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COAL CONSUMPTION AND ECONOMIC GROWTH: THE CAUSALITY PUZZLE. REVIEW OF INTERNATIONAL LITERATURE

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Abstract

The purpose of this paper is to review the existing literature on the relationship between coal consumption and economic growth, highlighting both the theoretical framework and the empirical evidence. The direction of causality between coal consumption and economic growth has been found to vary from one country to the next, depending on the dataset and the methodology employed by the researcher. However, there is overwhelming support for a bidirectional relationship between coal consumption and economic growth. This paper is different from other reviews, in that it critically evaluates the impact of coal consumption on economic growth, as well as the causal relationship between these two variables. The paper concludes that the causal relationship between coal consumption and economic growth is ambiguous.

Keywords: Coal Consumption, Economic Growth, Causality

JEL Classification: Q43; C23; O16

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1. Introduction

Coal has been a significant source of energy in augmenting economic growth in most developed and developing economies regardless of the direction of causality. Coal production is essential and competitive due to the volatility in prices of other energy sources such as natural gas and petroleum. A better understanding of the link between coal consumption and economic growth can help untangle questions on the direction of causality between the two variables and their policy implications.

Despite the vital role that coal plays as a major source of energy in a number of countries, it is currently becoming unpopular because of the ongoing global warming debate and the Kyoto Protocol[2]. This means that coal extraction and exploitation might decrease in the near future; as countries strive to meet the targets of the Kyoto protocol. This will give rise to a more efficient energy use, which can lead to a higher level of economic growth. According to the International Energy Agency (IEA) in 2016, the world's largest coal-consuming countries in the world are: China; the United states of America (USA); India; Canada; Germany; and Japan. China as the world's biggest producer, consumer and importer of coal is transiting away from coal to other renewable-energy sources, like solar energy. Russia and the USA have made a commitment to diversify their energy sources. In the climate change debate, energy is viewed as the problem; but in reality, affordable energy provides a solution to climate change; because it sustains the economic growth necessary to drive technology change and environmental protection.

[2] **The Kyoto Protocol** is the United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty agreed at the Rio de Janeiro "Earth Summit" in 1992. It operates on a climate-justice principle that industrialized countries should take the initial responsibility for the mitigation and reduction of greenhouse-gas emissions.

There have been four main strands in the literature that focused on the relationship between coal consumption and economic growth. The first school of thought concentrated on the unidirectional relationship between coal consumption and economic growth, from economic growth to coal consumption and vice versa. It asserts that economic growth may be predominantly determined by the causality between the two variables (Kraft & Kraft, 1978; Akarca & Long, 1979, 1980; Yang, 2000a; Wolde-Rafael, 2009; Narayan & Smyth, 2008; Yang, 2009; Liu et al, 2009; Wolde Rafael, 2004; Zahid, 2008; Ewing et al, 2007; Odhiambo, 2016). The second group consists of studies that examined the bidirectional relationship between energy consumption (coal consumption) and economic growth (Masih & Masih, 1997; Ang, 2008; Apergis & Payne, 2009a; Apergis & Payne, 2009b; Halicioglu, 2009; Wang & Yang, 2015; Yang, 2000b; Yoo, 2006; Belloumi, 2009). The third group of studies asserts that there is no causality between coal consumption and economic growth (Yu & Choi, 1985; Yu & Hwang, 1984; Sari & Soytas, 2004; Ocal et al, 2013; Lei & Pan, 2014; Payne, 2009; Ziramba, 2009).

The objective of this study is therefore to review the existing literature on the relationship between coal consumption and economic growth, highlighting both the theoretical framework and empirical evidence. The review is different from other reviews in that it critically evaluates the causal relationship between coal consumption on economic growth and its policy implications; the study found inconclusive evidence regarding the effect of coal emission on economic growth. The direction of causality between coal consumption and economic growth varies from one country to another depending on the data set, different time periods, different econometric methods employed, omitted variables, and biasness by the researcher. The paper is divided into three sections. Section 1 gives an introduction; section 2 reviews the empirical literature on the causal relationship between coal consumption and economic growth, and the conclusion is presented in section 3.

