國立交通大學

經營管理研究所

碩 士 論 文

各類進口能源消費與台灣貿易表現之關聯性分析

The Linkage between Imported Energy and Trade in Taiwan

研 究 生：楊子誠

指導教授：胡均立 教授

中 華 民 國 九十九 年 六 月

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研　究　生：楊子誠　　Student: Tzu-Cheng Yang
指導教授：胡均立　　Advisor: Jin-Li Hu

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國立交通大學經營管理研究所碩士班

摘　　　要

本研究對於台灣 1998 年到 2009 年能源消費量及貿易變數的月資料，做時間序列的共整合及 Granger 因果關係檢定，變數包含了實質進口總額(VTI)、實質出口總額(VTE)、總能源消費量(TEC)、石油消費量(OC)、煤消費量(CC)、天然氣消費量(NC)、實質工業部門出口額(EVI)、實質重工業部門出口額(EVHI)與實質非重工業出口額(EVHI)。根據 Granger 因果關係檢定與 VAR 下的衝擊反應檢測後，結果發現，總能源消費量對實質出口總額、實質工業部門出口額、實質重工業部門出口額有著單向的 Granger 因果關係，且為正向衝擊。石油消費量則是對所有貿易變數，包括了實質進口總額、實質出口總額、實質工業部門出口額、實質重工業部門出口額與實質非重工業出口額都有單向的 Granger 因果關係；其中對實質進口總額與實質非重工業出口額為負向衝擊，其餘皆為正向衝擊。另一方面，煤消費則是會受到所有貿易變數單向的衝擊，其中除了實質重工業部門出口額與實質非重工業出口額是負向衝擊外，其餘皆是正向衝擊。天然氣消費量在短期下除了會受到實質出口總額、實質工業部門出口額、實質重工業部門出口額的負向衝擊外；我們還發現在非重工業產品出口額與天然氣消費量間存在著回饋關係，並在短期下會互相產生負向衝擊。以上衝擊曲線都會隨著時間收斂至波動水平並逐漸穩定。

The Linkage between Imported Energy and Trade in Taiwan

Student: Tzu-Cheng Yang Advisor: Dr. Jin-Li Hu

Institute of Business and Management
National Chiao Tung University

ABSTRACT

This study examines co-integration and Granger causality between Taiwan's energy consumptions and trade variables, including real value of total imports (VTI), real value of total exports (VTE), total energy consumption (TEC), oil and petroleum products consumption (OC), coal and coal products consumption (CC), natural gas consumption (NC), real exports value of industrial sector (EVI), real exports value of heavy-chemical industrial products (EVHI), and real exports value of non-heavy-chemical industrial products (EVNHI) with monthly data during 1998-2009. Via applying Hsiao's version of the Granger causality method, causality running from TEC to VTE, EVI, and EVHI are found. The impulse-response simulations show that the above relations have positive responses at the initial period. OC will Granger cause all trade variables including VTI, VTE, EVI, EVHI, and EVNHI. The impulse directions to VTI and EVNHI are negative; and others are positive. On the other hand, CC will respond to impulses in all trade variables. The impulse-response simulations show that these relations have positive responses at the initial period except the causality running from EVHI and EVNHI to CC. VTE, NC negatively responds to impulses in EVI and EVHI at the initial period. The bi-directional Granger causality between NC and EVNHI are found, and both sides in this relationship negatively influence each other in short-run. In response to these shocks, all response curves will converge to the pre-shock level gradually and become stable after 20 months.

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楊子誠　　　　謹誌于

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Chapter 1. Introduction

After the 1973 energy crisis, countries all over the world have noticed the importance of energy to national security as well as economic development. Moreover, greenhouse gases produced by energy consumption have drastic impacts on global climate change, which attracts attention and efforts under the UN Framework Convention on Climate Change.

Since domestic energy sources in Taiwan is finite, Taiwan's dependence on imported energy rated up to 99.34% in 2008 (Bureau of Energy, 2009a). The cost of imported energy accounts for 10.02% of Taiwan's GDP (Bureau of Energy, 2009b). Total energy consumption has grown greatly over the past two decades, going from 48.04 million kiloliters of oil equivalent in 1989 to 113.09million kiloliters in 2009, which is an average annual growth of 4.41% (Table 1). The growing energy demand is causing several energy related issues, including cost competitiveness (Rourke et al., 2009) and customer welfare. In the face of constant rise of energy prices, the heavy cost of imported energy impacts not only household expenditures, but also the island's overall economic growth (Chien et al., 2007). As the international energy prices skyrocket, the rising energy prices increase the production cost higher for energy-consuming industries, and hence directly reduce their profit margins and production.

Table 1. Total domestic energy consumption quantity and growth rate

Year	Quantity (10^3KLOE)	Growth Rate (%)
1989	48,035.8	-
1990	50,986.7	6.14
1991	54,554.7	7.00
1992	57,952.6	6.23
1993	60,745.1	4.82
1994	65,021.4	7.04
1995	68,475.5	5.31
1996	71,754.8	4.79
1997	75,357.3	5.02
1998	80,291.0	6.55
1999	84,645.1	5.42
2000	91,736.5	8.38
2001	97,055.2	5.80
2002	100,495.0	3.54
2003	104,371.5	3.86
2004	108,766.3	4.21
2005	111,143.5	2.19
2006	113,738.6	2.33
2007	119,175.8	4.78
2008	115,701.2	-2.92
2009	113,085.2	-2.26
Average	85,385.18	4.4115

Data source: 2009 Energy Statistics Handbook

In Taiwan primary imported energy resources are petroleum, coal, and natural gas, accounting for 49.45%, 32.42% and 9.42%, respectively, of the value of energy imports in 2009. For energy demands, the biggest share in energy consumption belongs to electricity (49.28%) followed by oil products (41.35%), coal products (6.81%), natural gas (2.20%), solar energy (0.10%), and others (0.26%) (Figure 1). Since electricity price is fixed and the components of it are not clear, this study does not use it to be an observation variable. In addition, energy consumption in industrial sector accounts for 52.48% of total (Figure 2), and up to 98% in the value of total exports. The relations between international trade variables are discussed with economic growth in some articles, such as Ghartey (1993), Kwan et al. (1996), and Shirazi and Manap (2005). Furthermore, international trade is an important factor in shaping the industrial structure of a country and, consequently, in affecting a country's energy use and CO_2 emissions (Machado et al., 2001). In the other words, the imported energy prices may not only slow down the development of the industrial sector of Taiwan, but also influence the trade surplus in Taiwan. Trade surplus is an index to measure the difference in value between the total exports and total imports of an economy during a specific period of time and it will be used as one of research variables in this work.

