Energy Consumption, Carbon Dioxide Emissions and Economic Growth: Empirical Results for Selected Developed Countries

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ABSTRACT

This research investigates the association between energy consumption, CO_2 emissions and economic growth for the United States, Japan, Russia, Canada and Australia. It also estimates the impact of other macroeconomic fundamentals including inflation rate, investment rate and trade openness on economic growth. Multiple regression analysis is employed for annual data covering the timespan from 1989 to 2014.

The empirical findings indicate that energy consumption has a positive and significant impact on economic growth of the selected countries. This means that energy is a critical factor in economic development. CO_2 emissions, which is a proxy for fuel-based energy use, has a destructive influence on the environment. Therefore, in this study, various policies have been suggested to reduce carbon dioxide emissions. In addition, the results show that positive association exist between investment rate, trade openness and output growth. However, inflation rate in all of the selected countries has a negative but insignificant impact on economic growth.

Keywords: economic growth, energy consumption, CO_2 emissions, inflation rate, investment rate, trade openness

ÖZ

Bu araştırmanın temel amacı Amerika, Japonya, Rusya, Kanada ve Avusturalya gibi ülkelerde ekonomik büyüme ile enerji tüketimi ve CO2 salınımı arasındaki ilişkiyi analiz etmektir. Buna ek olarak enflasyon oranı, yatırımlar ve dış ticarette açıklık oranları gibi diğer makroekonomik parametrelerin de ekonomik büyümeye olan etkileri bu araştırma kapsamında incelenecek konuları teşkil etmektedir. Bu araştırmanın konuları çoklu regresyon analizi yöntemi ile 1989- 2014 dönemine ilişkin veriler kullanılarak ampirik olarak analiz edilmiştir.

Ampirik sonuçlar araştırmanın konusu olan ülkelerde enerji tüketimi ile ekonomik büyüme arasında pozitif bir ilişki olduğunu göstermiştir. Bu sonuçta tüketilen enerji miktarının ekonomik kalkınmanın önemli bir etkeni olduğuna işaret etmektedir. Karbon temelli enerji tüketiminin miktarını yansıtan CO2 salınım miktarı ise çevre üzerinde yıkıcı etkileri olan bir unsurdur. Buna ilişkin olarak bu çalışmada CO2 salınım miktarlarını azaltmaya yönelik bazı politika önerilerinde bulunulmuştur. Bunlara ek olarak enflasyon oranının tüm ülkelerde ekonomik büyüme hızı üzerinde negatif etkisi olduğu gösterilmiştir. Ancak yatırım ve dış ticarete açıklık oranlarının büyüme oranlarını üzerindeki öngörülen pozitif etkisi ise sadece bazı ülkelerde gözlenmiştir.

Anahtar Kelimeler: ekonomik büyüme, enerji tüketimi, CO2 salınımı, enflasyon oranı, yatırım oranı, ticaret açıklığı

DEDICATION

This thesis is dedicated to my parents and my brothers, Mohammad and Mehdi for their endless love and support that enriched my heart and inspired me to complete this research.

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Chapter 1

INTRODUCTION

1.1 Energy

It is undeniable fact that energy plays a significant role in economic development as an important material. The exploration of new sources of energy and the innovation of new energy reserves are indispensable aspects of economic growth. (Haung and Haung, 2019).

Currently, three factors mainly cause high rates of economic growth: industrialization, urbanization and transport infrastructure. These factors highly depend on energy consumption such as oil and other fossil fuels. The fossil fuels provide electricity for industrial operations and means of transportation.

Studies have shown that industrialized countries are accountable for the intense discharge of greenhouse gas into the atmosphere. However, according to International Energy Agency [IEA] (2012), it appears that the growth in greenhouse gas emissions has been higher in emerging market economies in recent years and the threat of global warming related to climate change has increased. These issues have attracted the attention of experts and motivated them to investigate the relationship among economic growth and energy consumption and environmental degradation.

Carbon dioxide emissions (CO2) is the most debatable greenhouse gas that causes environmental destruction through global warming and climate change phenomena. CO2 emissions are released in different ways, such as through burning oil, gas, coal, hydro carbon products and deforestation (Sanglimsuwan, 2011). The increase in the CO2 emissions and methane gas into the atmosphere has led to a rise in the temperature of the Earth's surface (Yavus, 2014).

An international agreement called the Kyoto Protocol was signed in 1997. The agreement aimed to achieve various targets in industrial countries. The aims include t Sustainable development, Environmental quality, Setting certain limitations on greenhouse gas emissions.

Therefore, the protocol requires that policy makers implement policies targeted at reducing environmental inequality (Waheed, et al, 2019). Based on the findings of different scientific studies, in terms of emissions, the top 25 countries account for approximately 80 percent of the world's carbon dioxide emissions. Thus, significant inequality exists around the world with regard to greenhouse gas emissions (Yavus, 2014). The list of high-ranked countries includes the United States, Japan, Russia, Canada and Australia.

1.1.1 United States

United States is known as a country that has access to various sources of energy. Extant literature categorizes the sources of energy into primary and secondary, and renewable and nonrenewable. The primary sources of energy can be described as fossil fuels like petroleum, natural gas, and coal. Electricity is defined as a secondary energy source that can be produced from fossil fuel energy sources. The United States has been heavily dependent on fossil fuels for more than 100 years. However, coal production is no longer used for the generation of electricity. Therefore, coal production has decreased in America, where its peak was around 24 quads in 1998. On the other hand, natural gas production increased and reached 31.5 quads in 2018. The significant increase in the production of natural gas subsequently led to a decrease in natural gas prices. Consequently, manufacturing and other industries increased their consumption of natural resources for the production of goods and services (EIA, 2018).

1.1.2 Japan

Japan is a country whose domestic energy resources are limited. Oil energy sources are largely found along the country's western coastline. Japan is extremely dependent on imports in order to meet its energy consumption needs. It is the fourth largest consumer in the world after USA, China and India. It is also recognized as the third largest net importer of crude oil, where most of the oil is consumed in the transportation and industrial sectors. Japan is also highly dependent on the imports of low sulfur fuel. According to EIA (2017), Japanese government strongly supports research and development centers specifically to achieve energy efficiency and reduce carbon dioxide emissions.

1.1.3 Russia

Russia is known as the world's largest producer of crude oil, the second largest producer of natural gas and also produces significant amounts of coal. Russia's economy is immensely reliant on its hydrocarbon products. Recent investigations have shown that revenues from oil and natural gas account for more than one third of the federal income. Russia and Europe are interdependent in terms of energy. More than one third of Russian hydrocarbon products were exported to European countries in the Organization for Economic Cooperation and Development (OECD) in 2016 (EIA 2017).

1.1.4 Canada

Canada is one of the largest energy producers in the world and also has the highest energy consumption per capita. The different sources of energy in Canada include petroleum products, natural gas, solar energy, wind energy and others (EIA, 2019). Canada is one of the massive suppliers of oil for the last 10 years and has the third largest reserves of uranium among other countries. The fact that it has such an abundance of energy resources is a source of strength that shapes the economy and society of the country (EIA, 2019). Energy consumption has increased by more than three times in Canada since 1965. Hughes (2018) submits that Canadian per capita energy consumption is five times more than the global average. It was also 29% greater than the per capita energy consumption of the United States and almost three times higher than that of the European Union in 2016. Therefore, it can be concluded that Canadian residents utilize greater volumes of energy than citizens of other countries do.

1.1.5 Australia

In terms of economic development, Australia is one of the sixth major developed countries that existed in South Hemisphere. The country has experienced development without recession for 26 consecutive years (Leal, 2018). Since it has a free market economy with a high gross domestic product (GDP) per capita, it also experiences a low level of poverty. According to IEA (2012) and Lim et al. (2012), Australia experienced sustainable economic growth rates of about 1.5% and 4.5% over a period of ten years.

Australia is considered as the ninth largest producer of substantial energy among the world's largest energy producers. The energy sources play fundamental role on

Australian economy. EIA (2012) reports that Parallel to producing energy, the energy sector accounts for between 16 and 17 per cent of the current GDP. With one of the largest energy production sectors, Australia can be considered as a country with massive natural resources. Its primary resources include fossil fuel reserves such as coal, oil, and natural gas, as well as uranium and thorium. Petroleum products are the major energy reserves that are intensely used in transportation systems. Therefore, in the study of EIA (2018), it was determined that the transportation sector is heavily reliant on oil products.

1.2 Research Question

a) Based on the empirical investigations, what effects do energy consumption and CO2 emissions (which is a proxy for consuming fossil-based energy) have on economic growth in the United States, Japan, Russia, Canada, and Australia?

b) How do macroeconomic parameters including investment rate, inflation rate and trade openness affect economic growth in the selected economies?

