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Energy consumption and economic development: Granger causality analysis for Vietnam

Loi, Nguyen Duy[1]

Institute of World Economic and Politics, Vietnam Academy of Social Sciences (VASS)

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Abstract

The paper aims at investigating the causal relationship between energy consumption, GDP and trade in Vietnam for the period of reform (Doi moi),1986- 2006. We apply the method of Granger causality test to examine this relationship. Both bivariate and multivariate models of Granger causality test have been applied. Our results indicate the existence of the strong long- and short- run bidirectional Granger causality relationship between GDP and trade, energy and GDP in the long run. In the short run, we also found the weak unidirectional Granger causality running from GDP to Energy and from trade to energy.

Keywords: Granger causality, energy consumption, GDP, trade

JEL: F14, F18, O11

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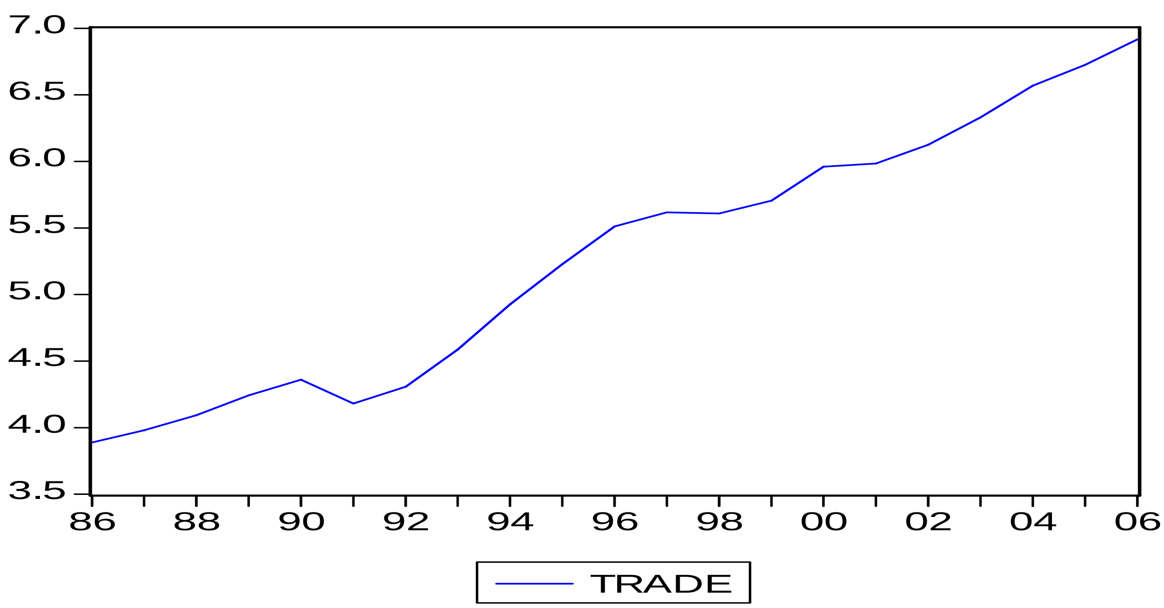
1.1 Overview of trade development in Vietnam

Since the adaptation of reform policy, domestic and international trade were liberalized, tariff and non- tariff barriers were also reduced and then alleviated gradually, 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 during the period of 1986- 2006, except the period of the Asian financial crisis. Trade per capita increased more than 20 time, from 49 US$ in 1986 to 1008 US$ in 2006; trade rose almost 3 times, from 29.5 billion US$ in 1986 to 88 billion US$ in 2006. Consequently, the percentage of trade in GDP rose from 21% in 1986 to 160% in 2006. Along with foreign direct investment (FDI), trade, particularly exports, has been the main source for 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 1: Trade per capita, 1986- 2006



