THE ROLE OF ENERGY IN THE JAPAN ECONOMY

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Abstract—the purpose of this research is to investigate how energy resources affect Gross Domestic Product or economic growth of Japan, using data over a period from 2000 to 2014. The Cobb-Douglas production function was used for two models using macroeconomic indicators. These indicators are GDP, energy production, capital, net energy import and energy consumption. GDP is the dependent variable and energy production and capital are the independent variables in the first model. GDP again is the response variable and net energy import and energy consumption are the predictor variables for the second model. A regression analysis was run on both models to know the relationship between all the variables. The empirical results showed a positive relationship between GDP and energy production, capital and net energy import. However, the results showed a negative correlation between GDP and energy consumption. The result also showed Japan highly reliability on overseas countries for its energy supply and this dependency even increased after the Fukushima accident in March, 2013.

Key Words— Cobb Douglas model, economic growth, energy, GDP, Japan, non-renewable energy, renewable energy.

1 Introduction

Japan is country with population of about 127 million. According to the International Monetary Fund (IMF) world economic outlook (April, 2016), Japan has a nominal GDP of 4,412.600 billion (USD) with GDP per capita of 32, 484 (USD). They were ranked the third largest economy in the world. Japan is one of the leading automobile manufacturing countries in the world and has the largest electronic goods industry. Their main industries are motor vehicles, electronic equipment, machine tools, steel and nonferrous metals, ships, chemicals, textiles and processed foods. Services sector contributes 71.4% to their GDP, followed by the industry sector which contributes 27.5% and finally by agriculture sector that accounts for 1.2% to GDP. Their main export goods are motor vehicles, semiconductors, iron and steel products, auto parts, plastic materials and power generating machinery. Their main import goods are petroleum, liquid natural gas, clothing, audio and visual apparatus and coal. This shows how Japan really rely on importation for their energy needs because their main import goods are energy resources.

According to the Statistic Bureau, "statistical handbook of Japan 2016", Japan is dependent on imports for 91.5 percent of its energy supply. Since experiencing the two oil crises of the 1970s, Japan has taken measures to promote energy conservation, introduce alternatives to petroleum such as nuclear power, natural gas, coal, etc., and secure a stable supply of petroleum through stockpiling and other measures.

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As a result, its dependence on petroleum declined from 75.5 percent in fiscal year 1973 to 43.5 percent in fiscal year 2010. However, since the Great East Japan Earthquake, the percentage of fossil fuels has been increasing, as a substitute for nuclear power as fuel for power generation. The level of dependence on petroleum, which had been on a declining trend in recent years, increased to 47.2 percent in fiscal year 2012"

Energy consumption in Japan doubled after the World War 2 due to rapid industrial growth in the country. The country lacks significant energy resources including crude oil, natural gas and uranium. One of the problems facing the world and Japan in particular is the depletion of energy resources. According to IEA (2013), "Japan's total energy production is 27958ktoe and its energy imports is 454807ktoe". These figures show how the country largely depend on importation of energy for its energy consumption. At the same time, the Japan economy has been showing inconsistent growth rate. The economic growth rate decreased from 1.7% in 2012 to 1.4% in 2013. It further decreased to 0.0% in 2014 and then showed an increase from 0.0% to 0.5% in 2015. The current growth rate in 2016 is 0.8%. The purpose of this paper is to demonstrate the role of energy resources on the Japan's economic growth. It will also evaluate the impact of energy resources depletion on economic activities, investment and standard of living in Japan. This paper will investigate the relationship between economic growth and net energy import.

There are many reasons for carrying out this research, firstly, following the Fukushima nuclear disaster, the Japanese government has come out with a drastic and proactive strategy for securing gas and other energy supply in sufficient volumes and reducing its purchase price through the establishment of long term contracts with producing countries. Therefore, it's very important to know the impact of this energy imports and its prices on economic growth. Secondly, Pollution and global warming is one of the major problems facing the world and economic policy makers. Energy production and consumption are one of the major sources of carbon dioxide emissions, therefore, economic and energy policy makers are in a state of confusion whether a decrease in energy production and consumption will reduce economic growth. Hence, there is the need to analyze this scenario.