1.3 Research Objective

The aim of this study is to examine the long-term association between energy consumption and CO2 emissions and economic growth (denoted by GDP growth) in the United States, Japan, Russia, Canada, and Australia. Annual data about the relevant variables has been obtained from the database of the World Bank for the period from 1989 to 2014**.** Moreover, this study empirically investigates the relationship between GDP growth and other macroeconomic parameters including the investment rate, inflation rate and trade openness.

1.4 Significance of the Study

This study aims to understand the important role and contribution of oil energy consumption and CO2 emissions in the economic growth of the top oil energy-consuming economies. In addition, examines the empirical impact of other macroeconomic variables on economic growth. Therefore, based on the results, this study offers some policies to have sustainable economic growth in the selected countries.

1.5 Structure of Study

This thesis comprises six chapters. The first chapter presents an overview of energy consumption and economic development in the top oil energy-consuming countries. Moreover, the effects of global warming and environmental degradation caused by CO2 emissions are stated. The second chapter is devoted to a presentation of the basic findings of previous studies within the context of this research. Chapter three presents a theoretical framework of the economic growth. In the fourth chapter, the data and methodology based on multiple regression analysis and an alternative specification of the growth model used are described. The empirical results based on the estimation of the alternative growth equations for each country are presented and discussed in Chapter five. Chapter 6 summarizes the basic research findings of the study.

Chapter 2

LITRATURE REVIEW

Economic development has been the subject of significant debate in recent decades. The first body of literature examined the nexus between energy consumption and CO2 emissions and economic growth. Later studies explored the relationship between different macroeconomic parameters such as investment, inflation and trade openness and economic growth.

2.1 Energy Consumption and CO2 Emissions

A large number of studies have shown that natural resources are crucial sources of energy for economic growth. The excessive use of natural resources will increase the level of carbon dioxide emissions, which cause pollution in the environment. Banday and Aneja (2019) submitted that a large proportion of theoretical and empirical works have been conducted on economic growth. Most of these studies have attempted to develop a model for the association between economic growth, energy consumption as well as economic growth and CO2 emissions based on the Solow growth model. Kolstad and Krautkraemer (1993) mentioned that energy resources are among significant determinants of economic growth. The study further reported that in the long run, the increased use of energy has negative impact on the environment.

Kraft and Kraft (1978) were among the initial authors to analyze the association between energy consumption and economic growth. The study found unidirectional causality running from economic growth to energy. Their study additionally revealed that energy exerts no causality effects on economic growth. In a different research, Akarca and Long (1979) used employment as a replacement for economic growth and reported that an increased level of energy consumption resulted in higher levels of employment. On the other hand, Akarca and Long (1980) applied different methodology as well as a variety of annual datasets to examine how gross national product (GNP) and energy consumption are related. They found no evidence of a causal relationship between energy and GNP.

Through the utilization of the method originally developed by Engle and Granger, (1987), in early studies, researchers examined bivariate Vector Autoregressive (VAR) models to discern the Granger causality between energy and output. However, recent studies have used cointegration methods. Since the variables of interest are doubtlessly non-stationary and trending randomly, it is necessary to conduct a cointegration test to find worthwhile results. For example, Asafu (2000) employed cointegration and error-free techniques to determine the nature of the association between energy use and income for India, the Philippines, Indonesia and Thailand. His results suggested that in the short term, a single direction of causality runs from energy to GDP growth in Indonesia and India. However, his analysis also showed a causal association running from energy consumption to income in the Philippines and Thailand.

Previous studies utilized different measurements and methods to discover the association between energy consumption and output growth. One of such studies conducted by Narayan et al. (2007) explored the association between energy consumption and economic growth in the group of seven (G7) countries by utilizing the Granger causality test. Outcome of their study revealed that causality does not exist between energy and economic development. Menegaki and Tugcu (2017) conducted another empirical research by applying the panel regression model. They indicated that a unidirectional causal relationship runs from energy consumption to economic productivity in the (G7) countries. Mahalik et al. (2016) performed a study by implementing the Auto-Regressive-Distributed-Lag (ARDL) methodology to explore the association between energy consumption and economic growth in Saudi Arabia. He argued that there is one-way direction of causal effect of GDP growth on energy consumption. On the contrary, Mirza and Kanwal (2017) determined that a reciprocal causal relationship exists between energy and economic development in Pakistan. His empirical methodology was based on the Auto-Regressive-Distributed-Lag (ARDL) model and the Johansen Julius test.

For the past two decades, a large number of studies have concentrated largely on the CO2 emissions that result from energy consumption. The studies have concluded that energy consumption has a notable impact on carbon dioxide discharge. As an illustration, Riti et al. (2017) applied the Environmental Kuznets Curve (EKC) hypothesis to investigate the nature of the relationship among economic growth and carbon dioxide emission and energy consumption over the sample period of 1970-2015 for China.

In past studies, the association between economic growth and carbon dioxide emissions that leads to environmental degradation can be explained through Environmental Kuznets Curve (EKC) theory. The Environmental Kuznets hypothesis explains the nexus between economic growth and carbon emissions in two phases. First, environmental degradation starts to increase as the economy develops. After reaching a peak, the second phase starts; environmental degradation begins to decrease although economy growth continues. An inverted u-shaped graph appeared from the theory (Kuznet, 1995).

Xu and Lin (2015) examined the nexus between economic growth and carbon dioxide emissions via the application of panel regression models over the period covering 1990-2011 for China. Their results showed that there is an inverted u-shaped relationship between GDP growth and CO2 emissions. However, the study of Abid (2015) rejected the Environmental Kuznets hypothesis. He examined the nexus between GDP growth and CO2 emission in Tunisia by implementing Granger causality and the Vector Error Correction Model (VECM) for the period of 1980-2009. His analysis indicated that there is a sustainable relationship between economic growth and carbon emissions. (Jardón et al., 2017) found an inverted u-shaped relationship between economic growth and carbon emissions in their study of Latin American countries for the period of 1971-2011.

Recent studies have also tried to explore the nexus between income and pollution. Kohler (2013) claimed that a long-run relationship exists between environmental inequality and energy consumption (per capita) as well as foreign trade in South Africa. Shahbaz et al. (2014) argued that energy consumption and carbon emissions have a causal and cointegrating association with economic activities in Bangladesh. He also investigated whether an inverted u-shaped relationship existed between economic activities and CO2 pollution.

Succinctly, all countries are highly reliant on energy consumption in order to develop their infrastructure and transportation, improve their social circumstances, increase their market size and grow investments in different sectors. However, inadequate fossil fuel energy restrains the speed of economic growth. The intensive increase in energy consumption and expansion of economic development are recognized as sources of carbon dioxide emission. Therefore, it is vital to implement appropriate policies for overcoming the problems (Hirschi, 2010). Carbon emissions are considered to be one of the global warming gasses that has a significant negative effect on human health. Hence, it will be beneficial to implement various pollution control policies such as tax credits on renewable energy production and to invest in energy-efficient technology projects in all countries around the world (Apergis and Payne, 2011).

2.2 Solow Growth Theory

Investment can be explained by the neoclassical Solow growth theory. According to Solow (1956), economic growth depends on a higher rate of savings or investment. Solow (1988) subsequently clarified that permanently increasing savings (investment) in countries will increase the rate of output, which will consequently lead to faster economic growth. Furthermore, stimulating investment will foster medium-term growth via the effect of transferring technology to industries. Additionally, savings (investment) which represent the key component of economic growth provide resources that can be used to increase capital accumulation (machinery, building, etc.) and labor force, which enhances the productive capacity.

2.2.1 Investment

Most previous studies have emphasized the importance of investment for growing and developing the economy. It is essential for investors to borrow high levels of capital to invest in production-related activities. Routinely, borrowing from outside is not an appropriate way to increase economic activity. Not only does it have an unfavorable impact on the balance of payments, but it increases the exposure to foreign exchange risk. A decline in value of currency is one of the circumstances associated with borrowing from the International Monetary Fund. Thus, instead of borrowing from other countries or organizations, it is better to save domestically so as to finance domestic capital formation, which speeds up the growth rate of the economy (Emeka et al., 2017).

According to Alfa and Garba (2012), domestic investment that leads to capital formation, productive activity, and improvement of infrastructure, can lead to rapid and sustainable growth of exports and economic development. Thus, investors endeavor to find appropriate investment options.

Masih et al. (2009) claimed that there is a positive relationship between productivity and investment. In another study, Benhabib and Spiegel (2000) argued that there is a favorable nexus among investment, economic growth and financial improvement.

Romer (2001) mentioned that capital formation is one of the significant factors needed to maintain sustainable economic growth. The capital formation is also a determining variable for creating long-run economic growth. The reason for this is that a relatively higher rate of investment is associated with a higher rate of accumulation of capital stock, which causes the economy to grow faster. Levine and Renelt (1992) used cross-country datasets and attempted to analyze the relationship between public investment and economic growth. Unfortunately, their results were not statistically robust. In another study, Ugwuegbe and Uruakpa (2013) used multivariate regression analysis to explore the association between the formation of capital and growth output in Nigeria. The empirical findings indicated that a favorable association exists between growth rate of output and capital formation.

