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ENERGY CONSUMPTION AND ECONOMIC DEVELOPMENT: GRANGER CAUSALITY ANALYSIS FOR VIETNAM

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Abstract

In the 1980s, after two oil crises, studies focused on the effects of energy prices, particularly oil prices, to economic activities. In recent years, the relationship between energy consumption and economic growth was examined. Energy is considered a vital input to the production processes for enterprises and household consumption. However, it is also reckoned as an indirect source of many serious environmental problems, particularly air pollution.

Since the adaptation of a reform policy, domestic and international trade were liberalized, tariff and non-tariff barriers were also reduced and alleviated gradually. Exports were promoted by the government through many economic policies and measures such as tax preferences, export- processing zones, industrial zones, etc. With the increase in foreign direct investment (FDI), trade channels the high rate of economic growth during the period of reform. The paper aims to investigate the causal relationship between energy consumption, Gross Domestic Product (GDP), and trade in Vietnam covering the period of reform or "Doi moi" from 1986 to 2006.

The method of Granger causality test has been considered to examine this relationship in order to answer the following questions:

1. Is high economic growth due to the energy-led growth or export-led growth?
2. Does energy-saving harm economic growth?

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3. Does the rapid trade growth intensify the level of energy consumption which in return causes environmental pollution?

On the basis of this empirical study, policy implications shall be identified and proposed for Vietnam's economic sustainability.

This paper aims to provide an estimate of the Granger causality relationship between energy consumption and economic development, consisting of per capita GDP and trade in Vietnam. Such would be a valuable contribution in enriching the discussion on the causal relationship between energy consumption and economic development. This paper is divided into the following sections. Section 1 covers the introduction and literature review. Section 2 presents the data and methodology. Section 3 discusses the results and Section 4 for the conclusion.

Keywords: Granger causality, energy consumption, GDP, trade

JEL: F14, F18, O11

1. Literature review

1.1 Granger causality with time series data

Recent literature about the Environmental Kuznets curve (EKC) shows the relationship between environmental degradation and income by an inverted U-shape. Many environmental degradation indicators such as energy consumption have been the subject of research studies. Such studies focus on the relationship between economic growth and energy consumption which are most commonly dominated by panel and time series analyses employing the Granger causality test.

Kraft and Kraft (1978) first made a study on Granger causality looking at the income to energy consumption in the US covering the period 1947-1974. He concluded that energy conservation policy may not be affected negatively on the economic side. Later, empirical studies included many developing countries in order to seek any relevant energy policies. Masih and Masih (1996), Glasure and Lee (1997), and Asafu-Adjaye (2000) examined the causal relationship between energy consumption and income for developing countries using cointegration and vector error correction (VEC). Studies yielded mixed results. Moreover, Soytas and Sari (2003) also investigated the causal relationship for emerging market for the period 1950-1992 which produced the following findings: (i) mixed results; (ii) bidirectional causality for some countries; and (iii) no cointegration for others. Oh and Lee (2004) estimated the causal links between energy and income in South Korea for the period 1970-1999. The result showed that the long-run bidirectional causal relationship between energy and GDP and short-run unidirectional causality running from energy to GDP exist.

Time series data were tested to determine the causal relationship between energy and economic development. Chieng-Chiang Lee and Chun-Ping Chang (2005) examined the causal relationship between energy consumption and economic growth in 1954-2003 in Taiwan. They found that energy acted as an engine of economic growth. However, there was unstable cointegration relation between energy consumption and GDP. Hence, policy implications showed that energy conservation policy may harm economic growth.

Mehrzad Zamini (2007) studied the causal relationship between the GDP and value added in industry and agriculture for the period 1967-2003 in Iran.

Findings revealed that there was a long-run unidirectional relation from GDP to energy. Jia-Hai Yuan, Jian-Gang Kang, Chang-Hong Zhao, and Zhao-Guang Hu (2008) investigated this relationship in China and discovered a short-run Granger causality running from GDP to energy. They proposed enhancing energy efficiency, diversifying energy resources, and exploring renewable energy. Lise and Montfort (2007) examined the Granger causality link between energy consumption and GDP in the period 1970-2003 and figured out a unidirectional causality running from GDP to energy consumption, and the saving of energy would harm economic growth.

Soytas and Sari (2007) used the cross-sector data to determine the causal links between energy and production in the Turkish manufacturing industry. Using a multivariate framework and vector error correction findings revealed: (i) a unidirectional causality from electricity consumption to manufacturing value added; and (ii) policy implications to enhance energy saving technologies to increase energy efficiency. Many studies explored cross-country data to investigate the Granger causality relationship between energy and economic development.

Chieng-Chang Lee (2005) examined the causal relationship between energy consumption and GDP in 18 developing countries for the period 1975-2001. Findings indicated the long- and short-run causality from energy consumption to GDP, but not vice versa. Such implied that energy conservation may harm economic growth in developing countries. Other authors such as Stern (2000), Lee and Chang (2005), Altinay and Karagol (2005), Richmond and Kaufmann (2006), also investigated this causal relationship which yielded the same mixed results.

Francis, Moseley, and Iyare (2007) investigated the causal relationship between energy consumption and projected growth in some Caribbean countries and found the short-run bidirectional Granger causality from energy consumption to per capita GDP. They emphasized on the increase of efficiency in energy use, production and distribution of energy, and the application of new technologies.

Zachariadis (2007) explored cross-country data to investigate the causal relationship between energy use and economic growth among G7 countries produced mixed results. Some countries having unidirectional Granger causality from energy to economic growth, the others having bidirectional causality.

Apergis and Payne (2009) studied the causal relationship between energy consumption and economic growth in Central America for the period 1980-2004 using the multivariate framework, panel cointegration, and vector error correction. They found both short- and long-run Granger causality from energy consumption to economic growth. Policy implications favored the increasing energy efficiency, reducing the long-run consequences on the dependence to imported energy.

Wolde-Rufael (2009) investigated the causal link between energy consumption and economic growth for African countries. Conflicting findings emerged because energy had been considered no more than a contributing factor to output growth and not as important as capital and labor. Hence, energy consumption plays a minor role in economic growth in Africa.

Many studies, with the use of time series or panel data, were able to determine the causal relationship between energy consumption and economic development. They took some similar steps like non-stationary test, cointegration test, and Granger causality test between energy and economic series. The following findings of the causal relationship were arrived at: (i) mixed; (ii) some unidirectional causality running from energy to economic growth or vice versa; (iii) others bidirectional causality; and (iv) sometimes a neutral hypothesis. The results of these studies largely depended on the following factors: (i) the individual country; (ii) groups of country; (iii) regions; or (iv) period of time.

1.2 Granger causality with panel data

A large number of empirical studies analyzed the relationship between energy consumption and economic growth in the past. The initial research in this area was conducted by Kraft and Kraft (1978) for the period 1947-1974 in the United States. Thereafter, numerous studies (i.e., Akarca and Long 1980; Erol and Yu 1987; Asafu-Adjaye 2000; Ghali and El-Sakka 2004; Soytas and Sari 2006; Climent and Pardo 2007; Sari and Soytas 2007; Odhiambo 2009; Tsani 2010; among others) looked into the relationship between energy consumption and economic growth in different countries or regions using various methods for different time periods. A cointegration method to test the long-run relationship was proposed by Engle and Granger (1987) and became a widely used method to study the relationship between the variables in economic literatures. However, few

researchers (i.e., Yu and Jin 1992; Masih and Masih 1996; Glasure and Lee 1998; Stern 2000; Oh and Lee 2004 a, b) have applied the cointegration technique to investigate the relationship between energy consumption and income or GDP. The results of previous empirical investigations have been mixed or conflicting due to the choice of data from the different time periods and countries as well as the methods applied.

As noted above, most of the previous studies have mainly focused on a single country or small sample group of countries using the time series technique. The major problem comes in applying time series methods in individual countries with a relatively short time period. Consequently, this reduces the power of the unit root and cointegration tests. In order to overcome this limitation of time series method, the panel data approach can be used. Panel data sets enhance the degrees of freedom and reduce the colinearity among the explanatory variables, thus improve the efficiency of econometric estimations (Hsiao 1986).

In panel data context, some recent empirical studies have investigated the relation between energy consumption and economic growth in developed and industrialized countries (i.e., Al-Iriani 2006; Narayan *et al*. 2007; Lee *et al*. 2008; Narayan and Smyth 2008; Lee hand Lee 2010; Belke *et al*. 2011; Hamit-Haggar 2012). Likewise, few studies (i.e., Lee 2005; Apergis and Payne 2009; Ozturk *et al*. 2010; Eggoh *et al*. 2011; Kahsai *et al*. 2012) have also examined the relationship between the variables in developing countries. More recently, some authors have mainly focused on the panel cointegration relationship between energy consumption and economic growth using panel data technique. Aslan and Kum (2010) examined the long-run cointegration relationship between energy consumption and economic growth in a sample of 11 East Asian countries. Findings showed that a strong relation runs from economic growth to energy consumption in most of the East Asian countries, except Indonesia and Philippines. Li *et al*. (2011) considered a sample of 30 provinces in China and tested the long-run cointegration relationship between real GDP per capita and energy consumption. They found a positive long-run cointegrated relationship between the variables. Similarly, Narayan *et al*. (2010) analyzed the long-run elasticities of energy consumption and GDP for 93 countries from 1980 to 2006 and found the positive relationship for only about 60 percent of the countries.

Sharif Hossain (2012) empirically examined the dynamic causal relationship between economic growth, electricity consumption, export values, and remittance for the panel of three South Asian Association for Regional Cooperation (SAARC) countries using the time series data for the period 1976-2009. Using four different panel unit root tests, all the panel variables were integrated of order 1. From the Johansen Fisher panel cointegration and Kao tests, all the panel variables were cointegrated. The panel Granger F test results supported a bidirectional short-run causal relationship between economic growth and export values but there was no evidence of long-run causal relationship. Results affirmed that the long-run elasticity of economic growth with respect to electricity consumption and remittance were higher than short-run elasticity. This means that over a period of time, higher electricity consumption and higher remittance from manpower supply in the panel of SAARC countries give rise to more economic growth.

Adhikari and Chen (2012) examined the long-run relationship between energy consumption and economic growth for 80 developing countries from 1990 to 2009. For this purpose, methods of panel unit root test, panel cointegration test, and panel dynamic ordinary least squares (DOLS) were applied. These 80 countries were divided into three income groups, namely, upper middle income countries, lower middle income countries, and low income countries. The empirical results revealed a long-run cointegrated relationship between energy consumption and economic growth for the whole panel of countries as well as for each group of countries. They found that strong relation runs from energy consumption to economic growth for upper middle income countries and lower middle income countries. While a strong relation runs from economic growth to energy consumption for low income countries. These findings clearly indicated that energy consumption had a positive and statistically significant impact on economic growth in the long-run for these countries.