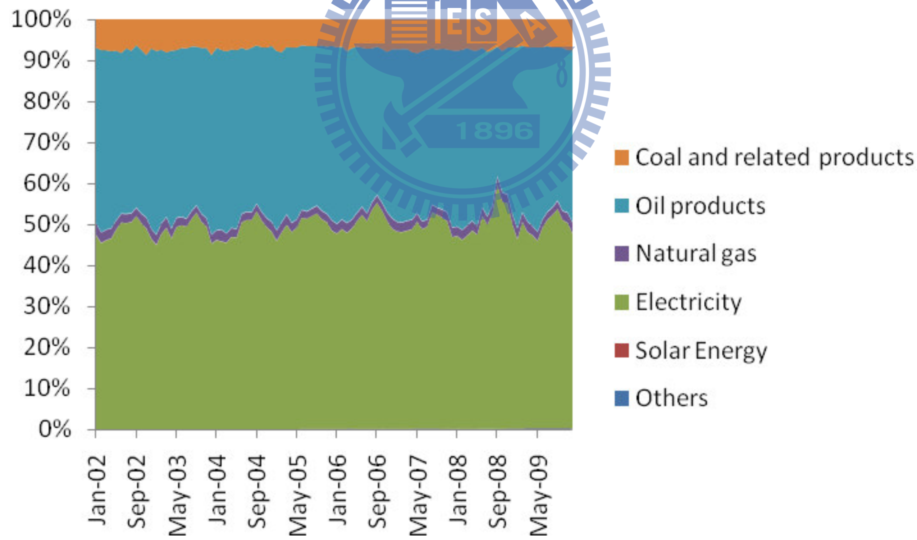


Figure 1. Energy consumption structure in Taiwan

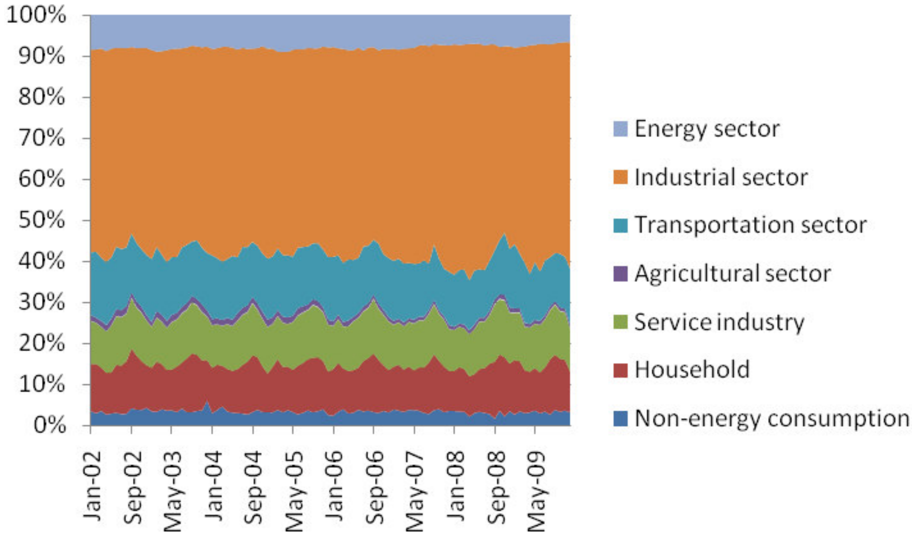


Figure 2.　Energy consumption structure in Taiwan (by sectors)

Chapter 2. Literature Review and Hypotheses

Kraft and Kraft (1978) address the idea of causal relationship between energy consumption and economic growth for USA, and it was the earlier paper examining the relationship between these variables. Recently, considerable attention still has been focused on this kind of relationship. In general, these related studies can be divided into four types: (1) Some of these studies find the causality running from energy consumption to economic growth, and it is referred to as 'the growth hypothesis', for example, Stern (1993), Wolde-Rufael (2004), Lee and Chang (2005), Ho and Siu (2007), Ang (2007), and Bowden and Payne (2009). (2) Some find causal relationship running from economic growth to energy consumption, for example, Kraft an Kraft (1978), Abosedra and Baghestani (1989), Cheng and Lai (1997), Cheng (1998), Aqeel and Butt (2001), Ang (2008), and Zhang and Cheng (2009). It is also called 'the conservation hypothesis'. (3) Some find that there are no causality between energy consumption and economic growth; people also call them 'the neutrality hypothesis', for example, Akarca and Long (1980), Yu and Hwang (1984), Yu and Jin (1992), Cheng (1995), Fatai et al. (2002), and Payne (2009). (4) Others find that there are bi-directional causality between energy consumption and economic growth; people call them 'the feedback hypothesis', for example, Hwang and Gum (1991), Hondroyiannis et al. (2002), Glasure (2002), Ghali and El-Sakka (2004), Paul and Bhattacharya (2004), Erdal et al. (2008), and Belloumi (2009). This study will consult these four categories to make a brief literature review.

The first type literature on the causal linkage running from energy consumption to economic growth includes:

Stern (1993) uses multivariate VAR model to explore the causal relation running from energy consumption to GDP in USA during 1947-1990, and obtains the same result in 2000 through use the data during 1948-1994 with co-integration and Granger causality approach. Wolde-Rufael (2004), and Bowden and Payne (2009) through a modified version of Granger causality approach which called Toda-Yamamoto causality test and find the causal relationship running from energy consumption to GDP in Shanghai during 1952-1999 and in USA during 1949-2006, respectively. Lee and Chang (2005), Ho and Siu (2007) use co-integration approach and VEC model to explore the outcome of Taiwan during 1954-2003 and Hong Kong during 1966-2002, respectively. Ang (2007) observe the causal relation running from energy use to GDP would appear in the short run in France with co-integration approach and VEC model.

The second type literature on the causal linkage running from economic growth to energy consumption includes:

Kraft an Kraft (1978), Cheng and Lai (1997), Cheng (1998) and Zhang and Cheng (2009) follow Hsiao's (1981) version of the Granger causality approach to find a causal linkage running from GDP to energy consumption in USA during 1947-1974, in Taiwan during 1955-1993, in Japan during 1952-1995, and in China during 1960-2007, respectively. Abosedra and Baghestani (1989) and Aqeel and Butt (2001) explore the results of this type in USA during 1947-1987 and in Pakistan during 1955-1996. Ang (2008) also uses co-integration approach and VEC model to observe the causal relations running from GDP to energy consumption in Malaysia during 1971-1999.

Type 3 literature finding no causality between energy consumption and economic growth contains the following:

Fatai et al. (2002) establish no causal relations between energy consumption and GDP in New Zealand during 1960-1999. Meanwhile, Akarca and Long (1980), Yu and Hwang (1984), Yu and Jin (1992), Cheng (1995), and Payne (2009) all observe no causal linkage between energy consumption and economic growth in USA under different approaches and periods.

Type 4 literature finding bi-directional causality between energy consumption and economic growth includes the following:

Hondroyiannis et al. (2002) explore the linkage between energy consumption, economic growth, and the consumer price index (CPI) for Greece during 1960-1996 and find a long-run relationship among them and a bi-directional causality between energy consumption and economic growth. Glasure (2002) establish a bi-directional causality between these two variables in Korea during 1961-1990. Hwang and Gum (1991), Ghali and El-Sakka (2004), Paul and Bhattacharya (2004), Erdal et al. (2008), and Belloumi (2009) observe a bi-directional causality between energy consumption and GDP.

The relations between international trade and economic variables are also discussed widely. Ghartey (1993) find that exports growth causes economic growth in Taiwan in short-run. Kwan et al. (1996) address the result of their research is conflict with the export-led growth hypothesis in Taiwan. Shirazi and Manap (2005) also discuss the export-led growth hypothesis in South Asia, and find a strong support for a long-run relationship among exports, imports, and real output for all the countries except Sri Lanka in South Asia. Furthermore, feedback effects between exports and GDP for Bangladesh and Nepal and unidirectional causality from exports to output in the case of Pakistan were found; a feedback effect between imports and GDP was also documented for Pakistan, Bangladesh, and Nepal, as well as unidirectional causality from imports to Output growth for Sri Lanka.

Mongelli et al. (2006) argue that there are strong dynamic inter-relationships between output, energy consumption, environmental pollutants and foreign trade, which should be investigated in the same multivariate framework. Therefore, the main objective of this study is to discuss whether high dependence of energy consumption has apparent influence to the trade activities performance in Taiwan. This study will examine the co-integration and Hsiao's version of Granger causality between trade and variety of imported energy consumption of Taiwan in bivariate vector autoregression (VAR) framework.

Figure 3 is the framework of this study. It prepares a discussion of the relations and directions between variety trade and energy consumption variables. Trade variables include real value of total imports (VTI), real value of total exports (VTE), real export value of industrial sector (EVI), heavy-chemical industrial products (EVHI), and non-heavy-chemical industrial products (EVNHI). Energy consumption variables include total energy consumption (TEC), oil and petroleum products consumption (OC), coal and coal products consumption (CC), and natural gas consumption (NC).