This paper is structured in the following way. The second part talks about the theoretical and empirical contributions and findings on the role of energy resources on Japan's economy. The third part shows the data and model used in the research. The fourth part gives empirical results and the final part gives conclusion and recommendations.

2 THEORETICAL AND EMPIRICAL FRAMEWORK ON ENERGY AND ECONOMIC GROWTH

The mainstream of economic growth theory gives minimum attention to the impact of energy in economic growth. However, to know the actual importance of energy in economic growth, it's essential to begin with the impact of energy in production. Looking at the theories of production, the neoclassical economic theory explains the economy as a closed system where output is produced by inputs of labour and capital. Hence, the increased inputs or their quality determines economic growth. Energy inputs have indirect significance on economic growth and they are considered as intermediate inputs. According to Stern (1999), the mainstream economists have accepted the concept of primary and intermediate factors of production. Primary factors of production are inputs that are already in existence at the beginning of the period you looking at and are indirectly used up in production, while intermediate inputs are those that are totally used in production process to produce other goods or services. The primary factors of production are land, capital, labour and entrepreneurship, while goods such as fuels and materials are intermediate inputs. This perspective has resulted in a focus in mainstream growth theory on the primary inputs, especially capital and labour, while intermediate inputs like energy have got an indirect role. According to them, the quantity of energy available to the economy is endogenously given, though determined by biophysical and economic constraints (Stern and Cleveland, 2004:5). The significance of energy in the economic growth was first mentioned by Georgescu-Roegen (1971) who argued that the physical dimension of economic production needed more explicit attention in growth theory. Other economists started to develop production functions that are dependent on energy and materials besides the normal labour and capital inputs, after the first oil crisis in 1973-74 (for example; Tintner et al., 1974; Berndt and Wood, 1979). During the time, the alternative views on economic growth have appeared. There are much of the essential literature outside the mainstream known as ecological economics that place a much value on the importance of energy in production and growth. In addition, energy is the only primary factor of production to some of them, while capital and labour are treated as flows of capital consumption and labour services, rather than stocks (Gever et.al., 1986). Energy is not just a vital production factor according to ecological economists, but some (Cleveland et.al., 1984) even conclude that energy availability drives economic growth, in the contrast to economic growth that result from increased energy use. The ecological economists focus on the material basis of the economy and consider an economy as an open subsystem of the global ecosystem. They think that economic growth depends largely on energy, hence depletion of energy resources will affect the economy. Although various schools of thought exist in the field, according to Dizdarevic and Zikovic, (2010), they all come from common principles – the laws of thermodynamics. The first law of thermodynamics states that energy cannot be created nor destroyed, only transformed. This means that the only available energy source is solar energy that can be used directly or in an embodied state such as fossil fuels. The second law states that the entropy of an isolated system, which is not in equilibrium, will tend to increase over time. It implies that energy can be reused, but it will increasingly reach a less useful state and therefore additional energy is required. This also implies limits to the extent to which energy can be substituted for by other inputs into the production process (Ockwell, 2008: 4601).

3 DATA AND THE MODEL

Data used in this analysis are real annual GDP in billions of USD, total energy production, capital, total energy consumption and net import of energy in kilotons of oil equivalent. The time period for this analysis is 2000-2014.
The variables used in the analysis were abbreviated and their meaning are as follows;

LN.GDP - natural logarithm of Japan real annual gross domestic product in billions of USD.

LN. Energy (E) - natural logarithm of total energy production of Japan.

LN. Capital (K) - natural logarithm of total asset of Japan.

LN.TEC (C) - natural logarithm of total energy consumption in kilotons of oil equivalent.

LN.NI (N) - natural logarithm of net import of energy in kilotons of oil equivalent.

In this paper, the first analysis was about the relationship between GDP and total energy production and capital. Then, the relationship between GDP and total energy consumption and net energy import was also analyzed.
The Cobb Douglas production function was used to show the relationship between GDP and the other variables. The Cobb Douglas production function takes into account the interactions between all the variable. Thus, the Cobb Douglas production function can be used to predict the effect of one variable on the other variable and can also be used to predict the effect of specific policy on the economy.
Firstly, the model used GDP, total energy production and capital, with GDP as the dependent variable and energy and capital as predictor variables. The Cobb Douglas function used for the first model was;

$$Y = A\,E^{\alpha}K^{\beta}$$

Where,
Y = GDP
E = Energy production
K = Capital
A = Constant
α and β are constants between 0 and 1.

