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The relationship between energy consumption and economic growth in Vietnam

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Abstract

The relationship between energy consumption and economic growth in Vietnam

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Energy plays a vital role for the economic growth of a country, especially when a country is in process of hastening its economy into the industrialization stage like Vietnam. The link between economic growth and energy consumption has been widely studied in economic literature. So far, however, there has been little or no discussion about the causal relationship between GDP and energy consumption for Vietnam. This study investigates the relationship between per capita GDP (PCGDP) and per capita energy consumption (PCEC) during the 1984 – 2010 period. In order to find out the causal nexus between them, the Johansen co-integration tests and vector error correction models (VECM) for Granger causality tests have been applied.

Results show that the PCGDP and PCEC are co-integrated and that there is a long-run (defined as longer than 1 year) unidirectional causality running from energy consumption to GDP for Vietnam in the sample period and a short-run (defined as 1 year or less) causality on the contrary, running from GDP to energy consumption but not vice versa. Therefore, based on the results, an important policy implies that an economy is energy dependent; energy is a stimulus to growth, hence any constraints put on energy consumption to help reduce emissions or any shock to energy supply will have an effect on economic growth. Furthermore, policymakers are suggesting taking not only short-term, but also long-term perspectives into consideration when designing energy conservation policies. At the moment, it is imperative to reduce energy intensity which means a more efficient use of energy and a reduction in greenhouse gas emissions using alternative energy options.

Key words: Energy consumption, economic growth, energy efficiency, co-integration test, Granger causality, Vietnam.

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Chapter 1. Introduction

In the process of socio-economic development of Vietnam over the last few decades, energy has played an important role not only as fuel to grow the economy, but also as a principal contributor to the country's export earnings, GDP and to government revenues. The significant contribution of energy to Vietnam's economy is considered to be roughly one fifth of all exports (VCR[1], 2010). However, accelerated exploitation of natural resources is posing serious risks to preservation and sustainable development of natural resources and is also to some extent discouraging innovation and investment to build up new capabilities instead of relying on natural endowments. The challenge for developing countries nowadays is that the luxury of having plenty of cheap oil is no longer the case and Vietnam is certainly not alone in having to face this problem.

[1] VCR – Vietnam Competitiveness Report

1.1 Problem Description

The link between energy consumption and economic growth has been widely studied in economic literature. However, there are very little or no research discussing about the causal relationship between energy consumption and GDP for Vietnam. There are two opposing views regarding the influencing of energy consumption on economic growth among energy economists. One point of view suggests that energy is the primary source of value because other factors of production such as labor and capital cannot do without energy. All production involves the transformation or movement of matter in some way and all such transformations require energy, and there must be limits to substitution of others factors of production for energy so that energy is also an essential factor of production (Stern, 2003). This perspective is the so-called “growth hypothesis” and advises that any shock to energy supply will strongly have a negative impact on economic growth.

The other point of views argues that energy is neutral to growth because the cost of energy is very small as a proportion of gross domestic product (GDP). Therefore, energy considered to be an “intermediate good” rather than a “primary input” into the production process. It is against “growth hypothesis” and stated that economic growth could remain in spite of limited sources of energy resources. It has also been discussed that the possible impact of energy consumption on growth will depend on the structure of economy, the phases of development, increasing from an agricultural stage to an industrial one and then decreasing for certain service based economies which are not energy intensive activities (Belloumi, 2009). Hence, understanding this relationship can provide insight for policy implementations to achieve sustained economic growth under various energy scenarios in the context of rising international debate on global warming and the reduction of greenhouse gas emissions.

1.2 Research Objectives

This study attempts to investigate the causal relationship between energy consumption and economic growth. We will try to identify evidence of this nexus: no causality, unidirectional causality or bi-directional causality between energy consumption and GDP in Vietnam by taking data from 1984 to 2010. The direction of causation between energy consumption and economic growth has a critical policy implication. If, for example, there is a unidirectional causality running from economic growth to energy consumption, it implies that energy conservation policies might be implemented with little adverse or no effects on economic growth. On the other hand, if unidirectional causality runs from energy consumption to economic growth, any constraints put on energy consumption could lead to fall in economic growth and if there is “no causality” in either direction, the so-called “neutrality hypothesis” would imply that energy conservation policies which do not affect economic growth (Chontanawat et al., 2008). To achieve the above objectives, the study has raised and will try to answer the

following research questions: a) Does long-term equilibrium exist between energy consumption and GDP? b) Whether or not economic growth leads to energy consumption or whether energy consumption leads to economic growth? c) How effective is the use of energy in Vietnam compared to other Asian countries?

1.3 Research Structures

The entire study is organized as follows. Chapter 2 will introduce and analyze the study background about Vietnam energy sector and the comparison of energy intensity between Vietnam and other Asian countries. In chapter 3, the existing literature between energy consumption and economic growth has been thoroughly reviewed. Chapter 4 delineates the methodology of the study. The data used and report on our empirical results are presented in chapter 5. Finally, conclusions and policy implication are discussed in Chapter 6. These findings will be used to provide advice for the effective management of Vietnamese energy sector.

Chapter 2. Study Background

2.1 General information

Vietnam – a developing country in Southeast Asia – has been one of the most impressive growth stories in the global economy over the last few decades. Following the economic reforms in 1986 which transformed the country from a centrally planned to a market economy, GDP per capita has grown at an average annual rate of 5.79 percent between 1984 and 1997 (pre-Asian Financial crisis) and at the higher rate of 7.09 percent between 1997 and 2008 (Fig. 1). Millions of Vietnamese have been lifted out of poverty. The Asian financial crisis and the current global economic downturn did not affect Vietnam as much as many other countries. International donors view Vietnam as one of their clear success cases, where foreign aid is generally well utilized and has a visible impact. Private investors also see Vietnam as an increasingly attractive destination (VCR, 2010).

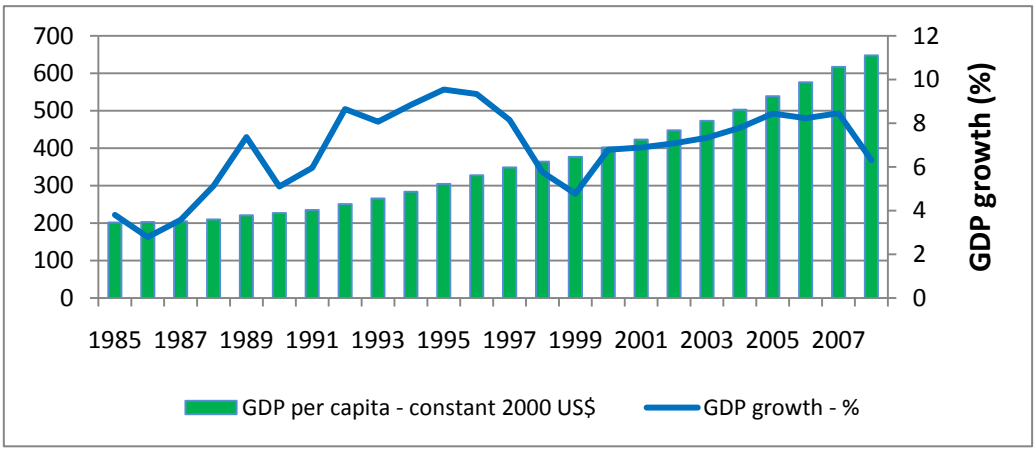


Fig. 1: Vietnam's GDP growth from 1984 to 2008 (World Bank, 2011)

According to Vietnam Competitiveness Report 2010, Vietnam stood out as one of the fastest growing economies in the world during this period (see Fig. 2) allowing it to reach the lower middle-income group in 2008 when its per capita income exceeded USD 1,000. And it continues to make significant progress, despite the recent financial crisis. While Vietnam's economic growth over the past two decades has been impressive in relative terms, the per capita GDP (measured using purchasing power parity) of the country remains low compared to other countries. In 2009, Vietnam ranked 113th in the world and it is still among the poorest countries in East Asia. In 2009 its per capita GDP was US$ 1052, in comparison to the following:

Philippines US$ 1745, Indonesia US$ 2349, China US$ 3747, Thailand US$ 3894 Malaysia US$ 6975.

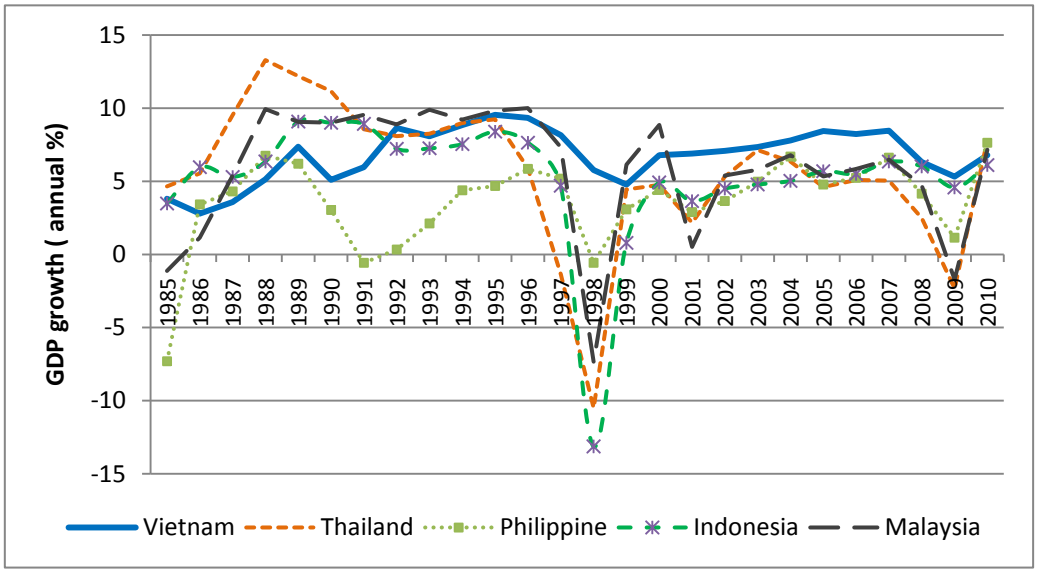


Fig. 2: Economic growth in Asian countries (World Bank, 2011)

Vietnam's economy has maintained a positive growth rate and it is expected that this trend will continue in the years to come. In this growth, the country's energy sector, which also provides approximately one fifth of the nation's foreign earnings (VCR, 2010), will continue to play a vital role. Despite the fast growth and being a net energy exporting country since 1990, a

large part of the rural population still relies heavily on non-commercial biomass energy sources, which still accounts for over one third of total energy demand in the country as of 2005 (Khanh Toan, P., N. Minh Bao, et al., 2011). Vietnam's per capita consumption of commercial energy[2] thus remains among the lowest in Southeast Asia (Fig. 3), which has historically been a key factor in representing the economic and human development each country. In 2008, this figure per capita in Vietnam was: 689 KgOE, in comparison to the following: Thailand 1591 kgOE, Indonesia 874 kgOE, China 1599 kgOE, Singapore 3828 kgOE, Malaysia 2693 kgOE (World Bank, 2011).