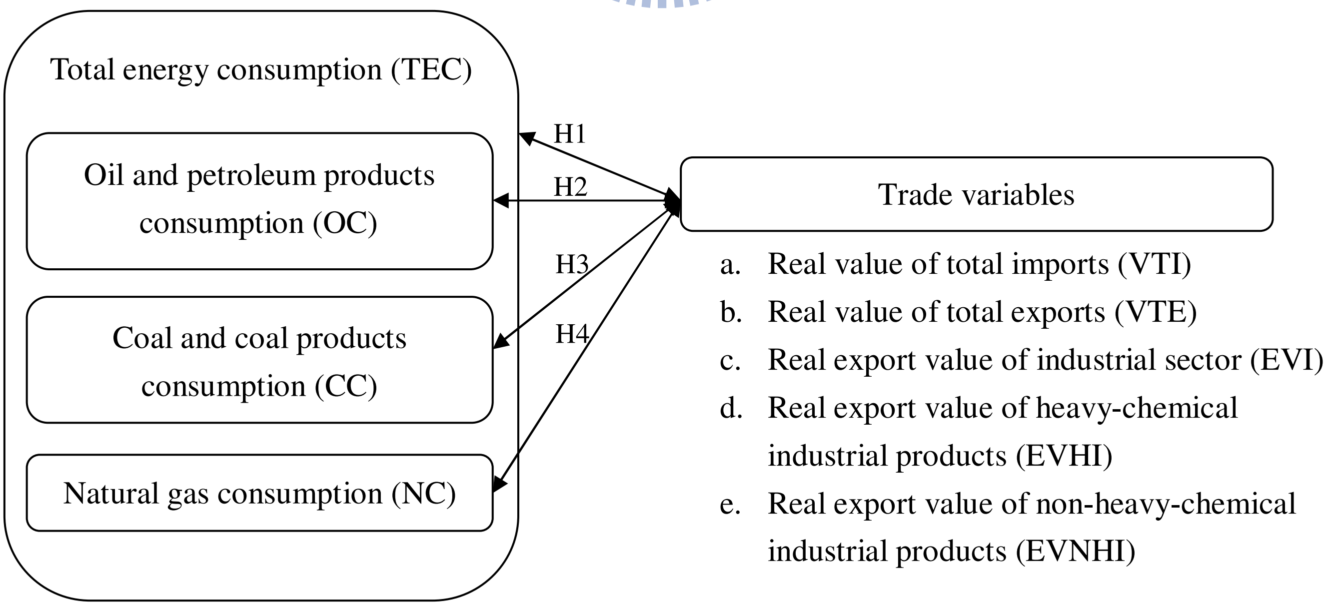


Figure 3. Research framework

After a brief literature review, this study provides *Hypothesis 1a to Hypothesis 1e*.

Hypothesis 1a: *There is a negative Granger causal relation between total energy consumption and real value of total imports.*

Hypotheses 1b ~ 1e: *There are positive Granger causal relations between total energy consumption and real value of export variables.*

Recent studies research individual energy consumption as well, most of them discuss the ideas with electricity and nuclear, for example, Ouedraogo (2010), Yoo and Kwak (2010), Yoo and Lee (2010), Pao (2009), Akinlo AE (2009), Odhiambo (2009), Balat (2009), Abosedra et al. (2009), Apergis and Payne (2010a), Wolde-Rufael and Menyah (2010), Wolde-Rufael (2010a), and Yoo and Ku (2009). Therefore, it is rare to find studies which discuss the ideas with petroleum, coal, and natural gas. Zou and Chau (2006) examine both the equilibrium relationship and the predictability between oil consumption and economic growth in China. They find that these two variables tend to move together in the long run, and oil consumption could be a useful factor that forecasts changes in the economy in the short run as well as in the long run. Therefore, the oil consumption is found to have great effects on the economy.

Yoo (2006b) investigates the short- and long-run causality issues between oil consumption and economic growth in Korea. The results show that bi-directional causality runs from oil consumption to economic growth in Korea, implying that an increase in oil consumption directly affects economic growth and that economic growth also stimulates further oil consumption. Apergis and Payne (2010b; 2010c) examine the relationship between coal consumption and economic growth for 25 OECD countries within a multivariate panel framework over period 1980-2005. The results reveal bi-directional effects between coal consumption and economic growth in both the short- and long-run; however, the bi-directional effects in the short-run are both negative. Wolde-Rufael (2010b) finds a unidirectional causality running from coal consumption to economic growth in India and Japan while the opposite causality running from economic growth to coal consumption was found in China and South Korea. In contrast, there was a bi-directional causality running between economic growth and coal consumption in South Africa and the United States, implying that to mitigate the adverse effects of coal consumption may be taken without harming economic growth in China and South Korea, but in India, Japan, South Africa, and the United States.

Yoo (2006a) investigates the short- and long-run causality issues between oil consumption and economic growth in Korea as well, and the overall results show that there exists bi-directional causality running from coal consumption to economic growth with feedback. Yang (2000) uses Granger causality test using 1954-1997 data of Taiwan to test the causality issue between coal consumption and economic growth. However, there is no literature discussing the causal relations between natural gas consumption and economic variables. Hence this study provides *Hypothesis 2a to Hypothesis 4e* which are listed as follows:

Hypothesis 2a: *There is a negative Granger causal relation between oil and petroleum products consumption and real value of total imports.*

Hypotheses 2b ~ 2e: *There are positive Granger causal relations between oil and petroleum products consumption and real value of export variables.*

Hypothesis 3a: *There is a negative Granger causal relation between coal and coal products consumption and real value of total imports.*

Hypotheses 3b ~ 3e: *There are positive Granger causal relations between coal and coal products consumption and real value of export variables.*

Hypothesis 4a: *There is a negative Granger causal relation between natural gas consumption and real value of total imports.*

Hypotheses 4b ~ 4e: *There are positive Granger causal relations between natural gas consumption and real value of export variables.*

The structure of this study is organized as follows: Chapter 3 briefly describes the econometric method applied in this study. Chapter 4 presents data, descriptive statistics, and empirical results. Concluding remarks are given in the final chapter.

Chapter 3. Model and Econometric Methodology

3.1 Unit Root Tests

If the mean, variance and covariance of a time series variable were independent with time, and any extraneous impact only make a short influence, then it is a 'stationary time series'; otherwise, it is a 'non-stationary time series'. Prior to the co-integration analysis, the stationarity of time series should be tested; this is also known as a unit-root test.

This research will test the stationarity of time series by two conventional unit root test techniques: the augmented Dickey-Fuller (ADF) (1981) and the Phillips-Perron (PP) (1988) test.

Dickey and Fuller proposed Dickey-Fuller test method in 1979. Since DF test did not consider the first order autoregression model (AR(1)) and the existence of autocorrelation in residual terms. Dickey and Fuller modified their equations with lag length in the process of producing data, so that the residual terms would turn into white noise. It is known as the augmented Dickey-Fuller test.

The three differencing AR models of ADF are expressed as follows:

$$\textit{Model 1}: \ \Delta Y_t = \gamma Y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i} + \varepsilon_t \qquad (1)$$

$$\textit{Model 2}: \ \Delta Y_t = \alpha + \gamma Y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i} + \varepsilon_t \qquad (2)$$

$$\textit{Model 3}: \ \Delta Y_t = \alpha + \beta_t + \gamma Y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i} + \varepsilon_t \qquad (3)$$

where Δ is the difference operator; t denotes time t; and $\gamma Y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i}$ is an augmented part of ADF test. Therefore, considerable time has been spent selecting the lag structure using the minimizing Akaike's information criterion (AIC) (Akaike, 1974) or Schwarz's Bayesian information criterion (SBC) (Schwartz, 1978). *Model 1* is defined as a pure random walk with lag terms; *Model 2* is a random walk with drift and *Model 3* is a random walk with drift around a stochastic trend. The null hypothesis and alternative hypothesis for the ADF test are H_0: $\gamma = 0$ and H_1: $-2 < \gamma < 0$.

Although the ADF test with long lag terms is thought to be superior to the others (Schwert, 1989), this research also apply the PP test which is robust in the presence of serial correlation and heteroscedasticity. Phillips (1987) and Phillips and Perron (1988) relax the assumption that residual terms must be iid and allow residual terms to have serially correction and heteroscedasticity. It is known as the PP test.

If the series are tested to be non-stationary in levels and become stationary when d*th*-order differenced, then they are said to be integrated of order d; i.e., I(d), and co-integration approaches are supposed to be applied to observe the possible long-run relationships among the variables.

3.2 Co-integration

According to Engle and Granger (1987) a linear combination of two or more non-stationary series (with the same order of integration) may be stationary. If such a stationary linear combination exists, the series are considered to be co-integrated and long-run equilibrium relationships exist (Erdal et al., 2008). The 'spurious problem' (Granger and Newbold, 1974) is the first task to be ruled out and with more powerful multivariate maximum likelihood co-integration test which is conducted by means of the method developed by Johansen (1988) and Johansen and Juselius (1990), is scheduled to investigate the common stochastic trend among variables.