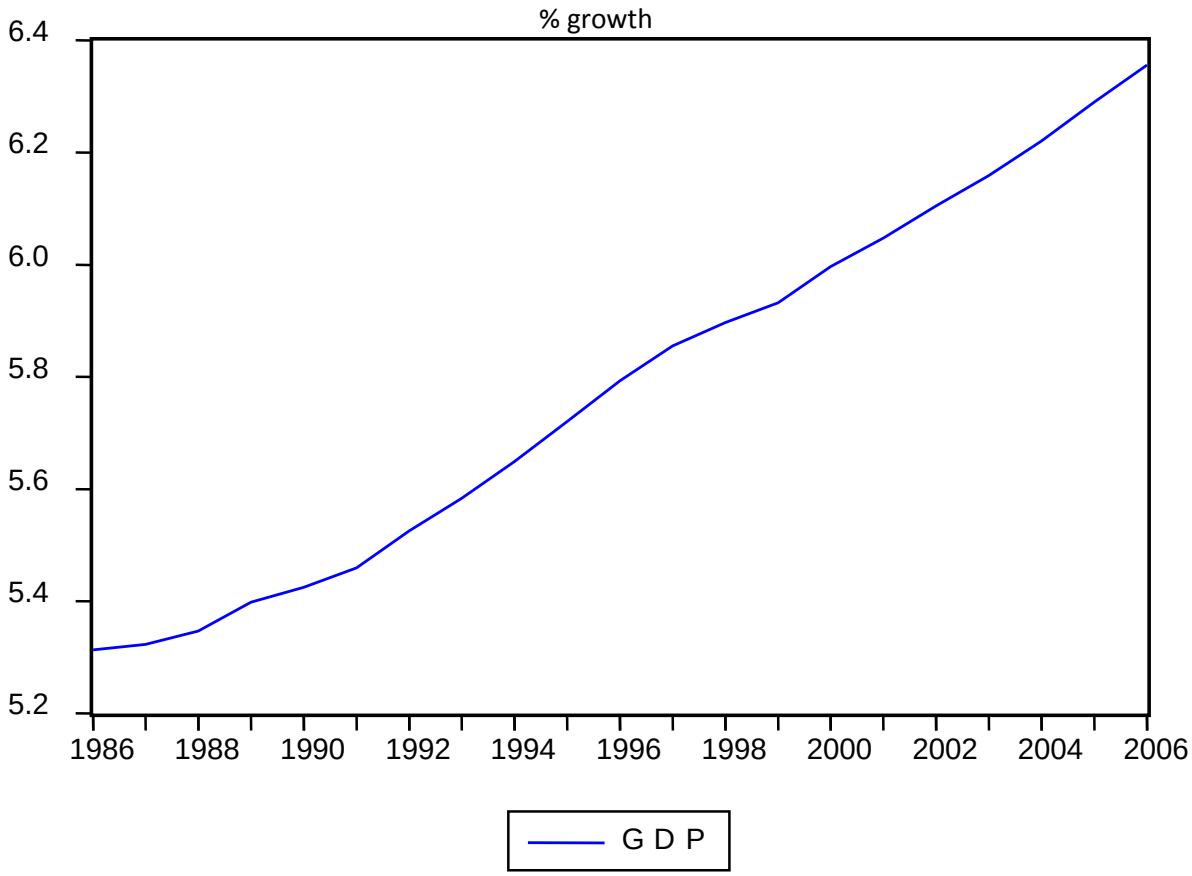
Ideally, the use of panel data sets provide a well cointegrated relationship between the variables and give the more reliable and more statistically powerful results over time series data sets.

2. Overview of economic development in Vietnam

Before reform or “Doi moi”, Vietnam was in a long economic hardship. Since the launching of “Doi moi” in 1986, Vietnam has successfully transformed from a centrally planned economy to a market economy. Becoming one of the most successful transitional economies in the world, inflation had been successfully reduced from 780 percent in 1986 to 12 percent in 1995. Vietnam, which is regarded as an Asian tiger, achieved an average growth rate of over 7 percent per annum from 1986 to 2006. Per capita GDP increased almost 10 times from 1986 to 2006, from about USD 80 to USD 830. The percentage of population living in poverty was significantly reduced by half within a decade—from 58 percent in 1993 to 29 percent in 2002 (World Bank, various years).

The overall adult literacy rate is very high, males at 95 percent and females at 91 percent. This rate is much higher than the other economies having the same level of development. The reform process is key to Vietnam economy’s opening up to the world— foreign trade liberalization, attractive foreign direct investment (FDI), and regional integration. Such milestones contributed significantly to Vietnam’s promising economic performances. Figure 1 shows the per capita GDP which has increased rapidly since the economic reforms in 1986.

Figure 1. Per capita GDP growth, 1986-2006.



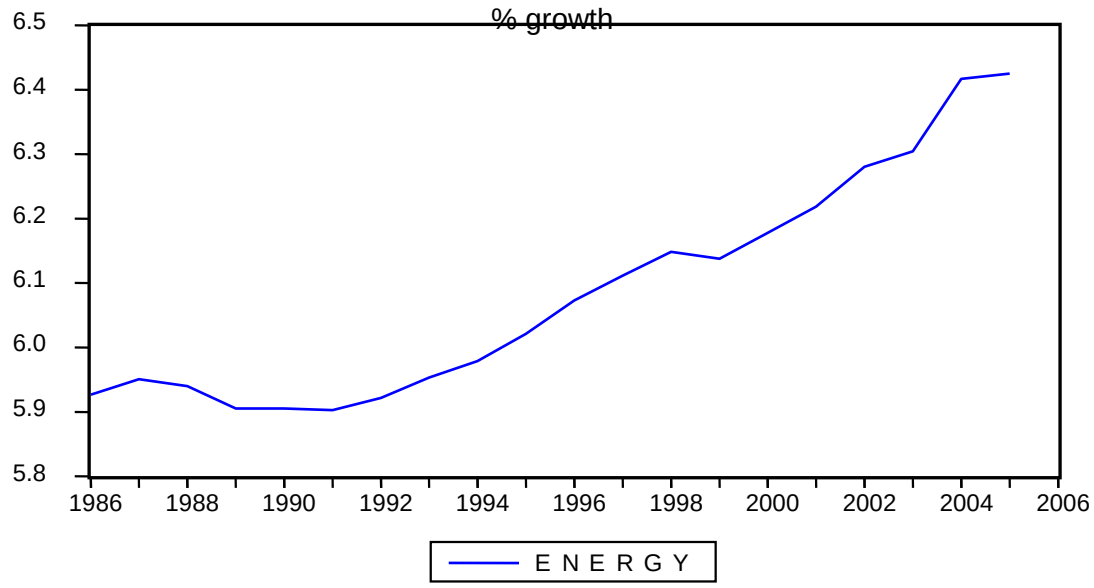
Energy fuels economic development. It is a vital input for the overall economic activities of a developing nation. Energy supports the consumption of the various sectors from individual households, to communities, to government agencies, to industries. The development of the energy sector targets to meet the demands for socioeconomic development, thereby, ensuring national energy security. However, energy becomes a threat to the environment.

The energy sector in Vietnam has expanded drastically in the post-reform period. In 2005, Vietnam produced 52.28 billion KWh of electricity, 35 million tons of coal, 18.6 million tons of crude oil, and 6.6 billion m^3 of gas. With

Vietnam's export of 11 million tons of coal in 2004, it has been ranked as the first exporter of coal in the world (Ministry of Industry 2006). Vietnam also released a national policy for energy development in 2005.

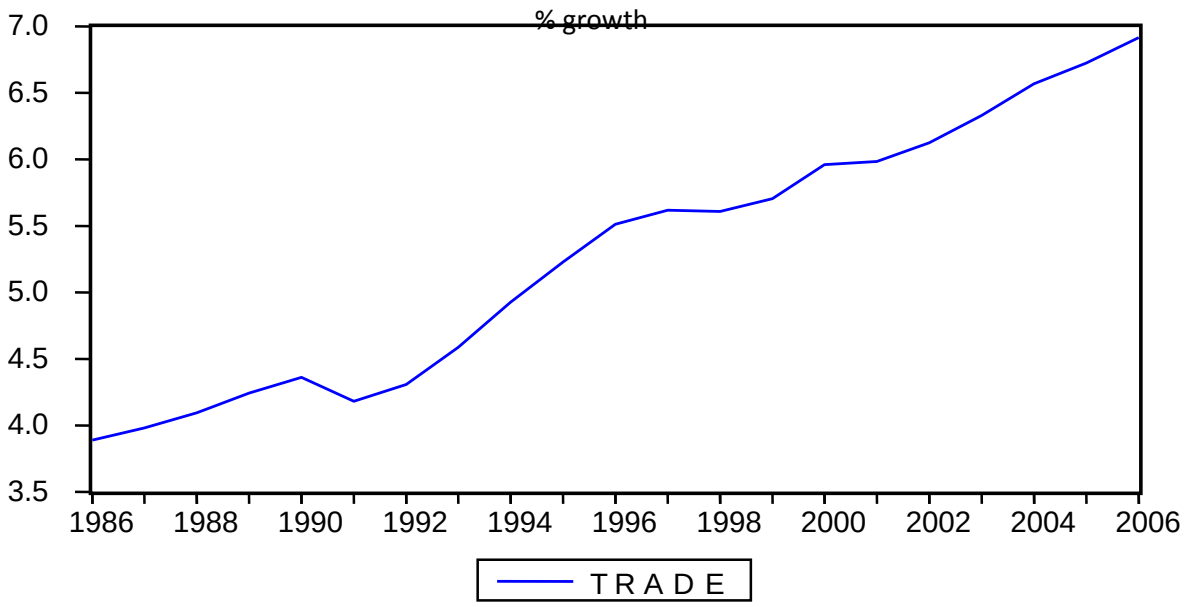
The industry, transportation, and household sectors consumed the most energy in Vietnam. The industry sector consumed 1.5 million TOE (tons of oil equivalent) in 1990 and 6.17 million TOE in 2003, with an average increase of 11.4 percent annually. The transportation sector increased energy consumption from 1.64 million TOE in 1990 to 5.63 million TOE in 2003, with an an average growth of 10 percent per year. The household sector consumed 0.46 million TOE in 1990 and 2.3 million TOE in 2003, with an average increase of 13.2 percent per year. The data for the trade and services sector were 0.35 million TOE in 1990 and 1.3 million TOE in 2003, with an average increase of 10.6 percent; while the data for the agricultural sector were 0.26 million TOE in 1990, and 0.8 million TOE in 2003, with an increase of 9.0 percent. The trading energy consumption per capita increased from 63 kgOE (oil equivalent) in 1990 to 315 kgOE in 2004; the trading electricity consumption per capita raised from 93 KWh in 1990 to 541 KWh in 2003 (Ministry of Industry, 2007). The energy consumption per capita is equal to one third of the average level in the world. Vietnam's structure of energy consumption mainly concentrated in coal, oil, and electricity with the following percentage distribution—25.3 percent for coal, 54.8 percent for oil, and 19.9 percent for electricity (Ministry of Industry, 2007). Figure 3 shows the graph of per capita energy consumption in Vietnam.

