
Narayan and Smyth (2005)	1966–1999	Australia	Granger causality	EG → EC
Yoo (2005)	1970–2002	South Korea	VECM	EG ↔ EC
Yoo and Kim (2006)	1971–2002	Indonesia	Granger causality	EG → EC
Ang (2007)	1960–2000	France	VECM	EG ← EC
Ang (2008)	1971–1999	Malaysia	VEC model	EG → EC
Erdal et al. (2008)	1970–2006	Turkey	Pair-wise causality	EG ↔ EC
Halicioglu (2009)	1960–2005	Turkey	Granger causality	EG ↔ EC
Bowden and Payne (2009)	1949–2006	USA	Toda–Yamamoto test	EG ← EC
Halicioglu (2009)	1960–2005	Turkey	ARDL	EG ≠ EC
Payne (2009)	1949–2006	USA	Toda–Yamamoto test	EG ≠ EC
Soytas and Sari (2009)	1960–2000	Turkey	Toda–Yamamoto test	EG ≠ EC
Shahbaz et al. (2013)	1971–2011	China	ARDL bounds test	EG ← EC
Alshehry and Belloumi (2015)	1971–2010	Saudi Arabia	Johansen cointegration	EG ↔ EC
Long et al. (2015)	1952–2012	China	Co-integration analysis	EG → EC
Shahbaz et al. (2016)	1970–2012	Australia	VECM	EG ↔ EC
Wang et al. (2016)	1990–2012	China	Granger causality	EG ↔ EC
Mirza and Kanwal (2017)	1971–2009	Pakistan	ARDL–VECM	EG ↔ EC
Jebli and Youssef (2017)	1980–2011	Tunisia	VECM	EG ↔ EC
Riti et al. (2017)	1970–2015	China	ARDL–VECM	EG ← EC
Shabestari (2018)	1970–2016	Sweden	ARDL–VECM	EG ↔ EC
Bekun et al. (2019)	1960–2016	South Africa	Pesaran et al. (2001) bounds test	EG ← EC

Note: ←, → represents unidirectional, ↔ is bidirectional, whereas, ≠ presents no relationship.

Le and Quah (2018) investigated the causal relationships between carbon emissions, energy consumption, and economic growth for 14 Asian countries for the time period 1984–2012. According to the results, there exists a long-run relationship between carbon emissions, energy consumption, and economic growth. The findings of full panel as well as the sub-panel of lower-to-upper-middle-income countries have confirmed the existence of Environmental Kuznets Curve (EKC) hypothesis. On contrary, the panel of high income countries have rejected 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. Pao and Chen (2019) conducted a study to assess the causal relationship among economic growth, energy consumption and carbon emissions, for the developed economies i.e. group of twenty (G20). The panel co-integration test results revealed that there is a long-run balanced relationship between carbon emissions, economic growth and various types of energy consumption (i.e. renewable, hydropower and nuclear). The study confirmed the feedback hypothesis amid economic growth and clean energy consumption.

2.3. Energy consumption and carbon emission

2.3.1. Single country studies

Table 5 highlights the studies on energy consumption and carbon emissions relationship for single-country analysis. Soyatas 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 labor and gross fixed capital. According to this study there exist no causality between economic growth and carbon emissions in the long run, but significant causal relationship exists between carbon emissions and energy consumption. The findings have confirmed the

unidirectional relationship from energy consumption to carbon emission. Ang (2007) has examined the dynamic causal relationship between emission and energy consumption for France, over the time period 1960–2000. The results indicated a unidirectional causality running from energy consumption to economic growth in the short run. In case of Turkey, Halicioglu (2009) found long-run relationships between the energy consumption and carbon emission. Zhang and Cheng (2009) reported the similar finding in case of China. Later, in a study of China, Wang et al. (2011) testified bidirectional relationship between energy consumption and carbon emission.