Following Johansen (1988) and let Y_t be a k×1 matrix, the VAR representation of general form can be set up:

$$Y_t = A_0 + A_1 Y_{t-1} + A_2 \Delta Y_{t-2} + \ldots + A_p \Delta Y_{t-p} + \varepsilon_t \tag{4}$$

$$\varepsilon_t \sim i.i.d.N(0, \sigma^2)$$

In order to apply the Johansen test, the VAR model above needs to be rewritten in error correction form:

$$\Delta Y_t = A_0 + \Pi Y_{t-1} + \Gamma_1 \Delta Y_{t-2} + \Gamma_2 \Delta Y_{t-3} + \ldots + \Gamma_{t-p} \Delta Y_{t-p-1} + \varepsilon_t \tag{5}$$

where Δ is the first-order difference operator, ΠY_{t-1} is termed as the equilibrium error or error correction, and define that $\Pi = \sum_{i=1}^{p} A_i - I$, $\Gamma_i = \sum_{j=1}^{i} A_j - I$.

The parameter matrix $r(\Pi)$ will be further marked, that the rank r of this matrix $r(\Pi)$, where $0 < r < p$, will determine the number of co-integrating vectors in the VAR system.

According to the property of the matrix $r(\Pi)$, there are three cases as follows:

1. Rank $(\Pi) = p$
2. Rank $(\Pi) = 0$
3. Rank $(\Pi) = r < p$

In case 1, Π is full rank and Y_t is a stationary series; i.e., $Yt \sim$ I(0), and we may directly estimate the VAR model with Yt. In case 2, none is stationary; i.e., $Yt \sim \mathrm{I}(1)$, there is no co-integration, and estimating the VAR model using ΔY_t is suggested. Under the condition of last case, which is called 'reduces rank', the matrix Π can be decomposed as $\Pi = \alpha\beta$, where α is known as the speed of adjustment vector; β is the co-integrating vector, and both α and β are $p \times r$ matrices.

The number of co-integrating vectors can be judged by determining the significance of the characteristic roots of Π. There are two test statistics for co-integration under the Johansen approach, which are formulated as:

$$\lambda_{trace}(r) = -2\ln(\theta) = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_i) \tag{6}$$

and

$$\lambda_{max}(r, r+1) = -2\ln(\theta, r \mid r+1) = -T\ln(1-\hat{\lambda}_{r+1}) \tag{7}$$

where r is the number of co-integrating vectors under the null hypothesis; T is the total number of observations; and $\hat{\lambda}_i$ is the estimated value for the ith ordered eigenvalue from the Π matrix. If both test statistics are greater than the critical value, we reject the null hypothesis that there are r co-integrating vectors in favor of the alternative that there are $r+1$ (for λ_{trace}) or more than r (for $\lambda_{\max}$) stationary relationships between the relevant variables. The Schwartz Bayesian information criterion (SBC) is again used to select the optimal number of lag length.

3.3 Granger Causality Test

If the predication of the current value of Y_t is improved by including past values of X_t, then it is supposed that the variable X_t Granger causes Y_t. The main concept to use Granger test is 'predictability' the causal relations between variables. The Granger causality mentioned goes in statistics, not completely the 'causation relations'. It can be deemed the lead and backward relation between variables.

The causal relationships between energy consumption and trade variables are detected by Hsiao's (1981) version of Granger causality test. If two variables are tested to be stationary, then the standard form of Granger causality approach can be expressed as follows:

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{P} \alpha_i \Delta Y_{t-i} + u_{1t} \qquad (8)$$

Hsiao's procedure involves two steps to determine the optimum number of own and cross-lagged terms and the direction of causality of variables using the final prediction error (FPE). The first step calculates the sum of squared errors (SSE) for Equation (8) where $i = 1, 2, ..., P$. The FPE(p) considering the lag terms which will be obtained in the following equation:

$$\text{FPE}(p) = \frac{\text{SSE}}{T - p - 1}(1 + \frac{p+1}{T}) \qquad (9)$$

where T is the total number of observations, p is the order of lags altering from 1 to P, and *SSE* is the sum of squared errors. The minimum FPE is decided by the corresponding SSE and p^*, which is expressed as FPE(p^*) to make a comparison in the next step. The second step shifts focus to the following equation:

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{P} \alpha_i \Delta Y_{t-i} + \sum_{j=1}^{Q} \beta_j \Delta X_{t-j} + u_{2t} \tag{10}$$

From the above equation, Y_t is defined as a controlled variable, with the order of lags set at p^* from Equation (2), and X_t as a manipulated variable. According to Equation (3), we estimate the *SSE* of Y_t by altering the lag order of X_t from 1 to Q and decide the order producing the smallest FPE, which is denoted as q^*. Finally, the corresponding two-dimensional FPE is of the form:

$$\text{FPE}(p^*, q) = \frac{\text{SSE}(p^*, q)}{T - p^* - q - 1}\left(1 + \frac{p^* + q + 1}{T}\right) \tag{11}$$

where q is known as the lag order of series X_t altering from 1 to Q; and p^* is the optimum number of lags estimated in the preceding step. Summing up the above, we may draw the conclusion that series X_t Granger causes series Y_t, if FPE(p^*, q^*) is smaller than FPE(p^*).

3.4 The Vector Autoregression Model (VAR)

Since many economic empirical works are traditionally established according to the prior knowledge, it is hard to settle the proper causality and the endogenous-exogenous relationship between variables until the vector autoregression model (VAR) unfolded by Sims (1980). The VAR model treats every variable as been endogenous and expresses their interaction relationship with multiple regression equations rather than one regression equation.

The general mathematic form of VAR model is given by:

$$Y_t = \alpha + \sum_{i=1}^{m} \beta_i Y_{t-i} + \varepsilon_t \tag{12}$$

$$E(\varepsilon_t \varepsilon_s) = 0; \quad E(\varepsilon_t \varepsilon'_t) = \Sigma \neq 0$$

where Y_t is a $n \times 1$ vector of variables; β_i is $n \times n$ matrices of coefficients; α is $n \times 1$ vector of intercept terms; and ε_t is a $n \times 1$ vector of disturbances, i.e., the process of one-step-ahead forecast errors.

To make sure that the residual terms are all white noise, AIC still will be the optimal lag length selection approach. If the common stochastic trend among non-stationary variables does not exist, the VAR model in first-order differences will be applied to carry out the analysis, which is as follows:

$$\Delta Y_t = \alpha + \sum_{i=1}^{m} \beta_i \Delta Y_{t-i} + \varepsilon_t \tag{13}$$

3.5 Impulse-Response Analysis with VAR

To better comprehend the dynamic response pattern in the VAR model, we further employ the impulse responses to trace out the responsiveness of the dependent variables to shocks to each of the variables. In other words, impulse response analysis makes it possible to examine how the variables can be destabilized by shocks that arise with other variables. By utilizing the Wold's decomposition theorem (1954), the VAR model can be transformed into the form of moving average (MA), that is, each variable can be expressed as a linear combination of current value and previous values of a white noise error term. The process is as follows:

$$\begin{cases} Y_t - \sum_{i=1}^{m} \beta_i Y_{t-i} = \alpha + \varepsilon_t \\ (1 - \beta_1 L - \beta_2 L^2 - \ldots - \beta_m L^m) Y_t = \alpha + \varepsilon_t \\ Y_t = (1 - \beta_1 L - \beta_2 L^2 - \ldots - \beta_m L^m)^{-1} \alpha + (1 - \beta_1 L - \beta_2 L^2 - \ldots - \beta_m L^m)^{-1} \varepsilon_t \\ Y_t = \alpha' + \sum_{i=0}^{\infty} C_i \varepsilon_{t-i} \end{cases} \tag{14}$$

where L is the lag operator; α' is $n \times 1$ vector of constants; C_i is $n \times n$ matrices; and $C_0 = \mathrm{I}$ is a unit matrix.