2. Data and Methodology

2.1 Data

The data, which was compiled from the World Development Indicators (WDI), the World Bank, cover the time series of per capita GDP (Gross Domestic Product), per capital energy consumption and per capita trade for the period 1986- 2006. In order to reduce fluctuations of the trade time series, we transform trade's data into trade per capita by using the equation below. Variables are total primary energy consumption per capita measured in kg of oil equivalent; GDP per capita in thousand real 2000 US dollars from the WDI. Trade per capita in current US dollars obtaining from the WDI is estimated as follows:

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

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

The structure of the total primary consumption consists of consumptions of petroleum, natural gas, coal, hydroelectric power, nuclear power and renewable electric power (geothermal, solar, wind, wood and waste). We aim at examining the Granger causality links between energy consumption and economic development as a whole, energy consumption and trade, and GDP and trade, therefore we don't calculate 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.

2.2 Methodology

In the paper, we try to examine the Granger causality links between energy, GDP and trade in both bivariate and multivariate framework for the sake of avoidance spurious results. Firstly, we test whether each variable is nonstationary or having unit root or not. Secondly, if the time series variables are nonstationary and same order integration series, then we will test cointegration relations. Thirdly, if cointegration relations exist, then we will test Granger causality among these time series variables.

2.2.1 Unit root test

We take the test of unit root in order to judge the stationarity of time series. There are several kinds of methods[2] for testing, however we just take two methods out of them as follows; Augmented Dickey- Fuller (ADF) and Phillips-Perron (PP) tests. The test critical values (p- value) of these methods are approximate for different sample of small size. In 1996, MacKinnon used annual data to estimate the critical values for 20 observations[3]. In this sample, we have 21 observations for the period of 1986- 2006, more than the number of observations used by MacKinnon[4]. This is why we use ADF unit root tests. We calculate the following equation for the ADF test

The equation for ADF test can be calculated with three different types: equation with constant, equation with constant and deterministic trend, and equation without constant. In this paper, we choose to run the test with constant and deterministic trend. The ADF test, which bases on the construction a parametric correction for higher-order correlation, may be incorrect if the series having a unit root and a structural break. For solving these problems, we take the PP test which produces a more robust estimation.

2.2.2 Cointegration test

Cointegration links between variables are necessary for Granger causality test. If two series of nonstationary same order integration, which have a stationary linear combination, calls a cointegration equation. In the paper, we explore 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

[2] 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.

[3] 20 observations are enough for test p-values available in the econometric software of Eview 5.0 and 6.0.

[4] MacKinnon (1996) figured out the advantage to use annual data over quarterly or monthly data under error terms. Annual data has been examined by us because of non- available monthly or quarterly data for energy consumption and GDP.

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, we apply a vector error correction model (VEC)

2.2.3 Granger causality test

The presence of the cointegration relation is necessary for Granger causality test. We need to test whether a long- term balance relation between variables can indicate Granger causality or not. We examine the causal relationships between the three series variables in both bivariate and multivariate framework. 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. We explore the bivariate tests for the series variables with the F- statistic for investigating the short run Granger causality between the variables. 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:

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

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 AIC with maximum lag equals to 3.

3. Etimation results

3.1 Unit root test

We first take the ADF and PP tests of level series for each variable of energy, trade and gdp. Table 1 show the test' results that energy, trade and gdp are nonstationary 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

1. The test equation includes constant, linear trend

2. The lag length is selected by minimum AIC with maximum lag = 4

3. In the ADF and PP tests for Energy series, the critical values for the 1%, 5% and 10% level are -4.4983, - 3.6584, -3.2689 respectively

4. In the ADF and PP tests for Trade, the critical values for the 1%, 5% and 10% level are -4.4678, -3.6449, -3.2614 respectively

5. In the ADF and PP test for GDP series, the critical values for the 1%, 5% and 10% level are -4.4678, -3.6449, -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