Figure 2. Per capita energy consumption, Kg of oil equivalent, 1986-2006.



Since the adaptation of the reform policy, domestic and international trade were liberalized, tariff and non-tariff barriers were also reduced and gradually alleviated, exports were promoted by the government through many economic policies and measures such as tax preferences, export processing zones, and industrial zones, etc. As a result, trade has been increasing rapidly from 1986 to 2006, except the period of the Asian financial crisis. Trade per capita increased more than 20 times, from USD 49 in 1986 to USD 1008 in 2006. Trade accelerated almost three times, from USD 29.5 billion in 1986 to USD 88 billion in 2006. Consequently, the percentage of trade in GDP advanced from 21 percent in 1986 to 160 percent in 2006. Along with FDI, trade, particularly exports, mainly contributed to the high economic growth during this period. The rapid growth of trade and the high level of openness, however, may result in dependence in external markets and could be sensitive to any economic shocks from the outside.

Figure 3. Trade per capita, 1986-2006.



3. Energy sector development

Vietnam is endowed with abundant energy resources, notably petroleum, coal, and hydropower. It has been a net energy exporter since 1990s. Its crude oil has accounted for over a fifth of total export value in recent years. Vietnam's energy consumption has been growing rapidly, in line with the country's industrialization and integration into the global economy. Primary energy consumption, excluding biomass, grew at an annual rate of 10.6 percent in the 2000-2005. Despite the fast growth, a large part of the rural population still relies heavily on non-commercial biomass energy sources, which still accounts for almost half of total energy consumption. Vietnam's per capita consumption of commercial energy thus remains among the lowest in Southeast Asia. Energy is being used inefficiently, and energy production and distribution are poorly managed.

Rapid change is resulting from Vietnam's socioeconomic development, which is expected to lead to an annual 4.4 percent growth in primary energy

demand and of 15-16 percent in electricity consumption over the next two decades. Oil will continue to account for the largest share in total primary energy demand for the foreseeable future. Demand for coal and natural gas—the latter the fastest-growing energy source—will soar, driven in particular by the rapid development of the electricity and industrial sectors. Commercial renewable energy and nuclear energy, which Vietnam hopes to develop by 2020, will make up for the balance.

The energy sector remains dominated by state ownership. Since 1995, energy sector operations have been organized into three general companies, which are among the largest firms in Vietnam: PetroVietnam, Vinacomin (former Vinacoal) and Electricity of Vietnam (EVN). However, private sector participation has been expanding recently.

The Ministry of Industry and Trade is responsible for the energy sector and has the task of supervising the state-owned companies and developing policies. To ensure the supply of energy meeting the rise in consumption, as well as the transition to market economy principles, the ministry has recently formulated a National Energy Policy for Vietnam for the period 2006 to 2015. The policy emphasizes the need to diversify the country's energy mix while maximizing the use of local energy reserves. The highlights of the policy are: 1) development of energy infrastructure and enhancement of long-term energy supply; 2) development of energy in consideration of environment; 3) improvement of energy efficiency; 4) restructuring the energy sector's structure and opening up the market for energy; and 5) enhancement of international energy cooperation while ensuring national energy security. Final endorsement of the policy by the government is still outstanding.

The national power development plan is an important policy to aim at increasing the electricity production to meet the needs arising from the country's development at reasonable costs. In the power structure, hydroelectricity development is still given a top priority given its ability to provide low-cost base load, and the development in gas- and coal-fired plants is also promoted. The long-term process of restructuring the power industry and developing a competitive electricity market, initiated with the 2004 Electricity Law, is to continue. For this purpose, EVN has equitized various subsidiary units, including most power plants and distribution companies, retaining, however, majority shares in the new entities.

The interplay between the current energy market and regulatory structures in the energy sector will also be considered for research in the coming months. Likewise, the Vietnam patterns of consumption, distribution, and production of energy will also be the focus of studies.

3.1 The reality of the energy market

The policy of Vietnam is to develop the economic market oriented toward socialism. Up to now, most of the sectors in the Vietnam's economy has been transiting to a market economy including the energy sector. Oil, gas, coal and electricity, and renewable energy are under the management of three state-owned business groups—PetroVietnam for oil, VinaCoMin for coal-minerals, and EVN for electricity—in the monopoly market structure. Thus, building competitive energy market for the country is an urgent need with complexities that requires both theoretical research and practical experience learning from other countries in the world. The energy sector needs to study the model building markets, pricing policies, and management mechanisms of the state in accordance with each type of energy products in various stages.

3.1.1 Electricity markets

For a competitive electricity market, a long-term development strategy for Vietnam's power sector is detailed in the Electricity Act of 2005. Specified under Decision No. 26/2006 / QD-TTg 01.26.2006 as replaced by Decision No 63/2013 / QD-TTg 11/08/2013 is the Prime Minister's policy roadmap. The structural conditions and power sector development plan for Vietnam will be a power market to be developed in three stages:

- Stage 1: Competitive electricity markets until the end of 2014;
- Stage 2: Wholesale electricity market competition—
  - 2015-2016: Implement a pilot wholesale electricity market competition.
  - 2017-2021: Implementation of the wholesale electricity market competition has been complete.
- Stage 3: Retail electricity market competition in 2021-2023.

Commenting on the implementation of the electricity market development:

1. The formation and development of the competitive electricity market is a need based on the views of the Government and the 2005 Electricity Law. This will initially create positive change in the electricity activities in Vietnam.
2. However, going through the three stages from 2005 to 2023 is too long. The implementation of the stages does not indicate if the completion of one stage means consequently moving on to another stage. The first stage in 2005-2011 was even a pilot. The almost 20 years implementation design for

Vietnam’s competitive electricity market needs to consider options to shorten the time.

3. The management of the state's electricity market is limited to the construction of models, organization, operation mechanism, and transactions between objects purchasing power in the market. After nearly 10 years of research and implementation, the competitive electricity market has not yet followed the principles of market competition-efficiency, equity, fair competition—without discrimination between stakeholders electricity market. Currently, EVN is the most dominant portion of the generator stages. According to Article 19 of the Electricity Law, it must have an operating unit for electricity market transactions. It should be responsible for the regulation and coordination of activities and trade of electricity supporting services in the market. However, such an operating unit has not been established; the activities are operated by EVN.

After a long time the Ministry of Industry and Trade, the Electricity Regulatory Bureau and related organizations studied, to build a system of legal documents, building infrastructure and training information, training units of market participants. The July 1, 2011 pilot operation of the competitive electricity market and eventually its the full operation in July 1, 2012 and 2013, signalled some initial success. After a year of official operation, 37 plants have a total capacity 9.500 MW bid directly involved in the power market, accounting for 40 percent of the total installed capacity of the power system. Some 55 factories have not directly bid on electricity market with a total capacity of 16,042 MW, accounting to 62.7 percent of the total system capacity. However, there are still many limitations needed to improve the experience for the next step. As scheduled,

after finishing level 1 competitive electricity market in 2014, moved to level 2 wholesale market competition (2015-2022), and later in 2023 for the retail market edge competition.

3.1.2 Oil and gas market

Products in the market includes crude oil, natural gas, and oil types in which gasoline market is the most important and in the best interest of providers as well as consumers in Vietnam. Along with the transition to a market economy, the petroleum distribution operation has also transformed from the quantitative supply mode of, applying a uniform price regulated by the State, to purchases based on demand through economic contracts.

Currently, for gasoline is operating under the traditional model. Petroleum Corporation (Petrolimex) currently accounts to over 50 percent market share, together with PV Oil and Saigon Petro. These three units account for over 80 percent market share in the country, with the duty of production, imports, distribution, and retail.

The petroleum market has achieved the following:

a. Created a system of state enterprises engaged in import breaking the monopoly in the import of some previous units; created a new stance for new importers and confirmed its dominance of the units invested under new vision of the market mechanism.

b. Contributed to price stability over a period of time even when the world oil price volatilities made impacts to economic growth; contributed as well to a stable political, economic, and social situation of the country.

c. Gradually established a competitive market between enterprises, thereby reducing social deadweight loss for petroleum operations and a reasonable profit margin for enterprises.

However, the market has some limits:

c.1. The operating price of gasoline is due to state regulations; implications of registration regulations, domestic prices that do not catch up to the market price; destabilizing market speculation before the rise of information; creating a mindset of expectation in gasoline price increases.

c.2 The petroleum market maintained subsidy mechanisms in a long period of time, caused loss of initiative of enterprises, raised costs and slow innovation.

c.3 The planning activities to develop petroleum trading system are not clear about the competence and responsibilities, etc.

Through the analysis of oil market situation, the present and the limited reach, the following perspectives on the development of the petroleum market may be considered:

a. Change the oil and gas business to a market mechanism managed by the State in order to: (i) to meet consumer demand and economic development of the country; (ii) stabilize the oil market in all circumstances; (iii) operate real oil price in accordance with market mechanisms under the management of the State; (iv) harmonize State benefits for consumers and businesses.

b. Encourage all economic sectors to invest, generate a market of participants from upstream to downstream stages in order to create the environment for fair competition between businesses; continuously improve quality and service for commercialism.

c. Create an environment for fair competition between businesses to enter the market. Decree promulgated new petroleum business to create a legal framework to encourage traders of all economic sectors to invest in distributed systems in accordance with the plans already approved by the Prime Minister.

d. Generate a mechanism for petroleum price derived from the requirements of international economic integration and domestic market needs. The mechanism for fuel price management should target the operating principles under the market price management of the State.

3.1.3 Coal market

The Coal and Mines Industry Group of Vietnam (VnaComin) is a primary coal provider in the domestic market of up to 98 percent as well as the only coal exporter of the country. Coal production for domestic consumption has a significant increase from 10 million tons in 2002 to about 28 million tons in 2013. This mainly accounts for the domestic coal production of 27.5 million tons (98.2%), while coal import is about 0.5 million tons (1.8%). In recent years domestic coal supply is abundant and competitively priced than imported coal. However, this relationship is increasingly losing.

Under the provisions of the Ordinance on Prices in 2002, the coal is not subject to commodity price stabilization and not subject to state pricing. The

pricing of coal by organizations and individuals producing and trading coal comply with the market mechanism.

The "Strategy for development of the coal industry in Vietnam in the period up to 2015 and orientations to 2025" and Decision No. 60 / QD TTg dated 09/1/2012 of the Prime Minister approves the development plan of Vietnam's coal industry until 2020, with a 2030 outlook. The targets are as follows:

1. Creation of a coal market and rapidly moving activities of the coal industry following the market mechanism, and market integration with the state regulation. But the construction and implementation of the coal market is still slow, asynchronous routine market development.

2. The output of domestic coal consumption increased significantly, mainly supplying the domestic market; imports accounted for very little. However, when the domestic coal resources decrease, coal imports are expected to rise. The state management of the domestic market and import market of coal is unclear, especially management mechanisms for the protection coal price for domestic consumption as well as export and import prices. According to the forecast of the coal industry development planning Vietnam until 2020, with perspective 2030 has been approved by the Prime Minister's Decision No. 60/2012 / QD-TTg the domestic coal demand next time rose very high, namely: 2015 was 56.2 million tons, 112.3 million tons in 2020, 145.5 million tons in 2025, 2030 is 220.3 million tons.