2. Coal consumption and economic growth: an empirical literature

There are four main hypotheses that examined the relationship between energy consumption and economic growth. The first hypothesis is the growth hypothesis, which asserts that there is a unidirectional causality between coal consumption and economic growth. Coal consumption plays a critical role in augmenting economic growth. Therefore, policy should be made towards encouraging efficient ways of depleting energy instead of allowing environmental protection and conservative policies. The second hypothesis is called the conservative hypothesis. This suggests there is a unidirectional relationship flowing from economic growth to coal consumption. In this case, conservative policies and environmental policies can be implemented to reduce coal consumption without adversely affecting economic growth. The third one is called the neutrality hypothesis. This suggests that there is no causality or relationship between economic growth and energy emission. The final one is the feedback hypothesis, which indicates that there is a bi-directional relationship between economic growth and coal emission. Studies have also tried to determine the energy usage by different energy sources (electricity, coal, nuclear and renewable). Among others are (Apergis & Payne, 2009; Chu-Wei et al, 2016; Akinlo, 2009). The Environmental Kuznets Curve (EKC) developed mainly by Gross and Krueger (1991). Most of their results in the literature are conflicting and contradictory, probably as a result of different data or methodologies being applied.

2.1 Causal relationship between coal consumption and economic growth

The first viewpoint is that a unidirectional causal relationship exits from economic growth to energy consumption. For example, Kraft and Kraft (1978) found a unidirectional causality running from economic growth to energy consumption in the United States of America (USA) while conducting a causality test between energy consumption and gross national product (GNP). Yu and Choi (1985) had a similar result in the case of the Philippines.

In a recent study, Odhiambo (2016) provided evidence of unidirectional causality from economic growth to coal consumption in South Africa. Lei and Pan (2014) examined the coal consumption-growth nexus in China from 2000 to 2010 and found the Granger causality from real GDP to coal consumption. Jin-ke et al (2009) examined the relationship between coal consumption and economic growth across developing and developed regions from 1990 to 2007 and the results showed that there was unidirectional causation from economic growth to coal consumption in the long run in Japan and China. Yang (2009) and Wolde-Rafael (2004) also found that there is a unidirectional relationship between economic growth and coal consumption in Taiwan and Shanghai respectively.

The second viewpoint posits that there is a unidirectional causal relationship from energy consumption to economic growth. Ewing et al (2007) analysed unidirectional causality from economic growth to coal consumption in the USA using monthly data from 2001 to 2005. The paper concluded that there was a unidirectional relationship from coal consumption to other variables. Sari et al (2008) analysed the relationship between coal consumption and economic development based on the ARDL Bound approach using a monthly series of data from the USA from 2001 to 2005. They determined that there was a unidirectional causality from energy consumption to gross domestic product. Odhiambo (2009a) found that there is a clear-cut unidirectional causal flow from energy consumption to economic growth in Tanzania, both in the short term and the long term.

Zahid (2008) examined the case of Pakistan, covering the period between 1973 and 2003, employing VECM and Granger causality tests. The result showed there was a unidirectional causality running from total energy consumption to gross domestic product (GDP). Wolde-Rafael (2010) investigated the dynamic relationship between coal consumption and economic growth in India and Japan from 1965 to 2005 and found strong evidence of a unidirectional relationship both in the short term and the long term.

The third indicates that a bidirectional causality exits between the two variables. Masih and Masih (1997) found a bidirectional relationship between energy consumption and economic growth in Korea and Taiwan. Bhattachrya (2004) found a similar result in India, while Odhiambo (2009b) investigated the causal relationship between electricity consumption and economic growth in South Africa, and also found a similar result.

Belloumi (2009) examined the causal relationship between coal consumption and economic growth in Tunisia between 1971 and 2004. Evidence shows that there was a bidirectional relationship between coal consumption and economic growth using a Vector error correction model. Lei and Pan (2014) also investigated the causal relationship between coal consumption and economic growth in the six biggest coal consumption countries (China, USA, India, Germany, Russia and Japan), using panel cointegration and Granger causality tests. Their result shows that there is a bidirectional relationship between coal consumption and economic growth in Germany, Russia and Japan.