The above function was transformed into linear equation and the resulted function was;

$Ln\,Y = Ln\,A + \alpha Ln\,E + \beta Ln\,K$

Secondly, the model used GDP, total energy consumption and net energy import, with GDP as the dependent variable and energy consumption and net energy import as predictor variables. The Cobb Douglas function used for the second model was;

$$Y = A\,N^{\alpha}C^{\beta}$$

Where,
Y = GDP
C = Energy consumption
N = Net energy import
A = Constant
α and β are constants between 0 and 1.

The above function was transformed into linear equation and the resulted function was;

$Ln\,Y = Ln\,A + \alpha Ln\,N + \beta Ln\,C$

4 Empirical Results and Discussion

A regression analysis was run on both models using R statistical software. Table 1 below shows the regression analysis on the first model.

Table 1.

Regression analysis for the first model

Model	B	Std. Error	t-value	Sig. value
Constant	**4.825**	**0.499**	**9.661**	**0.000**
lnenergy	**0.606**	**0.098**	**6.179**	**0.000**
lncapital	**0.071**	**0.016**	**4.465**	**0.001**

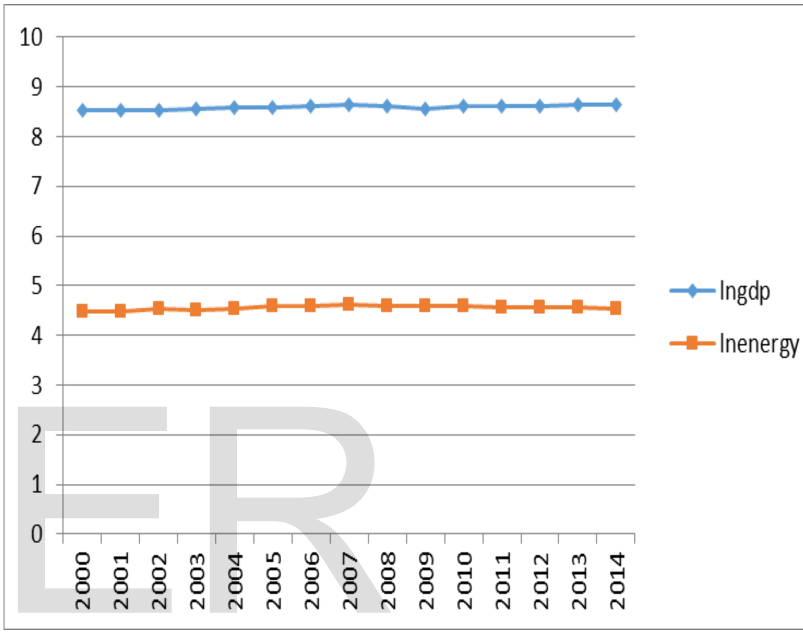
Dependent Variable: lngdp

The regression analysis yielded a positive coefficient for both energy production and capital. The coefficient of energy is 0.606 ($\alpha = 0.606$) and that of capital is 0.071 ($\beta = 0.071$). The result also showed a high t-values and very low significant values implying that the analysis is statistically significant.

The regression result shows a positive correlation between GDP and energy on one hand and GDP and capital on the other hand. This implies, GDP and energy has been moving in the same direction and this also shows how energy is contributing to the growth of Japan. Japan is highly a technological country that relies on energy for its economic activities. Hence, energy is a key determinant of economic growth of Japan. Japan's GDP has been undergoing inconsistent growth and this is highly attributed to the inconsistency in energy production. The relationship between GDP and energy production is illustrated with the diagram below.

FIGURE 1.

