A Multivariate Cointegration Analysis of the Role of Oil in the Thai Macroeconomy

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Abstract

This paper estimates an error correction model of the aggregate production function for Thailand. Unlike previous studies focusing on testing causal relationship between energy consumption and economic growth, this paper places an emphasis on measuring the elasticity of economic growth with respect to oil consumption and oil prices. The results suggest there is a constant-return to scale aggregate production function with the contribution of labor, oil and capital to output around 68, 19 and 13 percent respectively. The long-run and short-run contributions of oil consumption to the economy appear to be fairly close, suggesting that the role of oil in is critical propelling Thai economy. In the short run, oil shortage produces a much more severe impact on the Thai economy than the effect from oil price shock. A short fall in oil consumption by 10 percent might cause economic growth to shrink by 2 percent within the same year, while a sharp rise in the oil price by 10 percent can lead to a fall in output growth by about 0.5 percent. Also, we find an Okun's Law type relationship between output and employment. In the short run the response of output to increases and decreases in oil price is asymmetric. The model developed here is useful in oil-macroeconomic scenario analyses for Thailand.

I. Introduction

Thailand has experienced a remarkable record of economic expansion during the past three decades. The national output has grown by about six percent per year in real term between 1976 and 2007. The economy has developed gradually from traditional agriculture toward more modernized manufacturing and service industries. It has long been realized that energy enhances the productivity of capital, labor and other factor of production. Therefore, the continuing development in the energy sector has been necessary to serve the rapid increase in energy demand, of which oil has taken about 50 percent[1] share over time.

Oil consumption has risen more than fivefold since 1976. However, faced with the scarcity of indigenous resources, Thailand has relied heavily on crude oil and petroleum products from foreign sources especially the Middle East. This has made Thailand susceptible to the adverse impacts of both types of oil shocks: supply shocks and price shocks. Since the first oil shock in 1973, at least three more major oil shocks have occurred: the Iran/ Iraq crisis in the late 1970s, and the Gulf Wars I and II in 1990-1991 and 2003. Future oil shocks will occur. Consequently understanding the volatility of the oil markets and their impact on the performance of Thailand's economy are important.

There is a recurring question in the existing literature. What are the short-run and long-run macroeconomic impacts of oil shock? Numerous studies have been done in this area for developed countries. Less research has been conducted for developing countries. Moreover, the methodologies in these empirical studies are mostly geared towards testing the Granger causality relationship between output and energy rather than trying to measure the quantitative impact of energy on output. We contribute to the existing literature by examining the impacts of oil shocks in a dynamic model of economic growth using time-series data from 1976 to 2007. We believe this is the first research incorporating both short-run and long-run information to model aggregate output in Thailand from the supply-side perspective and accounting for oil price effects at the same time under an error correction modeling framework.

Our results suggest the existence of a long-run cointegrating relation between GDP and factors of production i.e. capital, labor and oil. In addition, the aggregate production function exhibits constant returns to scale. The short-run elasticity of output with respect to oil use is positive and almost equal to its long-run counterpart. We employ a time trend to capture technological effects and dummy variables to capture the effect of the Asian financial crisis in the period 1997-98. Both help to significantly improve the performance and stability of the model. The unrestricted VAR system is able to be reduced to a two equation conditional VeqM. This conditional model provides insights into the role of oil in economic growth and employment dynamics.

The paper is organized into six sections. Section II is a review of literature on energy and the macroeconomy. Section III has an explanation of the theoretical production function model. Section IV describes the data used in the analysis. Section V discusses model and the empirical results. Section VI of the paper summarizes the findings and policy implications.

[1] Oil has maintained its share at a steady level throughout the period of study. The data show that in 2007 the share of oil, electricity, natural gas, coal and renewable energy are 49, 18, 6, 10 and 17 percent of the final energy consumption respectively.

II. Literature Review

The role and importance of energy in the macroeconomy has long been controversial among economists and energy analysts. This is true for industrialized and developing countries. Empirical studies have examined the issues from reduced form, demand, and supply perspectives. Single time series equation and VAR techniques popularized by Sims (1972) are used to address the issues. One question has been to look at "causality" using Granger tests (1969). Cointegration analysis has been used to place more structure on the dynamics by distinguishing between the short-run and long-run. Investigators look at whether there is one way causality and feedback between GDP growth and energy. Oil consumption studies have focused on own price elasticity and income elasticity studies. Supply side research has used (aggregate) production functions. The results of these studies are inconclusive. This review focuses on the empirical macroeconomic-energy research for Asian developing countries.

Yu and Choi (1985) find mixed results in their analysis of the Philippines, South Korea, and Thailand. The results suggest that past income leads to future energy use, but not the reverse. The opposite appears to be true for the Philippines. They found feedback between income and energy for Thailand. ***more to follow***

Masih and Masih (1998) study energy demand in Thailand and Sri Lanka covering the period of 1955-1991. They employ cointegration techniques to study the causality between energy consumption and economic growth in these two countries. Specifically, they use a vector error correction model (VECM) instead of a vector autoregressive model (VAR) since they argue that the VECM can distinguish between the short-run and long-run relationship among variables and can identify sources of causation that cannot be detected by the usual Granger causality test. Their results suggest there is evidence to support a long-run cointegration relationship between total energy consumption, real income and price level for both countries. They argue that long-run causality runs from energy consumption to income but not in another direction for both countries. Masih and Masih found short-run causality from energy consumption to income in Sri Lanka but not Thailand.

Asafu-Adjaye (2000) conducted a demand study on India, Indonesia, Philippines, Thailand, and Turkey for 1973 through 1995. The causality runs from energy to GDP for India and Indonesia. The results suggest that GDP leads energy use in Turkey. The Philippines and Thailand have feedback between the two; the causality runs in both directions. ***check this one***

Oh and Lee (2004) use VECM techniques like Masih and Masih (1998). They construct two multivariate models. The first is a "demand side model" consisting of three variables: energy, income and energy price. The next one is a "production side model" with four variables: income, energy, capital and labor. Their objective was to test for causality relationships between energy consumption and economic growth for Korea. Their results suggest that there is a long-run unidirectional causal relationship running from GDP to energy, but there is no short-run relationship between energy and GDP.

Fatai ***et.al*** (2004) conduct a demand study for India, Indonesia, Philippines, and Thailand using data from 1960 to 1999. Their results are similar to Asafu-Adjaye. There appears to be

one way causation from energy to income in India and Indonesia. There is feedback between energy and the GDP in the Philippines and Thailand.
check this one

Lee (2005) studies the co-movement and causality relationship between energy consumption and GDP by looking at eighteen developing countries for the period 1975 to 2001. Lee employs panel-based error correction models using on GDP, energy consumption and capital. The results suggest there are long-run and short-run causation between energy consumption to GDP but not the reverse. ***Do he identify the relationship?***

Yoo (2006)

Lee and Chang (2008) reinvestigate the causal relationship between energy consumption and GDP, applying a panel-based error correction model and including capital stock and labor for 16 Asian countries during the period from 1971 to 2002. Their model is a production side model like Oh and Lee (2004). Their results suggest that although the evidence does not support a short-run relationship between economic growth and energy consumption, a unidirectional long-run relationship running from energy consumption to economic growth does exist.