Yoo (2006) and Yang's (2000a) results also show that there is a bidirectional relationship between coal consumption and economic growth in Korea and Taiwan respectively. Apergis and Payne (2010a) studied the relationship between coal consumption and economic growth in 25 OECD countries using a panel vector error correction model between 1980 and 2005. The finding revealed that there is bidirectional causality between coal consumption and economic growth. In another article, Apergis and Payne (2010b) examined the relationship between coal consumption and economic growth in 15 emerging economics using a panel cointegration model between 1980 and 2006. Their result also revealed that there is bidirectional causality between coal consumption and economic growth. Li and Leung (2012), using a panel cointegration test between 1985 and 2008, found that there is a bidirectional relationship between coal consumption and economic growth in the coastal and central parts of China.

In a recent study, Govindaraju and Tang (2013) examined the relationship between coal consumption and economic growth in China and India between 1965 and 2009. Their result shows a bidirectional relationship between coal consumption and economic growth in China. In a similar case, Yuan et al (2008) found the same result for China between 1963 and 2005. Shahbaz and Dube (2012) examined the causal relationship between coal consumption and economic growth in Pakistan between 1972 and 2009. Evidence shows that there is a directional relationship between coal consumption and economic growth using a Vector error correction model.

The fourth school of thought suggests no causality between the two variables. Sari and Soytas (2004) analysed the causal relationship between coal consumption and economic growth in Turkey between 1960 and 1999. Evidence shows no causality between coal consumption and economic growth using a Variance decomposition model and Granger causality tests. Payne (2009) applied the Granger causality technique on 1946 to 2006 data for the USA to examine causality between coal consumption and economic growth. Evidence shows that there is no relationship between coal consumption and economic growth.

Ocal et al (2013) investigated the causal relationship between coal consumption and economic growth in Turkey between 1980 and 2006, using a multivariate system and an asymmetric causality test. Their study found no causality between coal consumption and economic growth. Lei and Pan (2014) investigated the causal relationship between coal consumption and economic growth in India and the USA between 2000 and 2010. Their result shows no causality between coal consumption and economic growth. Ziramba (2009) applied the ARDL Bound test and Granger causality test to examine the relationship between the coal consumption and economic growth in South Africa. Their result shows no causality between the two variables. Table 1 gives a summary of the causality between coal consumption and economic growth from previous studies.

2.2 Causal relationships between coal consumption, energy consumption and economic growth

Proponents and energy scholars have linked economic growth and energy consumption. Following the seminal study of Kraft and Kraft (1978), many empirical studies have evaluated this relationship employing Granger causality, the cointegration model Bound test and VEC. The bivariate model is criticized in many studies for the problem of having omitted variables bias. Stern (1993), in a considerable number of studies, has tested the causal relationship between the energy consumption, carbon emission and economic output in a multivariate context. Zhang and Cheng (2009) examined the causal relationship between carbon emission, energy consumption and economic growth in China between 1960 and 2007. Evidence shows that neither carbon emissions nor energy consumption leads economic growth. Wang et al (2011) re-examined the causal relationship between carbon emission, energy consumption and economic growth in China between 1995 and 2007. They assert that there is a bidirectional relationship between carbon emission and economic growth and between carbon emission and economic growth.

Lee (2005) examined the causal relationship between energy consumption and economic growth in 29 countries between 1975 and 2001. The results show that economic growth causes energy consumption per capita in most countries. Soytas et al (2007) also analysed the effect of energy consumption and growth on carbon emission in the USA, using Granger causality. Their result shows that income does not granger cause carbon emission in the USA.

Narayan and Popp (2012) investigated the long-term relationship between energy consumption and real GDP for 93 countries. They had mixed results, but most of their results show that energy consumption has a negative long-term effect on real GDP. Akinlo (2008) also got mixed results for 11 African countries where energy consumption has a significant long-term effect on real GDP. Wold-Rufael (2005) had similar results, showing a directional result between energy consumption and real GDP in 19 African countries.