GDP AND ENERGY PRODUCTION RELATIOSHIP



In the above diagram, the changes in both GDP and energy production is very small but the positive correlation is highly illustrated. For instance, in 2008, total energy production decreased from 4.60208 to 4.58046 in 2009. Likewise, GDP also decreased from 8.62308 in 2008 to 8.56642 in 2009. Moreover, after the Fukushima's accident in 2011, all 50 of Japan nuclear reactors were progressively shutdown. Japan's power from nuclear energy in 2011 decreased from 30% to 0%. This affected Japan's energy production. This is shown in the above diagram, where, energy production decreased from 4.59873 in 2010 to 4.56392 in 2011. Also, GDP decreased from 8.61227 in 2010 to 8.60771 (in natural logarithm values). To throw more light on this, according to the International Energy Agency (IEA), Japan's energy production decreased from 99004ktoe in 2010 to 51065ktoe in 2011. This was as a result of the Fukushima accident and the shutdown of all their nuclear reactors. This again affected Japan's GDP, making it decrease from 5498.72 (billions of USD) in 2010 to 5473.74 (billions of USD) in 2011.

Table 2.

Regression analysis for the second model

Model	B	Std. Error	t-value	Sig. value
Intercept	10.7424	3.1058	3.459	0.00473
LN.NI	0.6175	0.2315	2.667	0.02052
LN.TEC	-0.7904	0.2200	-3.593	0.00369

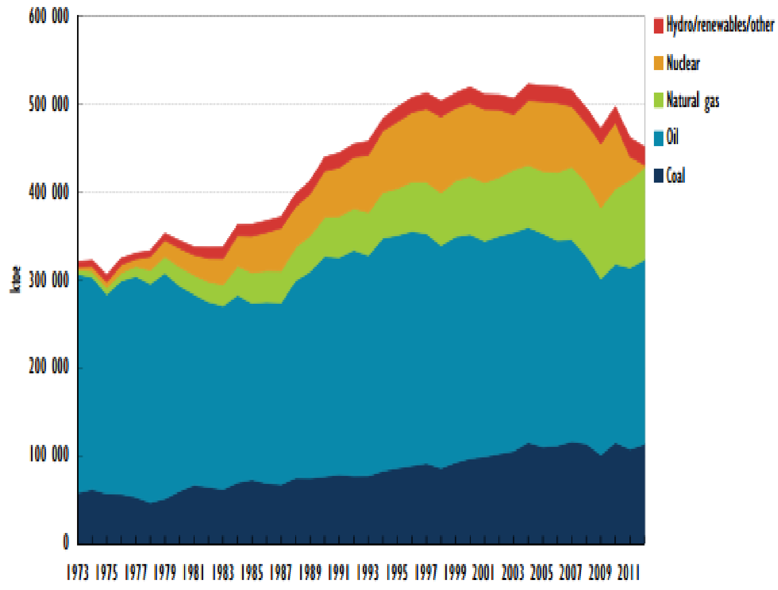
Dependent Variable: lngdp

The second regression analysis yielded a positive coefficient for net energy import and a negative coefficient for total energy consumption. The coefficient of net energy import is 0.6175 (α = 0.6175) and that of total energy consumption is -0.7904 (β = -0.7904). The result also showed a very low significant values and low P-value implying that the analysis is statistically significant.

The regression analysis for the second model showed that there is also a positive relationship between GDP and net energy import. However, the result also showed that GDP and total energy consumption are negatively correlated. This means, net energy import has significant influence on economic growth of Japan. This because, Japan depends hugely on importation for its energy needs. The negative relationship between GDP and total energy consumption doesn't mean that, total energy consumption has no influence on economic growth because, in reality, it does have major influence on economic growth, however, this negative relationship is as a result of advancement in technology, and thus, many items on the Japan's market are energy efficient. This has resulted in a decrease in energy consumption in Japan, even though, energy demand is still high. The dependency of Japan on foreign countries for its energy needs and the energy supply structure will be illustrated with the following diagrams.