Begum et al. (2015) investigated the dynamic impacts of energy consumption on carbon emissions in Malaysia for the time period 1970–1980. The results rejected the EKC hypothesis and mentioned a long term positive relationship of energy consumption with carbon emissions. In a study of Pakistan, Javid and Sharif (2016) have confirmed bidirectional relationship between energy consumption and carbon emission. Ahmad et al. (2016) found bidirectional association between energy consumption and carbon emission, in case of India. Whereas, in Pakistan, Waheed et al. (2018) examined the impact of renewable energy consumption on carbon emission and confirmed significant negative impact of energy on carbon emission, mentioning that higher renewable energy consumption leads to decrease the carbon emission.

Mirza and Kanwal (2017) estimated the data of Pakistan from 1971 to 2009 and mentioned a unidirectional relationship from energy consumption to carbon emission, reporting that higher energy consumption in Pakistan, leads to increase the carbon emission. In Iran, Ahmad et al. (2017) failed to confirm causal association between energy consumption and carbon emission. Hao and Huang (2018) assessed the impact of the energy consumption on carbon emission and demonstrated that a significant relationship exists between studied variables. For China, Yu and Kong (2017) suggested that carbon emission is directly related to

Table 4

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

Author	Time	Countries	Methodology	Relationship
Soytas and Sari (2003)	1950–1992	G-7 countries	VECM methodology.	EG → EC, EG ↔ EC
Fatai et al. (2004)	1960–1999	6 countries	Granger and Toda–Yamamoto procedure.	EG ← EC, EG ↔ EC
Lee (2005)	1975–2001	18 developing countries	Panel VECM methodology.	EG ← EC
Wolde-Rufael (2005)	1971–2001	19 African countries	Toda–Yamamoto procedure.	EG ↔ EC, EG → EC, EG ≠ EC
Al-Iriani (2006)	1970–2002	6 countries of GCC	Panel co-integration, GMM.	EG → EC
Lee (2006)	1947–1974	11 major industrialized countries	Toda–Yamamoto procedure.	EG ↔ EC, EG → EC, EG ≠ EC
Wolde-Rufael (2006)	1971–2001	17 African countries	Toda Yamamoto procedure.	EG ↔ EC, EG → EC, EG ← EC
Yoo (2006)	1971–2002	4 countries	Standard Granger causality test and VECM methodology.	EG → EC, EG ← EC
Chen et al. (2007)	1971–2001	10 Asian countries	VECM methodology.	EG → EC, EG ← EC
Francis et al. (2007)	1971–2002	Haiti, Jamaica, Trinidad and Tobago	BVAR models, cointegration technique	EG ↔ EC, EG ≠ EC
Mahadevan and Asafu-Adjaye (2007)	1971–2002	20 energy importers and exporters	Panel ECM methodology.	developing countries: EG ← EC developed countries: EG ↔ EC
Mehra (2007)	1971–2002	11 Oil Exporting countries	Panel cointegration technique.	EG → EC
Squalli (2007)	1980–2003	11 OPEC countries	Toda–Yamamoto procedure.	EG ← EC, EG ↔ EC
Akinlo (2008)	1980–2003	11 Sub Sahara African countries	ARDL bounds testing approach.	EG ↔ EC, EG → EC, EG ≠ EC
Huang et al. (2008)	1972–2002	82 countries	GMM system.	EG → EC
Chiou-Wei et al. (2008)	1954–2006	8 countries	VAR.	EG → EC, EG ← EC
Lee and Chang (2008)	1971–2002	16 Asian countries	Panel Co-integration	long run: EG ← EC Short run: EG ≠ EC
Narayan and Smyth (2008)	1972–2002	G-7 countries	Panel Co-integration	EG ← EC
Apergis and Payne (2009)	1971–2004	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama	VECM	Short run: EG ↔ EC
Lean and Smyth (2014)	1980–2006	5 (Asian countries)	Granger Causality	EG ← EC
Omri (2013)	1990–2011	14 (MENA)	GMM	EG ↔ EC
Kais and Sami (2015)	1990–2012	58	GMM	EG → EC
Kasman and Duman (2015)	1992–2010	New EU member	Panel cointegration	EG ↔ EC
Esso and Kehoe (2016)	1971–2010	12 Sub-Sahara African countries	Granger causality	EG ↔ EC
Chen et al. (2016)	1993–2010	188	VECM	EG → EC
Saidi and Mbarek (2016)	1990–2018	9 (developed countries)	Dynamic Panel	EG ≠ EC
Shahbaz et al. (2017)	1960–2014	157	Pooled mean group	Mix evidences
Sarwar et al. (2017)	1960–2014	210	FMOLS–DOLS	Mix evidences
Antonakakis et al. (2017)	1971–2011	106	PVAR	EG ↔ EC
Obradović and Lojanica (2017)	1980–2010	South Eastern Europe	VECM	Short run EG ← EC
Bekhet et al. (2017)	1990–2011	GCC countries	VECM	EG ↔ EC
Rahman (2017)	1960–2014	11 Asian populous countries	FMOLS–DOLS	EG ← EC
Le and Quah (2018)	1984–2012	14	Panel Co-integration–OLS	EG ← EC
Cai et al. (2018)	1965–2015	G7	ARDL	EG ← EC
Kahouli (2019)	1990–2015	OECD countries	Pooled OLS–GLS–GMM	EG ↔ EC
Maji and Sulaiman (2019)	1995–2014	15 West African countries	DOLS	EG ← EC