Thus, compared with consumption in 2013 to 2015 (after 2 years) domestic coal demand will rise 2 times, 2020 will increase by 4 times and 2030 will increase by 8 times. At the same time, the supply of domestic coal copes with difficulties

because: i) coal resources have been explored excessively; ii) the ability to increase mining production is limited and lower than the approved Master Plan; and iii) there is high investment demand and rising extraction costs.

However, the long-term coal import volume over tens of millions to hundreds of millions of tons per year is extremely difficult to achieve due to the increasing limited coal supply with the country's growing coal demand.

3.1.4 New markets and renewable energy

The Energy Development Strategy of Vietnam National 2020 Vision 2050 states that there is interest “in developing clean energy, priority development of new and renewable energy...” The specific goal to achieve is: "Striving to increase the proportion of renewable energy sources and renewable up over 3 percent of total commercial primary energy by 2010; approximately 5 percent in 2020 and around 11 percent in 2050".

With the state dwindling primary energy resources, inevitable climate change, and deteriorating environment, the market development requirements for energy becomes urgent. The current source of new and renewable energy has not been explored. Renewable technologies are potential energy sources for Vietnam’s growth centers. It is critical to develop a plan to implement the strategy and contribute to creating new markets for renewables.

4. Time series Ganger causality analysis

4.1 Data

The World Development Indicators (WDI) of the World Bank covered the time series of per capita GDP, per capita energy consumption, and per capita trade

for the period 1986-2006. In order to reduce fluctuations of the trade time series, the trade's data had been transformed into trade per capita by using the equation below. The variables included the total primary energy consumption per capita measured in kilogram (kg) of oil equivalent and the GDP per capita in thousand real 2000 US dollars from the WDI. The trade per capita[2] in current US dollars obtained from the WDI was estimated as follows:

$$Trade_t = (IM_t+EX_t)/P_t$$

Where IM refers to imports, EX to export, P to numbers of population at time t, and t is time trend.

The structure of the total primary consumption consists of petroleum, natural gas, coal, hydroelectric power, nuclear power, and renewable electric power (geothermal, solar, wind, wood, and waste). The Granger causality links between energy consumption and economic development as a whole, energy consumption and trade, and GDP and trade was examined. Therefore, it was not concerned any calculation on the percentage of coal, petroleum and gas, and hydroelectric, nuclear and renewable electric power in total energy consumption. All variables are logarithmic for the purpose of avoiding fluctuations and smoothing in the time series variables.

4.2 Methodology

[2] Import and export are available only in current term while GDP per capita is found both in current and real terms. Many countries have import and export price indexes that would allow one to deflate nominal import and export figures to arrive at an estimate of real exports and imports. However, Vietnam's statistical data is sometimes non-available and not long enough for studying. The limitation of this draft is that the needed data is not available.

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This study tried to examine the Granger causality links between energy, GDP, and trade, in both bivariate and multivariate framework, to avoid spurious results. First, each variable was tested for non-stationary, with unit root, or not. Second, if the time series variables were non-stationary and same order integration series, then cointegration relations were tested. Third, if cointegration relations existed, then Granger causality among these time series variables was tested.

4.2.1 Unit root test

The unit root test was opted in order to judge the stationarity of time series. There are several kinds of methods[3] for testing, where only two methods were considered in this study—Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The critical values (p-value) were approximated from different sample sizes. In 1996, MacKinnon used the annual data to estimate the critical values for 20 observations[4]. In this sample, there were 21 observations for the period of 1986-2006, more than the number of observations used by MacKinnon[5]. This is the reason why the ADF method was used for unit root tests.

The equation for ADF test can be calculated in three different types: (i) equation with constant; (ii) equation with constant and deterministic trend; and (iii) equation without constant. In this paper, we chose to run the test with constant and deterministic trend. The ADF test, based on the construction a parametric correction for higher-order correlation, may be incorrect if the series have a unit

[3] They are Dickey-Fuller (DF) test, ADF test, KPSS test, ERN test, PP test and NP test, of which DF and ADF tests are the most common uses.
[4] 20 observations are enough to test the p-values available in the econometric software of Eview 5.0 and 6.0.
[5] MacKinnon (1996) figured out the advantage of using annual data over quarterly or monthly data under error terms. The annual data has been considered because of the non-availablity of monthly or quarterly data for energy consumption and GDP.

root and a structural break. For solving these problems, the PP test which produces a more robust estimation can be considered.

4.2.2 Cointegration test

Cointegration links between variables are necessary for Granger causality test. If two series of non-stationary same order integration have a stationary linear combination, it calls for a cointegration equation. This paper explored the Johansen (1988) cointegraton test within a vector autoregressive (VAR) framework for examining the presence of cointegration links between the variables. The Trace and maximum-eigenvalue tests in the VAR model and vector error correction (VEC) show the level series of energy, trade and GDP, and the first-difference series denergy, dtrade, and dGDP respectively. For mitigating the spuriousness of the regression and investigating the long-term relation, a VEC model was applied.

4.2.3 Granger causality test

The presence of the cointegration relation is necessary for Granger causality test. Testing whether a long-term balance relation exist between variables can indicate Granger causality or not. The causal relationships between the three series variables in both bivariate and multivariate framework had been examined. Using the VEC model to test Granger causality with the t-statistic test includes the first difference series of the three variables so that spuriousness may be avoided. Likewise, the bivariate tests for the series variables with the F-statistic for investigating the short-run Granger causality between the variables has also been explored. Multivariables of denergy, dtrade, and dgdp in the VAR model estimate the interactions among their p-lag variables to test the Granger causality relations. The VAR (p) model is as below:

$$Y_t = \mu + A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + \varepsilon_t \quad (j)$$

Where y_t is a (3x1) column vector of the endogenous variables: denergy, dtrade and dGDP, μ is a (3x1) constant vector, p is the order of lags, each of $A_1, A_2, \ldots A_p$ is a (3x3) coefficient matrix, each of y_{t-1}, y_{t-2}, …, y_{t-p} is a (3x1) vector of the lag endogenous variables, and ε_t is a (3x1) vector of the random error term. The lag length p in level series VAR is chosen by the minimum Akaike information criterion (AIC) with maximum lag equal to 3.

5. Estimation results of time series Ganger causality analysis

5.1 Unit root test

Taken first are the ADF and PP tests of level series for each variable of energy, trade, and GDP. Table 1 shows the test results that energy, trade, and GDP are non-stationary because the test statistics do not exceed the critical value. Table 2 presents the ADF and PP tests of first difference that the series variables of first difference have first order integration. Therefore, cointegration relations exist among the three variables of energy, trade, and GDP.

Table 1. ADF and PP unit root tests: level series.

	ADF			PP	
	Lags	Test statistic	Prob.	Test statistic	Prob.

Energy	0	-1.0305	0.9162	-1.0305	0.9162
Trade	1	-2.7623	0.2246	-1.8839	0.6269
GDP	1	-3.6336	0.0511	-4.0880	0.0213

Note:
(i) The test equation includes constant, linear trend.
(ii) The lag length is selected by minimum AIC with maximum lag=4.
(iii) In the ADF and PP tests for the Energy series, the critical values for the 1%, 5%, and 10% level are -4.4983, - 3.6584, and -3.2689, respectively.
(iv) In the ADF and PP tests for Trade, the critical values for the 1%, 5%, and 10% level are -4.4678, -3.6449, and -3.2614, respectively.
(v) In the ADF and PP test for GDP series, the critical values for the 1%, 5%, and 10% level are -4.4678, -3.6449, and -3.2614, respectively.

Table 2. ADF and PP unit root tests: first difference.

	ADF			PP	
	Lags	Test statistic	Prob.	Test statistic	Prob.
Energy	0	-4.8183	0.0053	-4.8190	0.0053
Trade	0	-3.1660	0.1178	-3.0623	0.1402
GDP	3	-2.9436	0.1699	-2.2459	0.4424

Note:
(i) The test equation includes constant, linear trend.
(ii) The lag length is selected by minimum AIC with maximum lag=4.
(iii) In the ADF and PP tests for the Energy series, the critical values for the 1%, 5%, and 10% level are -4.4983, - 3.6584, and -3.2689, respectively.
(iv) In the ADF and PP tests for Trade, the critical values for the 1%, 5%, and 10% level are -4.4678, -3.6449, and -3.2614, respectively.
(v) In the ADF and PP tests for GDP series, the critical values for the 1%, 5%, and 10% level are -4.4678, -3.6449, and -3.2614, respectively.

5.2 Cointegration test

If the cointegration relations exist within the linear combination of non-stationary series, they must have Granger causality. Tables 3 to 6 show the results of Johansen cointegration test[6]. For the bivariate cointegration test, the trace and maximum-eigenvalue tests for three pairs of variables—energy-GDP, energy-trade, and trade-GDP—indicate that there is only one cointegration equation in the pairs of GDP-trade at the 5 percent level (Table 5). Table 5 shows that one cointegration equation exists for trade-GDP because the test statistic is higher than the critical value, hence, reject the null hypothesis.

Table 3. Johansen cointegration test for Energy-GDP.

Energy-GDP Cointegration rank (r)	Eigenvalue	Trace statistic	5% critical value	Prob.
r=0*	0.5837	24.8572	25.8721	0.0665
r≤1	0.3067	7.3266	12.5179	0.3117
		Max-Eigen statistic	5% critical value	Prob
r=0*		17.5305	19.3870	0.0912
r≤1		7.3266	12.5179	0.3117

Note:
(i) The cointegration equation includes linear deterministic trend.
(ii) Trace and Max-Eigen statistic tests indicate no cointegration equation at the 5% level.
(iii) * - denotes rejection of the hypothesis at the 5% level.

[6] Johansen 1991, Greene 2003.

Table 4. Johansen cointegration test for Energy-Trade.

Energy- trade Cointegration rank (r)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
r=0	0.383043	17.47835	25.87211	0.3801
r≤1	0.323594	7.819233	12.51798	0.2668
		Max- Eigen Statistic	Critical Value	Prob.**
r=0		9.659113	19.38704	0.6553
r≤1		7.819233	12.51798	0.2668

Note:
(i) Max-eigenvalue test indicates no cointegration at the 0.05 level.
(ii) * denotes rejection of the hypothesis at 0.05 level.

Table 5. Johansen cointegration test for GDP-Trade.

GDP-Trade Cointegration rank (r)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
r=0*	0.655281	33.64360	25.87211	0.0044
r≤1	0.415531	11.27809	12.51798	0.0798
		Max-Eigen Statistic	0.05 Critical Value	Prob.**
r=0*		22.36551	19.38704	0.0179
r≤1		11.27809	12.51798	0.0798

Note:
(i) Max-eigenvalue and Trace tests indicate 1 cointegrating equation at the 0.05 level.