[2] The term commercial energy refers to coal, petroleum products, natural gas, and electricity. Traditional biomass fuels are non-commercial energy

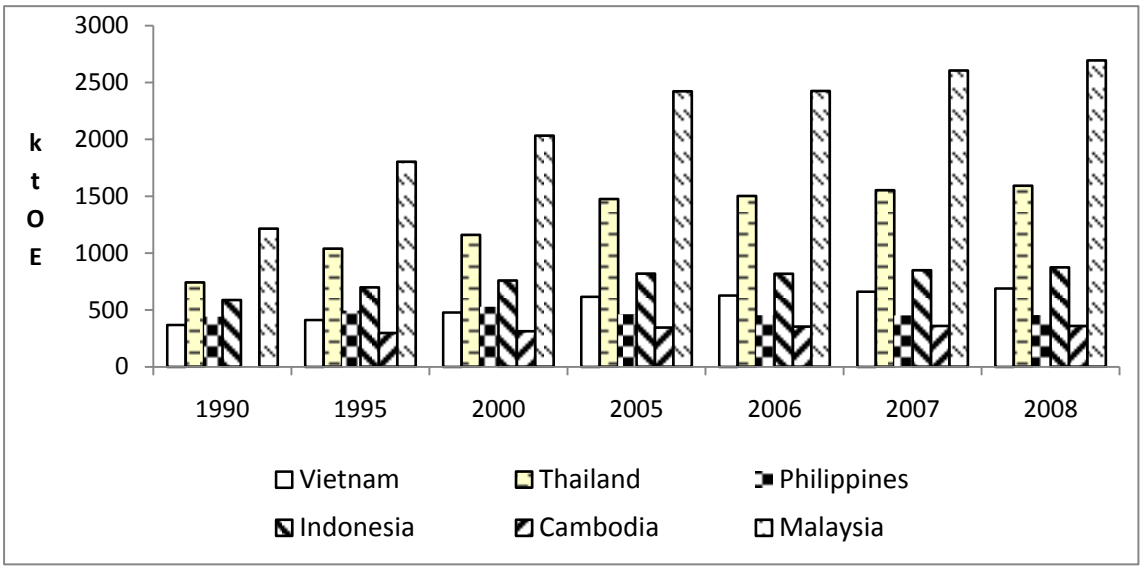


Fig. 3: Per capita energy consumption in Asian countries (World Bank, 2011)

Energy is explored, transformed, transported and used with low efficiency while the self-usage and loss rate is high. Energy is supplied not rationally among urban and rural, lowland and mountainous areas. In the rural and mountainous areas, where the source of commercial energy supply is very limited, the traditional non-commercial energy (wood, charcoal, rice husk and other agriculture by-products) is mostly used for cooking (United Nations, 2005).

2.2 Energy supply

Viet Nam's total commercial primary energy supply (TPES) in 2008 was 35 331 kilotonnes of oil equivalent (ktoe), whereas total commercial energy consumption was 28 479 ktoe. By energy source, 41% of this came from oil, 34% from coal, 18% from natural gas and 7% from other resources. Viet Nam is endowed with a variety of primary energy resources, including coal, oil, gas, uranium, and renewable energy. Coal resources are of the anthracite and lignite types, with anthracite coal found in Quang Ninh province, and lignite found in the Red river delta area. Most of the coal found in Viet Nam is anthracite, accounting for 93% of the country's coal reserves. As of 2008, Viet Nam's coal production stood at 39.8 million tonnes per year, matched by a growth in exports and domestic demand. Over 50% of coal production in 2008 was exported to China, Japan, Korea, Chinese Taipei, Thailand, France and other economies (APERC, 2010)

Table 1: Energy supply and Consumption, 2008 (APERC, 2010)

Primary energy supply (ktoe)		Final energy consumption (ktoe)	
Indigenous production	46 997	Industry sector	11 244
Net imports and other	–10 622	Transport sector	9 863
Total PES	35 331	Other sectors	7 312
		Total FEC	28 479
Coal	12 017	Coal	8 289
Oil	14 394	Oil	13 806
Gas	6 408	Gas	540
		Electricity	5 844
Other	2 512	Other	14 848

According to APEC Energy Overview 2010, Viet Nam's proven oil reserves of 615 Mt in 2005, the latest year for which figures are available, are likely to rise following increased exploration activity. Crude oil production has grown rapidly, from only 2530 ktoe in 1990 to 15 172 ktoe in 2008. From 2000 to 2008, oil production and exports grew at an average annual rate of 8%. Viet Nam has 14 producing oilfields: Bach Ho, Rong, Dai Hung, Rang Dong, Ruby, Emerald, Su Tu Den, Bunga Raya, Bunga Tulip, Ca Ngu Vang, Phuong

Dong, Song Doc, Cendor and Bunga Kekwa fields in Russia (PVN[3], 2009).

Viet Nam's gas reserves are more promising than its oil reserves. In 2005, the latest year for which figures are available, proven gas reserves were estimated at 600 bcm, although that figure is likely to increase as more oil and gas are discovered. Gas resources are found in many parts of Viet Nam, but large gas reserves are almost all found in offshore basins in the southern area of Vietnam (APERC, 2010).

In the case of petroleum products, Vietnam – despite being a net exporter – still has to import its almost entire requirements of refined petroleum products because the first refinery of Dung Quat with a capacity of 6.5 mn tons per year has started operation in early 2010 and is able to meet only one third of the domestic demand (PVN, 2011); and the second and third refineries with an annual capacity of 8.4 and 10 million tons are scheduled for commissioning in 2013 and 2014, respectively. In addition to this, the lack of stockpiling also makes Vietnam's energy supply system highly vulnerable to

[3] PVN – Vietnam Oil and Gas Group (PetroVietnam)

changes in the world energy market, especially when there is an oil supply disruption due to geopolitical conflicts.

With rapidly increasing energy demand and limited indigenous supply, Vietnam is expected to become a net energy importer within this decade. It is projected that by 2025 the country will need to import nearly 49% of its total commercial primary energy needs of which coal, oil and gas are expected to account for 19%, 23%, 5%, respectively, in the total imported energy. Meanwhile, Vietnam is considering the expansion or construction of hydroelectric and nuclear power plants, thermal power generation using imported coal, and electricity import (Khanh Toan, P., N. Minh Bao, et al., 2011).

2.3 Energy demand

Though Viet Nam's economic output was dominated by the agricultural sector for many years – agriculture accounted for about 38.7 percent of total output in the 1990 – the last nineteen years have seen a drastic decrease in the agricultural sector to 20.9 percent in terms of contribution to GDP. The total of the industrial and commercial/services sector accounted for about 80 percent of GDP in 2009, increasing to nearly 30 percent by 2009, with the remaining fraction of GDP being in the agricultural sector (GSO, 2010). Fig. 4 provides a contribution to GDP by sector during the period 1990–2009.

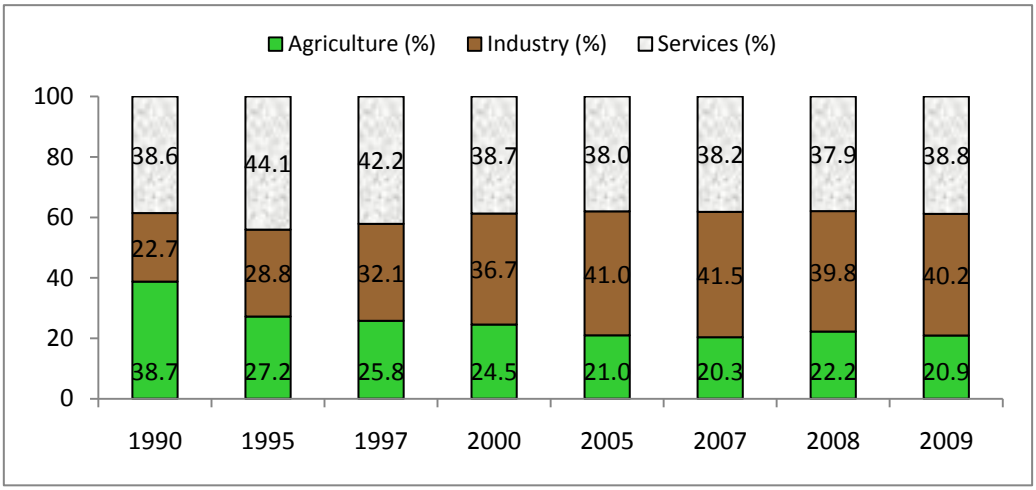


Fig. 4: Contributions to GDP by sector from 1990 – 2009 (GSO, 2010 and ADB , 2010)[4]

As seen in figure 4 above, in 2007, industry sector accounted for 41.5 percent, and then it slowed down to 39.8 percent in 2008. One of the reasons to explain this trend is negative indirect impacts of the global financial crisis. However, industry growth has mainly led to energy consumption; a rapid growth in industrial value added provided the stimulus for this growth in energy use. Because industry is the most energy-intensive main economic sector, this increase in the industrialization of Vietnam's economy by itself contributes to the increase in Vietnam's overall energy intensity. The steel,

[4] ADB – Asian Development Bank, GSO – General Statistical Official

construction materials, pulp and paper, textiles and fertilizer manufacturing industries consumed the most energy (ADB, 2009).