Note: ←, → represents unidirectional, ↔ is bidirectional, whereas, ≠ presents no relationship.

Table 5

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

Author	Time	Countries	Methodology	Relationship
Soytas et al. (2007)	1960–2004	USA	Granger	EC → CO
Ang (2007)	1960–2000	France	VECM	EC → CO
Ang (2008)	1971–1999	Malaysia	Co-integration analysis	EC ← CO
Hwang and Yoo (2014)	1965–2006	Indonesia	Granger causality test	EC ↔ CO
Begum et al. (2015)	1970–2009	Malaysia	ARDL–DOLS	EC → CO
Alshehry and Belloumi (2015)	1971–2010	Saudi Arabia	Johansen multivariate cointegration	EC ↔ CO
Long et al. (2015)	1952–2012	China	Co-integration analysis	EC ↔ CO
Zhang and Da (2015)	1996–2010	China	LMCI	EC → CO
Joo et al. (2015)	1965–2010	Chile	Granger causality test	EC ← CO
Ahmad et al. (2016)	1971–2014	India	ARDL–VECM	EC ↔ CO
Wang et al. (2016)	1990–2012	China	Granger causality	EC → CO
Shahbaz et al. (2016)	1970–2012	Australia	VECM	EC → CO
Javid and Sharif (2016)	1972–2013	Pakistan	Cointegration	EC ↔ CO
Mirza and Kanwal (2017)	1971–2009	Pakistan	ARDL–VECM	EC → CO
Jebli and Youssef (2017)	1980–2011	Tunisia	VECM	EC ↔ CO
Riti et al. (2017)	1970–2015	China	ARDL–VECM	EC → CO
Dong et al. (2018)	1965–2016	China	ARDL–VECM	EC → CO
Shabestari (2018)	1970–2016	Sweden	VECM–Granger causality test	EC ↔ CO

Note: ←, → represents unidirectional, ↔ is bidirectional, whereas, ≠ presents no relationship.

the energy consumption, however, the optimal use of energy assists to control the carbon emission. Shabestari (2018) conducted a study in order to investigate the causal relationship between carbon emissions and energy consumption in Sweden from 1970–2016. The results indicated that in the long-run, bidirectional

granger causality relationship exists between energy consumption and carbon emissions. Recently, Sarwar et al. (2019) have investigated the relationship between energy consumption and economic growth, in case of China. The findings have confirmed positive association between energy consumption, oil and coal, and carbon emission.