Investments made in economic activity can be categorized into three parts. First is "business fixed investment", such as investing in manufacturing systems, equipment, infrastructures in plant. Second is "residential investment", which includes significant investments in housing. Third is "inventory investment", which consists of the accumulation of inventories (Dornbusch et al., 2004).

The impact of investment on economic growth can be explained by aggregate demand. Aggregate demand is defined as the total demand of final goods and services at a given price and time in the economy. It is determined by the demand for investment goods. An increase in investment demand leads to an increase in capital stock. Therefore, increased capital stocks accumulation leads to increased production capacity, which enables the economy to produce larger amounts of output. Thus, investing in different manufacturing sectors by utilizing new technology will increase productivity and affects the economic growth rate (Manamba and John, 2016).

It can be concluded that in order to boost the economy, investment is necessary. Levine and King (1994) observed that physical capital accumulation is a significant element of the rise in economic growth. Therefore, in order to increase the nation's physical capital, national and international policies are implemented to strengthen the economy. In terms of policy actions, the government should always monitor the economic situation of the country. In critical situations, it provides subsidies and funds for industries to improve their productivity. It also supports entrepreneurs who have the ability to develop innovative production, which leads to greater competition in the market and will also attract foreign direct investment. (Tan and Tang, 2016)

2.3 Inflation

The primary objectives of every macroeconomic policy are to achieve a low and stable rate of inflation and also a high economic growth rate. Stability of prices is one of the prominent factors necessary for high economic growth rate. Hence, in most countries, the central bank takes necessary actions such as monetary policy to maintain the inflation rate at an appropriate level.

According to Temple (2000), a high inflation usually has a dramatic effect on the economy. However, past researchers have revealed that in some cases, moderate inflation can also decrease the rate of growth. On the other hand, Aiyagari (1990) and Cooley and Hansen (1991) claimed that it is not worthwhile to reduce the inflation rate to zero as the costs outweigh the benefits.

Based on the extant literature, divided the effects of the inflation rate on economic growth into four categories. First, positive association between inflation and economic growth does not exist (Dorrance, 1966; Sidrauski, 1967). Second, Mallik and Chowdhury (2001) and also Benhabib and Spiegel (2009) posit a positive association between inflation and economic growth. Third, Saeed (2007) claimed that inflation exerts a negative influence on economic growth. The last category suggests that inflation affects economic development through a specific threshold framework. In other words, inflation fosters economic growth when it is below a threshold level (Fischer, 1993). However, if the inflation is above the threshold level, it will have a negative influence.

A study conducted by Khan and Senhadi (2001) showed that the threshold is between 1–3% for industrialized countries and 11–12% for developing countries, and inflation prevents the economy from growing beyond these levels. However, it may not have a statistically significant effect below the threshold. A study by Mubarik (2005) examined the association between inflation and economic growth for Pakistan. The research was based on an annual dataset from 1973 to 2000 using threshold analysis. According to the results of the study, an inflation rate over 9%, which was found to be the threshold, had a negative impact on economic growth. Research by Akgül and Özdemir (2012) in Turkey showed a nonlinear relationship between inflation rate and economic growth via the two-regime Threshold Auto-Regression (TAR) model for the period 2003-2009. The results of the study revealed that an inflation threshold of 1.26% for the whole period of analysis exerted a negative effect on economic growth. Kremer et al. (2013) investigated the influence of inflation threshold on long-term economic growth in 124 industrialized and non-industrialized countries based on data for the period between 1950 and 2004. They forecasted that the inflation threshold would be 2% for industrialized countries. The rate for non-industrialized countries was 17%. According to the results of the study, an inflation rate over the threshold had a negative effect on economic growth. Conversely, an inflation rate below the threshold had an insignificant influence on economic growth.

(Jalil et al., 2014; and Boujelbene and Boujelbene, 2010; and Barro, 2013) argued that a large volume of studies has shown that a mild and stable inflation rate facilitates the decision-making processes of businesses.

Researches have shown that a high inflation crises lead to a significant decrease in growth rate. However, the growth rate will recover when the inflation falls. The effect of inflation on economic growth was examined by Gylfalson and Herbertsson (2001). Their study showed the effect of inflation on long-term economic growth based on data obtained for 170 countries covering from 1960 to 1992. The results suggested that inflation has a detrimental impact on growth rate by more than 10% to 20% annually. The increase in domestic inflation caused by increasing production costs in different sectors can have an influence on their competitiveness and reduces productivity. Inflation also exclusively affects labor costs because wages are often considered as a cost of living index. In the study conducted by Mahadevan and Adjaye (2005) the results indicated that domestic inflation affects prices of energy and capital. This is due to the fact that most of these inputs are sourced domestically in the economy.

One of the greatest problems of less-developed countries is macroeconomic instability. Therefore, the countries rely on international agencies for stabilizing their economies. The World Bank, International Monetary Fund, and Asian Development Bank are examples of such agencies.

These agencies have different guidelines and suggestions in terms of reducing or increasing prices but suffer from lack of effective coordination with each other in many cases. This situation can make it harder for policy makers to determine the levels of inflation required by Asian countries to stabilize their economies.

2.4 Trade Openness

The association between trade openness and economic growth has been one of the most important topics in recent decades. Neoclassical growth theories based on the Solow growth model state that there is no causal nexus between trade openness and economic development. The main reason for this argument is that the economic growth of a country is considered as an exogenous factor. This means that economic development can be designated by technological change or the population growth rate.

Consequently, it is not affected by the country's openness to international trade. On the contrary, the new growth theory considers economic growth as an endogenous factor. Based on new growth theory, trade openness can cause economic growth via the transfer of technology or by enlarging the size of the economy (Okuyan et al., 2012).

Growth theories based on endogenous and exogenous theory are highly reliant on the rate of knowledge accumulation. Knowledge accumulation can be improved by liberalizing the trade policy unilaterally and multilaterally and trade openness (Sakyi et al., 2014).

Studies from the past have indicated mixed and different results due to the selection of different countries and methodologies. Some researchers have found that trade and output growth are positively associated (Karras, 2003; Dollar and Kraay, 2004; Wang et al., 2004; Freund and Bolaky, 2008; Das and Paul, 2011; Nowbutsing, 2014).

In contrast, Ulaşan (2015) claimed that trade openness has a negative impact on economic growth. Rigobon and Rodrik (2005) argued that trade has a significant negative impact on income levels. In another study, Fenira (2015) examined the unsatisfactory nexus between trade openness and economic growth rate. According to Rassekh (2007), countries with lower incomes benefit more from international trade compared to higher income economies. He examined the trade-growth nexus for 150 countries.

Dufrenot et al (2010) claimed that the effect of openness on low-growth rate countries is higher than for high-growth rate countries. The study used the Quantile-Regression technique to explore the association between trade and growth for 75 nations. In another study, Kim et al. (2009) found that international trade is more beneficial in rich countries than in poor countries. The main reason for this is the inability of the poor countries to exploit the accumulation of knowledge and technology for economic growth. Therefore, it can be concluded that trade openness has different impacts in different countries.

Chapter 3

THEORETICAL BACKGROUND

3.1 Simple Theoretical Background

Past literature has confirmed that energy plays a crucial role in production. Undoubtedly, energy is a primary input for both production and transportation. According to Stern and Cleveland (2004) the classical macroeconomic theory mainly focuses on capital and labor and does not consider energy as a component of economic development. However, new growth theories pay more attention to energy and investigate the association between energy consumption and economic growth through the production function. As suggested by this theory, by using energy through technological progress, capital and labor transform materials to final goods and services (Ayres et al., 2007)

The transformation of energy in production sectors leads to high rates of carbon dioxide emissions. Economists emphasize the importance of reducing fossil fuel energy consumption to decrease the problems caused by climate change. On the other hand, sustainable economic development is now being encouraged globally. Hence, it is essential to focus on three areas :1-improving the efficiency of useful work[1], which means that extra output will be generated with lower amounts of useful work. 2-Improving the efficiency of conversion. Therefore, more output will be produced with

[1] In this study, useful work is defined in physics books as the amount of energy needed to lift an object against the force of gravity or the amount of energy applied to move an object over a distance. However, in Economics, useful work is what human capital or labor do for the purpose of production.

lower input and less carbon dioxide will be emitted. 3-Continue production at lower cost (Ayres et al., 2007).

Based on the production function, a higher rate of input depends on higher rate of capital. Therefore, there is a consensus among all economists that capital accumulation can be increased through the investment process. It cannot be underestimated that this process has a significant role in both growth and development. Ahortor and Adenutsi (2009) found evidence that increasing capital accumulation is one of the most important factors impacting long-run growth across countries.