(ii) * - denotes rejection of the hypothesis at the 0.05 level.

Table 6. Johansen cointegration test: mutilvariate model.

Cointegration rank (r)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
r=0*	0.759599	49.55804	42.91525	0.0095
r≤1	0.460088	21.04909	25.87211	0.1774
r≤2	0.353450	8.722090	12.51798	0.1982
		Max-Eigen Statistic	0.05 Critical Value	Prob.**
r=0*		28.50895	25.82321	0.0216
r≤1		12.32700	19.38704	0.3853
r≤2		8.722090	12.51798	0.1982

Note:

(i) Max-eigenvalue and Trace tests indicate 1 cointegrating equation at the 0.05 level.

(ii) * - denotes rejection of the hypothesis at the 0.05 level.

For the multivariate cointegration test, Table 6 shows the results of the Trace statistic test which indicates one cointegration equation at 5 percent level. However, the Max-Eigen statistic test also indicates one cointegration at 5 percent level. The test shows that cointegration is not stable and may be affected by some economic events.

5.3 The VEC model and Granger causality test

According to the VAR (p) equation (j), the optimal lag length in the level series was first estimated. Table 7 shows the optimal lag length in different criteria. The optimum lag is 4 under AIC, with no extra lag added in a model with limited number of observations. Based on the equations (d), (e), and (f), the optimum lag length was calculated.

Table 7. VAR lag order selection criteria.

Lag	LR	FPE	AIC	SC
0	NA	3.07e-06	-4.180373	-4.031013
1	129.8889*	2.29e-09	-11.39843	-10.80099*
2	10.45922	2.72e-09	-11.30298	-10.25746
3	16.14080	1.63e-09*	-12.01706	-10.52346
4	8.367582	1.91e-09	-12.31243*	-10.37075

Note:
(i) Indicates lag order selected by the criterion.
(ii) LR: sequential modified LR test statistic (each test at 5% level).
(iii) FPE: Final prediction error.
(iv) AIC: Akaike information criterion.
(v) SC: Schwarz information criterion.

The vector error correction model (VEC) to test the Granger causality to investigate the long-term relation between variables was applied, likewise, avoided the spuriousness in the series. The results are shown in Table 8 based on the first-difference series. The optimal lag length for the three endogenous variables is selected by the minimum AIC method. Table 9 shows the critical values.

Table 8. Vector Error Correction Model (VEC) Granger causality tests.

Error Correction:	D(ENERGY)	D(GDP)	D(TRADE)
CointEq1	-0.064885	0.006748	-0.221540

	(0.02804)	(0.01638)	(0.10184)
	[-2.31367]	[0.41186]	[-2.17542]
D(ENERGY(-1))	-0.433024	0.030129	-1.675716
	(0.26207)	(0.15311)	(0.95167)
	[-1.65231]	[0.19678]	[-1.76082]
			Trade →Energy
D(ENERGY(-2))	0.251991	0.170778	1.862625
	(0.29914)	(0.17477)	(1.08629)
	[0.84237]	[0.97717]	[1.71466]
D(GDP(-1))	0.893535	0.585243	2.165886
	(0.40483)	(0.23651)	(1.47006)
	[2.20720]	[2.47449]	[1.47333]
D(GDP(-2))	-0.143301	-0.036232	-0.562240
	(0.10888)	(0.06361)	(0.39540)
	[-1.31608]	[-0.56957]	[-1.42197]
	Energy →GDP		Trade →GDP
D(TRADE(-1))	0.059032	-0.014127	0.458997
	(0.06146)	(0.03591)	(0.22319)
	[0.96046]	[-0.39341]	[2.05654]
D(TRADE(-2))	0.123850	-0.014612	0.003347
	(0.08006)	(0.04677)	(0.29073)
	[1.54695]	[-0.31240]	[0.01151]
		GDP →trade	
C	-0.025387	0.024291	0.025133
	(0.01740)	(0.01017)	(0.06319)
	[-1.45902]	[2.38951]	[0.39777]

Note:
(i) Standard errors in ( ) & t-statistics in [ ].
(ii) →: mean Granger causality relation.

Table 9. Granger causality Wald tests.

	D(ENERGY)	D(GDP)	D(TRADE)
Wald test of coefficients causality direction (1)	7.973391 [0.046565]	8.553953 [0.035849]	9.324276 [0.025276]
Wald test of coefficients causality direction (2)	5.400254 [0.144728]	1.867456 [0.600367]	6.854937 [0.076668]

Note: Numbers in [ ] are p-values.

A strong long-term balanced bidirectional Granger causality between GDP and trade as the t-statistic indicates a significant causal effect. A weak unidirectional Granger causality link exists from trade to energy, while a Granger causality link runs from energy to GDP. With the bidirectional Granger causality between GDP and trade, indicates the latter, particularly export, as the driving force for rapid economic growth in Vietnam. Hence, the higher level of economic growth could increase trade volumes. This is consistent with the export-led growth hypothesis prevailing in East Asia. The unidirectional Granger causality running from trade to energy shows that an increase in trade may cause a rise in the level of energy consumption. This is consistent with the pollution haven hypothesis and industrial relocation hypothesis. The unidirectional Granger causality running from energy to GDP implies that energy leads economic growth in the long run. However, these unidirectional Granger causality links are weak. Thereby,

investigating the short-run causality relations among series variables in the pair Granger causality test (Table 10).

Table 10. Pairwise Granger causality tests.

Null Hypothesis:	F-Statistic	Probability
GDP does not Granger Cause ENERGY	2.86535	0.08832
ENERGY does not Granger Cause GDP	0.46816	0.63500
TRADE does not Granger Cause ENERGY	2.08738	0.15857
ENERGY does not Granger Cause TRADE	0.09108	0.91344
TRADE does not Granger Cause GDP	0.14353	0.86739
GDP does not Granger Cause TRADE	7.17933	0.00595

Table 10 indicates the results of the pairwise Granger causality test implying the short-run relations between variables. Three pairwises of Granger causality tests show that the tests statistics exceed the critical values, therefore, the null hypothesis was rejected. On the basis of the cointegration test, a strong unidirectional Granger causality running from GDP to trade was found. This means that the high level of economic growth increases volumes in trade. This bidirectional causality relation exists in the short-run as the F-statistic indicates. Results also revealed a weak unidirectional Granger causality running from GDP to energy, and another weak unidirectional causal relation running from trade to

energy. The Granger causality between energy and GDP is not clear in the short-run.

A Granger causality runs from GDP to trade, as well as from GDP to energy. This Granger causality relation is inconsistent with the export-led growth hypothesis. The growth in GDP leads to an increase in trade or being more open to trade, if trade itself is considered the index. The Granger causality running from GDP to energy indicates that an increase in GDP leads to an increase in the level of energy consumption.

As the economy grows, it demands for more energy consumption. Therefore, the efficient energy use should be given attention in order to lower energy consumption for a given level of economic growth. Vietnam may both have environmental and energy policies harmonized to decrease energy intensity, increase the efficiency of energy consumption, and develop a market for emission trading. An investment in research and development (R&D) for the creation of new technologies on alternative energy towards increasing the efficiency of energy consumption, thus, reduces environmental pressures.

5.4 Variance decomposition of variables

The variance decomposition provides information about the relative importance of each random innovation in affecting the VAR. Table 11 shows the separate variance decompositions for each endogenous variable. The standard error (S.E.) column contains the forecast error of the variable at the given forecast horizon. The source of this forecast error is the variation in the current and future values of the innovations in each endogenous variable in the VAR. The other

columns of endogenous variables give the percentage of the forecast variance in each innovation, with each row adding up to 100.

Measuring the variance decomposition of endogenous variable in the multivariate framework can find a similar trend in the bivariate framework. Table 11 shows the results of variance decomposition of variables. First, we look at the variance decomposition of energy variable. At the period of 10^{th} for example, the percentage of the forecast variance of energy is 37 percent by its own innovations or shocks, 55 percent by innovations of GDP, and 8 percent by innovations of trade. Second, the variance decomposition of GDP presents that at the period of 9^{th}, the percentage of the forecast variance of GDP is almost 85 percent because of its own innovations or shocks, 15 percent by energy's innovations, and 0.25 percent by trade's innovations. Finally, for the variance decomposition of trade, the forecast variance for trade is 14 percent by its innovations or shocks, 8.6 percent by energy's innovations, and 77 percent by GDP's innovation at the 8^{th} period.

The variance decomposition indicates that the relative importance of each random innovation affects variables in the VAR. The large percentage of variance decomposition of one variable is explained by the other two variables' innovations. This is consistent with the findings of the long- and short-term bidirectional and unidirectional Granger causality relations between energy, GDP, and trade.

Table 11. Variance decomposition of variables in the multivariate framework.

Variance Decomposition of ENERGY				
Period	S.E.	ENERGY	GDP	TRADE
1	0.025438	100.0000	0.000000	0.000000
2	0.028735	98.29503	0.848681	0.856287

3	0.032087	91.73976	4.026435	4.233809
4	0.035542	82.48570	5.951244	11.56306
5	0.037755	75.83506	8.486757	15.67818
6	0.039489	69.63570	14.11880	16.24550
7	0.042098	61.36983	23.92528	14.70489
8	0.046146	51.89036	35.78685	12.32279
9	0.051388	43.44832	46.57940	9.972288
10	0.057400	37.08524	54.90037	8.014391

Variance Decomposition of GDP

Period	S.E.	ENERGY	GDP	TRADE
1	0.015905	0.464559	99.53544	0.000000
2	0.028308	1.142712	98.77462	0.082672
3	0.039774	2.637153	97.03298	0.329864
4	0.050581	4.507999	94.96370	0.528300
5	0.061137	6.700169	92.79611	0.503718
6	0.071853	9.019900	90.59935	0.380745
7	0.082880	11.21684	88.49281	0.290348
8	0.094110	13.15543	86.58956	0.255014
9	0.105336	14.82755	84.91919	0.253261
10	0.116383	16.28160	83.44964	0.268761

Variance Decomposition of TRADE

Period	S.E.	ENERGY	GDP	TRADE
1	0.098413	0.004808	30.02834	69.96685
2	0.158120	2.035476	54.40499	43.55953
3	0.193973	1.712695	69.34029	28.94701

4	0.218622	1.564356	73.32725	25.10839
5	0.237040	2.109511	74.68720	23.20329
6	0.255406	3.774076	75.91757	20.30836
7	0.278650	6.200470	76.73336	17.06617
8	0.306772	8.601558	77.22053	14.17792
9	0.337077	10.62111	77.54512	11.83377
10	0.367406	12.31897	77.66768	10.01335