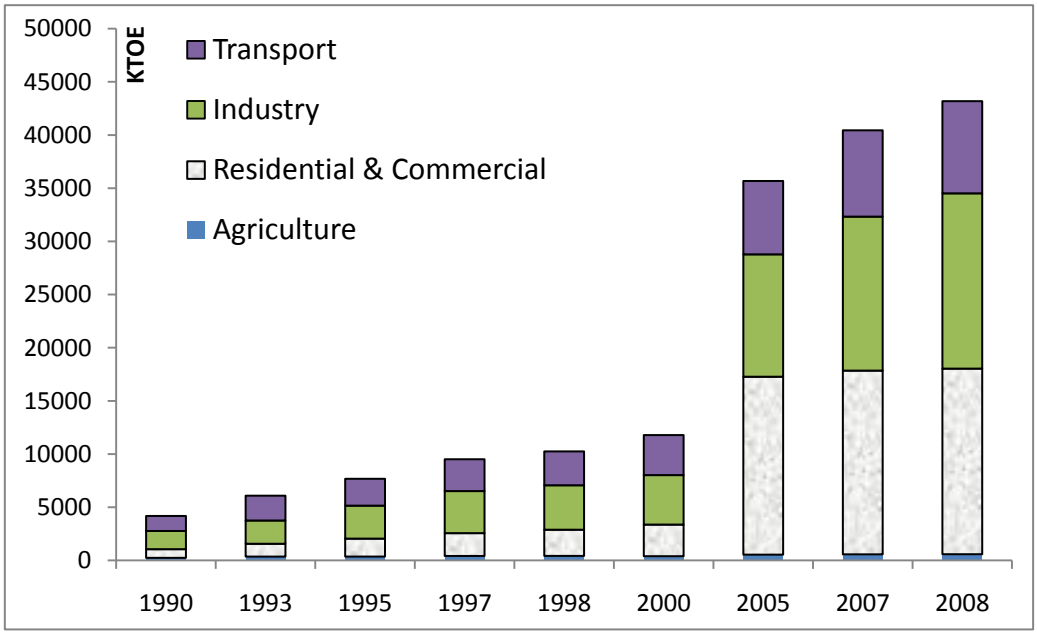


Fig. 5: Total energy use by sector in Vietnam, including non-commercial energy (APERC, 2010)

Industrial growth has been a key driver of Vietnam's increasing energy consumption, and, along with service sectors, it has become a key pillar in the economy, which in 2009 saw each accounting for around 40% of

GDP. Industrial energy use grew from 1.713 million toe in 1990 to 16.481 million toe in 2008 – an expansion of almost ten times over nearly two decades (figure 5). The transport sector also has undergone explosive growth in Viet Nam in recent decades, with the number of vehicles—especially private cars and two-wheeled motor vehicles (motorcycles and scooters) growing very rapidly, especially in cities. Another key driver of increased energy use has been population growth, during the period 2000–2008, total population growth in Viet Nam averaged 1.31 percent annually (Khanh Toan, P., N. Minh Bao, et al., 2011).

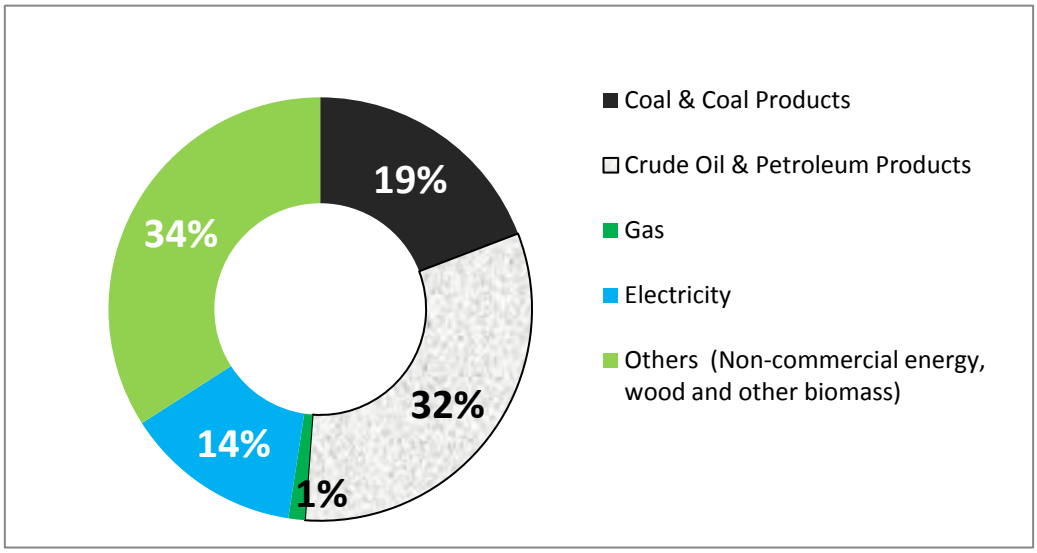


Fig. 6: Total final energy consumption in 2008 (APERC, 2010)

In 2008, by fuel source, despite the fast growth in the use of commercial fuels, biomass still contributed the largest share (34%), followed by oil (32%), coal (19%), electricity (14%) and gas (1%). Fig. 7 below provides a summary of trends in energy demand by fuels in Viet Nam. The main forms of commercial energy used by final consumers in Vietnam include coal, petroleum product fuels, and electricity. Except for a very small amount of natural gas used in industry, Vietnam's natural gas has been used in power generation and not by final consumers. Final use of all three main types of

energy grew faster during 1990–2008 than GDP that we discuss in the next section.

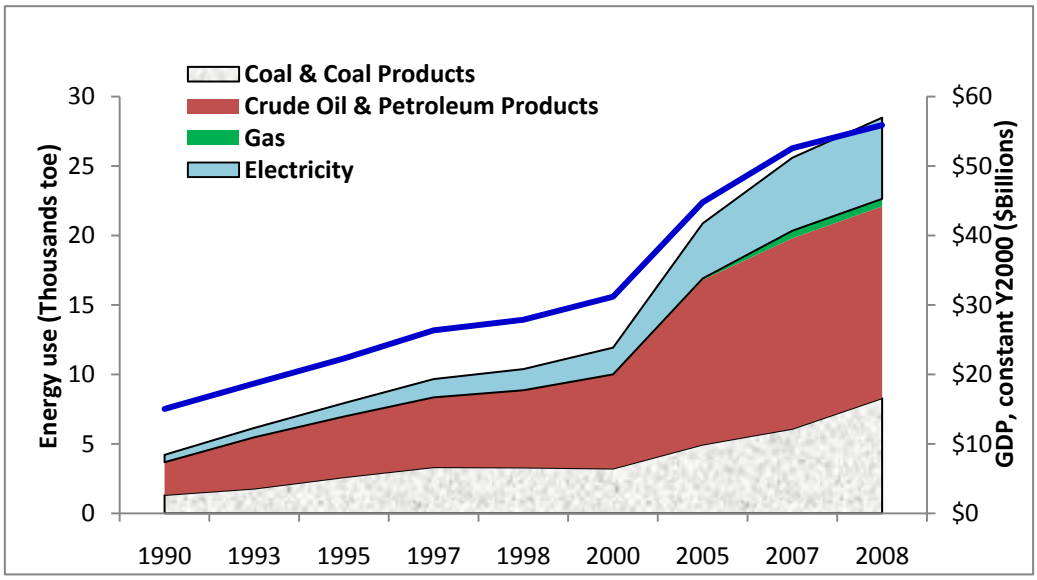


Fig. 7: Total final commercial energy use, 1990 -2008 (APERC, 2010)

2.4 Energy – GDP interactions

In response to the wide-ranging reforms called *Doi Moi* (renovation) undertaken since 1986, Viet Nam's rapid economic growth has resulted in a corresponding rapid increase in energy needs. Energy contributes greatly to Viet Nam's economic development, supporting industrial growth and generating foreign revenue from exports. Since 1990, Viet Nam has become a net energy exporter; its main energy exports are crude oil and coal. However, as the future energy demand escalates in order to sustain the country's socio-economic development, there are concerns about energy security, especially the dependency on imported energy.

Although Vietnam have one of the lowest per capita energy consumption rates amongst ASEAN nations (Fig. 3), but the country has at the same time one of the highest energy intense economies (Fig. 6). This indicates that the energy efficiency of Vietnam in both, the final users and the conversion sector is very low. Although this trend has undergone a sharp

decline in recent years, it is still the highest amongst other Asian countries.

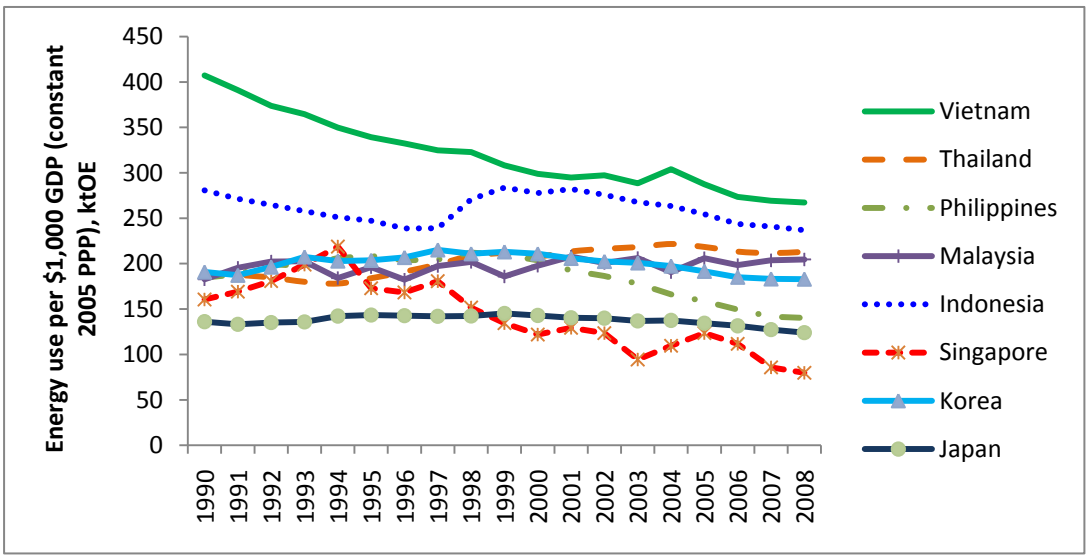


Fig. 8: Energy intensity in ASEAN countries from 1990 – 2008

(World Bank, 2011)

In fact, the usage of energy in Vietnam is extremely ineffective and lavish. For instance, in 1997 the energy intensity at the constant price (2005 PPP) of Vietnam was 324 kgOE/ 1000 USD. This figure in other countries is as follows: Thailand: 199; Indonesia: 238, Malaysia: 197, China: 406, South

Korea: 215, Japan: 142; OECD: 177; the world average: 214 (WDI[5], 2011).