Endogenous theory also focusses on the question of whether economic growth relies on the rate of return of capital. Therefore, inflation can reduce the capital accumulation and decrease the rate of economic development.

Capital accumulation also occurs through trade openness that facilitates the efficient use of resources and transfer of technology between countries, which exert a positive effect on economic growth. Additionally, international commerce leads to the import of capital goods and other inputs that are costly to produce domestically. Hence, these goods are important for production because they provide the opportunity to export to less-developed countries (Romer, 1992; Yanikkaya, 2003).

3.1.1 Theoretical Framework

Following the theoretical background, this study uses two models to investigate the association between energy consumption and CO2 emissions and economic growth rate. Additionally, this thesis investigates the relationship between other key macroeconomic parameters including inflation rate, investment rate and trade openness and economic growth. The following chapter explains the reasoning behind the selection of the two separate models. These models are based on simple multivariate analysis and are formulated as follows:

$$GDP = \beta_0 + \beta_1 EC + \beta_2 INF + \beta_3 INV + \beta_4 T \quad (1)$$

$$GDP = \alpha_0 + \alpha_1 CO2 + \alpha_2 INF + \alpha_3 INV + \alpha_4 TO \quad (2)$$

Where GDP represents economic growth, EC is energy consumption and CO2 stands for carbon dioxide emissions. INF is the inflation rate, while INV represents the investment rate and TO stands for trade openness.

The study hypotheses are as follows:

The null hypothesis based on the theories explained in this thesis suggest that energy consumption should increase the growth rate of the economy.

$\mathbf{H_1}$: There is a positive relationship between GDP growth and energy consumption.

$\mathbf{H_2}$: There is a positive relationship between GDP growth and CO2 emissions.

The explanation for $\mathbf{H_2}$ is that the amount of CO2 emissions is intuitively expected to be positively correlated with the amount of fossil-based sources of energy such as oil and coal.

This study subsequently estimates the equations above and investigates whether they reject the null hypothesis or not.

Chapter 4

DATA and METHODOLOGY

In this chapter, the data and variables specifications are presented and Multiple Regression analysis is explained, which is the main empirical methodology employed. Therefore, the model is specified to investigate the association between energy consumption, CO_2 emissions and economic growth in specific developed nations.

4.1 Data and Variables Specifications

This thesis used annual time series data from 1989 to 2014 for selected countries including the United States, Japan, Russia, Canada and Australia. These countries are highly dependent on oil energy consumption and their data are also available. All data have been collected from the electronic World Bank dataset.

The dependent variable in the estimated models is the annual growth rate of Real GDP (annual growth rate of gross domestic product per capita at 2010 constant US dollars), which is the proxy for economic growth. The second variable is EC (energy consumption in kg of oil equivalent per capita). The third variable is CO_2 (carbon dioxide emissions in metric tons per capita). The fourth variable is INF (inflation rate which is considered as annual consumer price as a percentage of GDP). The fifth variable is INV (investment rate that is considered as gross fixed capital formation as a percentage of GDP) and the last variable is TO (trade openness, which is the annual summation of the imports and exports of goods and services as a percentage of GDP).

4.1.1 Descriptive Analysis

Summary of descriptive statistics of variables from 1989 to 2014 are depicted in following tables.

Table 1: Descriptive Statistics of Variables

	Real GDP Growth (per capita at 2010 constant US dollars)					Energy Consumption (kg of oil equivalent per capita)				
	Mean	**Median**	**Max**	**Min**	**SD**	**Mean**	**Median**	**Max**	**Min**	**SD**
USA	2.52	2.71	4.75	-2.53	1.66	-0.44	0.13	1.68	-5.75	1.80
Japan	1.27	1.45	4.89	-5.41	2.14	0.30	0.53	5.98	-7.25	3.13
Russia	0.69	2.75	10.00	-14.53	6.79	-0.16	0.59	7.63	-12.43	4.64
Canada	2.31	2.64	5.17	-2.92	1.87	0.02	0.08	4.34	-4.85	2.10
Australia	3.18	3.74	5.07	-0.39	1.23	0.51	0.61	6.34	-3.49	2.44

Notes: Max, Min and SD are maximum and minimum and standard deviation, respectively. Data Period is 1989 to 2014.

Table 2: Descriptive Statistics of Variables

	CO2 emissions (Metric tons per capita)					Investment (Gross fixed capital formation %GDP)				
	Mean	**Median**	**Max**	**Min**	**SD**	**Mean**	**Median**	**Max**	**Min**	**SD**
USA	0.53	1.20	3.74	-7.37	2.55	21.11	21.31	23.14	18.38	1.39
Japan	1.02	0.94	13.07	-5.61	3.73	26.89	25.78	34.12	21.32	3.91
Russia	-1.46	-0.32	5.41	-18.21	5.15	20.76	21.04	31.76	14.39	3.63
Canada	0.88	1.03	4.14	-5.96	2.43	21.41	20.78	24.55	18.40	1.93
Australia	1.60	1.62	6.36	-2.20	1.78	25.99	26.12	28.76	22.88	1.71

Notes: Max, Min and SD are maximum and minimum and standard deviation, respectively. Data Period is 1989 to 2014.

Table 3: Descriptive Statistics of Variables

	Inflation (Annual consumer price %GDP)					Trade Openness (Annual summation of import and export of goods and services %GDP)				
	Mean	**Median**	**Max**	**Min**	**SD**	**Mean**	**Median**	**Max**	**Min**	**SD**
USA	2.71	2.81	5.39	-0.35	1.16	23.17	23.24	30.42	14.78	4.90
Japan	0.53	0.09	3.25	-1.35	1.27	23.23	22.14	32.21	16.55	5.08
Russia	24.73	15.27	85.75	5.07	19.34	40.19	38.82	54.45	20.77	9.84
Canada	2.19	1.95	5.62	0.16	1.27	57.26	60.95	65.61	39.67	7.90
Australia	2.96	2.65	7.53	0.22	1.72	1.15	33.47	33.57	43.66	22.19

Notes: Max, Min and SD are maximum and minimum and standard deviation, respectively. Data Period is 1989 to 2014.

4.1.2 Graphical Trend of Energy Consumption and GDP Growth

In the following figures graphical movement of energy consumption and GDP Growth of each country has been presented. The graph shows that in all the countries the energy consumption moves in the same direction with the GDP growth.