2.3.2. Multi country studies

The studies on energy consumption and carbon emissions relationship (multi-country) are enlisted in Table 6. Apergis and Payne (2009) used panel VECM causality test and reported unidirectional causality from energy consumption to carbon emission, in a study of 6 central American countries. Acaravci and Ozturk (2010) used the dataset of 19 European countries over the period 1960–2005 and mentioned mix evidences. Similarly, Al-mulali et al. (2013) used Canonical Cointegration Regression (CCR) to analyze the association among economic growth, energy consumption and carbon emission, by using the data of Latin America and Caribbean countries. The findings have suggested that 60% of the selected countries have positive nexus among economic growth, energy consumption and carbon emission, while, remaining have confirmed mix evidences. Pao and Tsai (2011) studied China, India, Russia and Brazil to investigate the causality among economic growth, energy consumption and carbon emission and confirmed unidirectional causality from energy consumption to carbon emission. Likewise, Omri (2013) analyzed 14 MENA countries and confirmed unidirectional relationship from energy consumption to carbon emission.

Alom (2014) carried out a similar research by utilizing the panel co-integration causality test to examine the relationship between economic growth, carbon 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 exist causal relationships between energy consumption and carbon emissions and also between the carbon emissions and economic growth, in the short term. On contrary, in the long run, no causality exists between the carbon emission and the energy consumption. 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 have applied and showed the existence of long-run relationships among economic growth, energy consumption and carbon dioxide emissions. Unidirectional causality has observed from energy consumption to carbon dioxide emissions for both developing and developed countries.

Dogan and Aslan (2017) confirmed bidirectional causality between energy consumption and carbon emission, in European countries. Bekhet et al. (2017) used the data of GCC countries and found mix evidences of energy consumption and carbon emission. Cai et al. (2018) examined the energy-economy-emissions nexus for the G-7 countries. The bootstrap ARDL bounds test with structural breaks have applied to examine the causality. According to the results of the study, no co-integration found among the economic growth, energy consumption and carbon emissions in France, USA, Italy, UK and Canada. Whereas, in Germany and Japan, co-integration was found between economic growth and carbon emission. Concerning the results of causality test, unidirectional causality run from clean energy consumption to economic growth for USA Canada, and Germany and from carbon emissions to clean energy consumption for Germany. Moreover, a bidirectional relationship between energy consumption and carbon emissions for Germany, and unidirectional causality runs from clean energy consumption to carbon emissions for the USA. Acheampong (2018) examined the association between energy consumption, economic growth and carbon emission for 116 countries. The outcomes have reported mix evidences; the relationship varies from region to region. Anwar et al. (2019) have analyzed the relationship between carbon emission and nuclear energy consumption for low-income, low-middle income, middle income and high income countries. According to findings, there is a bidirectional causality between nuclear energy consumption and carbon emission.

3. Concluding remarks

Greenhouse gases have adverse impacts on environment, human life etc. however, it is important to study about the main causes of emission and find some solutions to eradicate this critical issue. Furthermore, carbon emission is one of the major emitter in total greenhouse gasses, for this reason, our main focus is to study the carbon emission. Since last few decades, extensive energy consumption has play an important role in economic growth, transportation, improving the social conditions etc. On other side, the rise in energy consumption and rapid economic expansion have known as the major sources of carbon emission. Though, a large number of studies have examined the relationship among economic growth, energy consumption and carbon emission, by using single country analysis, multiple country analysis, on different time periods, several econometric estimations etc. Regarding numerous studies, the findings are inconclusive that mentioned mix evidences regarding the existence and direction. The aim of current study is to concise the previous literature and draw fruitful conclusion that helps in economic, energy and environmental policy making. Nevertheless, the findings of earlier studies have failed to draw effective solution and this issue still needs to explore in forthcoming researches.