Table 1 summarizes the empirical research on Thailand from their comparative survey.

III. The Aggregate Production Function Model

We employ a standard aggregate energy economic production function to explore the relationship of economic growth and energy. except that I focus more on a specific type of energy in the model and replace the whole energy consumption with only oil consumption which has long been a dominant energy for Thailand. The production function can be written as follows:

$$Y_t = f(K_t, L_t, Oil_t, A_t) \quad (1)$$

where Y_t is real GDP, K_t is lagged real total capital stock, L_t is total labor employment, Oil_t is the total oil consumption in the economy, and A_t is a proxy for institutional and technological change. The Cobb-Douglas functional form has been applied with Equation (1) and it follows that

$$Y_t = e^{\beta_1} K_t^{\beta_2} L_t^{\beta_3} Oil_t^{\beta_4} A_t^{\beta_5} e^{\varepsilon_t} \quad (2)$$

where ε_t is the random disturbance term. The model is estimated traditionally by taking natural logarithms and applying the ordinary least squares in which the assumption of constant return to scale can be tested for capital, labor, and oil, $\beta_2 + \beta_3 + \beta_4 = 1$. The functional form for single equation estimation can be written as

$$y_t = \beta_1 + \beta_2 k_t + \beta_3 l_t + \beta_4 oil_t + \beta_5 A_t + \varepsilon_t \quad (3)$$

The lower case letters in Equation (3) represent variables in natural logarithms while the upper case letters in previous equations are in levels. The deterministic elements such as trend and dummy variables can be included in Equation (3) if it is appropriate and it is represented by A_t.

IV. Data

This section of the paper discusses the data sources and the description of the variables that are used in the estimation. The data for the econometric analysis cover the period from 1974 to 2007. All nominal variables are converted into real values by deflating with GDP deflator with 1988 as the base year.

The annual GDP and capital stock series were obtained from the National Economic and Social Development Board (NESDB), Office of the Prime Minister. The GDP Deflator and Labor Employment are from the Bank of Thailand (BOT). The Oil consumption[2] series was obtained from the BP (British Petroleum) Statistical Review of World Energy June 2008 which is available online and has been updated annually.

We plot the main series against real GDP. Figure 1 shows real GDP and oil consumption; the scale for the later is on the right axis. Real GDP grew from 600 Billion Baht to almost 4,424 Billion Baht in 2007. The compound growth rate for the sample is about 6.1%. (Table 2 contains a breakout of the growth rates in real GDP, oil consumption, capital stock, and employment over the sample.) Oil consumption has moved closely with GDP. In 1974, total oil consumption was approximately 56 million barrels; by 2007 it had grown five times to over 332 million barrels; the compound growth rate was almost 6.1%.

When the economy grows, oil consumption tends to grow at a slightly faster rate than the output, but in the recession period oil consumption declines at a slower rate than that of the output. For example in the Asian Financial Crisis of 1997-98 the economy fell 1.4% and 10.5%. Oil consumption slowed down to 1.2% in 1997 and fell more than 6% in 1998. In 2005 through 2007 oil consumption did flatten out while GDP growth declined some just below 5% annual growth. The oil consumption to GDP intensity has stayed in the neighborhood of 85 barrels per real 1988 billion baht as shown in Figure 2.

Energy consumption has diversified to different fuels with economic growth and development. While data which illustrates this only goes back to 1980, the fuel mix picture would not have changed significantly if the 1970s were included. Figure 3 shows the shares of final energy consumption. Oil or petroleum's has stayed about 50% of total. The share of renewable energy declined steadily from over 40% in the early 1980s to below 20% by 1995 and has stayed at about 17%. Electricity consumption and share has more than doubled over the last 27 years. Prior to the 1980s electricity was generated almost exclusively from oil-fired plants. Coal and natural gas consumption shares have risen with the rapid growth in electricity. The growth in these three energy supplies has replaced the major role of renewable energy in the market.

[2] The definition of oil consumption data given by BP is: "*oil consumption data includes inland demand plus international aviation, marine bunkers and oil products consumed in the refining process. Consumption of fuel ethanol and biodiesel is also included.*"

Final energy consumption expenditure shares show that that importance oil or petroleum has not diminished either. See Figure 4. In fact the share of spending on oil has increase from 50% to over 60% in the last 17 years. The next largest share has been electricity which has been steady at about 70% since 1990. Data limitations restrict the sample to post 1990.

Oil is critical to the performance of the Thai economy domestically and in trade. Figure 5 contains two graphs; the sample is 1981-2007. The first shows the cost share of crude oil and petroleum products in total imports since 1981. In the early 1980s it was over 20% when the prices were very high. The share of oil imports fell to about 6% in 1996, but has risen back up to 16% by the end of the sample. The bottom graph illustrates oil imports as a share of energy imports. Oil imports comprised over 96% of energy imports prior to 2000. There is a sharp drop in 2001 to 88% where it has remained since then. The new imports are electricity from Laos and the net imports of natural gas.

During the period 1973 – 2007, the value of real capital stock has grown from 2,075 to 17,507 Billion Baht. The capital stock has grown at 6.1%, roughly the same rate as the GDP, over the full sample, but there have been divergences. In the 1970s GDP grew faster than investment, this reversed in the 1980s and most of the 1990s thereafter they have grown together. Following the Asian crisis GDP growth slowed down, but real net investment actually declined by 13% in 1999. However, it has bounced back later; since 2003 net investment increased by 20 percent to above previous level. These developments can be seen in Figures 6 and 7 which plot the variables and then the capital output ration respectively.

Employment has grown at an annualized rate of 2.25 percent annually from 17 million to 37 million. During the first two decades it grew more than three per cent per annum, slowed to less than one per cent, 0.7%, in the 1990s, and has increased about 1.7% per annum since 2000. Output per worker has growth about 3.7% per annum. The boom and bust in the economy appears to slightly affect fluctuations in the labor employment. These dynamics can be seen in Figures 8 and 9.

The oil price series is the weighted average of the real oil price of all refined petroleum products 1974. There are seven petroleum products: premium gasoline, regular gasoline, high-speed diesel, low-speed diesel, fuel oil, kerosene and LPG (Liquefied Petroleum Gas). The price and consumption data for petroleum products were obtained from the Energy Policy and Planning Office, Ministry of Energy of Thailand. The original units for the oil price are in baht per litre. The individual nominal prices are shown in Figure 10.This was converted to baht per barrel using the conversion factor[3] and then deflated by GDP deflator to become the real price. The weighted nominal price is largely dominated by the price of high-speed diesel which is about 42 percent share of the total oil consumption. The final step computed the average real price of petroleum products weighted by the consumption share of each respective petroleum product. Figure 11 shows the nominal and real weighted oil price per barrel.