Jo and Hong (2000) tested for the existence of the inverted U-shape relationship between economic growth and air pollution for the pollutants sulphur and nitrogen in Korea and found it present, using the simple ordinary least squares method. Chousa et al (2004) investigate whether the decline in environmental quality in Brazil, India, China and Russia (BRIC economies) is due to high energy consumption levels, which is a result of rapid economic growth. Through the panel data, a feasible general least squares (FGLS) procedure was employed to estimate the environmental degradation caused by the increase in energy consumption. Pooled regression analysis was used to estimate the relationship between energy consumption and growth variables. Results revealed that higher energy consumption indeed leads to CO_2 emission in the countries under consideration.

Most previous studies have shown that economic growth might lead to changes in CO_2 emissions. Wang et al (2011) insists that energy consumption and CO_2 emissions are inseparable. Therefore, it is important that most studies should investigate the relationships between the three variables in a modelling framework. Ang (2007); Belloumi (2009); Soytas and Sari (2007) and Apergis and Payne (2009) have all done a good analysis in examining the relationship between energy consumption, CO_2 emissions and economic growth. Belke et al (2011) investigated the causal relationship between carbon emission, energy consumption and economic growth in 25 OECD countries using a panel cointegration approach. The empirical finding shows a directional result between energy consumption and real GDP. Lau (2011) re-examined the case of 17 Asian countries; the result shows that economic growth granger cause energy consumption in most of the countries.

3. Relevant theoretical literature

3.1 The main-stream theory of Growth and Energy

Most theories believe the best way to understand the role of energy in economic growth is to first explore its role as a production function (Stern, 2011). The debate on energy and growth has traditionally focused on the “scarcity” of fossil fuels (coal, oil), renewable and non-renewable energy sources (Jevons, 1906; Stiglitz, 1974; Berndt and Wood, 1975; Dasgupta and Heal, 1979). The Neoclassical school of thought asserts that every society has a strict responsibility to produce and extract non-renewable resources' input. Consequently, there is a dilemma between "substitution, diminishing returns and technological change" (Smulders, 2005). Therefore, man-made inputs can be substituted for resource inputs, in order to reduce the risk of the scarcity of resources in the long run.

The exogenous technological progress and change augment the productivity of the factors of production and growth by relegating the diminishing-returns' assumption. Capital and energy are purported to be weak substitutes; and they are seen as more complementary. According to Stern, 2011, the degree of the complementarity between capital and energy depends on the country specified, the time frame, the methodology employed and the level of aggregation.

In the seventies, most theoretical focus was on the consequences of resource production to deplete the environmental quality, thereby causing pollution and toxic waste. This study looks at the nexus between economic growth and coal consumption on the environment in terms of what is called the 'Environmental-Kuznets' Curve.' Grossman and Krueger (1993) were the first economists to publish a study based on this concept, which indicated that environmental conditions deteriorate initially, according to *per capita* income increases; but it then improves as *per capita* income increases beyond a certain turning point. Their study is the most widely cited of several studies that purport to provide empirical evidence of the inverted 'U' relationship, which the well-known economist, Simon Kuznets, (1955, 1966) postulated exists between economic growth and inequality. The application of the Kuznet's Curve to the relationship between economic development and environmental pollution postulates that environmental conditions deteriorate in the early stages of development (especially with industrialization); and they improve, as countries reach the middle-income level of development. They then improve greatly as countries graduate into the higher-income bracket of development. The argument for the environmental Kuznet's curve is based on the following: in a developing industrial economy, little weight is given to environmental concerns, raising environmental-pollution by products. After attaining a certain standard of living from the industrial-production system; and when environmental pollution is at its greatest, the focus changes from self-interest to social interest. These interests give greater weight to a clean environment by reducing and reversing the environmental-pollution trend from industrialization. This is where the debate of “too poor to be clean” started – where the mainstream view maintains that the developing countries do not have the resources to ensure environmental protection and growth simultaneously.