The energy elasticity (the ratio between rate of energy consumption and growth rate of GDP in the same period) is one of the important indicators used to access the relations between Energy – Economy. In the period of 1990 – 2008 it was as follows:

Table 2: Energy – GDP elasticity during 1990 – 2008 (WDI, October 2011) and author's calculation

Indicators	1990 – 1998	1999 – 2008	1990 – 2008
Average growth rate of GDP (CAGR - percent)	7.71	7.21	7.45
Average growth rate of energy consumption (CAGR - percent)	11.94	16.31	13.03
Energy-GDP elasticity	1.54	2.26	1.75

[5] World Development Indicators, 2011

During the period 1990 – 1998, the energy elasticity increased to 1.54, equivalent to the developing countries in the beginning process of development. In the period 1999 – 2008, the energy-GDP elasticity increased to 2.26 proving the inefficiency of production of the economy. In sum, the Energy – GDP elasticity in the whole period was 1.75, which was very high in comparison with other countries (Thailand 1.4; America 0.8; Japan 0.95). Besides this, the energy subsidy and application of the policy of a low price for energy as well as operation of the factories, equipment with low efficiency and over the expiry date also contribute to this increase in energy intensity. This inefficient energy use has caused many problems for the country's economy and environment.

Recently, other study has demonstrated that Vietnam was one of the highest energy intense economies, as conducted by Nurdianto and Resonudarmo, (2011). These 6 ASEAN member countries, namely ASEAN-6 plus Vietnam in which illustrated their trends of energy intensity (energy use/GDP) in figure 9. This figure shows two important details. First, it shows

that ASEAN countries are more energy intensive than the more developed EU-15, with the exceptions being Brunei and the Philippines. Second, it also shows a trend toward convergence over time. The EU-15, which on average is more developed than ASEAN countries, has shown a more stable path since 1990, whereas relatively more energy-intensive countries, namely Vietnam and Indonesia, have undergone a sharper decline.

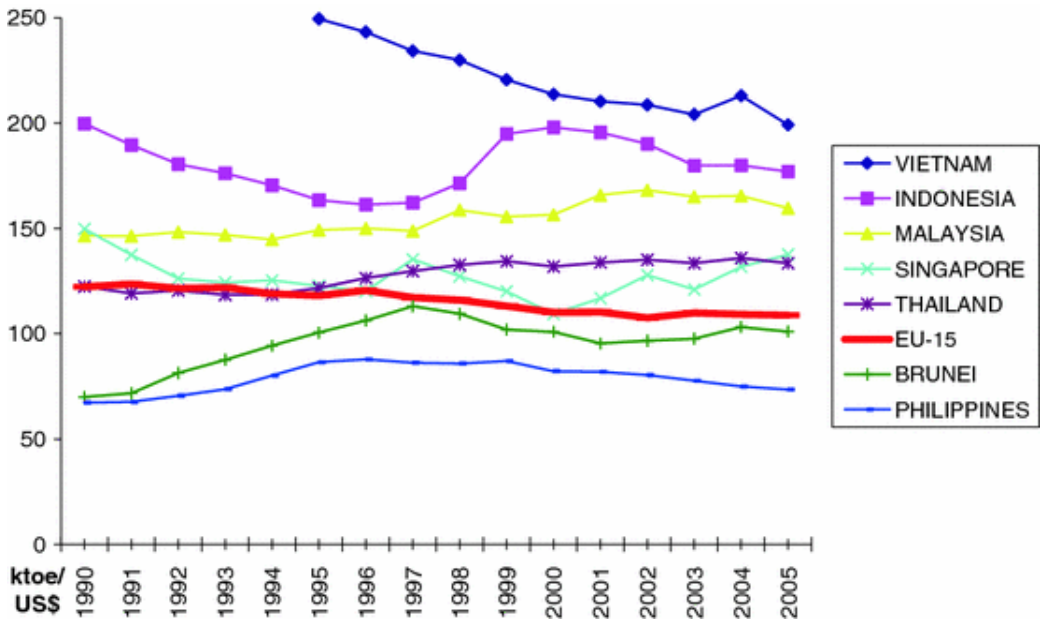


Fig. 9: Energy intensity in ASEAN countries from 1990 – 2005

(Nurdianto and Resonudarmo, 2011)

2.5 Government and Energy policy

For that reasons, Vietnam has recently developed a national program (VNEEP)[6] to enhance effective use of energy with emphasize on both, supply and demand sides. The program is aimed at saving from 3-5% and 5-8% of the total energy consumption for the period 2006-2010 and 2011-2015 respectively. The program includes six components: strengthen state management of energy efficiency and conservation by developing a management system for energy saving; strengthen education, disseminate information and enhance public awareness to promote energy efficiency and conservation (EE&C) as well as environmental protection; develop and popularize highly energy-efficient equipment by phasing out low-efficiency equipment; promote EE&C in industry; promote EE&C in building; and promote EE&C in transportation (VNEEP).

The energy sector is managed by the Ministry of Industry and Trade (MOIT) which was formed after the merger of the Ministry of Industry and

[6] VNEEP – Viet Nam National Energy Efficiency Program (http://www.tietkiemnangluong.com.vn/)

the Ministry of Trade. MOIT is responsible for the state management of all energy industries, including electricity, new renewable energy, coal, and the oil and gas industries. It is in charge of the formulation of law, policies, development strategies, master plans and annual plans for those sectors, and submits them to the Prime Minister for issuance or approval. The ministry is also responsible for directing and supervising the development of the energy sector and reporting its findings to the Prime Minister (MoIT, 2010)[7].

Inside MOIT, the General Directorate of Energy, the Viet Nam Electric Power Group (EVN), the Viet Nam National Coal and Mineral Industries Group (Vinacomin) and the Viet Nam Oil and Gas Group (PVN) that play an important role in operating, management, R&D the whole energy sector in the country.

[7] Ministry of Industry and Trade – www.moit.gov.vn

Chapter 3. Literature Review

3.1 Energy and Economic growth

There are different views among economists on the role of energy in the economy. By reviewing the relationship between energy consumption and economic growth it is necessary to explain the causality between them. For this reason, the theoretical literature of neoclassical and of ecological economic worldviews is examined.

3.1.1 Neo-classical views of economic growth

The basic growth model which examines the hypothetical economy is the Solow growth model (1956). In this model, Solow focuses on three variables output (Y), capital (K) and labour (L). The production is Y = f(K,L) which does not include resources at all. Economic growth is achieved by increasing inputs of labour or human capital. On the other hand, the only cause of

continuing economic growth is technological progress. When the level of technological knowledge accumulates the functional relationship between productive inputs and output changes, same quantity and quality of inputs can produce greater quantities and better qualities of output. Intuitively, increases in the state of technological knowledge raise the rate of return to capital, thereby offsetting the diminishing returns to capital that would otherwise apply a brake to growth (Stern, 2003).

However, the Solow model just described does not explain how improvements in technology come about and it treats technological progress as an exogenous variable. In endogenous growth models the relationship between capital and output can be written in the form Y = AK. Where the level of technology that is a positive constant (A) and Capital (K), is defined more broadly than in the neoclassical model. According to endogenous growth models, technological knowledge is thought as a form of capital, where it accumulated through research and development and other knowledge creating

processes. The technological knowledge through investment in capital exactly offsets the diminishing returns to manufactured capital and the economy can sustain a constant growth rate (Stern, 2003).

In these models, the contribution of energy to economic activity is only considered relative to its cost within production. Therefore, the model consider energy to be an “intermediate good” rather than a “primary input” into the production process. It argues that there are some mechanisms by which economic growth could remain in spite of limited sources of energy resources. Thus, the government can adopt energy conservation policies without having any harmful effect on economic growth (Bartleet and Gounder, 2010).

3.1.2 Ecological views of economic growth

Ecological economic theory on the contrary states that energy consumption is a limiting factor to economic growth, especially in modern economies. Ecological economists judge that technological progress and other physical inputs could not possibly substitute the vital role of energy in the production process. Most importantly, the ecological economists' worldview attempts to account for the laws of thermodynamics. The first law of thermodynamics, the conservation law, implies that the mass of inputs and output must be equal in the production process. Therefore, there are minimal material input requirements for any production process producing material outputs. The second law of thermodynamics, the efficiency law, implies that a minimum quantity of energy is required to carry out the transformation or movement of matter. All production involves the transformation or movement of matter in some way and all such transformations require energy, and there must be limits to substitution of others factors of production for energy so that energy is also an essential factor of production (Stern, 2003). This perspective

is the so-called “growth hypothesis” and advises that any shock to energy supply will strongly have a negative impact on economic growth. As a result, they are against energy conservation policies.

Without using energy, it is impossible to operate a factory, grow crops, travel, or deliver goods from producer to consumers. Economic growth almost always leads to increased energy use, at least in the early stages of economic development. Energy is included in the production function via empirical analysis conducted by IEA (2004). This study demonstrates the importance of energy in driving economic growth applied to several developing countries between 1981 and 2000 (IEA, 2004). This function is described as follows:

$$Y_t = A_t * (K_t)^{\alpha} (L_t)^{1-\beta} (E_t)^{1-\alpha-\beta}$$

where,

Y_t : Output

A_t : Economy's total factor productivity

K_t : Stock of capital

E_t : Energy use

L_t : Labour

Table 3: Contribution of factors of Production and Productivity to GDP growth in selected countries, 1980 – 2001 (IEA, 2004)

	Average annual GDP growth (%)	Contribution of factors of production and productivity to GDP growth (% of GDP growth)			
		Energy	Labour	Capital	Total factor productivity
Brazil	2.4	77	20	11	-8
China	9.6	13	7	26	54
India	5.6	15	22	19	43
Indonesia	5.1	19	34	12	35
Korea	7.2	50	11	16	23
Mexico	2.2	30	60	6	4
Turkey	3.7	71	17	15	-3
United States	3.2	11	24	18	47

According to the Table 3, capital, labour and energy contributed more to economic growth than total factor productivity in every country, except China. Energy contributed meaningfully to economic growth in all countries and was the leading driver of growth in Brazil, Turkey and Korea. Its contribution was smaller in India, China and the United States. Brazil and Mexico, where energy played the leading role in economic growth, have both

industrialized rapidly. Korea has depended heavily on the chemical industry as a major engine of growth (IEA, 2004). Meanwhile, as the economy matures, more energy-efficient technology, whose contribution is captured as a part of total factor productivity, kicks in and the amount of energy needed to produce a unit of GDP diminishes. Therefore, the United States had a less energy-intensive economy.