V. Empirical Results

[3] 1 litre is equal to 0.006289704 barrel

The approach used in this paper is the general-to-specific modeling approach advocated by Hendry (1986) and Hendry and Juselius (2000, 2001). As pointed by Joutz (2004), the principal concept of this approach is to characterize the properties of sample data in simple parametric relationships which remain reasonable constant over time and make sense in economic meaning. The model starts with a general model which includes all relevant explanatory variables and dynamic process. Then, the model reduction process has been conducted by testing for simplification and including relevant restrictions in order to achieve the final parsimonious model which can encompass several other alternative models.

We develop a time series econometric model of German goods exports utilizing information on relative cost competitiveness, export demand, and the structure of production in the export sector. The analysis makes use of integration, cointegration, and error correction in their reduction to the local data generating process and its interpretation.

There are five major steps involving in the general-to-specific modeling approach. First, examine the time series properties of the data by checking for the stationarity of the series and the order of integration. Second, formulate a system of vector autoregressive regression (VAR) which involves several tests including the appropriate lag length tests, residual diagnostic tests and system stability tests. Third, test for potential cointegrating relations of the variables. Fourth, interpret the cointegrating relations and test for weak exogeneity. Lastly, formulate the vector error correction model (VECM) which employs the cointegration result found in the previous step. The last step involves the model reduction process and conducting the residual diagnostic tests as well as model stability tests. The outcome from these five steps is the final specific (parsimonious) model which will be used for further economic interpretation and prediction.

V.1 Unit Root Tests

I follow Campbell and Perron's (1991) suggestions to investigate the presence of unit roots in the series by using Augmented Dickey-Fuller (ADF) test. There are three forms of ADF regression specifications used for the test.

$$\Delta z_t = \delta_1 z_{t-1} + \sum_{i=1}^{p} \theta_i \Delta z_{t-i} + \varepsilon_t \tag{6}$$

$$\Delta z_t = \delta_0 + \delta_1 z_{t-1} + \sum_{i=1}^{p} \theta_i \Delta z_{t-i} + \varepsilon_t \tag{7}$$

$$\Delta z_t = \delta_0 + \delta_1 z_{t-1} + \delta_1 t + \sum_{i=1}^{p} \theta_i \Delta z_{t-i} + \varepsilon_t \tag{8}$$

For any series z_t, three forms of ADF regression specifications have been used for unit root tests as shown in Equation (6) to (8). These three specifications differ in terms of the assumption underlying the deterministic component terms in the series. Equation (8) contains both intercept, δ_0, and trend term, t, while there is no intercept and trend term in Equation (6). Equation (7) has only the intercept term but not trend term.

The results of the unit root tests based on Equation (5) to (7) are presented in table A1. The tests have been applied with the log level series and the first difference series. The results of the log level series are shown in the upper panel of tale A1 while the results of the first difference series are reported in the lower panel of the same table. The null hypothesis of the ADF test is whether there exists the unit root in the series. If the null cannot be rejected by comparing the test statistics with the critical values of the ADF tests, it can be concluded that there is a unit root and the series is nonstationary.

The results on the upper panel of table A1 indicate that there are evidences to support that all level series contain unit root. This implies that they are nonstationary and possibly are integrated of order one, I(1). The results in the lower panel are from the test of the same hypothesis on the first difference series and it was found that the null hypothesis of unit root can be rejected in most cases. Combining the results in two parts, it can be concluded that GDP, capital, labor and oil consumption series are I(1) and stationary in their first difference.

V.2 The VAR system

I specify the VAR of a four variable system with a sample period from 1976 to 2007. The model includes the log level of the real GDP, the real capital stock, the labor employment, the total quantity of oil consumption, a trend term and a dummy variable. Between 1997 and 1998, there was a sharp decline in all variables as a result of the 1997 Asian Financial Crisis which took place in Thailand for the first country in Asia.
The Asian Financial Crisis originally took place in Thailand in July 1997 but the impact on each variable still persisted and reached its peak in 1998. Therefore, the dummy variable for the year 1997 and 1998 are introduced to control for the effect of this special event on the variables. A pulse dummy[4] with a value unity in 1998 was constructed and included in the model to capture this unusual effect of the crisis on the variables. The VAR system can be written as follows:

$$X_t = \prod_0 + \sum_{i=1}^{k} \prod_i X_{t-i} + E_t \tag{9}$$

where $X_t = \begin{bmatrix} y_t \\ oil_t \\ k_t \\ l_t \end{bmatrix}$ and the last term E_t is a matrix of white noise error terms. $\prod_0$ is a matrix of deterministic component which includes constant term, trend term and dummy. $\prod_i$ are a coefficient matrices at different lags. k is the appropriate lag length chosen by statistical criteria which will be discussed later.

The appropriate lag length for the VAR and cointegrated analysis was determined by the results from two statistical tests. First, I used the Information Criteria including AIC (Akaike

[4] A pulse dummy variable for 1997 is not included in the VAR system since the shock took place in the second half of the year and the effects from the shock are not explicitly displayed in the annual data. However, I did include a dummy 1997 in the error correction model to capture the effect that might take place in the short run during that year.

Criterion), SC (Bayesian Schwarz Criterion) and HQ (Hannan-Quinn) to consider the trade off between bias (too few lags) and variance (too many lags). Second, the Wald F-tests which compare the fit of the maintained model against the reduction model which excludes the number of lags of explanatory variables.

The VAR system was started at three lags called VAR(3) and then the tests as mentioned above had been conducted. The test results are presented in Table A2. For the Information Criteria, the results are not consensus. The SC values declines continuously from -12.33 at three lags to -13.46 at one lag. But, the AIC and HQ reduces from -15.08 and -14.16 at three lags to -15.12 and -14.46 at two lags respectively. Therefore, with the SC, it suggests that the appropriate lag length should be one while AIC and HQ supports the lag length of two. Considering the Wald F-tests, it was found that the null hypothesis of lowering the lag length from three to two could not be rejected with the *p*-value of 0.48 but the null hypothesis of reducing the lag from two to one was rejected with the *p*-value of 0.03. Hence, with the results from these tests, it seems reasonable and appropriate to use the lag length of two in this study.

V.3 Cointegration Analysis

Cointegration analysis helps us express the long-run relationship between integrated variables. On the theoretical point of view, it seems reasonable to expect such a long run relationship to exist between the log of GDP (*y*) and the log of other factors of production including capital stock (*k*), labor employment (*l*) and oil use (*oil*). In this study, I follow the Johansen's (1988) and Johansen and Juselius's (1990) cointegration test procedure which is the maximum likelihood approach. The procedure is run on the second-order VAR as it is statistically acceptable to simplify the third-order to second-order VAR as discussed in the earlier section. Given the chosen lag length of two, the VAR system in Equation (9) can be rewritten

$$X_t = \Pi_0 + \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + E_t \qquad (10)$$

The X_t is a (4x1) vector of nonstationary variables that are integrated of order one, I(1). The $\prod_i$ are (4x4) coefficient matrices at different lags. $\prod_0$ is a (4x3) matrix of deterministic component including a constant, a time trend and a dummy 1998 variable. E_t is a (4x1) vector of white noise error terms. The system in level can be converted to a model in first differences and the error correction term by subtracting X_{t-1} from both sides of Equation (10) and rearrange the terms to obtain a more appropriate form for cointegration analysis. The new form of this equation is known as vector error correction model (VECM).

$$\Delta X_t = \Pi_0 + \Gamma_1 \Delta X_{t-1} + \Pi X_{t-1} + E_t \qquad (11)$$

The ΔX_t is a vector of (4x1) containing only stationary, I(0), variables. The term ΠX_{t-1} contains the cointegrating relations among I(1) variables and must be I(0) by definition. The coefficient matrix $\Pi = -I + \Pi_1 + \Pi_2$ and $\Gamma_1 = -\Pi_2$. If the cointegrating relations exist, the matrix Π has a reduced rank of $r <$ 4 and it can be partitioned as $\Pi = \alpha\beta'$ where r is the number of cointegrating relations; α is matrix of speed of adjustment coefficients and β is matrix of cointegrating relation parameters. The rank of Π can be tested by using Johansen

(1998) approach. These tests check for the number of characteristic roots by using the trace statistics and the maximum eigenvalue statistics.