Typically, the estimated VAR residuals are deemed contemporaneously correlated. For dissecting the effects of innovations in one variable uncontaminated by contemporaneous innovations in other variables, one feasible implementation is to apply the Choleski decomposition to generate triangular orthogonalization matrices.

Equation (12) ensures the following equation:

$$Y_t = \alpha^{t} + \sum_{i=0}^{\infty} C_i K K^{-1} \varepsilon_{t-i}$$

Let $C_i^* = C_i K$ and $e_{t-i} = K^{-1} \varepsilon_{t-i}$. The above equation can be re-expressed as:

$$Y_t = \alpha^{t} + \sum_{i=0}^{\infty} C_i^* e_{t-i} \tag{15}$$

where C_i^* is an impact multiplier and e_{t-i} s are neither autocorrelated nor contemporaneously correlated.

In this way, each variables can be turned into the function of innovations and these matrices multiplied by the estimated VAR model create uncorrelated residuals, which aid to observe how the coefficients change when the objective variable receive spontaneous shocks from other variables.

Chapter 4. Data and Empirical Analysis

4.1 Data Sources and Descriptive Statistics

Time series variables over the periods from 1998 to 2009 are employed in empirical tests. Monthly imported energy consumption quantity including total energy consumption (TEC), oil and petroleum products consumption (OC), coal and coal products consumption (CC), and natural gas consumption (NC), are defined in KL oil equivalents and obtained from the *energy monthly report* by Bureau of Energy (2009c) , Ministry of Economic Affairs, Taiwan, covering a period which extends from 1998:1 to 2009:12. Since the oil, coal, and natural gas used in Taiwan are almost 100% imported, this study adopts individual total energy consumption quantity to substitute individual imported energy consumption quantity. Trade data including real value of total imports (VTI), real value of total exports (VTE), real exports value of industrial sector (EVI), real exports value of heavy-chemical industrial products (EVHI), and real exports value of non-heavy-chemical industrial products (EVNHI), are obtained from the *National Statistics Database* by the Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Taiwan and deflated with base period of 2005. These data are defined in million US dollars.

The trends and descriptive statistics for all imported energy consumption and macroeconomic variables are shown in Figure 4 and Table 2.

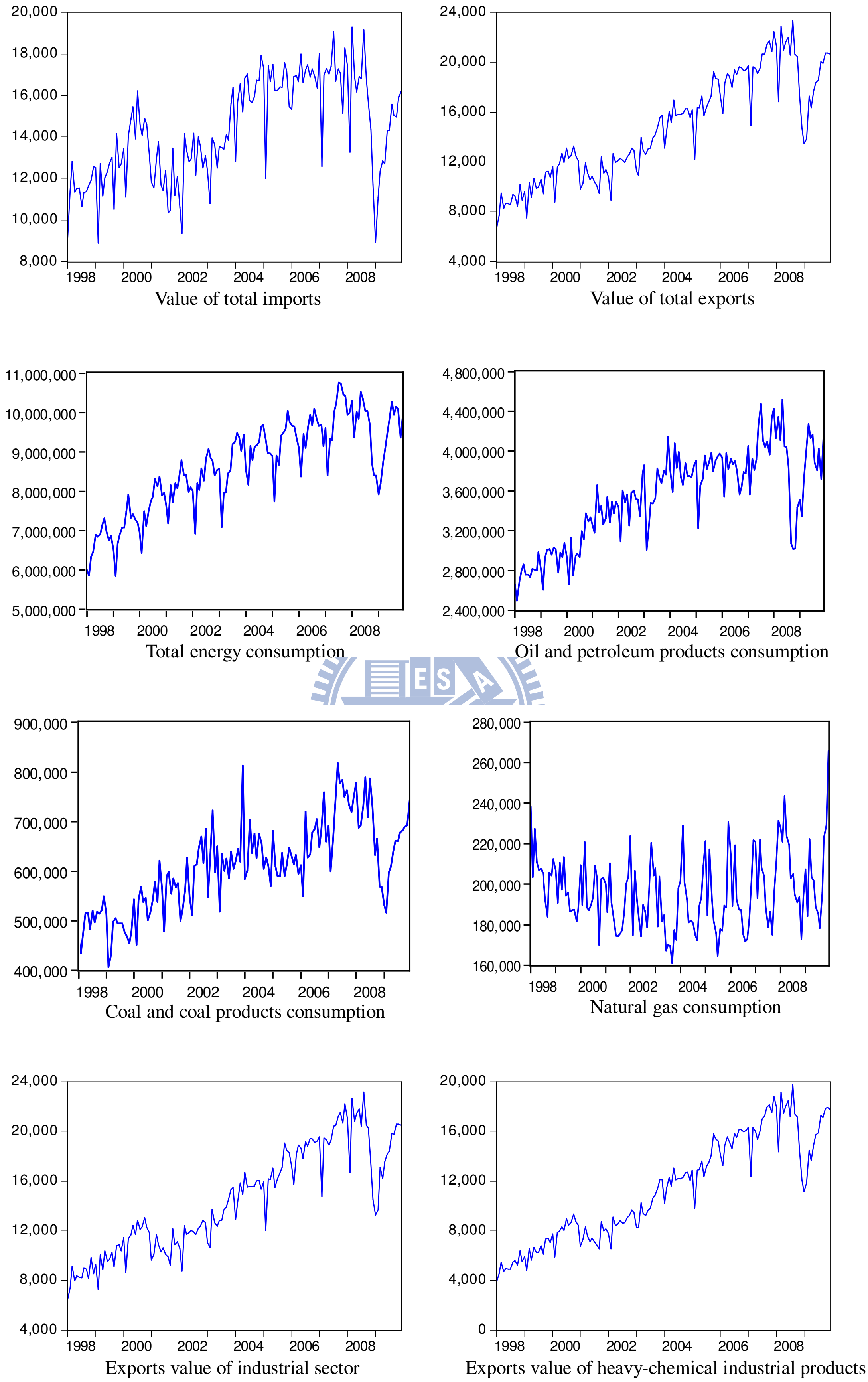
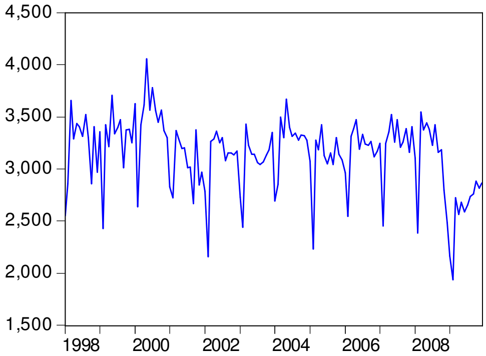


Figure 4. Trends of energy consumption and trade variables in Taiwan



Exports value of non-heavy-chemical industrial products

Figure 4. Continued

Table 2. Summary of descriptive statistics for each variable

Variables	VTI	VTE	TEC	OC	CC
Mean	14,344.07	14,697.77	8,612,447.00	3,534,980.00	608,598.60
Median	14,162.30	14,047.77	8,732,205.00	3,597,263.00	610,022.50
Maximum	19,304.83	23,346.08	10,767,180.00	4,520,889.00	817,602.00
Minimum	8,873.38	6,682.42	5,835,672.00	2,496,122.00	405,642.00
Std. Dev.	2,438.75	4,183.41	1,165,938.00	470,136.10	89,032.28
Skewness	-0.11	0.17	-0.34	-0.24	0.13
Kurtosis	2.06	1.86	2.27	2.14	2.48
Jarque-Bera	5.61	8.45	5.93	5.82	2.02
Variables	NC	EVI	EVHI	EVNHI	
Mean	196,386.70	14,477.83	11,331.66	3,145.34	
Median	193,052.50	13,807.70	11,277.06	3,228.32	
Maximum	265,803.00	23,160.29	19,793.93	4,061.47	
Minimum	161,029.00	6,453.43	3,894.20	1,933.31	
Std. Dev.	18,147.55	4,211.12	4,225.56	350.29	
Skewness	0.67	0.17	0.16	-0.90	
Kurtosis	3.52	1.86	1.78	3.99	
Jarque-Bera	12.53	8.45	9.56	25.09	

4.2 Unit Root Test

The time series properties of the variables are checked through augmented Dickey-Fuller test (ADF) (1981) and Phillips-Perron's (PP) (1988) unit root-testing procedures. As shown in Table 3, under testing equation computed with intercept, natural gas consumption is stationary; under testing equation computed with linear trend and intercept, real value of total exports, total energy consumption, coal and coal products consumption, oil and petroleum products consumption, natural gas consumption, real export value of industrial sector, and real export value of heavy-chemical industrial products are stationary; and no variable is stationary without intercept and linear trend in levels.