3.2 Previous Research

A number of studies in the literature have focused on the energy consumption and economic growth nexus; however no consensus results are achieved due to different countries characteristics or different times within the same country, and different research methodologies. The pioneering study of Kraft and Kraft (1978) provides evidence in support of a unidirectional long run relationship running from gross domestic product (GDP) to energy consumption for the case of the U.S. over the 1947-1974 period. The results imply that energy conservation policies might be enforced without having any

adverse effect on economic growth. On the other hand, Akarca and Long (1980) failed to obtain causality between energy consumption and GDP, so they argued that Kraft and Kraft's study could suffer from temporal time period instability (Belloumi, 2009).

Several researchers have since joined the debate, with some having either confirmed or contradicted Kraft and Kraft's results. Cheng and Lai (1997) found causality running from GDP to energy consumption but not vice versa for Taiwan for the 1955 – 1993 period. They concluded that, for the newly industrializing countries in general, energy is an important ingredient of economic development; which in turn boots employment also. However, Yang (2000) reexamined the causality between energy consumption and GDP for Taiwan using updated data for the 1954–1997 period. The findings of this paper totally deny the findings of Cheng and Lai (1997) of unidirectional causality from GDP to energy consumption. They found evidence of bi-directional causality between energy consumption and GDP.

Masih and Masih (1996) used co-integration analysis of Engle-Granger's version to study this relationship in a group of six Asian economies. Significant co-integration was found between energy consumption and economic growth in India, Pakistan, and Indonesia, but no co-integration in Malaysia, Singapore, and the Philippines.

Glasure and Lee (1997) examined the causality between energy consumption and GDP for South Korea and Singapore and reported different results from different methodologies used. The standard Granger causality tests revealed no causal relationship for South Korea and a unidirectional causal relationship running from energy consumption to GDP for Singapore, while the error correction models (ECM) gave signal of bi-directional causality for both countries.

Asafu-Adjaye (2000) tested the causal relationship between energy use and income in four Asian countries (including India, Indonesia, Thailand

and the Philippines) using the ECM models. The test results indicated a unidirectional causality running from energy to income in India and Indonesia, and a bi-directional causality in Thailand and the Philippines.

Chontanawat et al. (2008) investigated for causality between energy and GDP using a consistent data set and Granger test for 30 OECD countries and 78 non-OECD countries. They discovered that causality running from energy to GDP appeared to be more prevalent in the developed OECD countries compared to the developing non-OECD countries (70% in OECD countries compared to 46% in non-OECD countries); implying that a policy to reduce energy consumption aimed at reducing emissions is likely to have greater impact on the GDP of the developed rather than the developing world.

In short, a general judgment is that the results are still mixed: that is, while some studies find causality running from economic growth to energy consumption, others figure out causality running from energy consumption to

economic growth and even some studies suggest no causality and/or bi-directional causality between these two variables. We can conclude that, one should be cautious with the empirical results and explain them while carefully taking into account characteristic of each country.

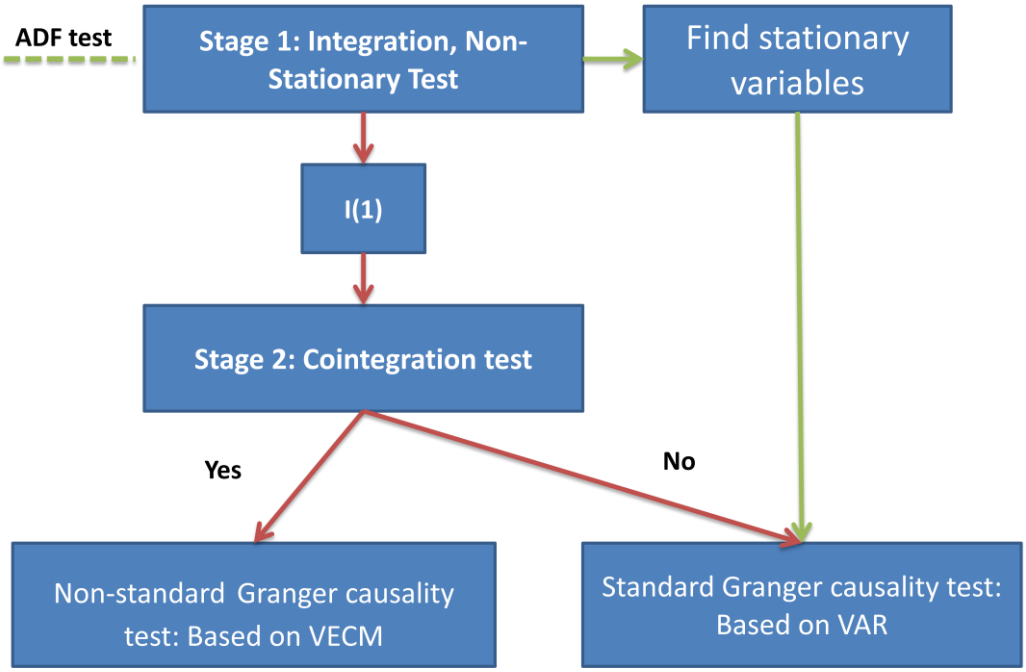
Chapter 4. Methodology

The rationale of threshold co-integration was introduced by Balke and Fomby (1997) as a feasible means to combine both non-linearity and co-integration. As pointed out by Balke and Fomby (1997), the concept of co-integration is used to capture the notion that non-stationary variables may nonetheless possess long-run equilibrium relationships and thus, have a tendency to move together in the long-run. According to Engle and Granger (1987), a linear combination of two or more non-stationary series, which have the same order of integration, may be stationary. If such a stationary linear combination exists, the series are considered to be cointegrated and long-run equilibrium relationships exist.

In regards to causality testing, we must check at first hand the stationary of variables to decide whether we can apply the standard Granger causality test or not. If the data sets prove to be stationary, then we can apply the standard vector autoregressive (VAR) Granger causality test, but if they prove to be non-stationary, we work with the first differences. This step is to

convert the non-stationary variables to stationary data. Next, we can check whether the variables are cointegrated. If it is shown that the variables have a cointegrating equation, then the Granger causality test based on the vector error correction models (VECM) is used to check the causality between variables. On the other hand, if they are not cointegrated, we examine also the interrelation between them using a VAR framework in the first differences. Figure 10 shows the process of causality testing we use to analyze the relationship between energy consumption and economic growth in Vietnam.

Fig. 10: Causality testing steps



4.1 Unit root test

Since many macroeconomic time series are non-stationary, they do not have the feature of stable process, meaning that the mean and standard deviation of the data have not remained constant as time elapses. It does not return to its original trend when substantial changes occur in the mean or standard deviation due to external shock. If we run regression using non-

stationary data, the results may spuriously indicate a significant relationship when there is none (Carter et al. 2008). Therefore, one should convert the non-stationary to stationary data before conducting a causality test.

Unit root test is just one of the statistical tests which are universally applied for determining whether a series is stationary or non-stationary. The most popular one is the Dickey – Fuller (DF) test among other unit root tests such as, the Phillips – Perron (PP) test, the Augmented Dickey – Fuller (ADF) test. The Dickey-Fuller (DF) test does not consider autocorrelation and heteroscedasticity issues. The ADF test is a modified version of the DF methodology, and considers autocorrelation. The ADF test carries out unit root, which includes three possible forms as follows:

Model 1: $$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta Y_{t-i} + u_t$$

Model 2: $$\Delta Y_t = \alpha_0 + \delta Y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta Y_{t-i} + u_t$$

Model 3: $$\Delta Y_t = \alpha_0 + \alpha_1 T + \delta Y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta Y_{t-i} + u_t$$

where, t is time variable. It stands for a certain tendency of time series varying with time. Null hypothesis H_0: $\delta = 0$, is that the series is non-stationary, alternative hypothesis H_1: $\delta < 0$. The lower-tail critical value is used for critical value, and its one-sided p-value in MacKinnon (1996) is used in our analysis.

4.2 Cointegraion test

As a general rule, non-stationary time series variables should not be used in regression models, to avoid the problem of spurious regression. However, there is an exception to this rule, according to Engle and Granger (1987), if Y_t and X_t are non-stationary I(1) variables, a linear combination of them may be stationary. If such a stationary linear combination exists, the series are considered to be cointegrated and long-run equilibrium relationships exist. Cointegration implies that Y_t and X_t share similar stochastic trends, and they never diverge too far from each other (R. Carter H. et al. 2008).

We conducted co-integration tests to find whether non-stationary series data are cointergrated or not. There are various approaches to test for co-integration, such as, the Engle and Granger approach, the Johansen approach, and the ARDL bounds testing approach. In our study, we use co-integration tests based on Johansen method. This approach estimates long-run or co-integration relationships between non-stationary variables using a maximum likelihood procedure which tests for the number of cointegrating relationships and estimates the parameters of those cointegrating relationships. Johansen (1988) proposes two likelihood ratio tests for the co-integration rank, a maximum eigenvalue test and a trace test (Balaguer and Jorda, 2002).

4.3 Granger causality test

It is worth noting that co-integration implies causality exists between two variables, but it does not indicate the direction of the causal relationship. If there exists a cointegrating relationship between variables, their causality relationship should be tested with the VECM method. The traditional VAR

model based on the Granger causality test is only for stationary variables. Engle and Granger (1987) showed that if two series are cointegrated, the vector error correction model for the per capita gross domestic product (PCGDP) and the per capita energy consumption (PCEC) series can be written as follows:

$$\Delta Y_t = \alpha_1 + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{j=1}^{q} \rho_i \, \Delta X_{t-j} + \sigma_1 ECT_{t-1} + u_{1t} \qquad (1)$$

$$\Delta X_t = \alpha_2 + \sum_{i=1}^{p} \gamma_i \Delta X_{t-i} + \sum_{j=1}^{q} \delta_i \, \Delta Y_{t-j} + \sigma_2 ECT_{t-2} + u_{2t} \qquad (2)$$

where Y_t and X_t represent per capita GDP and per capita energy consumption (EC), respectively; ΔY_t and ΔX_t are the differences in these variables that capture their short-run relationship among them. ECT is the error correction term (ECT) that is derived from the long-run Cointegration relationship and measures the magnitude of the past equilibrium. The coefficient, σ of the ECT_{t-1} represents the deviation of the dependent variables from the long-run equilibrium (Belloumi, 2009).