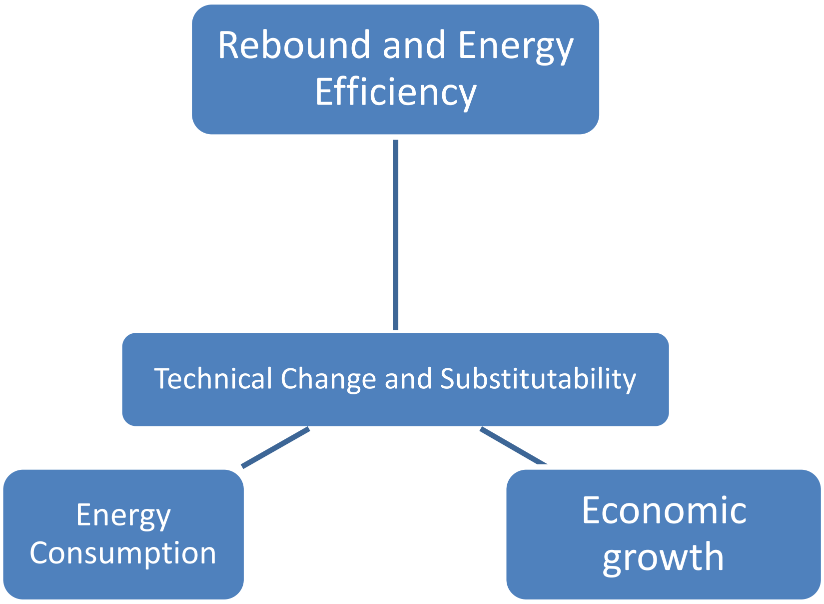
3.2 Technical Progress, Innovation and Substitutability

Without an adequate policy, technological change and innovation are likely to engender and enhance environmental degradation. Another line of thought is the “Energy Rebound[3] and Economic growth” theory, which emphasizes the relationship between changes in energy efficiency and total energy consumption in an economy. “Energy Rebound” has become a necessary condition for saving resource energy and reducing the depletion of non-renewable energy sources – by reducing the emission of fossil fuel and encouraging energy efficacy in the production process (Jevons, 1906; Brookes, 1978, 1990; Alcott, 2005; Madlener and Alcott,

[3] Rebound can be defined as the energy input per unit of output that produces additional energy consumption, enhanced by energy efficiency; but it implicitly reduces the cost of producing the output.

2009). Jevons (1906) asserted that “technological efficiency gains, and specifically the more “economical” use of coal in engines doing mechanical work, actually increases the overall consumption of coal, iron, and other resources, rather than “saving” them, as many claimed”. However, Alcott (2005) believes that efficiency gains reduce consumption and any negative environmental impact. There has been a widespread debate on the trend of energy efficiency and the consequences in many developed countries (Pearce and Turner, 1990; Kaufmann and Lee, 1991; Stern, 2011).

Figure1: Link between Energy Rebound and Economic growth



Source: Madlener, R., & Alcott, B. (2009: 371)

Today’s intriguing and propounding question is not about scarcity, or the diminishing returns of resources – especially coal reserves – but the risk of technological change and climate change. Adequate policies should be implemented to limit the production and consumption of coal, in order to avoid the perils of climate change in the future.

4. Conclusion

This paper aims to review the existing literature on the relationship between coal consumption and economic growth, highlighting both the theoretical framework and the empirical evidence. The review is different from other reviews; in that it critically evaluates the causal relationship between coal consumption and economic growth – and the policy implications. Evidence is inconclusive regarding the effect of coal consumption on economic growth and vice versa. Previous literature-survey studies failed to deliberate on these gaps. The direction of causality between coal consumption and economic growth has been found to vary from one country to the next, depending on the dataset and the methodology employed by the researcher. However, there is overwhelming support for a bidirectional relationship between coal consumption and economic growth. The study recommends that country-specific policies should be encouraged; when it comes to the relationship between coal consumption and economic growth.

Table1: Selected empirical findings on the causality between coal consumption and economic growth

STUDY	COUNTRY	YEARS COVERED	ESTIMATION METHOD	VARIABLES	CAUSALITY
Yang (2000a)	Taiwan	1954-1997	Engle-Granger	Coal consumption, Real GNP per capita	GDP→ CC
Sari and Soytas (2004)	Turkey	1960-1999	Granger Causality, VAR, Error Variance Decomposition Method	Coal consumption, Employment, Real GNP per capita	CC ≠ GDP
Wolde-Rufaei (2004)	Shanghai	1952-1999	Toda-Yamamoto Granger Causality	Coal consumption, Real GNP per capita	CC → GDP