The series of real value of total imports, real exports value of non-heavy-chemical industrial products appear to contain unit roots in their levels but stationary after first-order differences; i.e., they are I(1) variables. Therefore, the co-integration test can be prepared to examine the long-run equilibrium relationship between these I(1) series.

Table 3. Results of unit root tests

Variable		VTI	VTE	TEC	CC	OC	NC	EVI	EVHI	EVNHI
Level										
ADF	T_u	-2.23	-1.65	-1.58	-2.28	-2.62	-5.43***	-1.63	-1.23	-2.34
	T_t	-2.79	-3.84**	-3.76**	-4.58***	-4.14***	-5.55***	-3.80**	-3.56**	-2.97
	T	0.12	0.63	1.32	0.46	1.00	0.03	0.65	0.90	-0.55
PP	T_u	-4.92***	-1.99	-2.94**	-3.89***	-2.94**	-6.02***	-1.94	-1.39	-8.22***
	T_t	-6.18***	-5.85***	-5.23***	-7.51***	-5.71***	-6.10***	-5.79***	-5.29***	-8.64***
	T	0.28	1.23	0.64	0.58	1.36	-0.06	1.30	1.62	-0.24
First Difference										
ADF	T_u	-14.54***	-18.64***	-3.20**	-13.07***	-3.84***	-17.86***	-18.67***	-18.21***	-3.32**
	T_t	-14.49***	-18.58***	-3.21	-13.03***	-3.86**	-17.89***	-18.60***	-18.15***	-3.41
	T	-14.58***	-18.59***	-2.82***	-13.07***	-17.47***	-17.92***	-18.61***	-18.10***	-3.31***
PP	T_u	-29.08***	-26.19***	-17.03***	-28.54***	-23.22***	-18.02***	-25.57***	-22.45***	-60.55***
	T_t	-29.57***	-26.33***	-16.90***	-28.70***	-23.51***	-18.09***	-25.69***	-22.38***	-84.14***
	T	-28.76***	-22.43***	-17.01*	-27.23***	-22.20***	-18.08***	-22.19***	-19.39***	-61.41***

Note: 1. *** and ** represent significance at the 1% and 5% levels, respectively.

2. The numbers showed in this table represent t value. T_u, T_t, and T respectively denote test equation computed with intercept, with linear trend and intercept, and without intercept and linear trend. ADF and PP stand for augmented Dickey-Fuller and Phillips and Perron unit root tests with the same critical values at 5% are -2.86, -3.14, -1.94 and at 1% are -3.43, -3.96, -2.57, respectively.

4.3 Co-integration Test

This study using the Johansen multivariate maximum likelihood procedure (Johansen, 1988), which has been shown to be superior to Engle and Granger's residual-based approach (Engle and Granger, 1987) to test the co-integration relationship between variables. Although there are two non-stationary variables, this study only discusses the pairwise comparisons with energy consumption and trade variables. Hence, this study does not use co-integration test to observe the long-run relations between variables.

The next step is to apply Granger causality test to examine all pairwise comparisons which include stationary series and non-stationary series after first-order differences under research framework.

4.4 Granger Causality Test

The precondition to apply the standard Granger's is that the series of variables need to be stationary. According to the results of unit root test, real value of total exports, total energy consumption, coal and coal products consumption, oil and petroleum products consumption, natural gas consumption, real export value of industrial sector, and real export value of heavy-chemical industrial products are stationary; while real value of total import, and real exports value of non-heavy-chemical industrial products are appear to contain a unit root in their levels. Therefore, we need to transform these non-stationary variables into difference form to compare with stationary series in Granger causality test. According to frameworks, test results are built in Table 4.

The results of Granger causality test between total energy consumption and trade variables reveal that total energy consumption has a unidirectional Granger causal linkage running to real value of total exports, real export value of industrial sector, and real export value of heavy-chemical industrial products.

After examining the causal relationships between oil and petroleum products consumption and trade variables, this study observe that oil and petroleum products consumption would Granger cause real value of total exports and all real export values under industrial sector. On the other hand, coal and coal products consumption is Granger caused by all trade variables. The natural gas consumption is Granger caused by real value of total exports, real exports value of industrial sector, and real exports value of heavy-chemical industrial products. Furthermore, there is a bi-directional causality between natural gas consumption and real exports value of non-heavy-chemical industrial products, implying that there exists a feedback relationship between these two variables.

Table 4. Results of Granger causality tests

Null Hypothesis	F-Statistic	Probability	Result
TEC does not Granger cause ∆VTI	3.01185	0.0525	Accepted
∆VTI does not Granger cause TEC	0.90554	0.4067	Accepted
TEC does not Granger cause VTE	4.67160	0.0109	Rejected**
VTE does not Granger cause TEC	0.87260	0.4202	Accepted
TEC does not Granger cause EVI	4.55679	0.0121	Rejected**
EVI does not Granger cause TEC	0.92758	0.3980	Accepted
TEC does not Granger cause EVHI	4.24986	0.0162	Rejected**
EVHI does not Granger cause TEC	1.48400	0.2304	Accepted
TEC does not Granger cause ∆EVNHI	1.66973	0.1766	Accepted
∆EVNHI does not Granger cause TEC	0.38545	0.7637	Accepted
OC does not Granger cause ∆VTI	3.61486	0.0295	Rejected**
∆VTI does not Granger cause OC	0.21409	0.8075	Accepted
OC does not Granger cause VTE	9.13576	0.0002	Rejected***
VTE does not Granger cause OC	1.31452	0.2720	Accepted
OC does not Granger cause EVI	9.11179	0.0002	Rejected***
EVI does not Granger cause OC	1.42001	0.2452	Accepted
OC does not Granger cause EVHI	8.40103	0.0004	Rejected***
EVHI does not Granger cause OC	2.07448	0.1296	Accepted
OC does not Granger cause ∆EVNHI	4.45012	0.0052	Rejected***
∆EVNHI does not Granger cause OC	1.26568	0.2888	Accepted

Note: 1. *** and ** represent significance at the 1% and 5% levels, respectively.

2. ∆ denote the non-stationary series variable after first-order differences.

Table 4. Continued

Null Hypothesis	F-Statistic	Probability	Result
CC does not Granger cause △VTI	1.49041	0.2289	Accepted
△VTI does not Granger cause CC	7.77420	0.0006	Rejected***
CC does not Granger cause VTE	1.30278	0.2762	Accepted
VTE does not Granger cause CC	7.48613	0.0001	Rejected***
CC does not Granger cause EVI	1.29781	0.2779	Accepted
EVI does not Granger cause CC	7.67668	<0.001	Rejected***
CC does not Granger cause EVHI	2.28715	0.1054	Accepted
EVHI does not Granger cause CC	9.02300	0.0002	Rejected***
CC does not Granger cause △EVNHI	0.98330	0.4028	Accepted
△EVNHI does not Granger cause CC	3.38181	0.0202	Rejected**
NC does not Granger cause △VTI	2.32756	0.1014	Accepted
△VTI does not Granger cause NC	1.33712	0.2660	Accepted
NC does not Granger cause VTE	2.17586	0.1174	Accepted
VTE does not Granger cause NC	4.70585	0.0106	Rejected**
NC does not Granger cause EVI	2.12137	0.1238	Accepted
EVI does not Granger cause NC	4.73500	0.0103	Rejected**
NC does not Granger cause EVHI	2.37697	0.0966	Accepted
EVHI does not Granger cause NC	4.41751	0.0138	Rejected**
NC does not Granger cause △EVNHI	4.23376	0.0068	Rejected***
△EVNHI does not Granger cause NC	4.39757	0.0055	Rejected***

Note: 1. *** and ** represent significance at the 1% and 5% levels, respectively.

2. △ denote the non-stationary series variable after first-order differences.