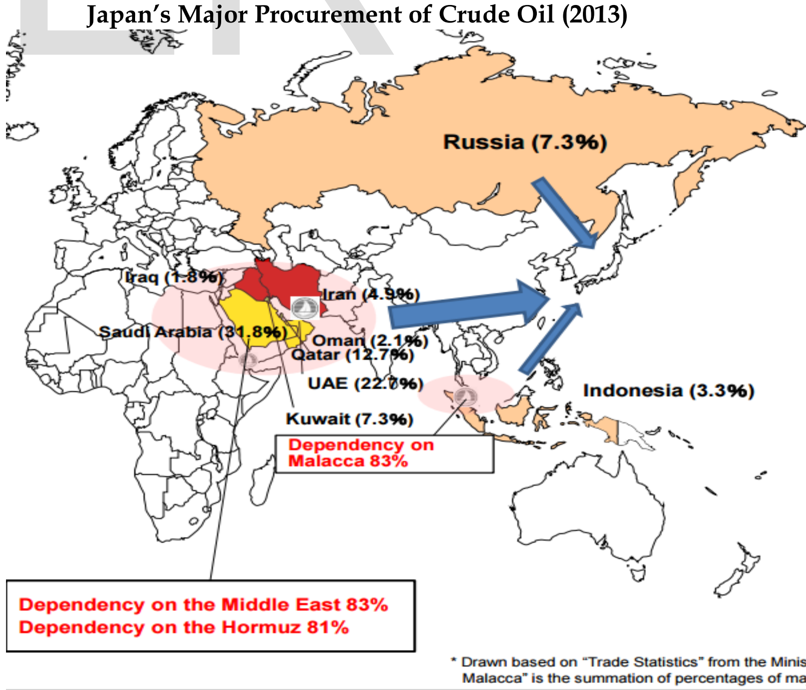
Figure 2.

Japan's Energy Structure



Source: International Energy Agency "Energy Supply Security 2014" Chapter 4: Emerging response system of individual IEA countries.

Figure 3.
Japan's Major Procurement of Crude Oil (2013)



*Drawn based on "Trade Statistics" from the Ministry of Finance and other sources. Dependency on Malacca is the

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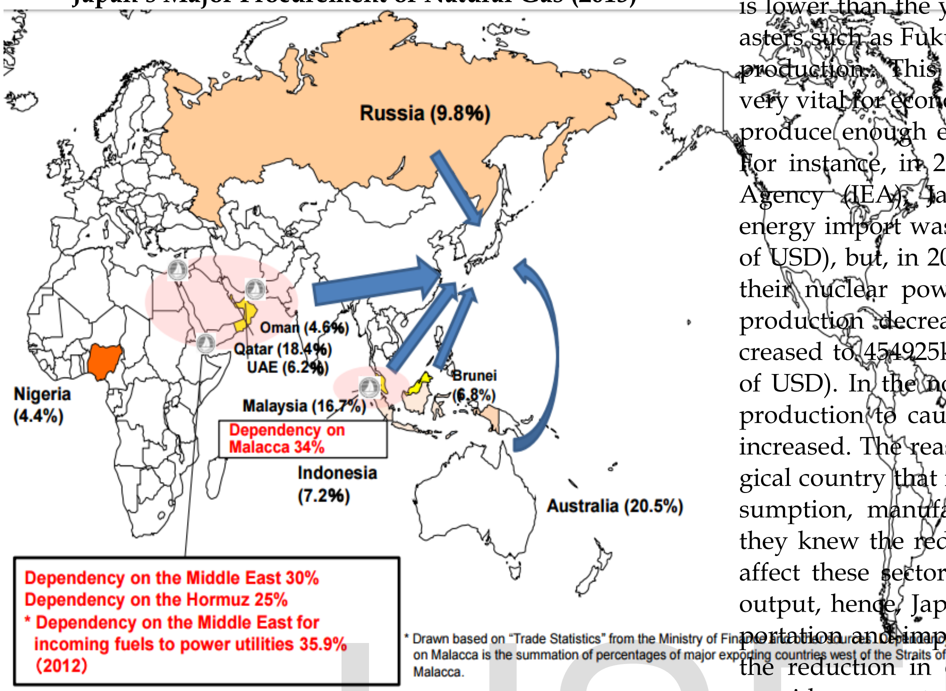
summation of percentages of major exporting countries west of the straits of Malacca.