The current study aims to assess the earlier literature available on the economic growth, energy consumption and carbon emissions nexus. Earlier studies of single country and multi country analysis have investigated for this literature survey. The causality relationship studies have categorized within six major categories on the basis of variables and countries 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).

In regard of economic growth and carbon emission nexus, most of the studies have confirmed a unidirectional relationship from economic growth to carbon emission; mentioning that higher economic growth leads to increase the carbon emission. Secondly, bidirectional relationship has also reported; suggesting that the increase (or decrease) in economic growth cause to increase (or decrease) the carbon emission. Notably, our results propose that carbon emission generates externalities that effects human health which resultantly lower their performances; hence the lower performance have direct impact on economic growth (Coondoo and Dinda, 2002; Yu and Kong, 2017; Farooq et al., 2019; Mardani et al., 2019). Accordingly, the results allow us to draw new and innovative findings concerning carbon emission and economic growth. The paper concludes that economic growth might affect the carbon emission of countries, but its magnitude may be different for different levels of economy e.g. developing, developed and transition economies etc. However, the developing countries requires high energy to meet industrial, urbanization and transportation needs, consequently it affects the carbon level. Most of these developing countries are using cheap source of energy generation, instead of renewable sources, as in start of developing phase the main objective of the country is to maintain and boost the economic development. For this reason, they have to forget the environmental consequences for the time being. Our findings are in consistent with the Environmental Kuznets Curve hypothesis, which is also supported for the case of several developing countries (Ahmad et al., 2016). The literature for developed countries, such as Saidi and Mbarek (2016) for nine developed countries, Cai et al. (2018) related to G7 economies, have concluded that the economic growth of developed economies

Table 6

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

Author	Time	Countries	Methodology	Relationship
Lean and Smyth (2014)	1980–2006	5 (Asian countries)	EKC	EC \leftarrow CO
Arouri et al. (2012)	1981–2005	12 (MENA)	Panel test	EC \rightarrow CO
Omri (2013)	1990–2011	14 (MENA)	GMM	EC \rightarrow CO
Tiwari et al. (2013)	1995–2005	25 OECD countries	Panel VAR model	EC \leftarrow CO
Saidi and Hammami (2015)	1990–2012	58	GMM	EC \leftarrow CO
Kasman and Duman (2015)	1992–2010	New EU member	Panel cointegration	EC \leftrightarrow CO
Kais and Sami (2016)	1990–2012	58	Panel data model	EC \leftarrow CO
Esso and Keho (2016)	1971–2010	12 Sub-Sahara African countries	Granger causality	EC \rightarrow CO
Chen et al. (2016)	1993–2010	188	VECM	EC \rightarrow CO
Antonakakis et al. (2017)	1971–2011	106	PVAR	EC \rightarrow CO
Bekhet et al. (2017)	1990–2011	GCC countries	VECM	EC \leftrightarrow CO
Wolde-Rufael and Idowu (2017)	1971–2010	China–India	ARDL	EC \leftrightarrow CO
Oganesyan (2017)	1980–2013	BRICS	Panel Co-integration	EC \leftarrow CO
Obradović and Lojanica (2017)	1980–2010	South Eastern Europe	VECM	EC \leftarrow CO
Rahman (2017)	1960–2014	11 Asian populous countries	FMOLS–DOLS	EC \rightarrow CO
Le and Quah (2018)	1984–2012	14	Panel Co-integration	EC \rightarrow CO
Cai et al. (2018)	1965–2015	G7	ARDL	Germany: EC \leftrightarrow CO US: EC \rightarrow CO

Note: \leftarrow , \rightarrow represents unidirectional, \leftrightarrow is bidirectional, whereas, \neq presents no relationship.

does not affect the carbon emission, which might due to active measures and policies of developed countries on climate change and environmental degradation such as; climate change policies of 2016 and climate action summit 2019 (European Environment Agency, 2016; United Nations, 2019).