The purpose of the causality test in this study is to choose an adequate explanatory variable, so we will analyze the causality relationship between just a pair of variables. In equation (1), EC causes GDP if the current value of GDP is predicted better by including the past values of EC that by not doing so. In other words, if EC causes GDP, then EC helps to forecast GDP. And from equation (2), GDP causes EC if the current value of EC is predicted better by including the past values of GDP than by not doing so, it means that GDP helps to forecast EC (Chontanawat, Hunt et al. 2008). Specifically, the following null hypotheses are necessarily tested:

$$(A)\ \mathrm{H}_0 \quad \sum_{j=1}^{q} \rho_i = 0$$

or energy consumption does not Granger cause economic growth

$$(B)\ \mathrm{H}_0 \quad \sum_{j=1}^{q} \delta_i = 0$$

or economic growth does not Granger cause energy consumption

It is possible to have that (1) economic growth causes energy consumption (reject B, but do not reject A), (2) energy consumption causes economic growth (reject A, but do not reject B), (3) there is a bi-directional feedback between energy consumption and economic growth (reject A and reject B), and (4) energy consumption and economic growth are independent (do not reject A and B). Cases (1) and (2) represent unidirectional or one way without feedback causality and case (3) represents bi-directional causality or both ways with feedback.

For non-stationary variables with no co-integration equation, a regular VAR based Granger causality test can be applied. The VAR model is a standard form of VECM. The difference between two models is that VAR model does not include an error correction term in the equation (R. Carter H. et al. 2008).

Chapter 5. Empirical Results

5.1 Data collection and Unit root tests

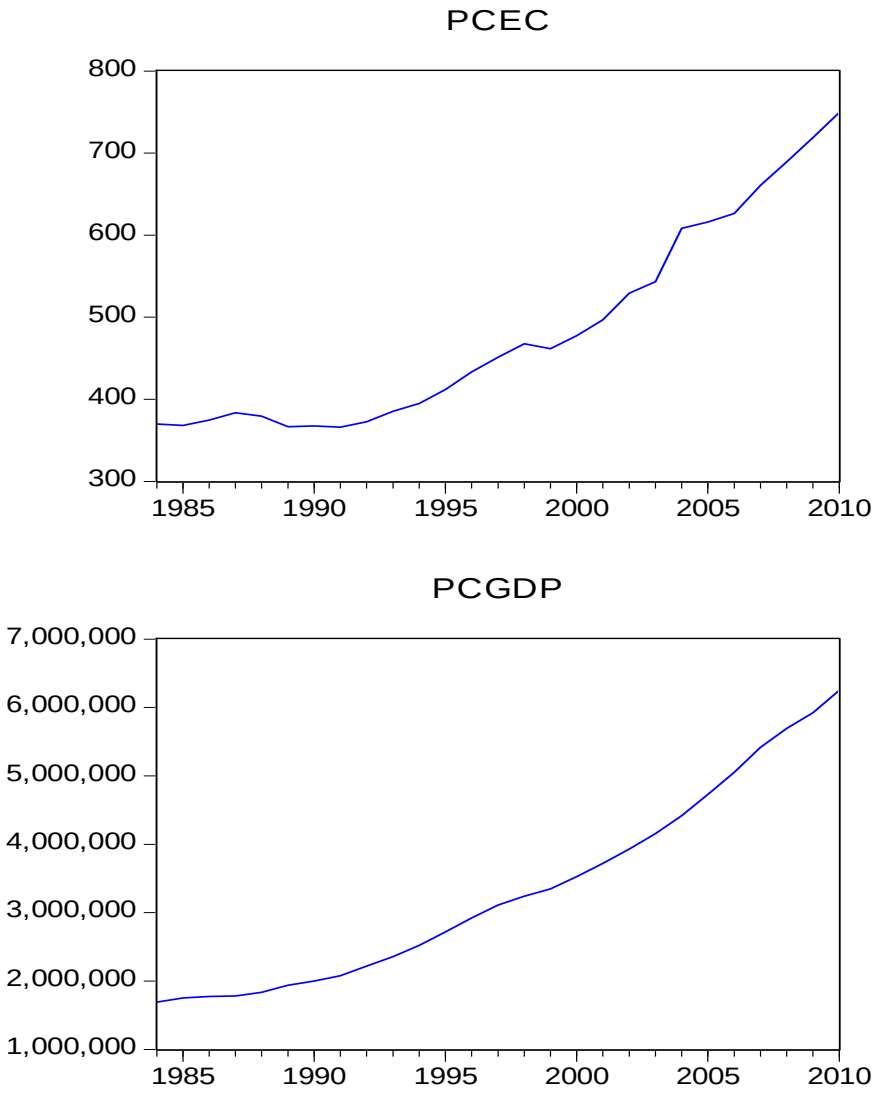
We use the time series data of per capita gross domestic product (PCGDP) and per capita energy consumption (PCEC) for the period 1984-2010 in Vietnam. The data set are obtained from three sources: (1) the World Development Indicators (2011); (2) the International Financial Statistics (2011); and (3) the Vietnam's General Statistics Office (VGSO 2011). In our study, per capita energy consumption, which is the sum of consumption of oil, natural gas, coal, and hydro electricity, is expressed in terms of kg oil equivalent and per capita GDP is expressed in constant at national currency. It is noted that the choice of the starting period was constrained by the availability of data on GDP and correct statistic data on energy consumption, energy consumed before the 1980s was mainly oil and was not used solely in production because of the war demands (Nguyen 2009), all the variables are in natural logarithms, which is called LPCGDP and LPCEC respectively.

Table 4 below provides the descriptive statistics of these two series.

Table 4: Summary statistics for both series

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
PCGDP	27	3336776	1434176	1691105	6250002
PCEC	27	484.0582	123.7949	366.0616	749.6148

Fig. 11: Vietnam's per capita energy consumption and per capita GDP from 1984 – 2010



As a first step of the analysis, we have to test for the unit roots of the variables and to examine the order of integration of each variables concerned by using the Augmented Dickey-Fuller (ADF). In general, the order of integration of a series is the minimum number of times it must be differenced to make it stationary, written by I(d) with d is number of time after differencing (R. Carter H. et al. 2008). When carrying out a ADF test for the existence of a unit root of the times series Y_t ($H_0 : \delta = 0$), we can select one out of the following three possible equations of the ADT test which is described in chapter 4. Table 3 reports the results of the ADF tests in the level as well as in first difference for both variables. We include a constant and a time trend in the ADF equation whereas when testing the first differences include a constant. For both, however, the number of lags is determined by using the Akaike Information Criterion (AIC) criteria, which is automatic setting in the Eviews software package.

When deciding whether to reject the null of a unit root (non-stationary) the 1% significance is used for the levels and the 10% for the first differences; disparity being based on the expectation that in general the variables will be I(0) in levels and I(1) in the first differences (Chontanawat, Hunt et al., 2008).

Table 5: Unit root tests results of LPCGDP and LPCEC series

Variables	ADF (Constant)		ADF (Constant and Time Trend)	
	Level	First difference	Level	First difference
LPCGDP	0.089683	-2.898981	-3.076390	-2.501645
LPCEC	2.382945	-3.788946	-1.653568	-4.838584
1% Critical value	-3.769597	-3.769597	-4.416345	-4.440739
5% Critical value	-3.004861	-3.004861	-3.622033	-3.632896
10% Critical value	-2.642242	-2.642242	-3.248592	-3.254671

1) The probability of rejection was calculated using one sided p-values in MacKinnon (1996).

As shown in Table 5, the test results suggest that both of the series LPCGDP and LPCEC are non-stationary at any levels because their test statistics are greater than the critical value for our model. For the first difference value, both have same I(1), but for LPCGDP indicates significance at 10% as proved by its test statistic is smaller than its critical value, which may show a lack of power. However, since the data appears to be stationary in the first differences, no further tests are performed. Consequently, the series of GDP and energy consumption are both in the integration order of 1 or I(1) during the period 1984 – 2010 in Vietnam.

5.2 Cointegration analysis

As integration of order one, I(1) is established for both variables under investigation, the next step is to determine whether a co-integration between them or a long-run relationship exists. If the variables are shown to be cointegrated, the non-standard Granger causality test based on VECM model can be used. We applied the Johansen co-integration test with a lag

selection based on the minimum AIC through the unconstrained VAR estimation (see Table 6).

Table 6: Lag selection for co-integration test

Lag	LR	AIC	SC	HQ
0	NA	-2.457404	-2.358665	-2.432571
1	166.5608*	-10.43762*	-10.14140*	-10.36312*
2	5.228497	-10.38026	-9.886569	-10.25610
3	2.297734	-10.17604	-9.484874	-10.00222
4	1.373743	-9.926343	-9.037695	-9.702851

* indicates lag order selected by the criterion

LR: Sequential modified LR test statistic (each test at 5% level)

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Therefore, we choose a co-integration test with a lag interval of 1 in first difference for both series. According to Johansen (1988), proposing two likelihood ratio tests for the co-integration rank, a maximum eigenvalue test and a trace test (Balaguer and Jorda, 2002). In these tests, we denote the number of cointegrating vectors by r_0; the maximum eigenvalue test is calculated under the null hypothesis H_0: $r_0 = r$, and the alternate hypothesis H_1: $r_0 > r$. The trace test is calculated under the null hypothesis H_0: $r_0 \leq r$ and the alternative hypothesis H_1: $r_0 > r$. The test results are presented in Table 7. If the test statistic is greater than the critical value at a given level of significance, we reject the null hypothesis, and vice versa.

Table 7: Cointegration test result

Number of cointegration	Eigen value	Trace test			Maximum eigenvalue		
		Trace statistics	5% critical value	1% critical value	Max-eigen Statistics	5% critical value	1% critical value
Non (r=0)	0.579261	29.55948*	25.32	30.45	21.64359*	18.96	23.65
At most 1 (r≤1)	0.271404	7.915889	12.25	16.26	7.915889	12.25	16.26

Note) *(**) denotes rejection of the hypothesis at the 5%(1%) level

As a result, starting with the maximum eigenvalue test, we can see that the null hypothesis of zero cointegrating equation is rejected at the 5% level of significance due to the maximal eigenvalue statistic is 21.64359, which is greater than its critical value of 18.96. Turning to the trace test, the null hypothesis of no co-integration is also rejected at the 5% significance level because its trace statistic equals 29.55948, which is greater than the 5% critical value of 25.32. On the other hand, under the null hypothesis ($r_0 \leq 1$ for the trace statistic, and $r_0 = 1$ for the maximum eigenvalue statistic), both maximum eigenvalue statistic and trace statistic are below the 5% level of significance. Thus, the null hypothesis is accepted at the 5% significance level. Accordingly, we can conclude that both PCGDP and PCEC series have one co-integrating equation, in other words, there must be a long-run relationship between per capita energy consumption and economic growth for Vietnam in the sample period.