Table A3 presents statistics and estimates for Johansen's procedure applied to the second-order VAR. The number of rank in the first column represents the number of cointegrating relations to be tested in the null hypothesis. The trace statistics test the null hypothesis of 0,1,2 or 3 cointegrating relations against the alternative hypothesis of more than 0,1,2 or 3 in each corresponding row. The maximum eigenvalue statistics test the null hypothesis of 0,1,2 or 3 cointegrating relations against the alternative of 1,2,3 or 4 cointegrating relations in each corresponding row. The maximum eigenvalue and trace eigenvalue statistics strongly reject the null hypothesis of no cointegration in favor of at least one cointegration relationship. Although there is evidence that there might be more than one cointegration relation, the result is not strong enough and it can be safely ignored.

Table A5 reports the standardized eigenvector (β vector in the upper panel) and adjustment coefficients (α vector in the lower panel). These vectors are conditional on different set of assumptions imposed on the cointegrating vectors. The first column of the table is the original standardized cointegrating vector without any restrictions imposed. The implied cointegrating relationship can be written in the form of:

$$y = 0.182 * oil + 0.273 * k + 0.563 * l + 0.013 * trend \qquad (12)$$

All coefficients in Equation (12) have their anticipated signs. The test for weak exogeneity has been conducted to test whether disequilibrium in the cointegrating relationship feeds back into a subset of the associated endogenous variables. Oil, capital and labor appear weakly exogenous, whether tested individually or jointly. For the individual test, the null hypothesis of weak exogeneity cannot be rejected at 5 percent for all three variables i.e. $\chi^2(1)$ = 0.011 with *p*-value of 0.915 for oil, $\chi^2(1)$ = 3.776 with *p*-value of 0.052 for capital, and $\chi^2(1)$ = 1.955 with *p*-value of 0.162 for labor. However, one might argue that the result of weak exogeneity test for capital and labor might turn out to be significant if the significance level is set at 10 and 20 percent respectively. I agree with this concern and will proceed to the next step with high caution when formulating the VECM.

The results of the joint tests of weak exogeneity conducted in pairs and all three variables together are reported in lower panel of Table A6. The test statistics indicate that all three variables are jointly weakly exogenous with $\chi^2(1)$ = 7.291 and *p*-value of 0.063, but the joint test of weak exogeneity for only capital and labor can be rejected with $\chi^2(2)$ = 6.959 and *p*-value of 0.03. These results seem to suggest that the possibility of feedback into endogenous variables from the cointegrating relation cannot be fully eliminated from my consideration. Therefore, I will proceed to the next step in two ways by formulating the VECM of single equation and the VECM of a system of two equations. The details of these two approaches will be discussed at the end of this section.

With the weak exogeneity restriction imposed on all three variables, the cointegrating relationship becomes Equation (13). The estimated coefficients in Equation (13) are not much different from those in Equation (12).

$$y = 0.235 * oil + 0.128 * k + 0.719 * l + 0.016 * trend \quad (13)$$

If the weak exogeneity conditions are imposed only on capital and labor, the cointegrating relation becomes

$$y = 0.275 * oil + 0.087 * k + 0.727 * l + 0.017 * trend \quad (14)$$

In addition, the tests of individual and joint significance of parameters in β vector were conducted. The null hypothesis of zero coefficient for labor is strongly rejected with $\chi^2(1)$ = 5.7490 [0.0165] as shown in table A6 while for oil and capital it cannot reject the null individually. However, with the joint test, oil and capital appear to be jointly significant at 10% with $\chi^2(2)$ = 4.9363 [0.0847] and the result becomes statistically stronger when the weak exogeneity condition was also imposed in the test with $\chi^2(5)$ = 10.985 [0.0517]. This may be partially explained by the fact that Thailand is a labor intensive economy. Historically, the aggregate output was dominated by the agricultural sector while currently it is driven by the service sector where both sectors rely largely on labor input. Moreover, to run machines and capital-intensive equipments, it requires the use of energy like oil and electricity. Thus, it might be the reason in explaining the jointly significant results rather than individually significant results for capital and oil.

It is noticeable that the sum of the three inputs' coefficient is roughly close to unity. The long-run unit homogeneity test has thus been conducted and it shows that the null cannot be rejected: $\chi^2(1)$ = 0.018561 [0.8916]. This implies that the aggregate production function of the Thai economy appears to exhibit a constant-return-to-scale (CRTS) characteristic in the long run. I also conduct the homogeneity test along with the jointly weak exogeneity test and the result shows that the null still cannot be rejected as well with $\chi^2(4)$ = 7.6757 [0.1042] and the cointegrating vector then becomes

$$y = 0.192 * oil + 0.128 * k + 0.680 * l + 0.019 * trend \quad (15)$$

The results from cointegration analysis suggest that Thailand's elasticity of output with respect to oil, capital and labor are approximately equal to 0.19, 0.13 and 0.68 respectively i.e. Labor takes the largest share of contribution in output by about 68 percent followed by oil at 19 percent and capital at 13 percent. The aggregate output tends to grow normally by about 0.02 percent every year given other things constant. If there is only homogeneity assumption imposed, the coefficient estimates for oil, capital and labor are still fairly close at 0.17, 0.28 and 0.55 as shown in column 4 of table A5.