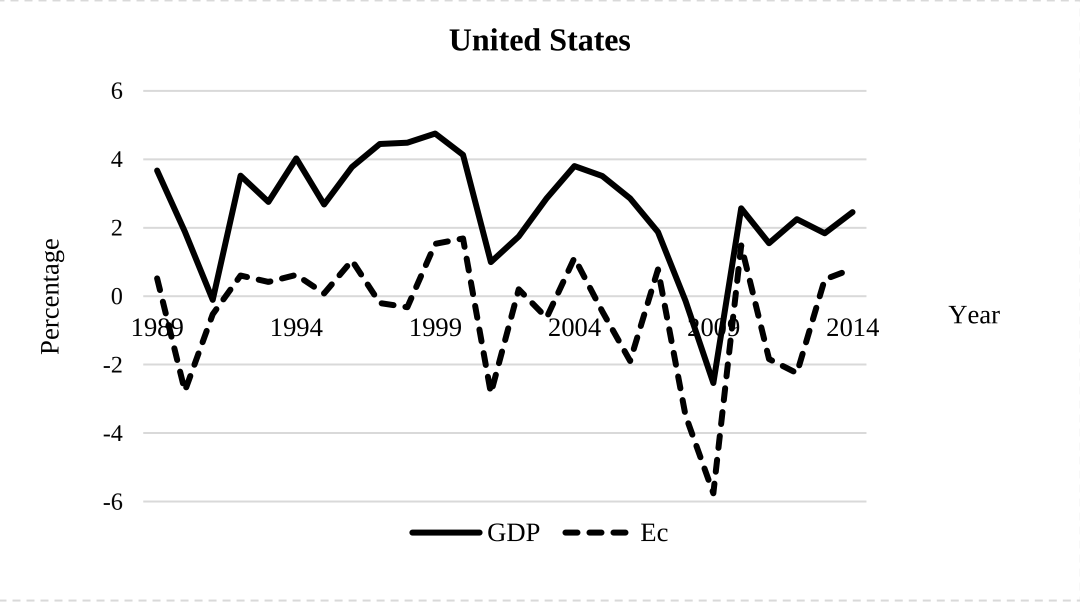

Figure 1: Energy Consumption and GDP Growth in U.S.A

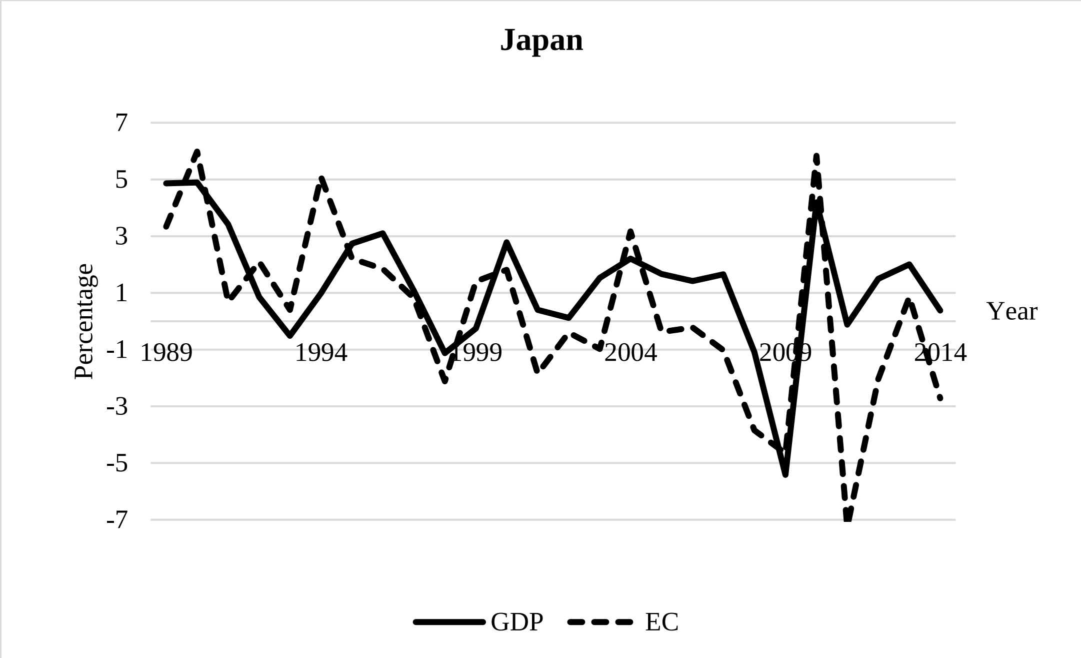

Figure 2: Energy Consumption and GDP Growth in Japan

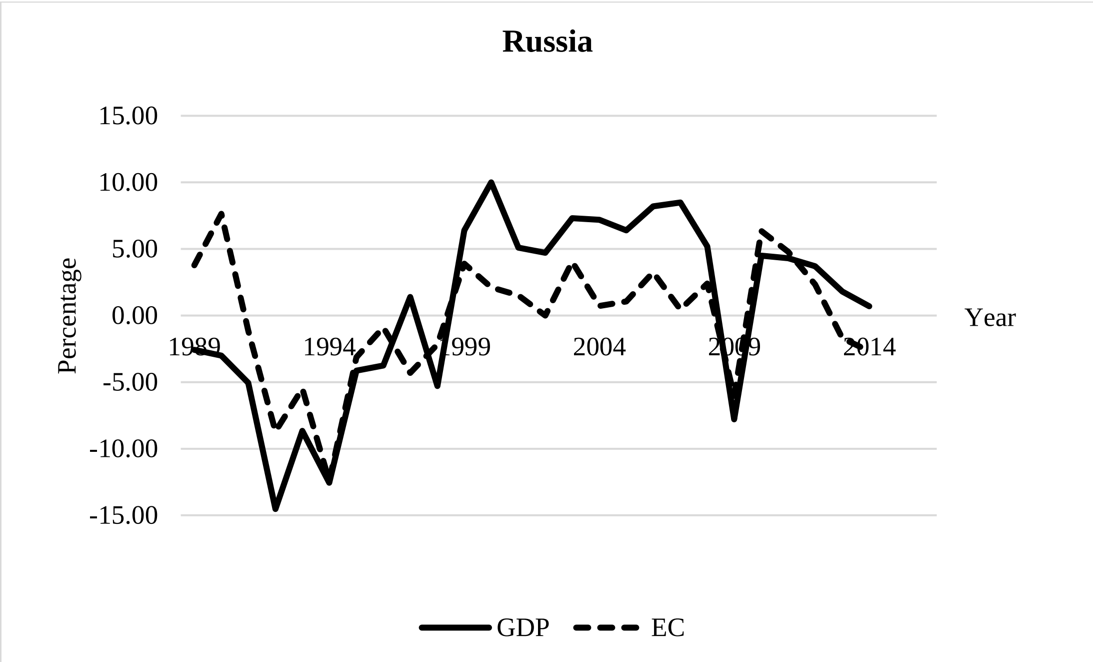

Figure 3: Energy Consumption and GDP Growth in Russia

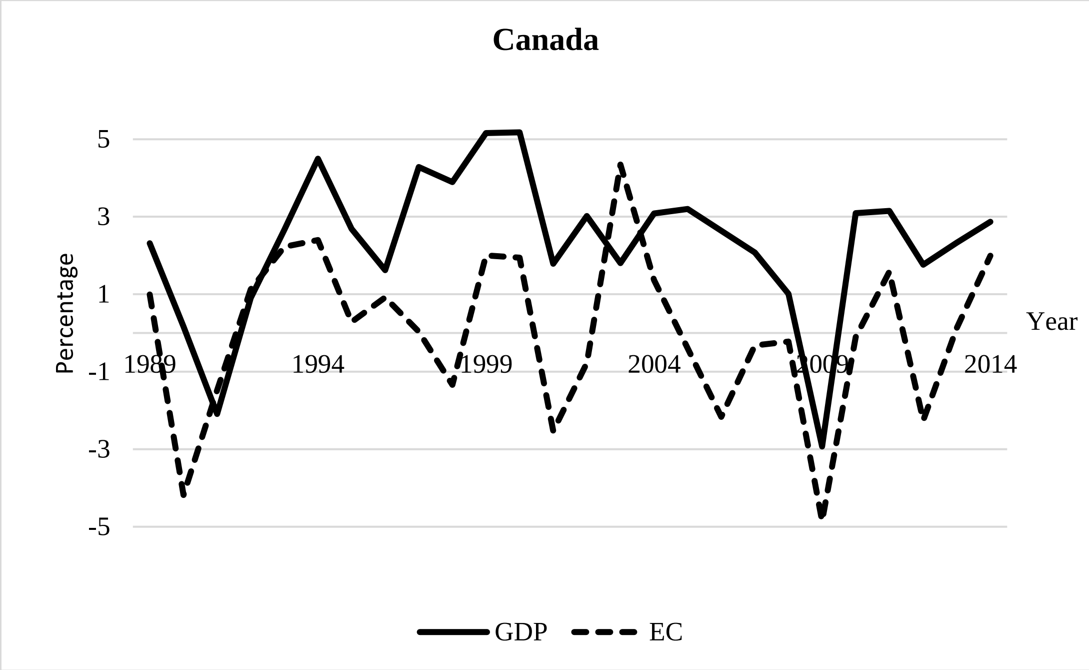

Figure 4: Energy Consumption and GDP Growth in Canada

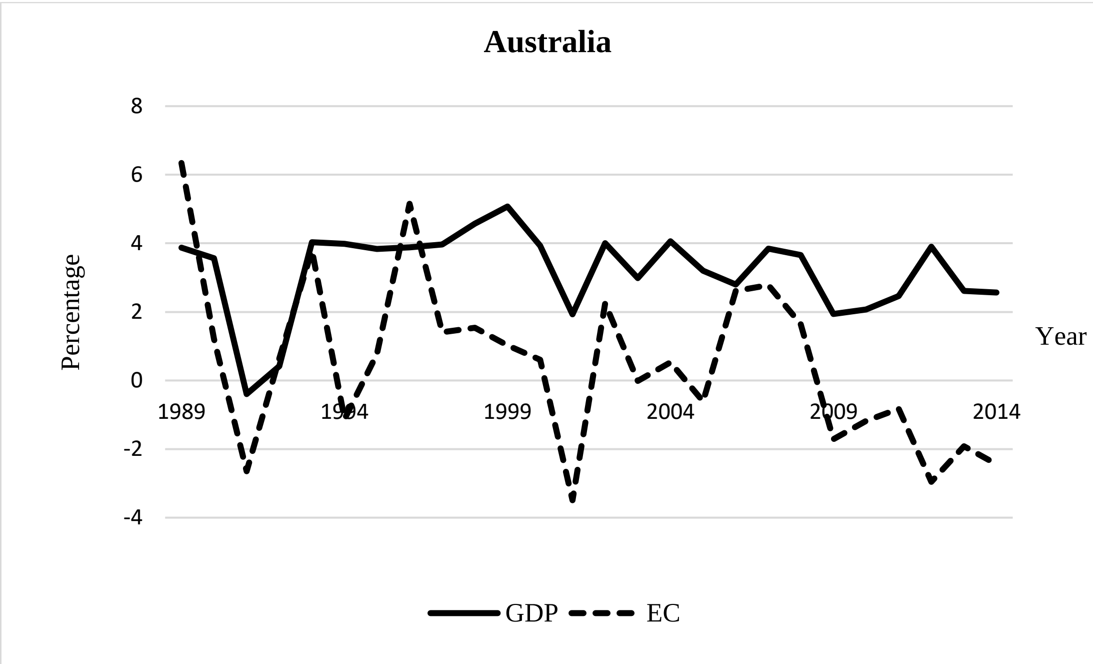

Figure 5: Energy Consumption and GDP Growth in Australia

4.1.3 Correlation Matrix

A correlation matrix is a table that is used in advanced statistical analysis to determine correlation coefficients between variables. Each variable (X_i) in the table is correlated with another variable (X_j) in the table. This will help to understand the nature and strength of correlation between the variables. It shows whether the variables have strong or weak correlation (association). Normally, a correlation coefficient that is greater than 0.6 indicates multicollinearity problem between the variables. In such case, one of the variables should be drop in regression model or try to find better solution.