5.3 Granger causality test

It's already known that co-integration implies the presence of a significant long-run relationship between economic growth and energy consumption, but it does not indicate the direction of the causality relationship. We employ the non-standard Granger causality test based on VECM model to determine which one is causal relationship direction as described in equation (1) and (2): 1/ unidirectional, 2/ bi-directional and 3/ no Granger causality exists (neutrality). We will apply the Wald test on the coefficient of the first difference value (ΔY_t and ΔX_t) that capture their short-run relationship among them. Besides, we use t-test for checking the significance of the error correction term (ECT) that is derived from the long-run co-integration relationship and measures the magnitude of the past equilibrium. This coefficient of error correction term represents the deviation of the dependent variables from the long-run equilibrium (Belloumi, 2009).

Table 8: Granger causality test result from VECM model

Null hypothesis	Short-run relationship		Long-run relationship	
	chi2	Prob>chi2	T-statistics	Prob>t
LPCGDP does not Granger cause LPCEC	5.166133	0.0230**	0.75025	0.46010
LPCEC does not Granger cause LPCGDP	0.472533	0.4918	-5.01265	0.000036***

*, **, *** indicates rejection of null hypothesis at the 10%, 5%, 1% level

The results of a VECM – based causality test are shown in Table 8. Short-run causality is found only from per capita GDP to per capita energy consumption; it means that there is unidirectional short-run (defined as 1 year or less) Granger causality. The result is significant at the 5% level. This empirical finding strongly supports the neoclassical view or conservation hypothesis that energy consumption is not a limiting factor to Vietnam's economic growth. Thus, energy conservation polices can be enforced without having any adverse effect on economic growth. From Table 8, it is also shown

that the null hypothesis of energy consumption does not Grange-cause economic growth in the long-run can be rejected at the 1% level of significance. Therefore, there is Granger causality running from energy consumption to economic growth in the long-run (defined as longer than 1 year) relationship, any constraints put on energy consumption could lead to fall in economic growth.

When we investigate the causality between energy consumption and economic growth into a country, these could exhibit different outcomes from the short-run and long-run in several cases of literature. For instance, Asafu-Adjaye (2000) tested the causal relationship between energy use and income in four Asian countries (including India, Indonesia, Thailand and the Philippines) using the VECM models. In the case of Philippines, the results observed bidirectional Granger causality running from energy to income in both short and long run relationships. Furthermore, Belloumi (2010) by using the same VECM model for Tunisia during the 1971-2004 period, showed

results indicating that there is a long run bidirectional causal relationship between energy consumption and GDP and a short run unidirectional causality from energy to GDP. In addition to this, the case of Korea 1970-1999 applies a multivariate model of capital, labor, energy and GDP, which was studied by Oh and Lee (2004). The empirical results revealed a long run bidirectional causal relationship between energy consumption and GDP, and short run unidirectional causality running from energy to GDP.

As a result, a policymaker should take not only short-term, but also long-term perspectives into consideration when they are trying to making a decision in order to sketch effective energy and environmental policies.

Chapter 6. Conclusion and Policy implications

Energy plays a vital role for the economic growth of a country, especially when a country is in the process of hastening its economy into industrialization stage like Vietnam. In this study, we attempted to investigate the causal relationship between economic growth and energy consumption in Vietnam during the 1984 -2010 period. We relied on a literature review and analyzed the intensity of energy use in Vietnam compared to other ASEAN countries to develop an overview of how effective energy use is among these countries which have experienced a similar history of development. We then employed the Johansen co-integration test with a lag of 1 which found a long-run relationship between per capita energy consumption and economic growth for Vietnam in the sample period. The Granger causality test which was conducted based on the VECM; revealed unidirectional long-run (defined as longer than 1 year) Granger causality running from energy consumption to economic growth. This result can be interpreted as follows: Energy is deeply involved in each economic activity. Economic growth causes expansion in the

industry sector which is the most energy-intensive main economic sector. Production in industries such as manufacturing, construction and transportation demands a huge amount of energy (Cheng and Lai, 1997, Ozturk et al. 2010). This view is supported by recent economic growth in Vietnam which has lead to tremendous change in the industry and service sector. In 2009, the total of the industrial and commercial/services sectors accounted for about 80 percent of GDP increasing by nearly 20 percent from 1990 (see Fig. 4). Industrial energy use grew from 1.713 million toe in 1990 to 16.481 million toe in 2008—almost ten times over nearly two decades. Furthermore, with economic growth people's incomes have grown higher, and consequently households have been using higher energy consuming goods and services. These circumstances stimulate further energy consumption.

This empirical finding implies that an economy is energy dependent, it supports the "growth hypothesis" in which energy is also an essential factor of production, and hence energy is a stimulus to growth implying that energy conservation policies may negatively affect economic growth (Chontanawat et

al., 2008). Therefore any constraints put on energy consumption to help reduce emissions or any shock to energy supply will have an effect on growth. In order not to adversely affect economic growth in the long term, the government should treat as the most important issue the diversify sources of energy supply from renewable energy and promote the efficiency of energy usage.

On the other hand, there is Granger causality running from energy consumption to economic growth in the short-run (defined as 1 year or less) relationship. This implies that an economy is not energy-dependent, and energy is only one of the non-essential inputs in the production process supported by the neoclassical view or conservation hypothesis. This hypothesis alleges that energy supply restrictions might not have any harmful effect on economic growth, thus energy conservation policy might be enforced without having or having little effect on growth and employment (Chontanawat et al., 2008; Masih and Masih, 1997; Bartleet and Gounder, 2010).

From a policy perspective, as the Vietnamese economy has very high energy intensity compared to other Asian countries, which means the inefficiency of energy use, this in turn implies a good opportunity for the government to pursue the energy conservation policy that aims at tightening lavish energy usage rather than find ways of reducing consumer demand. Energy use has been always growing faster than GDP growth, which proves that energy efficiency is very low and adverse to economy. Authorities should gradually establish a competitive energy market to ensure productive usage of resources in the economy. Such a policy could be achieved through implementing a new tariff structure, subsidies and eliminating use of the equipment, or technology with low efficiency and over the expiry date. Specifically, some of policies, mechanisms may have to seriously consider as quickly as possible:

1. No more delaying to enter a competitive electricity market aims to ensure competition in power production and pricing, improve efficiency and attract more funding for power generation. As the power generation

market develops, customers will have more opportunities to select power providers. The market will operate under the model of a cost-based pool in which power producers will charge prices based on the market and hence it strives to satisfy to the utmost consumer interests.

2. In parallel with diversifying new energy sources which have had a great potential such as wind, solar, biomass resources; applying energy-saving technologies, enhancing effective use of energy is considered a key task to guarantee energy security and national development. Planning needs to consider realistic assignment of priorities for the short term – there is insufficient human capacity now to try to achieve everything at once. Responsibilities among different organizations, as well as leadership and coordination mechanisms, need to be clear. It is also very important to systematically monitor and evaluate the actual energy savings achieved and continuously extensive review and analysis of energy implications of industrial development policy, consumer energy pricing.

In conclusion, we argue that a better understanding of the relationship between economic growth and energy consumption in Vietnam will help policymakers to disentangle the question of whether or not economic growth leads to energy consumption or whether energy consumption leads to economic growth, thus economic growth can be sustained under various energy scenarios in the context of rising international debate on global warming and the reduction of greenhouse gas emissions. The government should take not only short-term, but also long-term perspectives into consideration when they are trying to making a decision on designing energy conservation policies. At the moment, it is imperative to reduce energy intensity which means a more efficient use of energy and a reduction in greenhouse gas emissions using renewable energy options such as wind, solar power which was examined a great potential in Vietnam.

Bibliography

[1] Asafu-Adjaye, J., (2000). "The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries." *Energy Economics* 22, 615-625.

[2] Asia Pacific Energy Research Center (APERC), the Institutes of Energy Economics, Japan (2010). "APEC Energy Overview 2010".

[3] Asian Development Bank (2009). "Energy Outlook for Asia and the Pacific."

[4] Balke, N. S. and T. B. Fomby (1997). "Threshold Cointegration." *International Economic Review* 38(3): 627-645.

[5] Balaguer, L. and Cantavella-Jorda, M. (2002). "Tourism as a Long-run Economic Growth Factor: The Spanish Case." *Applied Economics*, 34, 877–884.

[6] Belloumi, M., (2009). "Energy consumption and GDP in Tunisia: Cointegration and causality analysis." *Energy Policy* 37, 2745–2753.

[7] Central Institute for Economic and Management (CIEM), Vietnam's Ministry of Planning and Investment and Asia Competitiveness Institute (ACI), National University of Singapore (2010). "Vietnam Competitiveness Report 2010"

[8] Cheng, B.S., Lai, T.W., (1997). "An investigation of co-integration and causality between energy consumption and economic activity in Taiwan." *Energy Economics* 19, 435-444.

[9] Chontanawat, J., Hunt, L.C., Pierse, R., (2008). "Does energy consumption cause economic growth? Evidence from a systematic study

of over 100 countries." *Journal of Policy Modeling* 30, 209–220.

[10] Engle, R.F. and Granger, C.W.J., (1987). "Cointegration and error correction: representation, estimation and testing." *Econometrica,* Vol 55, 251–276.

[11] Glasure, Y.U., Lee, A.R., (1997). "Cointegration, error-correction, and the relationship between GDP and energy: The case of South Korea and Singapore." *Resource and Energy Economics* 20, 17-25.

[12] International Energy Agency (2004). "Energy and Development, in: World Energy Outlook 2004" pp. 329-333.

[13] Khanh Toan, P., N. Minh Bao, et al. (2011). "Energy supply, demand, and policy in Viet Nam, with future projections." *Energy Policy* 39(11): 6814-6826.

[14] Kraft, J., Kraft, A., (1978). "On the relationship between energy and GNP." *Journal of Energy Development* 3, 401-403.

[15] Masih, A.M.M., Masih, R., (1996). "Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modeling techniques." *Energy Economics* 18, 165-183.

[16] Nguyen Trung Hieu, (2009). "Analyses of petroleum damand and economic development in Vietnam", *Economic and Development magazine*, No 223, May 2009 [in Vietnamese].