Figure 4.
Japan's Major Procurement of Natural Gas (2013)

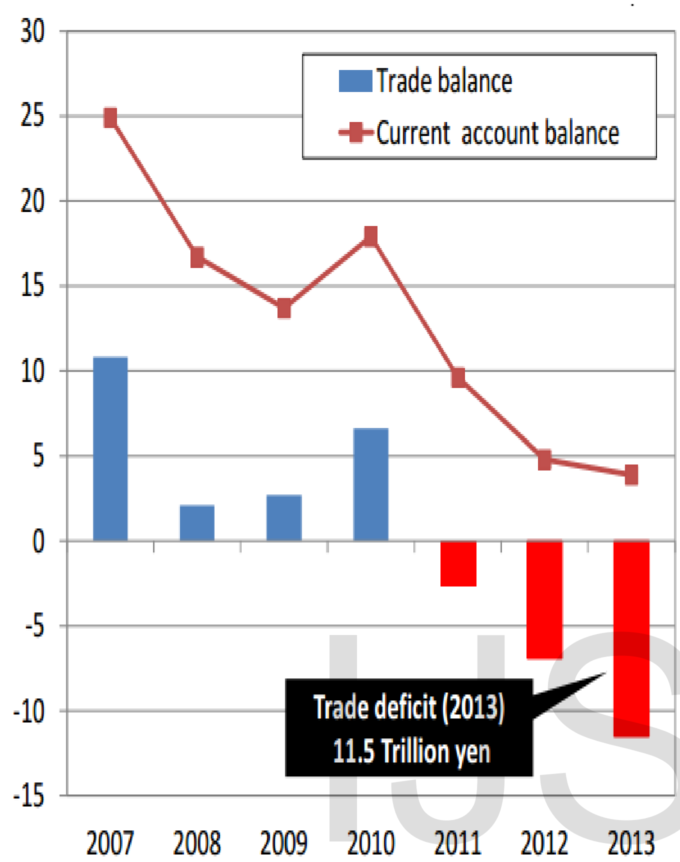


*Drawn based on "Trade Statistics" from the Ministry of Finance and other sources. Dependency on Malacca is the summation of percentages of major exporting countries west of the straits of Malacca.

Japan relies on foreign countries for its energy supply. Figure 3 and 4 shows the countries where Japan energy is imported from. Non-renewable energy resources (crude oil and natural gas) are mainly what they import. Japan depend on Middle East for 83% for its crude oil importation and 30% for its natural gas importation. In Middle East, their most energy supply is from UAE and Qatar. Japan also relies on other countries like Australia, Russia, Indonesia, Malaysia, Nigeria, Oman, Brunei, Saudi Arabia, Iran, Iraq and Kuwait for all its fossil fuel importation. Due to Japan's high dependency on overseas countries for its fossil fuel, Japan's energy supply is highly affected by external factors. Due to increase in fossil fuel imports, Japan faces further dependency on Middle East, a rise in electricity prices, a rapid increase in greenhouse gas emissions, and an outflow of national wealth. However, though Japan's economic growth is experiencing inconsistent growth which is attributed to these above reasons, yet importation of fossil fuel into the country is a key figure for sustaining GDP growth, since, the country's domestic production of energy is less but the country needs huge energy supply to meet its energy demands, these importation of energy resources ensure that Japan is able to supply its citizens and industries with the necessary energy demand to ensure production, manufacturing and other economic activities. Thus, though, Japan spends so much money on importation of fossil fuels which affect annual expenditure, but, these energy imported enable them to meet all energy demands and increase their productivity, hence, in effect, Japan's GDP is currently growing, though, the growth is lower than the years before they started having natural disasters such as Fukushima accident which affected their energy production. This means, importation of energy resources is very vital for economic growth of Japan since the country can't produce enough energy internally for its economic activities. For instance, in 2009, according to the International Energy Agency (IEA), Japan's energy production was 92504ktoe, energy import was 402633ktoe and GDP was 5251.31 (billions of USD), but, in 2013, after the Fukushima accident, where all their nuclear power plants were shutdown, Japan's energy production decreased to 27651kteo, energy importation increased to 454925ktoe and GDP increased to 5644.66 (billions of USD). In the normal case, we expect a decrease in energy production to cause GDP to decrease but, in this case, GDP increased. The reason is that, since Japan is a highly technological country that relies largely on energy for production, consumption, manufacturing, construction and other activities, they knew the reduction in its energy production is going to affect these sectors, which will results in low production or output, hence, Japan increased its expenditure on energy importation and imported more energy resources to take care of the reduction in energy production. This enabled Japan to provide energy to all sectors of the economy to carry on their daily economic activities. Thus, the reduction in energy production effect wasn't felt by these sectors, but what was affected was the budget of the country, as more money was needed to be spent. This ensured more production, which in return, enabled them to have the rise in GDP in 2013. This the reason GDP and net energy import is positively correlated. As a result, though more money is being spent to meet their energy demands, but these energy imported are used to increase output, which result in increase in GDP and ensure economic growth of Japan. The balance of trade and current account of Japan will be illustrated in the following diagram.