The following tables show correlation coefficient among the variables. Table 4 and table 6 contain the correlation matrix for USA and Russia. The results show that strong correlations, (0.8220) and (0.8727), exist between energy consumption and CO2 emissions. These results could cause multicollinearity problem. Therefore, to avoid the multicollinearity problem, energy consumption and CO2 emissions have been estimated in two separate regression model. All other variables are weakly or moderately correlated with each other. (Bock ,2019).

Table 4: U.S.A Correlation Matrix

U.S.A	EC	CO2	INF	INV	TO
EC	1.0000				
CO2	0.8220	1.0000			
INF	0.0743	0.3006	1.0000		
INV	0.2008	0.2182	0.3392	1.0000	
TO	-0.1487	-0.3353	-0.5019	-0.1167	1.0000

Table5: Japan Correlation Matrix

Japan	EC	CO2	INF	INV	TO
EC	1.0000				
CO2	0.5823	1.0000			
INF	0.2352	0.1672	1.0000		
INV	0.5176	0.3399	0.5893	1.0000	
TO	-0.5068	-0.2981	-0.3262	-0.5904	1.0000

Table 6: Russia Correlation Matrix

Russia	EC	CO2	INF	INV	TO
EC	1.0000				
CO2	0.8727	1.0000			
INF	-0.1876	-0.3054	1.0000		
INV	0.0625	-0.1793	0.0191	1.0000	
TO	0.4907	0.4574	-0.4334	-0.0302	1.0000

Table 7: Canada Correlation Matrix

Canada	EC	CO2	INF	INV	TO
EC	1.0000				
CO2	0.5864	1.0000			
INF	-0.0860	-0.0704	1.0000		
INV	-0.2764	-0.3080	0.0348	1.0000	
TO	0.0991	0.0218	-0.4955	0.3041	1.0000

Table 8: Australia Correlation Matrix

Australia	EC	CO2	INF	INV	TO
EC	1.0000				
CO2	0.5951	1.0000			
INF	0.2385	0.1590	1.0000		
INV	0.0675	-0.0692	0.4135	1.0000	
TO	-0.4627	-0.5595	-0.2851	0.4201	1.0000

4.1.4 Unit Root Test

Unit root tests are used to determine whether time series data are stationary or non-stationary. A time series might be equal to its value plus an error terms. This means random walk phenomenon. Stationary series have constant means, constant autocovariance and constant variance for each lag.

Starting point of unit root test is with this equation:

$$\mathrm{Y_t} = \rho \mathrm{Y_{t-1}} + \mathrm{u_t} \qquad (4.1.4.1)$$

u_t is considered as error term. In the above equation:

$$-1 \leq \rho \leq 1 \qquad (4.1.4.2)$$

$$\mathrm{Y_t} - \mathrm{Y_{t-1}} = \rho \mathrm{Y_{t-1}} - \mathrm{Y_{t-1}} + \mathrm{u_t} \qquad (4.1.4.3)$$

$$= (\rho - 1)\mathrm{Y_{t-1}} + \mathrm{u_t} \qquad (4.1.4.4)$$

$$\Delta \mathrm{Y_{t-1}} = \delta \mathrm{Y_{t-1}} + \mathrm{u_t} \qquad (4.1.4.5)$$

The equation (4.1.4.5) shows that the first difference of a random walk time series is stationary. Therefore, with the last equation, if $\delta = 0$ then $\rho = 1$, and the series has unit root and not stationary. On the other hand, if $\delta = 0$ then < 1 , the series is stationary.

Famous unit root tests are Phillips-Person (PP) , Kwiatkowski-Phillips-Schmidt-Shin (KPSS) ,and Augmented-Dicky-Fuller (ADF). ADF is one of the widely used and simplest test that is largely used in analysis (Xlstat support center ,2019).

The following equation is use for ADF test:

$$Y_t = C + \beta t + \alpha Y_{t-1} + \varphi \Delta Y_{t-1} + e_t \qquad (4.1.4.6)$$

In the above equation Y_{t-1} is a first lag of time series. ΔY_{t-1} is the first difference of time series at $t-1$ time. The null hypothesis is $\alpha = 1$.

If the coefficient of $Y_{t-1} = 1$, it indicates that the series has unit root and it is non-stationary. Otherwise, we reject the null hypothesis and conclude that the series is stationary at levels (Prabhakaran, 2019).

Augmented Dicky-Fuller (ADF) test for unit root is used individually for each variable of each country. The null hypothesis is that the series has unit root in series. This means that the series are not stationary at levels. The alternative hypothesis is that the series is stationary at levels. The decision rule is to reject the null hypothesis when the t-statistics is more negative than the critical value at a chosen level of significance. Otherwise, do not reject the null hypothesis.

Table 9: Critical Value Table

Significance level	**1%**	**5%**	**10%**
critical value for constant and linear trend	-4.37	-3.58	-3.23

The results in table 10 through table 14 clearly show that, for each country, some of the variables are stationary at levels while others are stationary at first difference. Put differently, some variables are integrated of order zero, that is I(0), while others are integrated at order one, that is I(1). This means the former are stationary at levels but the latter only become stationary after taking the first difference.

Table 10: U.S.A Unit Root Test

Unit root test ADF	**Level t-stat**	**First difference t-stat**	**Result**
U.S.A			
GDP		-6.05***	I(1)
EC	-4.94***		I(0)
CO2	-4.80***		I(0)
INF	-3.87**		I(0)
INV		-3.43*	I(1)
TO		-5.38***	I(1)

Note: I(0) denotes the variable is stationary at the level, while I(1) denotes the variable is stationary after the first difference. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 11: Japan Unit Root Test

Unit root test ADF	**Level t-stat**	**First difference t-stat**	**Result**
Japan			
GDP	-4.57***		I(0)
EC	-5.71***		I(0)
CO2	-3.29*		I(0)
INF		-5.38***	I(1)
INV		-3.64**	I(1)
TO	-3.35**		I(0)

Note: I(0) denotes the variable is stationary at the level, while I(1) denotes the variable is stationary after the first difference. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 12: Russia Unit Root Test

Unit root test ADF	Level t-stat	First difference t-stat	Result
Russia			
GDP		-4.31**	I(1)
EC	-3.44*		I(0)
CO2	-4.32**		I(0)
INF	-4.86***		I(0)
INV	-3.28*		I(0)
TO		-3.79**	I(1)

Note: I(0) denotes the variable is stationary at the level, while I(1) denotes the variable is stationary after the first difference. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 13: Canada Unit Root Test

Unit root test ADF	Level t-stat	First difference t-stat	Result
Canada			
GDP		-5.91***	I(1)
EC	-5.24***		I(0)
CO2	-4.18**		I(0)
INF	-3.44*		I(0)
INV	-3.83**		I(0)
TO		-4.30**	I(1)

Note: I(0) denotes the variable is stationary at the level, while I(1) denotes the variable is stationary after the first difference. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 14: Australia Unit Root Test

Unit root test ADF	Level t-stat	First difference t-stat	Result
Australia			
GDP	-3.32*		I(0)
EC	-4.88***		I(0)
CO2	-4.43***		I(0)
INF		-6.45***	I(1)
INV	-3.49*		I(0)
TO		-5.38***	I(1)

Note: I(0) denotes the variable is stationary at the level, while I(1) denotes the variable is stationary after the first difference. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

4.2 Multiple Regression

Regression analysis is the most effective for econometric analysis use to evaluate the effects of variables on other variables. In a simple way, regression analysis evaluates the nature of relationship and impact of one or multiple independent variables on a dependent variable.

Particularly, regression analysis tries to estimate variation in one variable in relation to change in one variable or other variables. By knowing more information about independent variables, multiple regression helps to provide accurate prediction about the effect of these variables on dependent variable (Higgins, 2005). If the regression analysis examines the relationship between multiple independent variables and the dependent variable, it is identifying as a Multiple Regression method.