Considering the relationship between energy consumption and economic growth, mostly studies have reported bidirectional relationship between energy consumption and economic growth; proposing that higher energy consumption (economic growth) boosts the economic growth (energy consumption), in selected studies. The findings refer that energy is one of the main ingredients of economic growth and without energy it seems to be difficult to attain economic objectives. For the countries having leading economic growth, such as China, India, Malaysia etc., previous studies have reported a unidirectional relationship from economic growth to energy consumption, which states that higher economic growth leads to increase the electricity consumption. Resultantly, this energy generation is further utilized for industrial processing, agricultural purposes which further boost the economy, as documented by Ghosh (2002), Shiu and Lam (2004), Yoo and Kim (2006) and Ang (2008). In case of developed countries, the findings vary across studies, despite of this, it is not hard to conclude that there is no significant relationship between economic growth and energy consumption, as reported by Ghali and El-Sakka (2004) for Canada, Payne (2009) for USA, Saidi and Mbarek (2016) for nine developed countries. The core reason for this insignificance between energy consumption and economic growth is multifold: (i) during high phase of development, the countries find alternate measures of energy consumption to fulfill daily needs. (ii) The development and utilization of advanced energy saving and green technologies for household, farming, industrialization and transportation purposes which decreases the dependence of economic growth on energy consumption. Gozgor et al. (2018) reported that economic complexity and energy consumption helps to strengthen the economic growth in Organization for Economic Co-operation and Development (OECD) countries. On the basis of these findings, we propose that developed, developing and transition countries should do efforts to find alternative sources of energy e.g. renewable, solar, nuclear etc., which may help to achieve long term economic objective and help to reduce the dependence of economic growth on energy sources.

For energy consumption and carbon emission nexus, earlier empirical evidences, for developing and developed countries, have mentioned that energy consumption is main source of carbon emission, while less evidences have reported the vise-versa.

The reasons for unidirectional causality from energy consumption to carbon emission are given as: (i) higher dependence of non-renewable energy in total energy mix; (ii) use of oil for transport purposes etc. (iii) high consumption of energy for industrialization, urbanization and farming. This means that current energy consumption policies are harmful for environmental degradation. The unidirectional relationship of energy to carbon concerns the environmental policy makers, which allow us to conclude that there is need of global awareness on the use of renewable and cleaner energy sources.

Focusing the findings of economic growth, energy consumption and carbon emission, it is clearly stated that higher energy consumption helps to boost the economic growth but at the cost of environmental degradation. However, the given study provides some policy implications which address the government and industries to take necessary actions, such as, (i) the government and industries have to replace the non-renewable energy sources with renewable sources into energy mix and industrial processing, respectively. Recently, most of the developing countries are relying on coal and oil for electricity generation (e.g. China, India, Pakistan etc.); (ii) government have to impose carbon tax on industries that force them to install carbon treatment plants. These type of taxes have been imposed earlier by number of countries which reported fruitful results. (iii) Industries have to replace the traditional technologies with the latest, energy efficient and environmental friendly technologies. By doing so, there is a significant reduction in energy consumption which tend to reduce the cost of production, improve the productivity and helps to maintain green economy. By using this course of actions, the governments can achieve the economic objectives without having adverse effect on environment (Soytas et al., 2007; Waheed et al., 2018; Mardani et al., 2019).

The current study attempt to investigate the literature for last two decades in domain of economic growth, energy consumption and carbon emission, but it still has limitations that future researchers can address to draw more reliable conclusions. Firstly, the authors have to divide the literature in underdeveloped, developing and developed countries, which make it easy to discuss the nexus of variables across these categories. Secondly, future studies have to form an appropriate analyzing methods that defines the way to report the decision. Earlier studies have used large number indicators related to this topic, such as, energy efficiency, energy intensity, renewable energy etc., however, this study addresses few of the factors that have direct impact with economic growth and carbon emission.

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