As discussed earlier that the jointly weak exogeneity condition for capital and labor is significant, it is interesting to test this condition again along with the homogeneity condition. The result shows that it cannot reject the null hypothesis that the aggregate production function exhibits the constant-return-to-scale characteristic while imposing the weak exogeneity condition on capital and labor which can be expressed in the following equation:

$$y = 0.227 * oil + 0.089 * k + 0.684 * l + 0.02 * trend \quad (16)$$

Details of Equation (16) are presented in the last column of table A5. As mentioned earlier that I will proceed to the next step by using two approaches i.e. 1) formulating the VECM of single equation and 2) formulating the VECM of a system of two equations. Each VECM has its own *ECM* term which reflects the underlying assumption of each approach. For the VECM of single equation approach, the *ECM* term must reflect the assumption that there is no feedback into endogenous variables and thus it should be derived from Equation (15) given that the CRTS assumption also holds. This *ECM* term is called $ECM1$ which is of the form:

$$ECM1_t = y_t - 0.192 * oil_t - 0.128 * k_t - 0.680 * l_t - 0.019 * trend \quad (17)$$

The other *ECM* term for the VECM of two-equation system is derived from Equation (16) which assumes that the CRTS assumption holds and there is a feedback into the variables either labor or capital. This *ECM* term is called $ECM2$ and it can be written as follows:

$$ECM2_t = y_t - 0.227 * oil_t - 0.089 * k_t - 0.684 * l_t - 0.02 * trend \quad (18)$$

The ECM term is derived from the long-run relationship and it expresses the deviation in aggregate output from its long-run mean. The single equation approach implies that the cointegrating vector and the feedback coefficients enter only the GDP equation. Therefore, inferences about the parameters can be conducted from a conditional model of the GDP alone without any loss of information. But the system of two equations assumes that the cointegrating vector and the feedback coefficients enter both the GDP equation and the other variable simultaneously. The VECM analysis will be discussed in the next section.

V.4 The Short-run Error Correction Model

The cointegration analysis in the previous section gives the long-run relationship among the variables. However, to capture both short-run and long-run effect of output growth, a short-run error correction model must be employed. Under the error correction model framework, the variables are modeled in first differences (i.e. the growth rate) and the coefficient of variables represents the short-run elasticity of output with respect to the corresponding variable. Within the model, it also includes the ECM term derived from the previous part. The coefficient of the ECM term represents the speed of adjustment in current output production to the previous equilibrium level. It is interesting to understand how oil price affects the aggregate output in the short run. Therefore, the real oil price derived from the weighted real price of all petroleum products in Thailand has been included in the model at this point. This section is divided into two parts. The first part focuses on the VECM of single equation while the second part considers the VECM of system of two equations. The results will be compared at the end of this section.

V.4.1 VECM of single equation

The general form of the aggregate output model can be written as:

$$\Delta y_t = \beta_0 + \sum_{j=1}^{p} \beta_{1i} \Delta y_{t-j} + \sum_{i=0}^{p} \beta_{2i} \Delta k_{t-i} + \sum_{i=0}^{p} \beta_{3i} \Delta l_{t-i} + \sum_{i=0}^{p} \beta_{4i} \Delta oil_{t-i} + \sum_{i=0}^{p} \beta_{5i} \Delta oilprice_{t-i} + \beta_6 dummy97 + \beta_7 dummy98 + \alpha ECM1_{t-1} + \varepsilon_t \quad (19)$$

where p is the lag length set at one lag. The contemporaneous values of oil, oil price, capital and labor are included to capture the immediate short-run effect on output of the respective variable. The dummy variables, $dummy97$ and $dummy98$, were included in the model to represent the effects from the shocks of the Asian financial crisis which started in July 1997 and spread its negative impacts throughout the whole economy in 1998.

The results of the single-equation model are presented in table A7. The graphical analysis of the model including the residual diagnostic and the parameter constancy tests are presented in figure A8 and A9 respectively. The test results in table A7 show that the general model of the aggregate output has performed well on the statistical point of view. No evidence shows that there is a problem of autocorrelation, conditional heteroscedasticity and normality. These results are also confirmed by the residual diagnostic tests in figure A7. The graphical analysis in figure A8 shows that one-step residuals lie within two standard error confidence bounds. The stability of the model as indicated by one-step and break point Chow test suggest the rejection of the null hypothesis of structural breaks.

In the next step, the final parsimonious model of the aggregate output was obtained from the model reduction procedure by applying general-to-specific modeling algorithm known as Autometrics to the General Unrestricted Model (GUM). The basic ideas of this model reduction is that it eliminates irrelevant variables from the general model and retains only meaningful variables by employing statistical tests of misspecification through residual diagnostics and evaluating the final models through encompassing tests as suggested by Hendry and Krollzig (2001). In this study, the significance level of 5 percent was chosen as a cut off point of irrelevant variables. The final results of the parsimonious model are presented in table A8. These results show that the model does not have any problem of autocorrelation, conditional heteroscedasticity and normality. The residual diagnostic test in figure A10 also confirms these test results graphically. The stability test conducted by one-step and break point Chow test in figure A10 indicate no evidence of structural breaks. The model in Equation (19) therefore has been reduced to Equation (20). The number of estimated parameters has been reduced from 13 to 8 in the final model which can be shown as follows:

$$\underset{(4.86)}{\Delta y_t = 1.86} + \underset{(5.80)}{0.22} * \Delta oil_t + \underset{(4.82)}{0.17} * \Delta oil_{t-1} - \underset{(-2.40)}{0.04} * \Delta oilprice_t \quad (20)$$

$$- \underset{(-2.69)}{0.15} * \Delta l_{t-1} - \underset{(-3.99)}{0.05} * dummy97 - \underset{(-10.5)}{0.13} * dummy98 - \underset{(-4.73)}{0.21} ECM1_{t-1}$$

where t-statistics are reported in parentheses. Equation (20) explains the relationship between the growth rate of output, Δy_t, and relevant explanatory variables. As capital variables have been completely dropped out during the process of model reduction, it might suggest that the immediate impact on output growth of Thai economy is mainly influenced by oil and labor. Capital has only the long run effect on output through the long run adjustment process. The *ECM* term is significant and negative as theory predicts. It indicates that a deviation either above or below the long run output growth in this period is corrected by about 21 percent in the next year. Although the sign of the lagged labor growth is negative, this finding is quite similar to what found in the study by Gardner and Joutz (1996) using U.S. data. The dummy variables of financial crisis in 1997-98 are significant and have negative signs as expected. The year 1998 has a stronger negative impact on economic growth than 1997.

Oil consumption has a positive and significant impact on output in the short-run. A one percent increase in oil consumption in this period and the previous period can lead to an increase in aggregate output by 0.22 and 0.17 percent respectively. Since the coefficient of Δoil_t and Δoil_{t-1} are close to each other, the coefficient equality restriction has been tested. The test result shows that the $\chi^2(2)$ is 0.49 with a *p*-value of 0.48 thus the null hypothesis of coefficient equality cannot be rejected. As a result, the two series were combined to be $\Delta oilcmb_t$. The model has been re-estimated and the results are as follows:

$$\underset{(4.97)}{\Delta y_t = 1.87} + \underset{(10.5)}{0.19} * \Delta oilcmb_t - \underset{(-2.96)}{0.05} * \Delta oilprice_t \tag{21}$$

$$- \underset{(-2.92)}{0.16} * \Delta l_{t-1} - \underset{(-4.19)}{0.05} * dummy97 - \underset{(-11.1)}{0.13} * dummy98 - \underset{(-4.83)}{0.21} ECM1_{t-1}$$

From the estimated result, it can be interpreted that an increase in oil consumption by one percent in the short run leads to a higher economic growth by 0.19 percent. If the output response to increases and decreases in oil consumption is assumed to be symmetric in the short run, it can be claimed that a sudden reduction in oil consumption by 10 percent, which might be due to a huge oil supply shock around the world, can cause the economic growth to fall by 1.9 percent within the same year.