Multiple Regression equation is specified as follows;

$$Y_j = \beta_0 + \beta_1 + \beta_1 X_{1j} + \beta_2 X_{2j} + \cdots \beta_p X_{pj} + \varepsilon_j \qquad (4.2.1)$$

In the above equation, X represents independent variables while Y is the dependent variable. In addition, j is denotes the cross-sections while the βs refers to the unknown regression coefficients and ε is stochastic error (residual) term.

The most widely effective technique of Multiple Regression method is Ordinary Least Square (OLS) analysis. In this analysis, b's are selected instead of β. Function of the b is to maximize the sum of squared residuals.

Ordinary Multiple Regression equation is:

$$Y_j = b_0 + b_1 X_{1j} + b_2 X_{2j} + \cdots + b_p X_{pj} \qquad (4.2.2)$$

If $p = 1$ the above equation will be Linear Regression. b_0 is the constant or intercept of the regression equation and b_i are the slope coefficient of the regression equation. b_i can also be called partial regression coefficient. By holding the remaining X's in the equation constant, b_i illustrate net effect of the first variable on the dependent variable.

Null hypothesis (H_0) for testing linear regression model is that coefficient relating to the independent (explanatory) variable is equal to zero. Which means there is no association between independent (explanatory) variable and dependent (predictor) variable. On the other hand, alternative hypothesis H_1 is that coefficient relating independent variable to the dependent variable is not equal to zero. Therefore, there is an association between dependent and independent variable.

4.2.1 Econometric Model

In this study, regression analysis has been conducted to estimate the relationship between selected explanatory variables and economic growth in each country. Therefore, ordinary least square (OLS) regression analysis has been conducted for each country to test the hypotheses. The main focus of the analysis in this research is to explore impact of energy consumption and CO2 emissions on economic growth. Based on production function, the empirical regression models are as follows:

GDP=f (EC, INF, INV, TO) (4.2.1.1)

$$GDP = \beta_0 + \beta_1 EC + \beta_2 INF + \beta_3 INV + \beta_4 TO + u_t \quad \ldots \quad (4.2.1.2)$$

Where variables are defined as follows:

GDP= GDP Growth Rate

EC= Energy Consumption

INF=Inflation Rate

INV=Investment Rate

TO= Trade Openness

u_t = Error Term

β_0 = Constant Term

β_1, β_2, β_3 and β_4 are the slope coefficients of the variables respectively.

GDP=f (CO2, INF, INV, TO) (4.2.1.3)

$$GDP = \alpha_0 + \alpha_1 CO2 + \alpha_2 INF + \alpha_3 INV + \alpha_4 TO + e_t \quad (4.2.1.4)$$

Variables are define as following:

GDP= GDP Growth Rate

CO2= Carbon Dioxide Emissions

INF=Inflation Rate

INV=Investment Rate

TO= Trade Openness

e_t = Error Term

α_0 = Constant Term

α_1 ... α_4 are the slope coefficients of the variables.

Chapter 5

EMPIRICAL FINDINGS

5.1 Multiple Regression Results

In this section, two separate regression analyses have been conducted individually for the selected high oil energy-consuming countries (USA, Japan, Russia, Canada and Australia). Annul time series data obtained from World Bank database covering the period from 1989 to 2014 for each country is used. The main purpose of conducting regression analysis is to test the research hypotheses mentioned in previous chapter.

For each country, the results are presented in equation forms. The equations display the coefficients, t-statistics and R-squared statistics of the regression estimates. The t-statistics are in parentheses. For 90% and 95% confidence levels, the critical (tabular) values of the t-statistics are 1.70 and 2.06 respectively. If the estimated t-statistics are greater than the critical values, the coefficient is significant and the corresponding variable has significant impact on the dependent variable. On the other hand, if the estimated t-statistics are less than the critical value, the coefficients is significant and the corresponding variable do not have significant effect on the dependent variable. In addition, *** ** and * denote 1%, 5% and 10% levels of significance respectively. in the results, GDP = GDP Growth Rate, C= Constant Term, EC = Energy Consumption, CO2= Carbon Dioxide Emissions, INF= Inflation Rate, INV= Gross Fixed Capital Formation (Investment rate), TO= Trade Openness (sum of import and export of goods and services share of GDP).

5.1.2 Regression Results for U.S.A

5.1.2.1 Regression Model 1: Impact of Energy Consumption, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

= -4.39 + 0. GDP 61EC -0.04 INF +0.38 INV - 0.03 TO

(-1.25) (5.16)*** (-0.19) (2.33)** (-0.64) R-squared =0.66

The result above clearly indicates that both energy consumption and investment rate have positive impact on GDP. The coefficients of the Energy consumption and the investment rate are significant at 1% and 5% respectively.

Holding other variables constant, 1% increase in energy consumption is associated with the increase of 0.61% increase in the growth rate of GDP. Similarly, 1% increase in investment rate results to about 0.38% increase in GDP growth. Moreover, the R-squared showed the variation in explanatory variables explains 66% of the variation in GDP growth. This indicates that the regression is a good fit and the estimates are valid for policy inferences.

Table 15: U.S.A Regression Results Model 1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.39	3.51	-1.25	0.22
EC	0.61	0.11	5.16	0.00
INF	-0.04	0.22	-0.19	0.84
INV	0.38	0.16	2.33	0.02
TO	-0.03	0.05	-0.64	0.52

5.1.2.2 Regression Model 2: Impact of CO2 Emissions, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

GDP = -5.93 + 0.43 CO2 -0.23 INF +0.43 INV -0.01 TO

(-1.58) (4.47)*** (-0.97) (2.47)** (-0.22) R-squared=0.61

In the above estimated regression equation, the parameter estimates of the CO2 emissions and investment rate are positive and statistically significant at 1% and 5%.respectively. This indicates that CO2 emissions and investment rate have significant positive impact on growth rate of GDP.

By magnitude, holding other variables constant, 1% increase in investment rate is associated with about 0.43% increase in GDP growth in USA. Furthermore, R-squared indicates that changes in the explanatory variables explain about 61% variation in GDP growth. This show a good fit of the regression model.

Table 16: U.S.A Regression Results Model 2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-5.93	3.75	-1.58	0.12
CO2	0.43	0.09	4.47	0.00
INF	-0.23	0.23	-0.97	0.33
INV	0.43	0.17	2.47	0.02
TO	-0.01	0.05	-0.22	0.82

5.1.3 Regression Results for Japan

5.1.3.1 Regression Model 1: Impact of Energy Consumption, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

GDP = -30.62 + 0.48 EC -0.46 INF +0.73 INV+0.52 TO

(-2.34) (4.68)*** (-1.01) (2.24)** (2.64)*** R-squared=0.65

The regression result for the case of Japan shows that energy consumption, investment, and trade openness have positive nexus with growth rate of GDP. Both energy consumption and trade openness rate are highly significant at 1% while investment rate is significant at 5%. The size of the coefficients indicate that, holding other variables constant, 1 % increase in energy consumption, investment rate and trade openness bring about 0.48% and 0.73% and 0.52% increase in GDP growth respectively, R-squared indicated variation in independent variables explains 65% variation in GDP growth.

Table 17: Japan Regression Results Model 1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-30.62	13.04	-2.34	0.02
EC	0.48	0.10	4.68	0.00
INF	-0.46	0.45	-1.01	0.31
INV	0.73	0.32	2.24	0.03
TO	0.52	0.19	2.64	0.01

5.1.3.2 Regression Model 2: Impact of CO2 Emissions, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

GDP = -28.49 +0.32 CO2-0.43 INF +0.72 INV +0.44 TO

(-1.95) (3.73)*** (-0.84) (1.97)* (1.98)* R-squared= 0.57

According to the regression result, CO2 emissions, investment rate and also trade openness have positive association with GDP growth rate. This is shown by the positive value of the coefficients.

CO2 emissions is statistically significant at 1% while both Investment rate and trade openness are positively significant at 10%. Other variables held constant, 1% increase in investment and trade openness will lead to increase of 0.72% and 0.44% increase in GDP growth respectively. This implies that investment and trade openness have significant impact on economic growth. The result is validated by the R-squared statistic (0.57) which show that variations in independent variables explain 57% variation in GDP growth.

Table 18: Japan Regression Results Model 2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-28.49	14.59	-1.95	0.06
CO2	0.32	0.08	3.73	0.00
INF	-0.43	0.50	-0.84	0.40
INV	0.72	0.36	1.97	0.06
TO	0.44	0.22	1.98	0.06

5.1.4 Regression Results for Russia

5.1.4.1 Regression Model 1: Impact of Energy Consumption, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

GDP= 15.74 +0.92 EC -0.07 INF -0.84 INV + 0.11 TO

(2.43) (5.90)*** (-1.48) (-5.08)*** (1.03) R-squared=0.83

The above regression result showed that investment rate has significant negative relationship with GDP growth. This is not acceptable. Therefore, regression analysis has been applied without this variable.