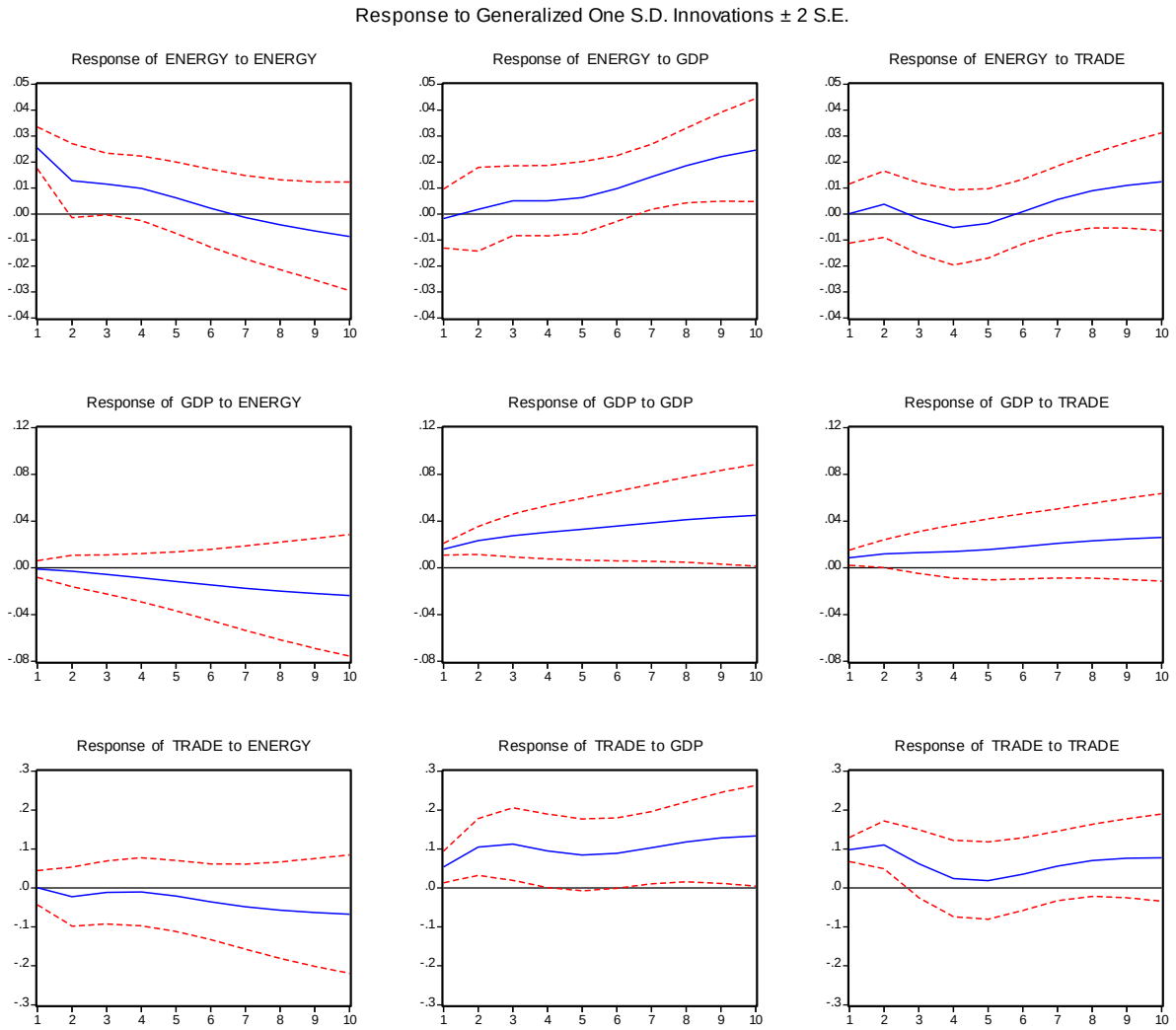
5.5 Generalized impulse response

In order to trace the effects of a shock to one endogenous variable on to the other variables in the VAR, impulse response functions were applied. A shock does not only directly affects a variable but also transmitted to all other endogenous variables through the dynamic (lag) structure of the VAR. An impulse response function traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables. A decomposition method in the impulse response function is developed by Pesaran and Shin (1998) referred to as generalized impulses. Pesaran and Shin construct an orthogonal set of innovations that does not depend on the VAR ordering. The generalized impulse responses, therefore, measure a response from an innovation to a variable.

Figure 4, Graphs 1, 4, and 7 indicate the response of each endogenous variable to a shock or an innovation in energy. A shock in energy may bring about negative effects to trade and GDP. Graphs 2, 5, and 8 show the extent each endogenous variable respond to a shock in GDP. It seems that a change in GDP has little effect on trade, and a positive effect on energy. Graphs 3, 6, and 9

indicate that a change of trade may cause a little effect in energy consumption and GDP.

Figure 4. The graphs of impulse responses.



6. Estimation results of panel Ganger causality analysis

Vietnam not only exports crude oil but also imports petroleum products because it does not own any petrochemical technology. Its foreign currency spending for fuel imports is higher than revenues from crude oil exports. For example, according to the General Administration of Customs, the value of oil export reached US$6.32 billion but petroleum product imports stood at US$6.83 billion in the first 10 months of 2014. Oil consumption accounted for a large share in energy consumption. Vietnam exports coal and import electricity from China. Crude oil exports play an important role in Vietnam's exports structure and revenues.

The time series Ganger causality analysis is complemented by the panel Ganger causality analysis. Only exports are considered instead of trade to investigate the panel Ganger causality among energy consumption (EC), real gross domestic product (GDP), and export (EX).

6.1. Variables description and data source

This study uses the secondary annual data of energy consumption, real GDP and export. This study covers the sample period 1995 to 2012. However, these indicators are reported separately in the three sectors, namely, industry, agriculture and forest, and services. The data are considered for panel analysis. GDP and export are collected from the websites of the General Statistic Office (GSO) and Trading Economics, Energy consumption is obtained from the International Energy Agency (IEA) website. The structure of the total primary consumption consists of coal, crude oil, oil products, natural gas, nuclear, hydro, geothermal solar, biofuel and waste, electricity, and heat. The Granger causality examined the links between energy consumption and economic development, energy consumption and trade, and GDP and export. It is not about percentage calculation

but transforming all series into natural logarithm to obtain stationarity in the variance-covariance matrix (Chang *et al.* 2001; Fatai *et al.* 2004). Therefore, the first difference that may occur on the variables can be interpreted as growth rate.

Table 12. Descriptive statistic for panel.

Variables	Mean	Median	Maximum	Minimum
GDP	13706.23	8878.422	60186.86	1467.422
EC	10895.35	10202	30159	375
EX	13227.73	6532.55	91526.9	0

6.2. Methodology and results

In the present study, the panel data approach was used to investigate the long-run relationship between energy consumption and economic growth. The econometric methods and results of the present study are discussed in the subsequent sections. Three empirical methods were followed namely, panel unit root tests, panel cointegration test, and panel Granger causality test.

6.2.1 Unit root test

Panel unit root test is one of the most popular tests in the economic community because of its higher power compared to the unit root tests for individual time series. The panel unit root test is used to identify the order of integration of each variable. It has become well-known that the traditional Augmented Dickey-Fuller (ADF)-type of test for unit root suffer from the problem of low power in rejecting the null of stationarity of the series, especially for short-spanned data. Recent literature suggests that panel-based unit root tests have higher power than unit root tests based on individual time series. A number of such tests have been mentioned in the literature. Recent developments in the panel unit root

tests include: Levin, Lin, and Chu or LLC (2002); Im, Pesaran, and Shin or IPS (2003); Maddala and Wu (1999); Choi (2001); and Hadri (2000). In this paper, four panel unit root test: LLC, IPS, and Fisher-type tests using ADF and PP tests of Maddala and Wu, and Choi tests are applied. This test has a null hypothesis of unit root, whereas the alternative hypothesis does not have a unit root.

From among different panel unit root tests developed in the literature. The LLC and IPS tests assume that there is a common unit root process across the cross-sections. Both of the tests are based on the ADF principle. However, LLC assumes homogeneity in the dynamics of the autoregressive coefficients for all panel members.

The conventional ADF test for single-equation is based on the following regression equation:

$$\Delta X_{it} = \alpha_i + \beta_i X_{i,t-1} + \gamma_i t + \sum_{j=1}^{k} \theta_{ij} \Delta X_{i,t-j} + \varepsilon_{it}, \qquad (5)$$

where Δ is the first difference operator, X_{it} is energy consumption, ε_{it} is a white-noise disturbance with a variance of σ^2, and t = 1, 2,…., T indexes time. The unit root null hypothesis of $\beta_i = 0$ is tested against the one-side alternative hypothesis of $\beta_i < 0$, which corresponds to X_{it} being stationary. The test is based on the test statistic $t_{\beta_i} = \hat{\beta}_i / se(\hat{\beta}_i)$ (where $\hat{\beta}_i$ is the ordinary least squares (OLS) estimate of β_i in Equation (5) and $se(\hat{\beta}_i)$ is its standard error) since the single-equation ADF test may have low power when the data are generated by a near-unit-root but stationary

process. Levin, Lin, and Chu (2002) found that the panel approach substantially increases power in finite samples when compared with the single-equation ADF test. They proposed a panel-based version of Equation (5) that restricts $\hat{\beta}_i$ by keeping it identical across cross- industries as follows:

$$\Delta X_{it} = \alpha_i + \beta\, X_{i,t-1} + \gamma_i t + \sum_{j=1}^{k} \theta_{ij} \Delta X_{i,t-j} + \varepsilon_{it}, \qquad (6)$$

where i =1, 2,…N indexes across cross-industries. LLC tested the null hypothesis of $\beta_1 = \beta_2 = ... = \beta = 0$ against the alternative of $\beta_1 = \beta_2 = ... = \beta < 0$, with the test based on the test statistic $t_\beta = \hat{\beta} / se(\hat{\beta})$ (where $\hat{\beta}$ is the OLS estimate of β in Equation (6), and $se(\hat{\beta})$ is its standard error.

In contrast, IPS is more general in the sense that it allows for heterogeneity—Heterogeneous Panel Unit Root Test. It is particularly reasonable to allow for such heterogeneity in choosing the lag length in ADF tests when imposing uniform lag length is not appropriate. In addition, slope heterogeneity is more reasonable in the case where cross-country data is used. In this case, heterogeneity arises because of differences in economic conditions and degree of development in each country. As a result, the test developers have shown that this test has higher power than other tests in its class, including LLC.