Comparing with the long-run elasticity of output with respect to oil found in Equation (15), the short-run combined effect of oil consumption on output is approximately equal to its long run counterpart. This result implies that the role of oil consumption to Thai economy has never been declined even in the long run. The impact of oil shortage is still great and this can reflect the degree of oil dependence for Thai economy fairly well.

Considering the oil price effect on output growth, Equation (21) suggests that a one percent increase in oil price can slow down the economic growth in the short run by 0.05 percent. However, this is based on the assumption of symmetric effect of oil price on the economic growth. Therefore, I divided the oil price variable into a positive price change called $\Delta poilup_t$ and a negative price change called $\Delta poildown_t$ and then tested the hypothesis of symmetric effect of oil price. The estimated equation is as follows:

$$\Delta y_t = 1.87 + 0.19 * \Delta oilcmb_t - 0.05 * \Delta poilup_t - 0.05 * \Delta poildown_t \quad (22)$$
$$(4.69) \quad (10.2) \quad (-2.13) \quad (-0.77)$$

$$- 0.16 * \Delta l_{t-1} - 0.05 * dummy97 - 0.13 * dummy98 - 0.21 ECM1_{t-1}$$
$$(-2.83) \quad (-4.10) \quad (-10.9) \quad (-4.57)$$

It turns out that the positive oil price change is significant at 5 percent with approximately the same magnitude as what found earlier in Equation (21) in which assumption of symmetric price effect holds. But, the negative oil price effect turns out to be not statistically different from zero. This finding is quite interesting since from the historical records oil price had been partially regulated by the Thai government. The national oil fund had been established by law as an important tool for the government to intervene the market when it was necessary to ensure that domestic oil prices were not radically adjusted through time. This reason might explain why the increase in oil price seems to produce a smaller effect on Thai economy comparing with what had been found by Gardner and Joutz (1996) at 0.08 for the U.S. economy.

V.4.2 VECM of a system of two equations

As it might be suspected that there is another transmission channel which can affect the aggregate output, this part examines another alternative way to model output growth by using the system of two equations. The system of two equations consisting of equation of output and labor will be incorporated with the *ECM2* derived from the earlier part to represent the long-run adjustment mechanism. The system starts with one lag like the single equation approach and includes all possible explanatory variables namely labor, capital stock, oil consumption, oil price and dummy variables of financial crisis. Then, the model reduction process with the significant level cut off point at 10 percent had been conducted to attain the final parsimonious model which retains only relevant explanatory variables. The results of the final model are presented in table A12. The summary results for the estimated system are shown as follows:

$$\Delta y_t = 2.03 + 0.10 * \Delta y_{t-1} + 0.21 * \Delta oil_t + 0.14 * \Delta oil_{t-1} - 0.05 * \Delta oilprice_t$$
$$(5.02) \quad (1.51) \quad (3.33) \quad (-2.60) \quad (-2.60)$$

$$- 0.17 * \Delta l_{t-1} - 0.05 * dummy97 - 0.12 * dummy98 - 0.22 ECM2_{t-1}$$
$$(-2.99) \quad (-3.91) \quad (-9.83) \quad (-4.90)$$

$$(23)$$

$$\Delta l_t = 3.26 + 0.43 * \Delta y_{t-1} + 0.27 * \Delta oil_t - 0.27 * \Delta oil_{t-1} - 0.09 * \Delta oilprice_t$$
$$(2.20) \quad (1.78) \quad (1.94) \quad (-1.77) \quad (1.49)$$

$$- 0.52 * \Delta l_{t-1} + 0.05 * dummy97 + 0.03 * dummy98 - 0.35 ECM2_{t-1}$$
$$(-2.53) \quad (1.09) \quad (0.62) \quad (-2.19)$$

The equation system (23) consists of two parts. The upper part reports the results of the output growth, Δy_t, equation while the lower panel presents the results of the labor growth, Δl_t, equation. Comparing with the results of single equation (20), the one-period lagged output growth, Δy_{t-1}, turns out to be significant and has a positive effect in labor equation but it is still insignificant in output equation. The lagged labor growth is highly significant and has a negative impact on both equations. This seems to suggest that more labor use in this period tend to follow by lower labor employment and output in the next period given other things being constant. One possible explanation is that labor might be voluntarily unemployed in the next period if they can earn enough in this period and use their saving for the next period. Another possible reason is that there is a phenomenon of labor mobility from agricultural sector to manufacturing and service sector temporarily and then shift back to their homeland in the rural areas when conditions permit to work on farmland again. However, as the coefficient of Δy_{t-1} is positive and significant, it can be interpreted that the economic growth in the current period still has a positive influence in drawing more labor back to the metropolitan area in the next period. Nevertheless, labor is not the topic of interest in this paper; therefore, I will leave it here and focus more on oil.

Considering other coefficient estimates in the output equation in system (23), the results are fairly close to what have already obtained in Equation (20). The oil consumption growth has a positive impact on output growth: a one percent increase in oil consumption in this period and the last period produces a combined effect of about 0.35 percent increase in economic growth in this period. When considering the labor equation, an increase in oil consumption in the current period has a positive impact on the labor employment but the lagged oil consumption generates the negative effect on labor growth. It might be interpreted that oil and labor are complement and reinforce each other within the same period in the short run.

Oil price is significant and generate a negative impact on output: a one percent increase in oil price leads to a 0.05 percent reduction in economic growth. Although the sign of oil price coefficient in labor equation is negative as well, it is not statistically significant. This implies that it cannot be certainly claimed that labor is a substitute input for oil.

The error correction term is negative and significant in both equations: -0.22 for output equation and -0.35 for labor equation. These results indicate that when output and labor deviates from its long-run growth, output can adjust by 22 percent and labor can adjust by 35 percent within the first year back to the long-run equilibrium.

The models overall have coefficients with expected signs and reasonable magnitudes. The models also perform well statistically: no problems of autocorrelation, conditional heteroscedasticity and normality have been detected. The residual diagnostic test in figure A14 also confirms these test results graphically. The stability test conducted by one-step and break point Chow test in figure A15 indicate no evidence of structural breaks.

Hence, the system of two equations and single equation approach appear to yield very close results. The result from the system of two equations not only helps confirm the results found by the single equation approach but it also provides more understanding of how the variables affect the economy over time and reveals the linkage between these two equations via the long run adjustment mechanism.

VI. Conclusion

We estimate an error correction model of aggregate production function for Thailand using the data from 1976 to 2007. Thai economic growth is modeled as a function of labor, capital and oil consumption. Oil prices are incorporated in the short-run model to study their impact on economic growth. The equilibrium correction framework allows us to measure both short run dynamics and long run responses of GDP.

The null hypothesis of constant-return-to-scale for the production function could not be rejected. The implied long run elasticities for labor is about 68 percent followed by oil at 19 percent and capital at 13 percent. *LONG-RUN ENERGY CAPITAL RATIO* We tested the null hypothesis of weak exogeneity for all three production inputs. The results show that the null could not be rejected for capital and energy, but not labor. Thus, we are able to reduce the unrestricted system to a two equation conditional equilibrium correction model. This system provides an interesting look at the dynamics between output and labor in response to oil shocks. Capital plays a major role in the long run with other factors influencing economic growth through the long run adjustment mechanism. Oil and labor appear to be complements and reinforce each other in the short run. No evidence was found to support that labor is a substitute input for oil during the high oil price periods in the short run.