4.5 Impulse-Response Simulations

In order to obtain additional insight into how the volatility of energy consumption variables to trade performance variables which have causal relations from one to the other, we conduct impulse response analysis. Before establishing impulse-response simulations, we have to choose an optimal lag order of the VAR model. The optimal lag order of the VAR model is selected as 1 on the basis of SBC as in Table 5. Impulse response analysis makes it possible to examine how the variables can be destabilized by shocks that arise with other variables. Figure 5 presents the results of variables which are observed with causal relationships in Granger causality test from the impulse-response analysis based on VAR (1). It shows the impulse-response paths of variables up to 20 months after a one standard deviation shock stimulated from others.

Table 5. Lag length determination for VAR model

Model	SBC	Model	SBC
VAR(1)	167.5419*	VAR(6)	175.5312
VAR(2)	168.9623	VAR(7)	176.6639
VAR(3)	170.5082	VAR(8)	177.7346
VAR(4)	172.5123	VAR(9)	178.7649
VAR(5)	174.0371	VAR(10)	179.5172

Note: SBC is the Schwarz information criterion.

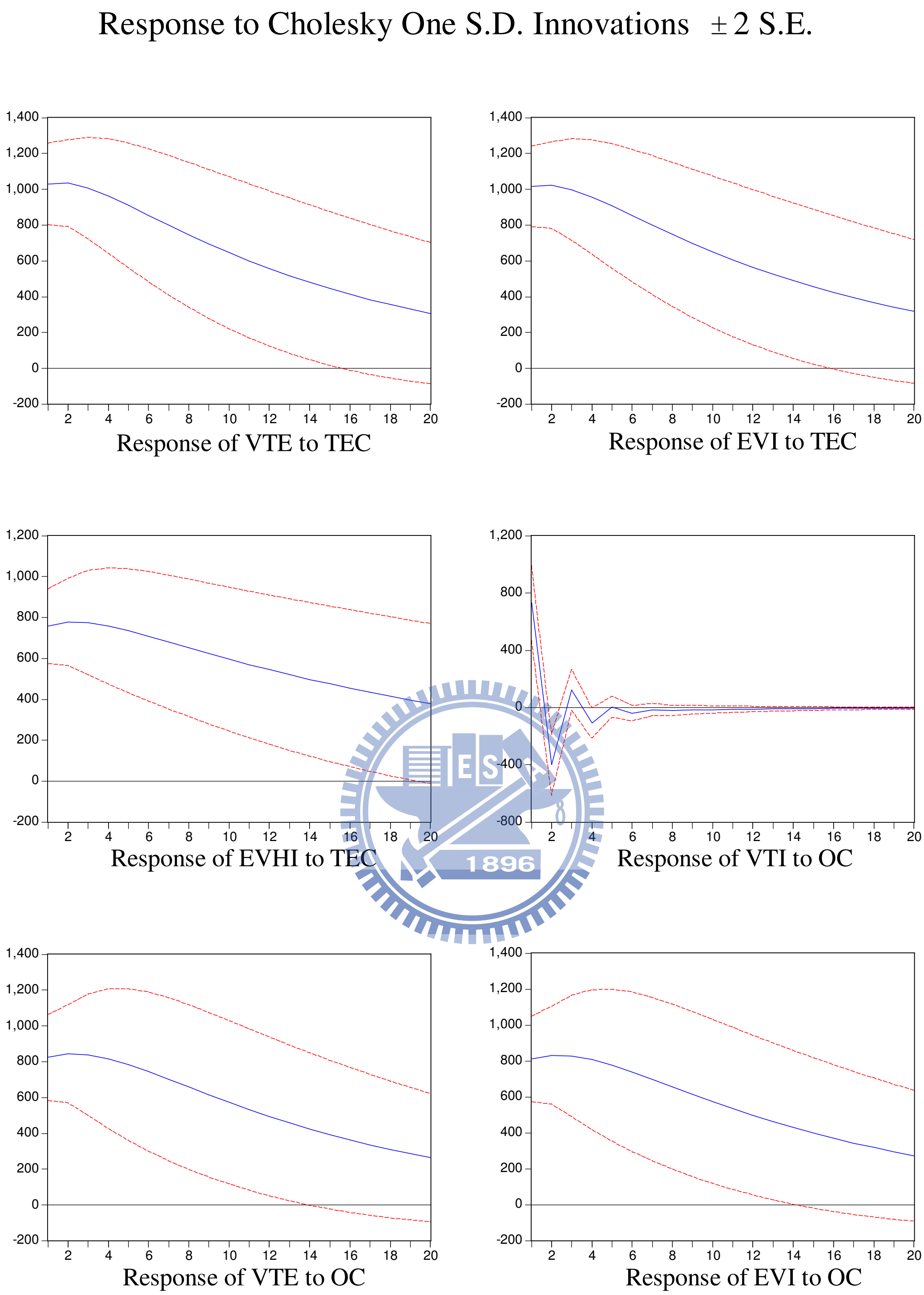


Figure 5. Impulses-responses of variables with Granger causal relations

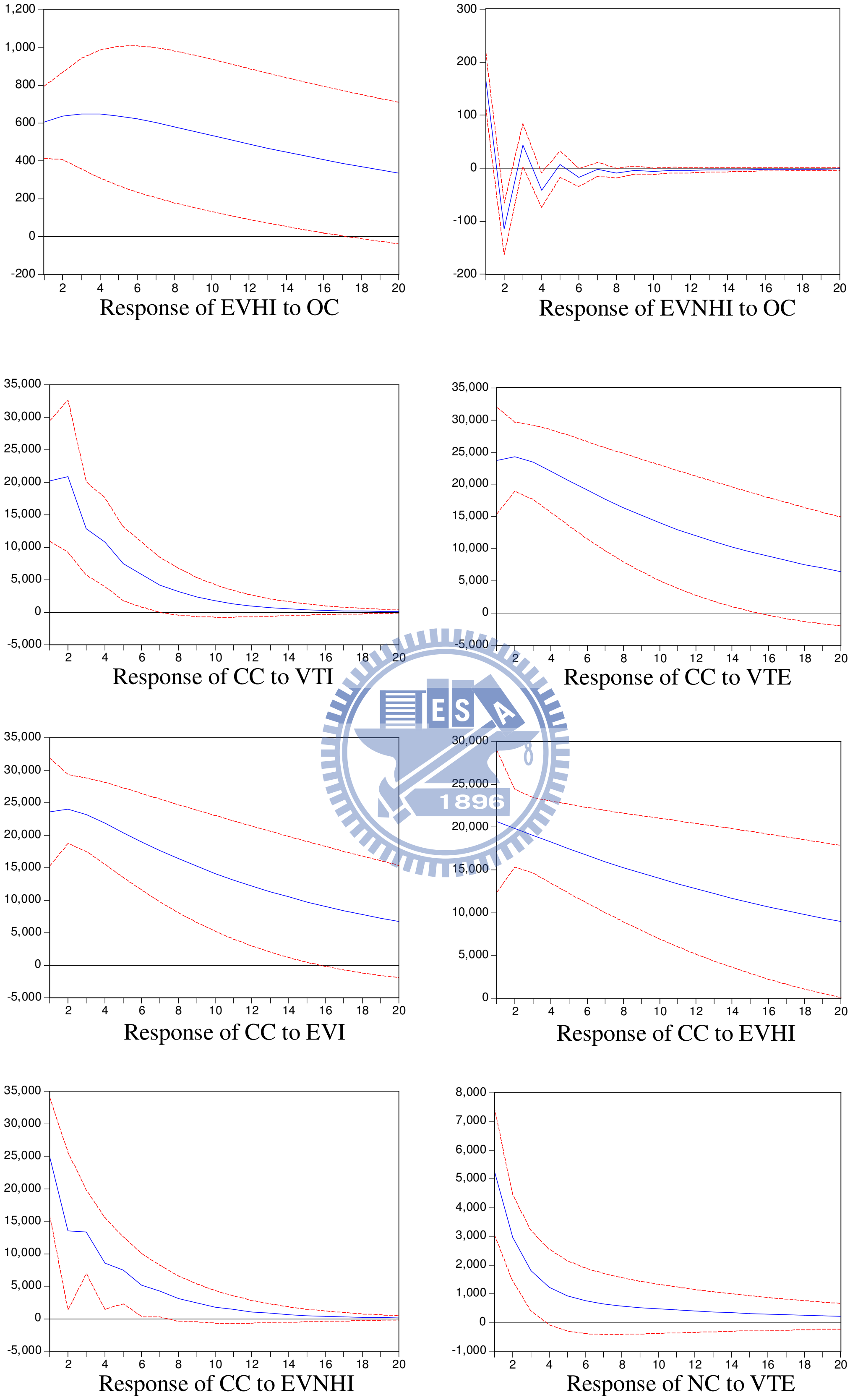


Figure 5.　Continued

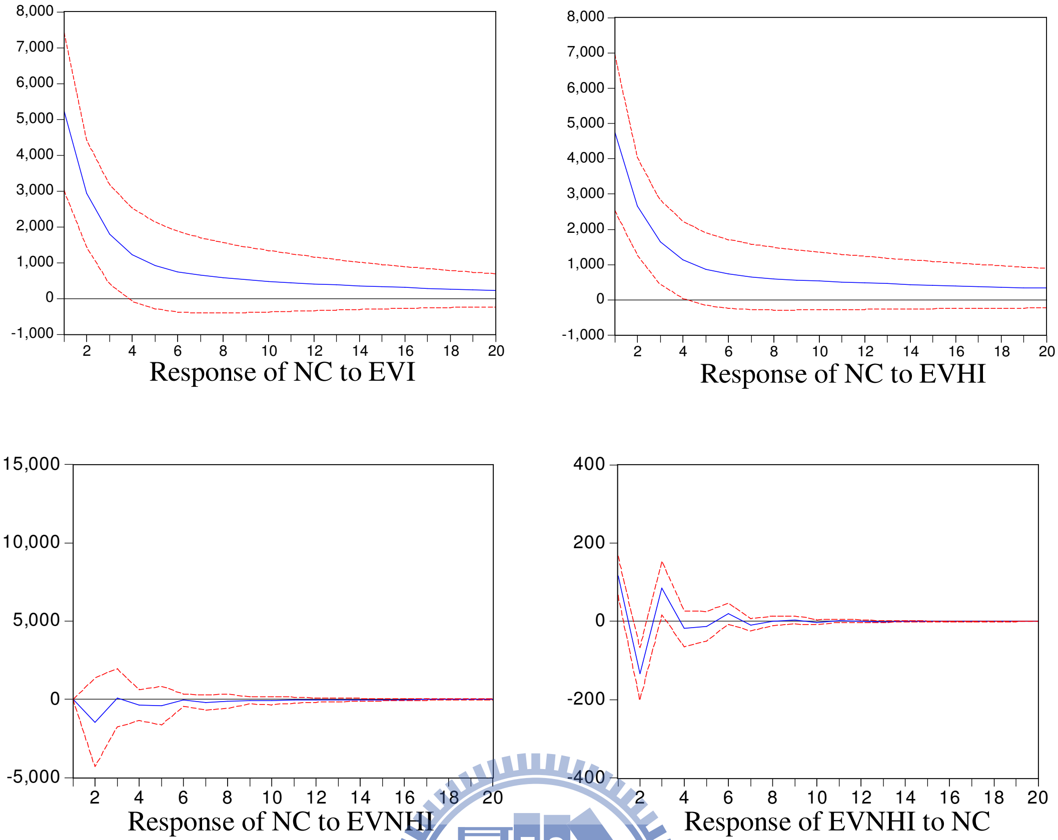


Figure 5. Continued

From the test results, real value of total exports, real exports value of industrial sector, and real exports value of heavy-chemical industrial products tend to have positive responses to the shock of total energy consumption at initial period, and then move downward to the pre-shock level smoothly.

Real value of total imports and real exports value of non-heavy-chemical industrial products tend to have negative responses to the shock of oil and petroleum products consumption and fluctuates up and down around the pre-shock level and become stable gradually. Furthermore, real value of total exports, real exports value of industrial sector, and real exports value of heavy-chemical industrial products have positive responses to oil and petroleum products consumption at initial period, and the trend to approach the pre-shock level is downward smoothly.

To discuss the responses of energy consumption which is shocked by all trade variables, coal and coal products consumption tends to have positive responses to the shock of real value of total imports, real value of total exports; real exports value of industrial sector at initial period, and have negative responses to the shock of real exports value of heavy-chemical industrial products and real exports value of non-heavy-chemical industrial products at initial period. These curves also move downward to the pre-shock level smoothly.

On the other hand, real value of total exports, real export value of industrial sector and real value of heavy-chemical industrial impulses natural gas consumption with negative response directions and converge to the pre-shock levels. Furthermore, natural gas consumption and real value of non-heavy-chemical industrial products would impulse each other negatively, and fluctuates up and down around the pre-shock level gradually and become stable during the period.

Chapter 5. Conclusion

As has been demonstrated, this study provides an outlook that we can enhance our exports value such as real value of total exports, real export value of industrial sector, and real export value of heavy-chemical through total energy use and oil consumption. Ghartey (1993) follows the Granger causality tests of Hsiao's (1979) version to confirm that exports growth causes economic growth in Taiwan. Following this literature, increasing total energy consumption and oil consumption quantity may causes economic growth. However, Kwan et al. (1996) address the result of their research is conflict with the export-led growth hypothesis in Taiwan. Furthermore, this study finds oil consumption may Granger causes real value of total imports and real export value of non-heavy-chemical industrial products negatively. It implies oil conservation may enhance our imports value and reduce our trade surplus. Lee and Chang (2005) show unanimously in the long run that energy acts as an engine of economic growth in Taiwan, and it implies that energy conservation may harm economic in the long-run.