1. The test equation includes constant, linear trend

2. The lag length is selected by minimum AIC with maximum lag = 4

3. In the ADF and PP tests for Energy series, the critical values for the 1%, 5% and 10% level are

-4.4983, - 3.6584, -3.2689 respectively

4. In the ADF and PP tests for Trade, the critical values for the 1%, 5% and 10% level are -4.4678, -3.6449, -3.2614 respectively

5. In the ADF and PP tests for GDP series, the critical values for the 1%, 5% and 10% level are

-4.4678, -3.6449, -3.2614 respectively

3.2 Cointegration test

If the cointegration relations exist within the linear combination of nonstationary series, they must have Granger causality. Tables from 3 to 6 show the results of Johansen cointegration test[5]. 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% level (table 5). Table 5 shows that one cointegration equation exists for the pair of trade-gdp because the test statistic is higher than the critical value, so we reject the null hypothesis.

Table 3: Johansen cointegration test for a pair of 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

1. The cointegration equation includes linear deterministic trend

2. Trace and Max-Eigen statistic tests indicate no cointegration equation at the 5% level

* Denotes rejection of the hypothesis at the 5% level

Table 4: Johansen cointegration test for a pair of Energy-trade

Energy- trade Cointegration rank	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**

[5] Johansen 1991, Greene 2003

(r)				
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

Max-eigenvalue test indicates no cointegration at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

Table 5: Johansen cointegration test for a pair of 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

Max-eigenvalue and Trace tests indicate 1 cointegrating equation at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

Table 6: Johansen cointegration test: mutilvariate model

Cointegration rank (r)	Eigenvalue	Trace	0.05	Prob.**

		Statistic	Critical Value	
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

Max-eigenvalue and Trace tests indicate 1 cointegrating equation at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

For the multivariate cointegration test, table 6 shows the results of the tests that the Trace statistic test indicates one cointegration equations at the 5% level; however, Max-Eigen statistic test also indicates one cointegration at the 5% level, on the one hand. The test shows that cointegration is not stable and may be affected by some economic events.

3.3 The VEC model and Granger causality test

According to the VAR (p) equation (j), we first estimate the optimal lag length in the level series VAR. Table 7 shows the optimal lag length by different criteria. The optimum lag is 4 for AIC, and we don't have to add an extra lag in a model with limited number of observations. We based on the equations (d), (e), and (f) for calculating the optimum lag length.

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

* Indicates lag order selected by the criterion

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

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

We apply the vector error correction model (VEC) to test the Granger causality, with the aim of avoiding the spuriousness in the series and investigating the long- term relation between variables. The results in table 8 base 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 for tests.

We found a strong long-term balanced bidirectional Granger causality between GDP and trade as the t-statistic indicates the significant in long- term causal effect. We also found a weak unidirectional Granger causality link from trade to energy; and Granger causality link running from energy to GDP. The bidirectional Granger causality between GDP and trade indicates that trade, particularly export, is a driving force for rapid economic growth in Vietnam, and the higher level of economic growth could increases trade volumes. This is consistent with the export- led growth hypothesis which is prevailing in East Asia. The unidirectional Granger causality running from trade to energy states 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. We then investigate the short- run causality relations among series variables in the pair Granger causality test (table 10).

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]

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

→: 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]

Numbers in [ ] are p-values

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 we reject the null hypothesis. 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. We also found 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 in Vietnam.

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

The results of the Granger causality test show that there is a Granger causality running from GDP to trade; the Granger causality running from GDP to energy. This Granger causality relation is inconsistent with the export-led growth hypothesis, the increase in GDP growth leads to an increase in trade or more openness to trade, if we consider the trade as the openness 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 rises, it demands for more energy consumption. Therefore, the efficiency in energy uses is paid attention to with the aim of lower energy consumption for a given level of economic growth. Vietnam may have environmental policies in general and energy- use policies in particular aiming at decreasing energy intensity, increasing the efficiency of energy consumption, and developing a market for emission trading. The country also needs to invest in research and development (R&D) for the creation of new technologies that makes the alternative energy sources possible, increases the efficiency of energy consumption, and thus reduces environmental pressures.