Our study contributes to the existing literature confirming the important role of energy in the production side of developing economy. When thinking of oil crises, they occur in two forms: high oil prices and oil shortages or a combination of both. Many studies have focused purely on measuring the impact of high oil prices on the macroeconomy. Fewer studies had been devoted to study the combined impact of oil price shocks and shortages.

Our research attempts tries to balance the existing literature by distinguishing between the effects from both factors. The equilibrium correction framework, enables us to discover several interesting empirical findings about the role of oil in the Thai economy. As expected, we find that an oil shortage produces a much more severe effect on Thai economy than that of the high oil price. The results suggest that a short fall in oil consumption by 10 percent will cause economic growth to shrink by 2 percent within the same year while a sharp rise in oil price of 10 percent can lead to a fall in output growth by about 0.5 percent. Moreover, the response of output growth to increases and decreases in oil prices are asymmetric. The estimates obtained in this study can be considered as basic rules of thumb in calculating the short run and long run effects of oil on the Thai economy.

The short-run elasticity for GDP to oil consumption is nearly the same as its long-run counterpart. This suggests that the reliance on oil for the Thai economy is very important. The policy implication is that emergency oil preparedness is critical for Thailand to avoid an economic contraction following a major oil crisis.

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Table 1: Empirical results from various studies on causality between income and energy consumption

Authors	Model	Period	Subject	Causal Relationship
Yu and Choi (1985)	Production side	1954-1976	South Korea Phillipines **Thailand** and Phillipines	Income → energy Energy → income Energy ←→ income
Masih and Masih (1998)	Demand side	1955-1991	Sri Lanka and **Thailand**	Energy → income
Asafu-Adjaye (2000)	Demand side	1973-1995	India and Indonesia **Thailand** and Phillipines Turkey	Energy → income Energy ←→ income Energy → income
Fatai et al. (2004)	Demand side	1960-1999	India and Indonesia **Thailand** and Phillipines	Energy → income Energy ←→ income
Yoo (2006)	Production side	1971-2002	Malaysia and Singapore Indonesia and **Thailand**	Energy ←→ income Income → energy

Source: Lee and Chang (2008)

Note: Energy → income *denotes causality running from energy consumption to income.* Income → energy *denotes causality running from income to energy consumption.* Energy ←→ income *denotes bidirectional causality between income and energy consumption.*

Table A1: Augmented Dickey-Fuller Test

	Intercept & Trend		Intercept		None	
Levels	**t-statistics**	**Lag**	**t-statistics**	**Lag**	**t-statistics**	**Lag**
y	-1.86	1	-1.38	3	2.31	1
oil	-1.99	1	-0.92	1	1.61	1
k	-1.51	1	-0.70	1	2.86	1
l	-1.44	1	-2.47	0	1.68	3
First Differences						
y	-3.16	0	-3.10*	1	-1.56	0
oil	-3.11	0	-3.12*	0	-2.49*	0
k	-3.86*	0	-3.91**	0	-2.32*	0
l	-8.84**	0	-7.43**	0	-5.29**	0

Note: The ADF test covers the sample period from 1981 to 2007. All variables are in natural logarithms. A maximum of three lags is used to examine the autocorrelation of the residuals. Three types of ADF regression specifications are considered: (1) with intercept and trend, (2) with only intercept (3) without intercept and trend. The critical values for *t*-tests at 5% for the three ADF regression specifications are -3.56, -2.96 and -1.95, respectively and at 1% the values are -4.27, -3.65 and -2.64 respectively. The rejection of the hypothesis of the presence of unit roots is denoted by * and ** for 5% and 1% respectively.

Table A2: Lag length specification tests, Wald F test for the sequential reduction for sequential reduction from the third-order VAR to the second-order with sample period 1981-2007

Test of Lag Length

System	*No. of parameters*	*Log-likelihood*	*SC*	*HQ*	*AIC*
VAR(3)	60	301.205	-12.327	-14.164	-15.075
VAR(2)	44	285.982	-13.109	**-14.456**	**-15.124**
VAR(1)	28	263.923	**-13.463**	-14.320	-14.745

Test of Model Reduction

From	*To*	*Test Statistics*
VAR(3)	VAR(2)	F(16,43) = 0.99123 [0.4831]
VAR(3)	VAR(1)	F(32,53) = 1.4655 [0.1072]
VAR(2)	VAR(1)	F(16,55) = 1.9830 [0.0313]*

Note: * indicates the level of significance at 5%. SC stands for Bayesian Schwarz Criterion. HQ stands for Hannan-Quinn criterion. AIC stands for Akaike criterion. VAR(s) is the VAR system with s lags of explanatory variables. The Wald F-test tests the null hypothesis of reducing the lag length of the VAR system. F(p,q) is the value of F-statistic where p and q represent number of restrictions and the degree of freedom respectively. The value in square bracket is the tail probability associated with the F-statistic.

Table A3: Summary of Cointegration Analysis to Second-order VAR

Rank	Eigenvalue	Log-likelihood	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0		243.2608	85.44 [0.000]**	37.72 [0.007]**	64.08 [0.046]*	28.29 [0.139]
1	0.69235	262.1217	47.72 [0.014]*	24.73 [0.067]	35.79 [0.217]	18.55 [0.350]
2	0.53834	274.4885	22.99 [0.109]	14.91 [0.205]	17.24 [0.405]	11.18 [0.507]
3	0.37248	281.9443	8.08 [0.253]	8.08 [0.253]	6.06 [0.464]	6.06 [0.465]

Note: The VAR system is estimated over the period of 1976-2007. It includes two lags of each variable (**y,oil,k,l**), an intercept, a trend term and a pulse dummy of the year 1998 is entered the system in unrestricted form. The number of rank denoted by r represents the number of cointegration relations to be tested in the null hypothesis. The trace statistics test the null hypothesis that the number of rank r is less than or equal to the number specified in that row. The maximum eigenvalue statistic tests the null hypothesis of r cointegrating relations against the alternative r+1 cointegrating relations. The p-values are reported in brackets; * and ** denote rejection of hypothesis at 5% and 1% significance level respectively.

Table A4: Standardized cointegrating vector (β) and coefficient of adjustment Vector (α) without restrictions

Standardized Eigenvectors β (in columns)				
Variable	**y**	**oil**	**k**	**l**
y	1	27.292	6.1890	-0.43132
oil	-0.18179	1	-4.4894	-0.044809
k	-0.27265	-40.448	1	0.22874
l	-0.56291	3.1404	-5.1019	1
trend	-0.013492	0.91592	-0.055779	-0.010879
Standardized Adjustment Coefficients α (in columns)				
y	-0.31792	0.00052873	0.032063	0.10271
oil	0.028864	-0.0015452	0.14969	0.16365
k	0.60460	0.0087633	0.022343	0.11747
l	-0.26281	0.0027417	0.067845	-0.18344

Note: The VAR system is estimated over the period of 1976-2007. It includes two lags of each variable (**y,o,k,l**), an intercept, a trend term and a pulse dummy of the year 1998 is entered the system in unrestricted form. No restrictions on cointegrating vectors are imposed at this state.