Yang (2000b)	Taiwan	1952-1997	Engle-Granger	Coal consumption, Real GNP per capita	CC↔ GDP
Payne (2009)	United States	1946-2006	Toda-Yamamoto Granger Causality	Coal consumption, Real GDP, Real Gross Capital formation, Employment	CC≠GDP
Yoo (2006)	Korea	1968-2002	Johansen Cointegration Approach	Coal consumption, Real GNP per capita	CC↔ GDP
Zahid (2008)	Five South Asian countries (Pakistan, India, Sri-Lanka, Bangladesh and Nepal)	1980-2006	Johansen Panel Cointegration, Panel VEC, Granger Causality	Coal consumption, Real GNP per capita	CC→ GDP

Jin-ke et al (2009)	Developed and developing countries	1990-2007	Granger Causality, VEC	Coal consumption, Real GNP per capita	GDP→CC (China and Japan) GDP≠CC (South Africa and India)
Apergis and Payne (2010a)	25 OECD countries	1980-2005	Panel Vector Error Correction model	Real GDP, coal consumption, real gross fixed capital formation, and the labour force	CC↔ GDP
Apergis and Payne (2010b)	15 Emerging economies	1980-2006	Panel Cointegration	Real GDP, coal consumption, real gross fixed capital formation, and the labour force	CC↔ GDP
Lei and Pan (2014)	6 Biggest coal consumption countries (China, United States,	2000-2010	Panel Cointegration and Granger Causality	Coal consumption, Employment, Real GNP per capita	GDP→ CC (China) GDP ↔ CC (Germany, Russia and Japan)

	India, Germany, Russia and Japan)				CC ≠ GDP (USA and India)
Govindaraju and Tang (2013)	China and India	1965-2009	Granger Causality test , Cointegration test,	Coal consumption, Employment, Real GNP per capita	GDP→ CC (India) GDP ↔ CC (China)
Li and Leung (2012)	China	1985-2008	Panel Cointegration test	Coal consumption, Employment, Real GNP per capita	CC↔ GDP (coastal and central region) GDP→CC (western region)
Ocal et al (2013)	Turkey	1980-2006	Autoregressive conditional heteroskedasticity (ARCH) effects)	Real GDP, coal consumption, real gross fixed capital formation, and the labour force	CC ≠ GDP

Ziramba (2009)	South Africa	1980-2005	ARDL Bound Testing approach to Cointegration Toda Yamamoto Granger Causality	Coal consumption, Employment, Real GNP per capita	CC ≠ GDP
Odhiambo (2016)	South Africa	1980-2012	ARDL Bound Testing approach	Coal consumption, Employment, Real GNP per capita	GDP→ CC
Bertleet and Grounder (2010)	New Zealand	1960-2004	Granger Causality test, Bound test	Coal consumption, Real GNP per capita, gross fixed capital formation, and the labour force	GDP→ CC

Belloumi (2009)	Tunisia	1971-2004	Vector Error Correction Model and Granger Causality	Per capita energy consumption and per capita gross domestic product	EC↔ GDP
Shahbaz and Dube (2012)	Pakistan	1972-2009	Vector Error Correction model and Granger Causality	Coal consumption, Real GNP per capita, gross fixed capital formation, and the labour force	CC↔ GDP
Sari et al (2008)	United States	2001M1-2005M6	ARDL Bound Testing approach	Coal consumption, industrial production employment ,Real GNP per capita	CC→ GDP
Liu et al (2009)	China	1978-2007	Engle-Granger Causality test	Coal consumption , Real GNP per capita	GDP→ CC

Yuan et al (2008)	China	1963-2005	Johansen Cointegration , Generalised Impulse Response Analysis	Coal consumption , Real GNP per capita	CC↔ GDP
Ewing et al (2007)	United States	2001M1-2005M6	VAR ,Variance Decomposition Method	Coal consumption, industrial production employment, Real GNP per capita	CC→GDP
Bloch et al (2012)	China	1965-2008	Granger Causality and Cointegration test	Coal consumption, Real GNP per capita, gross fixed capital formation, and the labour force	GDP→ CC (under demand side analysis) CC→GDP (under supply side analysis)

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