IPS begins by specifying a separate ADF regression for each cross-section:

(1)

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \sum_{j=1}^{p_i} \rho_{i,j}\, \Delta y_{i,t-j} + \varepsilon_{i,t}$$

where $y_{i,t}$ (i=1, 2,…..,N; t=1, 2,……,T) is the series for panel member (country) *i* over period *t*, p_i is the number of lags in the ADF regression, and the error terms $\varepsilon_{i,t}$ are assumed to be independently and normally distributed random variables for all *i*'s and *t*'s with zero means and finite heterogeneous variances σ_i^2. Both β_i and the lag order ρ in (1) are allowed to vary across sections (countries). Hence, the null hypothesis to be tested is:

$$H_0 : \beta_i = 0, \ \forall i$$

against the alternative hypothesis:

$$H_1 : \begin{cases} \beta_i = 0 & \text{for some } i\text{'s.} \\ \beta_i \prec 0 & \text{for at least one } i. \end{cases}$$

The alternative hypothesis simply implies that some or all of the individual series are stationary. IPS developed two test statistics and called them the LM-bar and the t-bar tests. The t-bar statistics is calculated using the average t-statistics for β_i from the separate ADF regressions as follows:

$$\tilde{t-bar}_{NT} = \frac{\sum_{i=1}^{N} t_{i,T}(p_i)}{N} \qquad (2)$$

where $t_{i,T}$ is the calculated ADF statistics from individual panel members. Using Monte Carlo simulations, IPS show that the t-bar is normally distributed

under the null hypothesis, and it outperforms M-bar in small samples. They then use estimates of its mean and variance to convert t-bar into a standard normal 'z-bar' statistic so that conventional critical values can be used to evaluate its significance. The z-bar test statistic for 0-lag is defined as:

$$z_{\tilde{t}-bar} = \frac{\sqrt{N}\,(\tilde{t}-bar_{NT} - E[\tilde{t}_T \mid \rho_i = 0])}{\sqrt{\mathrm{var}[\tilde{t}-bar_{NT} \mid \rho_i = 0]}} \rightarrow N(0,1) \qquad (3)$$

where $\tilde{t}$ is as defined before, $E[\tilde{t}_T \mid \rho_i = 0]$ and $\mathrm{var}[\tilde{t}-bar_{NT} \mid \rho_i = 0]$ are the mean and variance of t_{it}. In Table 2, IPS (2003) provide exact critical values of the *t-bar*$_{NT}$ statistic for some N, T ranges and for the 1, 5, 10 percent confidence levels. The IPS unit root test is used in this paper to test for stationarity of the panel data obtained for the GCC countries.

The results of the LLC, IPS, Fisher-ADF, and Fisher-PP panel unit root tests for each of the variable are given below (Table 13).

Table 13. LLC, IPS, ADF, and PP panel unit root test.

Level form						
	lngdp		lnEC		lnEX	
Method	Statistic	Prob	Statistic	Prob	Statistic	Prob.
Levin, Lin and Chu t*	-2.07553	0.019	0.53329	0.7031	1.14345	0.8736
Im, Pesaran and Shin W-stat	-0.92486	0.1775	2.32048	0.9898	3.38558	0.9996
ADF-Fisher Chi-square	7.89682	0.2458	0.85113	0.9906	0.28574	0.9996
PP-Fisher Chi-square	10.2781	0.1134	1.09461	0.9818	2.10004	0.9103
First diference form						
	lngdp		lnEC		lnEX	
Method	Statistic	Prob	Statistic	Prob	Statistic	Prob
Levin, Lin and Chu t*	-3.59394	0.0002	-3.7109	0.0001	-5.41721	0.0000
Im, Pesaran and Shin W-stat	-2.26574	0.0117	-2.76091	0.0029	-4.3865	0.0000
ADF-Fisher Chi-square	15.2154	0.0186	18.301	0.0055	28.6474	0.0001
PP-Fisher Chi-square	20.5729	0.0022	26.3789	0.0002	52.6753	0.0000

Each test was performed for the level and first difference of energy consumption and gross domestic product and export variables. For all variables, the null hypothesis of unit roots cannot be rejected in their level. However, when applying each variable at first difference of the panel unit root test, all tests reject the null hypothesis at the 1 percent level of significance. Thus, the panel unit root tests results support that all the panel variables are integrated of order 1.

6.2.2 Panel cointegration

Panel cointergation test is mainly used to confirm whether there exists a long-run equilibrium relationship between two or more variables. From the statistical perspective, the long-run equilibrium relationship defines the variables that move together over time. If the series contain a panel unit root, then panel cointegration test technique was used. Indeed, panel cointegration test can be used

in various ways such as the Kao (1999) ADF-type test and Johansen Fisher panel cointegration test proposed by Maddala and Wu (1999), the most popular panel cointegration test developed by Pedroni (1999, 2004).

Kao (1999) homogeneous panel cointegration tests with the null of non-cointegration

The various tests summarized in this section are based on the OLS estimators, and study the null hypothesis of non-cointegration, being residual-based tests. Those tests are based on regressing a non-stationary variable on a vector of non-stationary variables and may suffer the spurious regression problem. However, after appropriate normalizations, these tests converge in distribution to random variables with normal distributions.

Kao (1999) proposed two sets of specifications for the Dickey-Fuller (DF) test statistics. The first set depends on the consistent estimation of the long-run parameters, while the second one does not. Under the null hypothesis of no cointegration, the residual series e_{it} should be non-stationary. The model has varying intercepts across the cross-sections (the fixed effects specification) and common slopes across *i.*

The DF test can be calculated from the estimated residuals as:

$$\hat{e}_{it} = \rho\hat{e}_{it-1} + v_{it} \qquad (16)$$

The null hypothesis of non-stationarity can be written as $H_0 : \rho = 1$. Kao (1999) constructed new statistics whose limiting distributions, $N(0,1)$, are not dependent on the nuisance parameters, that are called DF_ρ^* and DF_t^* (where it is assumed that both regressors and errors are endogenous). Alternatively, he defines a bias-corrected serial correlation coefficient estimate and, consequently, the bias-

corrected test statistics and calls them DF_ρ and DF_t. In this case, the assumption is the strong exogeneity regressors and the errors. Finally, Kao (1999) also proposed an ADF type of regression and an associated ADF statistic.

Pedroni (1997, 1999) heterogeneity panel cointegration tests for the null of non-cointegration with multiple variables

Pedroni (1997, 1999) developed a number of statistics based on the residuals of the Engle and Granger (1987) cointegration regression. The tests proposed in Pedroni (1997, 1999) allow for heterogeneity among individual members of the panel, including heterogeneity in both the long-run cointegrating vectors and in the dynamics. Consequently, Pedroni (1997, 1999) allows for varying intercepts and varying slopes. Assuming a panel of N industries each with m regressors (X_m) and T observations, the long run model is written as:

$$Y_{it} = \alpha_i + \lambda_i t + \beta_{1i} X_{1,it} + \beta_{2i} X_{2,it} + \ldots + \beta_{mi} X_{m,it} + \varepsilon_{it} \quad t = 1,\ldots,T \quad i = 1,\ldots N \quad (17)$$

Equation (17) implies that all coefficients, of vectors that vary across industries, allow full heterogeneity across individual members of the panel. In these tests, the null hypothesis for each member of the panel involved variables that are not cointegrated. The alternative for each member of the panel exists a single cointegrating vector. Moreover, this vector need not be the same in all cases. This fact makes the tests interesting, since frequently the cointegrating vectors are not strictly homogeneous.

Pedroni (1997, 1999) also developed seven panel cointegration statistics. Four of these statistics, called panel cointegration statistics, are *within-dimension* based statistics. The other three statistics, called Group mean panel cointegration statistics, are *between-dimension* panel statistics. The asymptotic distributions of

these statistics are derived in Pedroni (1997). Thus, the former statistics pool the autoregressive coefficients across different members for the unit root tests on the estimated residuals, while the latter are based on estimators that simply average the individually estimated coefficients for each member *i*. The distinction is reflected in the autoregressive coefficient, ρ_i, of the estimated residuals under the alternative of cointegration: in the *within-dimension* statistics, the tests presume a common value for ρ, whereas the *between-dimension* statistics is otherwise. Thus, the *between-dimension* introduces an additional source of heterogeneity across the individual members of the panel. Following Pedroni (1995, 1997), the heterogeneous panel and heterogeneous group mean panel of rho (ρ), parametric (ADF) and non-parametric (PP) statistics are calculated as follows.

Panel *v*-Statistic

$$Z_v = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^{2} \right)^{-1} \tag{18}$$

Panel ρ-Statistic

$$Z_\rho = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^{2} \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right) \tag{19}$$

Panel non-parametric (PP) *t*-Statistic

$$Z_{pp} = \left(\sigma^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^{2} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \tag{20}$$

Panel parametric (ADF) *t*-Statistic

$$Z_t = \left(\hat{S}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^{*2} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1 i,t-1}^{*} \Delta \hat{e}_{i,t}^{*} \tag{21}$$

Group ρ-Statistic

$$\tilde{Z}_{\rho} = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{e}_{i,t-1}^{2}\right)^{-1}\sum_{t=1}^{T}\left(\hat{e}_{i,t-1}\Delta\hat{e}_{i,t} - \hat{\lambda}_{i}\right) \quad (22)$$

Group non-parametric (PP) *t*-Statistic

$$\tilde{Z}_{pp} = \sum_{i=1}^{N}\left(\hat{\sigma}^{2}\sum_{t=1}^{T}\hat{e}_{i,t-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{e}_{i,t-1}\Delta\hat{e}_{i,t} - \hat{\lambda}_{i}\right) \quad (23)$$

Group parametric (ADF) *t*-Statistic

$$\tilde{Z}_{t} = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{S}_{i}^{-2}\hat{e}_{i,t-1}^{*2}\right)^{-1/2}\sum_{t=1}^{T}\hat{e}_{i,t-1}^{*}\Delta\hat{e}_{i,t}^{*} \quad (24)$$

Where $\hat{\sigma}^{2}$ is the pooled long-run variance for the non-parametric model given as $1/N\sum_{i=1}^{N}\hat{L}_{11i}^{-2}\hat{\sigma}_{i}^{2}$; $\hat{\lambda}_{i} = 1/2\left(\hat{\sigma}_{i}^{2} - \hat{S}_{i}^{2}\right)$, where $\hat{L}_{i}$ is used to adjust for autocorrelation in panel parametric model, $\hat{\sigma}_{i}^{2}$ and $\hat{S}_{i}^{2}$ are the long-run and contemporaneous variances for individual *I*, and $\hat{S}^{2}$ are obtained from individual ADF-test of $e_{i,t} = \rho_{i}e_{i,t-1} + v_{i,t}$; S^{*2} is the individual contemporaneous variance from the parametric model, $\hat{e}_{i,t}$ the estimated residual from the parametric cointegration, while $\hat{e}_{i,t}^{*}$ is the estimated residual from the parametric model and $\hat{L}_{11i}$ is the estimated long-run covariance matrix for $\Delta\hat{e}_{i,t}$, and L_{i} is the *i*th component of the lower-triangular Cholesky decomposition of matrix Ω_{i} for $\Delta\hat{e}_{i,t}$ with the appropriate lag length determined by the Newy-West method.

Given that the alternative statistics might yield conflicting evidence, it's important to have some information on the properties of these statistics. First, there is a difference between panel and group statistics in terms of alternative hypothesis. For the *within-dimension* statistics, the test for the null of

cointegration is implemented as a residual-based test of the null hypothesis $H_0: \rho_i = 1$ for all i*'s*, versus $H_1: \rho_i = \rho < 1$ for all *i*, so that it presumes a common value for the first order autocorrelation coefficient. By contrast, the statistics between 1986 and 2014 then do not presume a common value for ρ_i under the alternative. Second, the small sample size and power properties of all the seven statistics are examined in Pedroni (1997). In general, the size distortion tends to be minor and the power is very high for all statistics when the time span is long (T>100). But for shorter panels, the evidence is more varied. In terms of power, Pedroni showed that the group-ADF statistic generally performs best, followed by the panel-ADF statistic, while the panel-variance and the group-rho statistic do poorly.