[17] Nurdianto, D. and B. Resosudarmo (2011). "Prospects and challenges for an ASEAN energy integration policy." *Environmental Economics and Policy Studies* 13(2): 103-127

[18] Oh, W. and K. Lee (2004). "Causal relationship between energy

consumption and GDP revisited: the case of Korea 1970-1999." *Energy Economics* 26(1): 51-59.

[19] Ozturk, I., A. Aslan, et al. (2010). "Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries." *Energy Policy* 38(8): 4422-4428.

[20] R. Carter H., William E.G., and Guay C.L., (2008), Principles of Econometric. 3th edition, John Wiley and Sons.

[21] Stern D. I. (2003). "Energy and Economic growth." Rensselaer Working Papers in Economics, Rensselaer Polytechnic Institute, Department of Economics.

[22] Stern, D. I. (2011). "The role of energy in economic growth." Annals of the New York Academy of Sciences 1219(1): 26-51.

[23] United Nations (2005). "Impacts of current energy policies and energy development in Vietnam from sustainability point of view." Available at: http://www.greengrowth.org/download/green-business-pub/Greening_of_the_Business/Governments/Vietnam_Impacts_of_Current_Energy.pdf, retrieved on August 1, 2011

[24] Yang, H.Y., (2000). "A note on the causal relationship between energy and GDP in Taiwan." *Energy Economics* 22, 309-317.

[25] World Bank (2011). "World Development Indicators (WDI) and Global Development Finance (GDF)", available at: http://data.worldbank.org/ retrieved on September 2, 2011

Publications arising from dissertation

[1] Buu-Quoc Hoang, Youah Lee and Eunnyeong Heo (2011), "The relationship between energy consumption and economic growth in Vietnam, an update", *Proceeding of the IEPP Conference on Major Issues and Opportunities in Energy and Resource, Development in Developing Countries,* Seoul, Korea.

[2] Hoang Buu Quoc and Eunnyeong Heo (2011), "The relationship between energy consumption and economic growth in Vietnam", *Proceeding of the 2nd International Conference on Sustainable Energy Development,* Hanoi, Vietnam.

[3] Hoang Buu Quoc (2011), "Biogas development in Vietnam: Status, Prospects and Constraints", *The 1st Asia-Pacific forum on Renewable Energy (AFORE-1),* Busan, Korea.

[4] Hoang Buu Quoc and Mi-Ae Jung (2010), "Socio-economic impacts of biogas heating system: a case study of Vietnam", *International Symposium on Low Carbon and Renewable Energy Technology*, Jeju, Korea.

Appendix

Appendix A: Summary of variables

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
PCGDP	27	3336776	1434176	1691105	6250002
PCEC	27	484.0582	123.7949	366.0616	749.6148

PCGDP represents per capita gross domestic products in constant of national currency (dong)

PCEC represents per capita energy consumption in kg oil equivalent (kgOE)

obs	PCEC	PCGDP
1984	369.8975	1691105.
1985	368.0947	1752035.
1986	374.5788	1774885.
1987	383.5628	1779807.
1988	379.2896	1835228.
1989	366.6286	1939466.
1990	367.4471	1999009.
1991	366.0616	2076577.
1992	372.5192	2217411.

1993	385.2687	2355434.
1994	394.8563	2520794.
1995	411.7841	2716378.
1996	433.4859	2922945.
1997	451.0867	3112282.
1998	467.6686	3241558.
1999	461.5752	3345732.
2000	477.4368	3525016.
2001	496.7097	3717761.
2002	529.2283	3928980.
2003	543.2225	4156316.
2004	608.3624	4418198.
2005	615.9341	4729271.
2006	626.4916	5054580.
2007	660.8193	5417690.
2008	689.1829	5691314.
2009	718.7640	5923180.
2010	749.6148	6250002.

Appendix B: Unit root test results of PCGDP and PCEC series

Variables	ADF (Constant)		ADF (Constant and Time Trend)	
	Level	First difference	Level	First difference
LPCGDP	0.089683	-2.898981	-3.076390	-2.501645
LPCEC	2.382945	-3.788946	-1.653568	-4.838584
1% Critical value	-3.769597	-3.769597	-4.416345	-4.440739
5% Critical value	-3.004861	-3.004861	-3.622033	-3.632896
10% Critical value	-2.642242	-2.642242	-3.248592	-3.254671

Null Hypothesis: LPCGDP has a unit root

Exogenous: Constant

Lag Length: 4 (Automatic based on AIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.089683	0.9574
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LPCEC has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic based on AIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		2.382945	0.9999
Test critical values:	1% level	-3.711457	
	5% level	-2.981038	
	10% level	-2.629906	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LPCGDP has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 3 (Automatic based on AIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.076390	0.1349
Test critical values:	1% level	-4.416345	
	5% level	-3.622033	
	10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LPCEC has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic based on AIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.653568	0.7427
Test critical values:	1% level	-4.356068	
	5% level	-3.595026	
	10% level	-3.233456	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LPCEC) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic based on AIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.788946	0.0086
Test critical values:	1% level	-3.724070	
	5% level	-2.986225	
	10% level	-2.632604	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LPCGDP) has a unit root

Exogenous: Constant

Lag Length: 3 (Automatic based on AIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.898981	0.0616
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LPCEC) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic based on AIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.838584	0.0036
Test critical values:	1% level	-4.374307	
	5% level	-3.603202	
	10% level	-3.238054	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LPCGDP) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 3 (Automatic based on AIC, MAXLAG=6)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.501645	0.3240
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Appendix C: Johansen cointegration test results between series of PCGDP and PCEC series

Rank Test (Trace)

Hypothesized No. of CE	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.579261	29.55948	25.87211	0.0166
At most 1	0.271404	7.915889	12.51798	0.2586

* denotes rejection of the hypothesis at the 0.05 level

Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.579261	21.64359	19.38704	0.0231
At most 1	0.271404	7.915889	12.51798	0.2586

Appendix D: Granger causality tests

Null hypothesis	Short term		Long term	
	chi2	Prob>chi2	T-statistics	Prob>t
LPCGDP does not Granger cause LPCEC	5.166133	0.0230**	0.75025	0.46010
LPCEC does not Granger cause LPCGDP	0.472533	0.4918	-5.01265	0.000036***

*, **, *** indicates rejection of null hypothesis at the 10%, 5%, 1% level

Dependent variable: D(LPCEC)

Exclude	Chi-sq	df	Prob.
D(LPCGDP)	5.166133	25	0.0230
All	5.166133	25	0.0230

Dependent variable: D(LPCGDP)

Exclude	Chi-sq	df	Prob.
D(LPCEC)	0.472533	25	0.4918
All	0.472533	25	0.4918

Vector Error Correction Estimates

Date: 11/23/11 Time: 13:52

Sample(adjusted): 1986 2010

Included observations: 25 after adjusting endpoints

Standard errors in ( ) & t-statistics in [ ]

Cointegration Restrictions:

B(1,2)=1

Convergence achieved after 1 iterations.

Restrictions identify all cointegrating vectors

Restrictions are not binding (LR test not available)

Cointegrating Eq:	CointEq1	
LPCEC(-1)	-0.200222	
	(0.08869)	
	[-2.25760]	
LPCGDP(-1)	1.000000	
@TREND(84)	-0.048829	
	(0.00292)	
	[-16.7400]	
C	-13.01398	
Error Correction:	**D(LPCEC)**	**D(LPCGDP)**
CointEq1	0.157092	-0.386403

	(0.20939)	(0.07709)
	[0.75025]	**[-5.01265]**
D(LPCEC(-1))	0.082166	0.050167
	(0.19824)	(0.07298)
	[0.41449]	[0.68741]
D(LPCGDP(-1))	0.713004	0.610723
	(0.31370)	(0.11549)
	[2.27291]	[5.28823]
C	-0.009484	0.018918
	(0.01554)	(0.00572)
	[-0.61041]	[3.30717]
R-squared	0.261696	0.753549
Adj. R-squared	0.156224	0.718341
Sum sq. resids	0.014954	0.002027
S.E. equation	0.026685	0.009824
F-statistic	2.481185	21.40316
Log likelihood	57.29700	82.27863
Akaike AIC	-4.263760	-6.262291
Schwarz SC	-4.068740	-6.067270
Mean dependent	0.028449	0.050872
S.D. dependent	0.029051	0.018511

Determinant Residual Covariance	6.51E-08
Log Likelihood	140.2443
Log Likelihood (d.f. adjusted)	135.8855
Akaike Information Criteria	-9.990841
Schwarz Criteria	-9.454535

초록

베트남의 에너지 소비와 경제성장의 인과관계 분석

에너지의 소비는 국가의 경제성장에 중요한 역할을 한다. 특히 베트남과 같이 산업화 과정에 있는 국가에서는 그 중요성이 더 크다. 따라서 경제성장과 에너지 소비의 관계를 규명하려는 많은 연구들이 수행되어 왔다. 하지만, 베트남의 사례에 대한 연구는 충분히 이루어 지지 못하였다. 이에 본 연구에서는 1984년- 2010년 기간을 대상으로 베트남의 일인당 GDP와 일인당 에너지 소비의 인과관계를 분석하였다. 분석 방법론으로는 요한센공적분검정과 벡터오차수정모형을 기반으로 한 그래인져 인과관계분석을 적용하였다. 연구결과 일인당 GDP와 일인당 에너지소비 사이에는 공적분 관계가 존재 하는 것으로 나타났다. 이는 장기적으로 두 요인이 균형관계에 있음을 의미한다. 장기적인 관점에서는 에너지소비가 GDP를 인과하고, 단기의 관점에서는 GDP가

에너지소비를 인과하는 것으로 분석되었다. 본 연구결과는 경제성장은 에너지 소비에 의존적임을 의미한다. 에너지의 소비는 경제성장을 촉진한다. 하지만 에너지 소비를 제한하게 되면 이산화탄소 배출을 줄일 수는 있지만 경제성장에 부정적인 영향을 미치게 되는 것이다. 또한, 에너지 절약 정책을 계획하는데 있어서는 단기뿐만 아니라 장기적인 시점을 함께 고려해야 함을 알 수 있다. 에너지 원단위를 개선하여 에너지소비의 효율을 높이고 이산화탄소배출을 줄이는 것은 에너지정책에 있어서 주요한 대안이 될 수 있다.

주요어: 에너지소비, 경제성장, 에너지효율, 공적분검정, 인과관계, 베트남

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