3.4 Variance decomposition of variables

We decompose the variance for the sake of separation the variation in an endogenous variable into the component shocks to the VAR. Therefore, the variance decomposition provides information about the relative importance of each random innovation in affecting the variables in the VAR. Table 11 shows separate variance decompositions for each endogenous variable. The 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 to each endogenous variable in the VAR. The other columns of endogenous variables give the percentage of the forecast variance due to each innovation, with each row adding up to 100.

In this part, we just measure the variance decomposition of endogenous variable in the multivariate framework because we can find a similar trend in the bivariate framework. Table 11 shows the results of variance decomposition of variables. Firstly, 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% by its own innovations or shocks, 55% by innovations of GDP and 8% by innovations of trade. Secondly, the variance decomposition of GDP presents that at the period of 9^{th}, the percentage of the forecast variance of GDP is almost 85% because of its own innovations or shocks, 15% by energy’s innovations and 0.25% by trade’s innovations. Lastly, for the variance decomposition of trade, the forecast variance for trade is 14% by its innovations or shocks, 8.6% by energy's innovations and 77% by GDP's innovation at the 8th 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 variable's 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

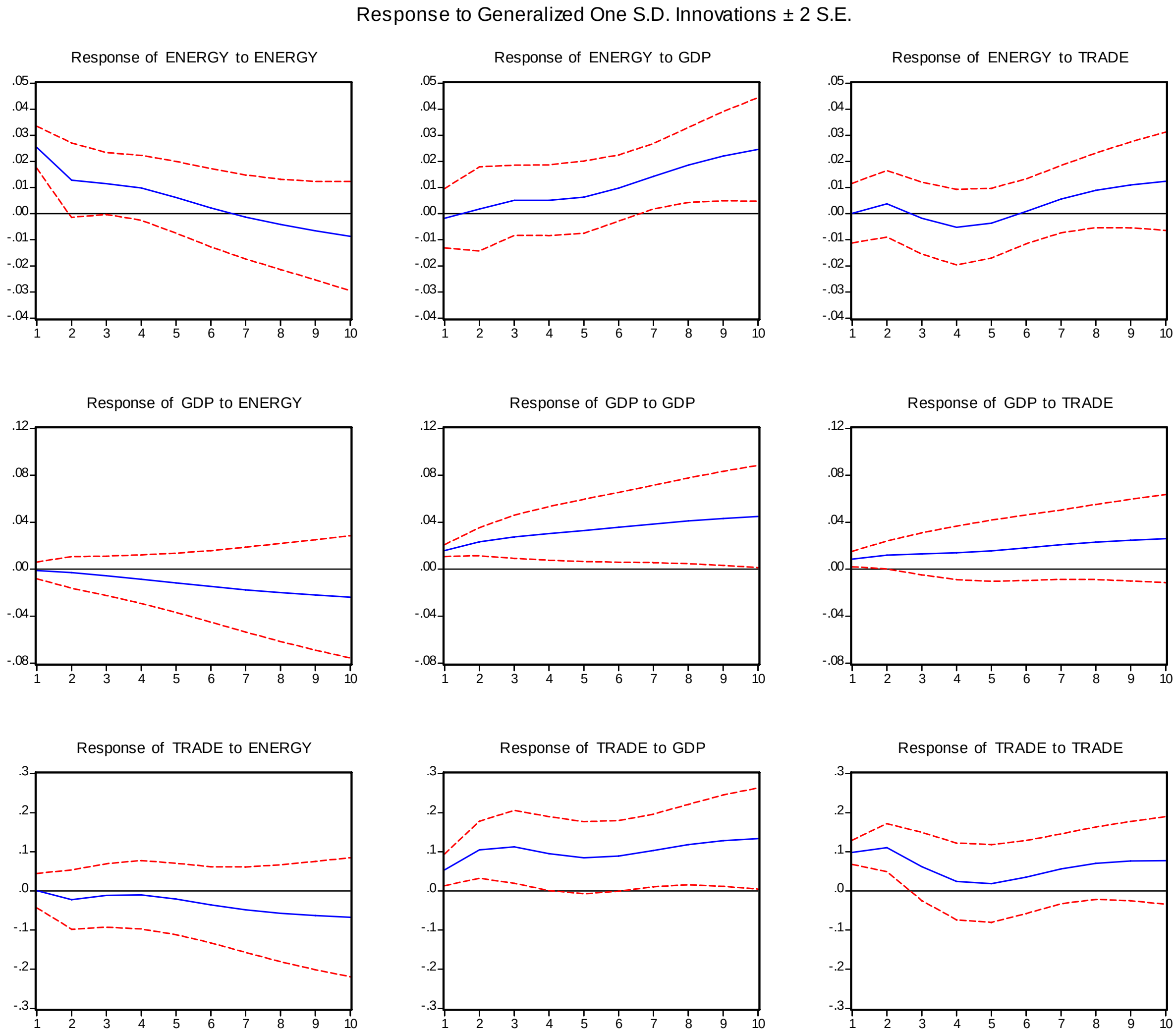
5	0.061137	6.700169	92.79611	0.503718
6	0.071853	9.019900	90.59935	0.380745
7	0.082880	11.21684	88.49281	0.290348
8	0.094110	13.15543	86.58956	0.255014
9	0.105336	14.82755	84.91919	0.253261
10	0.116383	16.28160	83.44964	0.268761
Variance Decomposition of TRADE				
Period	S.E.	ENERGY	GDP	TRADE
1	0.098413	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