Yang (2000) uses Granger causality test based on 1954-1997 in Taiwan to test the causality issue between coal consumption and economic growth. The co-integration and Granger causality test are applied to investigate the relationship between the two economic series. Results of the co-integration show a unidirectional causality from economic growth to coal consumption, and support the neutrality hypothesis of coal consumption with respect to economic growth. Even though this study does not find the neutrality relationship between coal consumption and export variables, but the conclusion is the same. That is, to make a suitable policy decision in the area of macroeconomic planning, coal conservation is a feasible policy with no damaging repercussions on economic growth.

Yoo (2006a) shows that there exists bi-directional causality running from coal consumption to economic growth with feedback. Our findings only observe Granger causal relations running from trade variables to coal consumption. It is likely that the greater value industrial sector produce is, the greater coal demand in the next period will be, implying that coal is one of the major raw materials of industrial sector. Once we separating industrial sector to two parts- heavy-chemical industrial sector and non-heavy-chemical industrial sector, this study finds both of their value of export products will Granger cause coal consumption negatively. These results coincide with *Hypothesis 3d* and *Hypothesis 3e* of this study.

The bi-directional causality between natural gas consumption and real value of non-heavy-chemical industrial products is observed in this study. Both shock directions in this Granger causal relationship are negatively. It seems that the development of non-heavy chemical industry contains close relation with natural gas consumption. Since there is no research to discuss this before, this study infers that it is a kind of index to predict the development of non-heavy-chemical industry. For example, if the consumption of natural gas arises, the development of non-heavy-chemical industry will probably enhance.

However, Taiwan is an extreme example that its dependence degree of imported energy is approaching 100%, and it is really a serious problem while energy resources get exhausted. Under the circumstances that economic development and trade performance enhance stability, energy demand will still increase continuously. The increasing energy consumption will influence national security, economic development, and carbon dioxide. Therefore, we should be more positive to develop renewable energy, even the process of expanding renewable energy has been started for a long time. However, public subsidies could be a measure, but it also increases government expense and budget deficit. The preferential loan is also a feasible measure to promote the use of clean energy. According to the *Second-Stage Rules of Preferential Loan for Purchasing Clean Energy Equipment* (Bureau of Energy, 1999), there have been preferential loans to enterprises and households to adopt clean energy. Compared to direct subsidies, preferential loans make the users pay more but still provide incentive and can ease the government's deficit. Moreover, the development of clean energy industry in Taiwan, such as wind energy, solar energy, biomass energy, hydro energy, and geothermal energy, can also provide employment opportunity and promote export.

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