Combined individual tests (Fisher/Johansen) Fisher (1932) derives a combined test that uses the results of the individual independent tests. Maddala and Wu (1999) used Fisher's result to propose an alternative approach to testing for cointegration in panel data by combining tests from individual cross-sections to obtain a test statistic for the full panel.

If p_i is the p-value from an individual cointegration test for cross-section *i*, then under the null hypothesis the test statistic for the panel is given by:

$$-2\sum_{i=1}^{n}\log(p_i) \sim \chi^2_{2n}$$

In this study, the Kao test and Johansen-type panel cointergration were used. Tables 3 and 4 present the results of the panel cointegration test statistics.

Table 14. Panel cointegration tests Kao (1999) ADF tests.

	t-Statistic	Prob.		
ADF	-2.103101	0.0177		
Residual variance	0.001957			
HAC variance	0.003625			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.254008	0.079235	-3.20575	0.0025
D(RESID(-1))	0.431593	0.125049	3.451402	0.0012

Table 15. The Johansen-Fisher panel cointegration test statistics.

Hypothesized No. of CE(s)		Fisher stat (trace test)	Prob.	Fisher stat (max-eigen test)	Prob.
None		40.86	0	23.07	0.0008
At most 1		24.83	0.0004	23.21	0.0007
At most 2		8.834	0.1832	8.834	0.1832
Hypothesis of no cointegration of individual cross section results					
None	Industry	56.1105	0.0001	32.9229	0.0012
None	Agriculture	37.7868	0.0257	17.9478	0.1817
None	Services	50.3724	0.0006	22.5164	0.0466
At most 1	Industry	23.1876	0.0192	19.9633	0.0108
At most 1	Agriculture	19.839	0.0571	15.6006	0.0555
At most 1	Services	27.856	0.0037	19.0798	0.0152
At most 2	Industry	3.2243	0.5396	3.2243	0.5396
At most 2	Agriculture	4.2384	0.3778	4.2384	0.3778
At most 2	Services	8.7762	0.0592	8.7762	0.0592

Kao test statistics in Table 14 reject the null hypothesis of no cointegration among the three variables at the significance level of 1 percent. The Johansen-Fisher test statistics in Table 15 show that there is two cointegrating equation at 1 percent for the panel system. For separate cross-sectional units, there are only two cointegrating vector at 1 percent for the industry and services sector, but there is no cointegration in agriculture, forest, and fishing sector. Thus, we find existence of a cointegration relationship between energy consumption, gross domestic product and export variables, implying that these variables move together in the long-run. Thus, the Kao and Johansen Fisher panel cointegration test results confirmed that there is a long-run cointegration relationship among the panel variables.

6.2.3 Panel Granger causality

In this study, a panel causality test developed by Dumitrescu-Hurlin (2012) was used. This test can be used when N is growing and T is constant. Moreover, it can also be used when T>N and when N>T. The test, which is based on VAR, assumes that there is no cross-sectional dependency. Yet, the Monte Carlo simulations show that even under the conditions of cross-sectional dependency, this test can produce strong results. This test is used for balanced and heterogeneous panels. There are two different distributions in this test: asymptotic and semiasymptotic. Asymptotic distribution is used when T>N, while semi-asymptotic distribution is used when N>T. When there is cross-sectional dependency, simulated and approximated critical values, obtained from 50.000 replications, are used. If the panel data model is taken into consideration:

$$y_{it} = \sum_{k=1}^{K} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t}$$

Here, K stands for the lag length. Moreover, the panel for the test is a balanced panel. The $\gamma_i^{(k)}$, an autoregressive parameter, and $\beta_i^{(k)}$, the regression coefficient pitch, can change among the groups. In addition, the tests do not have a random process. This test has a fixed coefficient model. Apart from these, individual remainders for each cross-sectional unit are independent. This test is based on normal distribution and allows for heterogeneity. Also, individual remainders are independently distributed among the groups. In this test, homogenous non-stationary (HNC) hypothesis was used for the analysis of causality relationship and heterogeneous models. For T>N asymptotic and for N>T semi-asymptotic, a distribution was used in HNC hypothesis. When there is cross-sectional dependency, simulated and approximated critical values are used. According to this, the null and alternative hypotheses of HNC are as follows:

$$H_0 : \beta_i = 0 \qquad \forall_i = 1,...N \quad \text{with} \quad \beta_i = \beta_i^{(1)}.....\beta_i^{(k)}$$

$$H_0 : \beta_i \neq 0 \qquad \forall_i = 1,...N$$

$$\beta_i \neq 0 \qquad \forall_i = 1,...N$$

The alternative hypothesis of HNC allows for some of the individual vectors β_i to be equal to zero. For the Dumitrescu-Hurlin test, the average statistic, $W_{N,T}^{HNC}$ hypothesis can be written as follows:

$$W_{N,T}^{HNC} = \frac{1}{N}\sum_{t=1}^{N} \quad _{i,T}$$

Here, $W_{i,T}$ stands for the individual Wald statistical values for cross-section units. The average statistic , $W_{N,T}^{HNC}$, which has asymptotic distribution, associated with the null HNC hypothesis, is defined as:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2K}}(W_{N,T}^{HNC} - K)\ T\ , N \to \infty \mathrm{N}(0,1)$$

$$W_{i,T} = (T - 2K - 1)\left(\frac{\varepsilon_i \phi_i \varepsilon_i}{\varepsilon_i M_i\ \varepsilon_i}\right), \quad \mathrm{i}=1,\ldots,\mathrm{N}$$

The average statistic, $W_{N,T}^{HNC}$, which has a semi-asymptotic distribution, associated with the null HNC hypothesis, is defined as:

$$Z_N^{HNC} = \frac{\sqrt{N}\left(W_{N,T}^{HNC} - N^{-1}\sum_{i=1}^{N} E(W_{i,T})\right)}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(W_{i,T})}} \qquad N \to \infty\ \mathrm{N}(0,1)$$

Here, E(Wi,T) is also Var(Wi,T) and is the variant statistic of Equation (27). If there is cross-sectional dependency, 5 percent of the simulated critical values from 50,000 replications of the benchmark model and 5 percent of the approximated values are used.

After analyzing whether a long-term relationship exists among the variables, the potential for a causal relationship among the variables was also analyzed. The causality test developed by Dumitrescu and Hurlin (2012), which can return successful results, even under the conditions of cross-sectional dependence, was used for the analysis. According to the results shown in Table 15, a unidirectional causal relationship was found from energy consumption to GDP between the years of 1995 and 2012 in Vietnam. No causal relationships were found between GDP and energy consumption or export and GDP for the same period. A relationship of unidirectional causality was also found from export to GDP. Finally, unidirectional causal relationships were found from energy consumption export.

Table 15. Pairwise Dumitrescu Hurlin panel causality test.

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
EC does not homogeneously cause GDP	11.7065	5.2353	2.00E-07
GDP does not homogeneously cause EC	1.63852	-0.45554	0.6487
EX does not homogeneously cause GDP	12.0339	5.3139	1.00E-07
GDP does not homogeneously cause EX	0.8539	-0.89337	0.3717
EX does not homogeneously cause EC	1.7102	-0.41794	0.676
EC does not homogeneously cause EX	9.95236	4.15819	3.00E-05

In the long-term, there exists the strong relation running from energy consumption to economic growth in Vietnam. The consumption of energy is not only related to rapid urbanization, industrialization, infrastructures building, among others, but also affects policies, laws, and regulations. In summary, findings showed that energy consumption is statistically significant to economic growth and export in the long-run. However, export does not show a Granger causality to energy consumption. Therefore, energy is an important contributing factor to economic growth for Vietnam. It is important to note that energy serves as an engine of economic growth and changes in energy consumption bring a significant impact on economic activity (Lee and Chang 2008).

7. Conclusion and policy implications

This paper employed Vietnam's time series data for 1986-2006 and panel data for 1995-2012 to estimate the Granger causality relationship between energy consumption and economic development. In many previous studies, data of developed countries covered a long period of time to ensure a robust analysis of the times series.

However, for a developing country like Vietnam, data covering a long period of time was insufficient and unavailable for testing. MacKinnon (1996) found out the advantage of using annual data over quarterly or monthly data, with

error considerations. There were 20 observations available to test the p-value in econometrics. However, having a relatively low number of observations was not ensured robust for time series analysis. The non-available monthly and quarterly data made the test results become less strong. The feasibility of finding higher frequency data was very low because quarterly and monthly data had not been found either in Vietnam or international data sources. Therefore, having time series analysis for this sample size, the results and critical values of the test should be considered approximations only.

In this study, both bivariate and multivariate frameworks for the cointegration test were applied. The vector error correction model was used to test long-run Granger causality. The results indicated the existence of Granger causality running from GDP to trade, and from GDP to energy. The GDP-trade Granger causality indicated that the GDP growth led to an increase and more open trade.

For the short-run, there was a strong unidirectional Granger causality running from GDP to trade; the average unidirectional Granger causality running from GDP to energy; and another weak unidirectional causal relation running from trade to energy. The Granger causality between energy and GDP, as well as between trade and GDP, are not clear in the short-run.

The results of the studies on Granger causality between energy and economic development vary, depending on countries and timeframe of studies. In this study, results showed weak evidence to support the important role of energy for economic growth. Energy just acts as an input factor to economic development in Vietnam. Higher levels of economic development may or may not induce more energy consumption. However, the long-run trend in energy consumption plays an

important role because it relates to environment protection and economic development.

For panel Granger causality analysis, energy consumption has Granger causality economic growth and export in the long-run. However, export has no strong unidirectional Granger causality to energy consumption. This is similar to the Granger causality analysis with time series data that the unidirectional Granger causality from trade to energy is weak. Therefore, energy is an important contributing factor to economic growth and export for Vietnam. It is important to note that energy serves as an engine of economic growth and changes in energy consumption bring a significant impact on economic activity (Lee and Chiang 2008).

On the basis of this study, some policy implications could be drawn as such: (i) the government should propose and implement comprehensive policies for increasing efficiency in consumption, distribution, and production of energy, as well as engage in research and development for new technologies; (ii) guarantee energy supply by executing corresponding measures to enhance energy efficiency, diversify energy sources, and develop alternative and renewable energy; (iii) cope with rising oil prices and energy crisis, through a sound economic analysis based energy-related strategies.

As the Kyoto Protocol set a goal to cut down on emission to reduce global warming, energy policies for many countries, especially for a developing country like Vietnam, need to be changed in accordance with this Protocol. Therefore, in the long-run, Vietnam should mainstream sustainable development to reduce long-run environmental consequences through cutting reliance on resource- and energy-dependent industries.

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