3.5 Generalized Impulse response

In order to trace the effects of a shock to one endogenous variable on to the other variables in the VAR, we apply impulse response functions. A shock to a variable not only directly affects this variable but is also transmitted to all of the 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) and called 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.

In 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 what extent each endogenous variable response 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



4. Conclusion and policy implications

This paper employs time series data of Vietnam for the period of 1986- 2006 to estimate the Granger causality relationship between energy consumption and economic development. In many previous studies, data for developed countries is available for a period of sufficient long time to ensure a robust analysis of times series. However, data for developing country like Vietnam is not available for a period of long time for test. We estimated the critical values for

ADF and PP tests for the sample of small size. Therefore, the critical values should be considered as the approximations.

In this study, we applied both bivariate and multivariate frameworks for the cointegration test. The vector error correction model has been conducted to test long- run Granger causality. The results indicate the existence of Granger causality running from GDP to trade, and from GDP to energy. The GDP- trade Granger causality indicates that the GDP growth lead to increase in and more openness to trade.

For the short run, we found a strong unidirectional Granger causality running from GDP to trade; the 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, between trade and GDP are not clear in the short run in Vietnam.

The results of the studies on Granger causality between energy and economic development vary, depending on countries and times of studies. In this study, we found weak evidence to support the important role of energy for economic growth. Energy just acts as a factor of input for 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.

On the basis of this study, some policy implications could be drawn as such: (i) the government should propose and implement a series of comprehensive policies to aim at increasing efficiency in consumption, distribution and production of energy, and developing research & development measures to adopt new technologies; (ii) guarantee energy supply by executing corresponding measures to enhancing energy efficiency to save energy, diversifying energy sources, and developing alternative and renewable energy, and supplying adequate electricity; (iii) Cope with rising oil prices and energy crisis, energy- related strategies should be based on sound economic analysis.

As the goal set by Kyoto Protocol to cut down emission for reducing global warming, energy policies for many countries, especially a developing country like Vietnam need to be changed in accordance with this Protocol. Therefore, in the long- run, the country should transform development pattern for reducing the long- run environment consequences and ensuring sustainable development; cutting reliance on resource- and energy- dependent industries./

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