GDP= -3.55 +0.84 EC -0.06INF + 0.14 TO

(-0.46) (3.73)*** (-0.90) (0.95) R-squared=0.63

The result obviously shows that energy consumption is positively associated with GDP growth. It is also significant at 1% respectively. By holding other factors constant, 1% increase in energy consumption leads to roughly 0.84% increase in growth rate of GDP. Hence, energy consumption has significant effect on economic growth.

Moreover, the model has a good fit because the R-squared statistic show that changes in predictor variables explain 63% variations in GDP growth.

Table 19: Russia Regression Results Model 1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3.55	7.66	-0.46	0.64
EC	0.84	0.22	3.73	0.00
INF	-0.06	0.06	-0.90	0.37
TO	0.14	0.15	0.95	0.34

5.1.4.2 Regression Model 2: Impact of CO2 Emissions, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

GDP = 11.64 +0.77 CO2 -0.05 INF -0.57 INV+ 0.08 TO

(1.46) (3.91)*** (-0.97) (-2.74) *** (0.62) R-squared= 0.74

The above regression result showed that investment rate has significant negative relationship with GDP growth. This is not acceptable. Therefore, regression analysis has been applied without this variable.

GDP = 1.92 +0.89 CO2 -0.06 INF + 0.04 TO

(0.23) (4.05)*** (-0.99) (0.26) R-squared= 0.65

The above result indicates a positive relationship between CO2 emission and GDP growth. It also shows that the coefficient of CO2 is significant at 1%. The R-square also shows that variation in explanatory variables explains 65% variation in GDP growth.

Table 20: Russia Regression Results Model 2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.92	8.06	0.23	0.81
CO2	0.89	0.22	4.05	0.00
INF	-0.06	0.06	-0.99	0.32
TO	0.04	0.16	0.26	0.79

5.1.5 Regression Results for Canada

5.1.5.1 Regression Model 1: Impact of Energy Consumption, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

GDP = -0.39 + 0.43 EC – 0.05 INF - 0.13 INV + 0.09 TO

(-0.10) (2.97)*** (-0.19) (-0.76) (2.10)** R-squared =0.49

Regression analysis showed that energy consumption and trade openness positively associated with GDP growth. The positive coefficients of both variables indicate the positive relationship. Further, the result shows that Energy consumption is significant at 1% while trade openness is significant at 5 %. By magnitude of the coefficients, 1% increase in energy consumption results to 0.43% rise in GDP growth. Likewise, 1% increase in trade openness leads to about 0.09% increase in GDP growth while holding other factors constant. R-squared values indicates that variation in predictor variables explains 49% variation in GDP growth.

Table 21: Canada Regression Results Model 1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.39	3.70	-0.10	0.91
EC	0.43	0.14	2.97	0.00
INF	-0.05	0.27	-0.19	0.85
INV	-0.13	0.17	-0.76	0.45
TO	0.09	0.04	2.10	0.04

5.1.5.2 Regression Model 2: Impact of CO2 Emissions, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

$$GDP = -2.08 + 0.46\,CO2 - 0.03\,INF - 0.09\,INV + 0.10\,TO$$

(-0.62) (4.15)*** (-0.13) (-0.60) (2.58)*** R-squared =0.60

The result reported above demonstrate that CO2 emissions and trade openness have positive relationship with GDP growth. The coefficients of both of variables are significant at 1%. According to the regression result, one percent increase in trade openness brings about 0.10 percent increase in GDP growth. In addition, the R-squared illuminated variation in predictor variable explains 60% variation in GDP growth. this implies that the model is a good fit and the estimates are valid for policy recommendations.

Table 22: Canada Regression Results Model 2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.08	3.34	-0.62	0.53
CO2	0.46	0.11	4.15	0.00
INF	-0.03	0.23	-0.13	0.89
INV	-0.09	0.15	-0.60	0.55
TO	0.10	0.04	2.58	0.01

5.1.6 Regression Results for Australia

5.1.6.1 Regression Model 1: Impact of Energy Consumption, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

$$GDP = -0.11 + 0.30\,EC - 0.09\,INF + 0.08\,INV + 0.03\,TO$$

(-0.03) (2.79)*** (-0.54) (0.44) (0.69) R-squared=0.31

It is obvious in the fitted regression above that energy consumption positively associated with GDP growth. It is also significant at 1%. Ceteris paribus, 1%increase in energy consumption is likely to be associated with 0.30% increase in GDP growth. The R-squared showed variation in explanatory variables explains 31% variation in GDP growth. This indicates that the independent variables weakly explained the variation in economic growth.

Table 23: Australia Regression Results Model 1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.11	3.79	-0.03	0.97
EC	0.30	0.10	2.79	0.01
INF	-0.09	0.17	-0.54	0.59
INV	0.08	0.19	0.44	0.65
TO	0.03	0.05	0.69	0.49

5.1.6.2 Regression Model 2: Impact of CO2 Emissions, Inflation Rate, Investment Rate and Trade Openness on GDP Growth

GDP = -1.82 + 0.40 CO2 – 0.06 INF + 0.11 INV + 0.04 TO

(-0.47) (2.53)*** (-0.34) (0.60) (0.78) R-squared = 0.28

The result demonstrates that CO2 emission has positive relationship with GDP growth and the parameter estimate of CO2 emission is significant at 1%. The R-squared statistic indicated that variation in predictor variables explains 28% variation in GDP growth.

Table 24: Australia Regression Results Model 2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.82	3.84	-0.47	0.64
CO2	0.40	0.16	2.53	0.01
INF	-0.06	0.17	-0.34	0.73
INV	0.11	0.19	0.60	0.54
TO	0.04	0.05	0.78	0.44

Chapter 6

CONCLUSION

Mainly, this research provides an empirical evaluation of the association among energy consumption and CO_2 emissions and economic growth in the USA, Japan, Russia, Canada and Australia. In addition, the study analyzes the impact of some primary macroeconomic variables including inflation rate, investment rate, trade on economic growth of the selected countries. This study employs the multiple regression analysis annual data for the timespan ranging from 1989 to 2014.

The findings show that inflation rate do not have significant impact on economic growth in all of the countries. The plausible explanation is that the governments of the sampled countries maintain the rate of inflation as low and stable as possible to boost economic growth. This is one of the policy explanation deducible from the empirical results.

The investment rate has a positive impact on economic growth in the USA, Japan. This suggests that in these countries, the accumulation of physical capital is essential for the process of economic growth. The low interest rate and low unemployment combined with the high rate of savings in Japan have a positive influence on economic growth. Moreover, because of globalization, the countries have significantly transformed their economies and provide investment opportunities over the years (Hamada, 2019).

Furthermore, the findings of this study revealed that trade openness has a significant positive relationship with economic growth in Japan and Canada. This means that relative GDP shares of exports and imports are likely to influence the rate of economic growth positively in these two countries. Possibly, through their positive effects on productivity growth. Therefore, policies in terms of trade liberalization and trade agreements that eliminate trade barriers for these countries would propel long-run economic growth.

Therefore, the main conclusion of this study is that significant positive association exists between economic growth and energy consumption and between economic growth and CO2 emissions in the selected countries. Thus, hypotheses have been accepted based on this finding. Furthermore, the results suggest that in the top oil-consuming countries, energy is indeed an indispensable part of economic development. This conform to the submission of Ang (2008) that fossil fuel energy is vital for the purposes of industrialization, agriculture and transportation to enhance economic activity. Consequently, carbon dioxide gas emission results from the consumption of fossil fuel energy. This has unfavorable impact on the environment. In a nutshell, even though the level of GDP can increase as a result of using more fuel-based sources of energy, this may have an adverse effect on the environment and quality of life.

Since carbon emissions are destructive for the environment, various policies should be implemented to reduce environmental inequality. For instance, by using bio-diesel fuel instead of fossil fuel energy, the industrial and transportation sectors can mitigate the effects of greenhouse gas problems (Ozturk and Acarvci, 2010). In addition, based on the feasibility in the individual countries, governments can invest more in renewable sources of energy including solar energy, wind energy, hydro energy, nuclear energy to augment productivity (Siddique, et al, 2016). Moreover, increasing the rate of tax or price of energy for industries that have high energy consumption will encourage them to use energy efficiently (Hou, 2009). Therefore, implementing advanced technologies to augment the efficient use of energy in industries or plants is necessary.

It is highly recommended that special funds be allocated and support be given to scientific research centers in developed countries to find solutions for converting carbon emissions into green energy. This will be beneficial for both the environment and the citizens of those countries. Furthermore, the standardization of manufacturing systems will lead to the efficient use of energy and promote sustainable and low carbon economies.

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