Figure 5.

Balance of Trade Balance and Current Account Balance of Japan



Source: Collaborative Research Center for Energy Engineering, Institute of Industrial Science, the University of Tokyo.

In the above diagram, both balance of trade and current account of japan has been showing decreasing trend. Balance of trade before 2011 was positive, this implies, before the Fukushima accident, Japan's total exportation exceeded importation. However, after the Fukushima accident in March, 2011, Japan's energy production reduced drastically due to the shutdown of their nuclear power plants, therefore, Japan increased their importation of energy resources which affected their balance of trade. In 2013, Japan recorded a balance of trade deficit of 11.5 trillion yen, which was highly due to increase in importation of energy resources to meet its energy needs. Thus, due to high dependency of Japan on overseas country for fossil fuel, Japan's expenditure has increased which has resulted in balance of trade deficit. However, though, there is balance of trade deficit, but the economy has been doing well. This because, the energy imported are used by the various sectors of the economy efficiently to increased production, which increase GDP and promote the growth of the economy.

The regression analysis for model two also showed a negative relationship between GDP and energy consumption in Japan. The reason for these negative relationship is as a result of advancement in technological products which are energy efficient. Japan's improvement in energy efficiency was achieved by using more energy efficient technology or production process and by using energy efficient products. A decreased in energy consumption caused Japan's GDP to increase because, reducing energy use reduces energy costs and result in a financial cost saving to consumers. Reducing energy use is also a solution to the problem of reducing greenhouse gas emissions. Modern appliances, such as, freezers, ovens, stoves, dishwashers, and clothes washers and dryers, use significantly less energy than older appliances. Installing a clothesline will significantly reduce one's energy consumption as their dryer will be used less. Current energy efficient refrigerators, for example, use 40 percent less energy than conventional models did in 2001. Following this, all households in Japan tried to change their more than ten-years-old appliances into new ones, this helped Japan to save billion kWh of electricity annually, hence reducing CO_2 emissions. Moreover, the severe power supply deficiency caused by the earthquake also affected the energy use attitude and stimulated the implementation of more efficient systems.

5 Conclusion and Recommendations

This paper examined the impact of energy resources on economic growth of Japan over the period from 2000 to 2014. The findings showed that, energy is a major contributor to the growth of the Japan's economy and due to Japan's dependency on energy from foreign countries, its energy supply will always be affected by external factors, which increase the government budget on importations. The findings also shows that reduction in energy consumption saves cost and benefits consumers, which in tend result in higher production and economic growth. In this regards, Japan government needs to ensure the safety of its domestic energy production, so that, Japan can increase domestic energy production and reduce it over reliance on foreign countries for its energy use. Thus, policies aimed at decreasing energy consumption, increasing domestic energy production and reducing energy dependency will have to be implemented by the Japan's government to ensure sustainable economic growth of the country.

In addition, the findings show that, Japan's energy imports and domestic production are mainly non-renewable energy resources such as crude oil and natural gas. These resources are depleting at a very fast rate, which means, a time will come that production of non-renewable energy will be low and hence its prices will be extremely high. With Japan's over reliance on these resources, means when this period come, Japan will be in serious energy crises. In order not to have such experience in the future, Japan should reduce its dependency on non-renewable energy and focus on renewable energy production, which is much reliable because these renewable energy resources replenish itself.

To sum it up, Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy and are high priorities in the sustainable energy hierarchy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted, hence Japan should implement such policies.

The limitation of this study is the short period of time used. In the future, it will be more interesting to investigate on this topic over a longer period of time. Despite this limitation, this research provides some useful insights on Japan's energy situation and its impact on economic growth.

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