Table A5: Coefficient of Cointegrating Vector (β) and Coefficient of Adjustment Vector (α)

	Number of cointegrating vector = 1					
	Unrestricted Cointegrating vectors	***Weak exogeneity of oil, capital and labor***	***Weak exogeneity of capital and labor***	***Constant-return-to-scale restriction***	***Weak exogeneity of oil, capital and labor & constant-return-to-scale restriction (ECM1)***	***Weak exogeneity of capital and labor & constant-return-to-scale restriction (ECM2)***
β vector						
y	1 (0.00000)	1 (0.00000)	1 (0.00000)	1 (0.00000)	1 (0.00000)	1 (0.00000)
oil	-0.18179 (0.068129)	-0.23517 (0.076393)	-0.27451 (0.073866)	-0.17138 (0.00000)	-0.19183 (0.00000)	-0.22653 (0.00000)
k	-0.27265 (0.085215)	-0.12752 (0.095552)	-0.087189 (0.092392)	-0.27600 (0.085061)	-0.12812 (0.10600)	-0.088857 (0.10372)
l	-0.56291 (0.081445)	-0.71902 (0.091325)	-0.72698 (0.088305)	-0.55262 (0.049178)	-0.68005 (0.061282)	-0.68461 (0.059963)
trend	-0.013492 (0.0044384)	-0.016358 (0.0049767)	-0.016784 (0.0048122)	-0.014038 (0.0025522)	-0.019464 (0.0031804)	-0.020139 (0.0031120)
α vector						
y	-0.31792 (0.097882)	-0.36246 (0.053178)	-0.32096 (0.096169)	-0.31079 (0.093295)	-0.32609 (0.047811)	-0.29314 (0.084148)
oil	0.028864 (0.27278)	-0.00000 (0.00000)	0.17096 (0.25362)	0.020430 (0.26042)	-0.00000 (0.00000)	0.12972 (0.22428)
k	0.60460 (0.23391)	-0.00000 (0.00000)	0.00000 (0.00000)	0.58315 (0.22388)	-0.00000 (0.00000)	0.00000 (0.00000)
l	-0.26281 (0.18155)	-0.00000 (0.00000)	0.00000 (0.00000)	-0.26583 (0.17272)	-0.00000 (0.00000)	0.00000 (0.00000)
LR test of restrictions	n.a.	$\chi^2(3)$ = 7.2914	$\chi^2(2)$ = 6.9592	$\chi^2(1)$ = 0.018561	$\chi^2(4)$ = 7.6757	$\chi^2(3)$ = 7.4371
P-value	n.a.	[0.0632]	[0.0308]*	[0.8916]	[0.1042]	[0.0592]

Note: The VAR system is estimated over the period of 1976-2007. It includes two lags of each variable (**y,o,k,l**), an intercept, a trend term and a pulse dummy of the year 1998 is entered the system in unrestricted form. The weak exogeneity test of a given variable tests whether or not disequilibrium in the cointegrating relation can feed back onto the associated variable under the assumption that there is only one cointegrating relation has been found. The constant-return-to-scale assumption tests whether or not the sum of coefficients of **o**,**k** and **l** in the β vector is equal to unity. These test statistics are based on the Likelihood-ratio (LR) test which is asymptotically distributed as χ^2. Standard errors are reported in (). * denote rejection of hypothesis at 5%.

Table A6: Restrictions on Coefficient of Cointegrating Vector (β) and Coefficient of Adjustment Vector (α)

H₀: β_i = 0	**LR Test of Restrictions**	***P-value***	**H₀: α_i = 0**	**LR Test of Restrictions**	***P-value***
y	$\chi^2(1)$ = 9.2846	[0.0023]**	**y**	$\chi^2(1)$ = 8.8485	[0.0029]**
oil	$\chi^2(1)$ = 1.2421	[0.2651]	**oil**	$\chi^2(1)$ = 0.011173	[0.9158]
k	$\chi^2(1)$ = 3.2814	[0.0701]	**k**	$\chi^2(1)$ = 3.7767	[0.0520]
l	$\chi^2(1)$ = 5.7490	[0.0165]*	**l**	$\chi^2(1)$ = 1.9553	[0.1620]
trend	$\chi^2(1)$ = 5.6136	[0.0178]*			

Joint restrictions on β coefficients	**LR Test of Restrictions**	***P-value***
H₀: $\beta(oil) = \beta(k) = 0$	$\chi^2(2)$ = 4.9363	[0.0847]
H₀: $\beta(oil) = \beta(l) = 0$	$\chi^2(2)$ = 9.5917	[0.0083]**
H₀: $\beta(k) = \beta(l) = 0$	$\chi^2(2)$ = 8.0524	[0.0178]*
H₀: $\beta(oil) = -\beta(y) - (\beta(k) + \beta(l)) = 0$	$\chi^2(1)$ = 0.018561	[0.8916]

Joint restrictions on α coefficients	**LR Test of Restrictions**	***P-value***
H₀: $\alpha(oil) = \alpha(k) = 0$	$\chi^2(2)$ = 3.7768	[0.1513]
H₀: $\alpha(oil) = \alpha(l) = 0$	$\chi^2(2)$ = 2.1709	[0.3377]
H₀: $\alpha(k) = \alpha(l) = 0$	$\chi^2(2)$ = 6.9592	[0.0308]*
H₀: $\alpha(oil) = \alpha(k) = \alpha(l) = 0$	$\chi^2(3)$ = 7.2914	[0.0632]
Jointly restrictions on coefficients		
H₀: $\beta(oil) = \beta(k) = 0$ $\alpha(oil) = \alpha(k) = \alpha(l) = 0$	$\chi^2(5)$ = 10.985	[0.0517]
H₀: $\beta(oil) = -\beta(y) - (\beta(k) + \beta(l)) = 0$ $\alpha(oil) = \alpha(k) = \alpha(l) = 0$	$\chi^2(4)$ = 7.6757	[0.1042]
H₀: $\beta(oil) = -\beta(y) - (\beta(k) + \beta(l)) = 0$ $\alpha(k) = \alpha(l) = 0$	$\chi^2(3)$ = 7.4371	[0.0592]
H₀: $\beta(oil) = -\beta(y) - (\beta(k) + \beta(l)) = 0$ $\alpha(k) = 0$	$\chi^2(2)$ = 3.8062	[0.1491]
H₀: $\beta(oil) = -\beta(y) - (\beta(k) + \beta(l)) = 0$ $\alpha(l) = 0$	$\chi^2(2)$ = 2.5620	[0.2778]

The Single Equation Model

Table A7: The General Model of Aggregate Output in first differences with one lag and ECM term

Modeling Δy_t by OLS

Variables	Coefficient	Standard error	t-value	P-value
Constant	2.24858	0.4426	5.08	0.0001
Δy_{t-1}	0.138308	0.06788	2.04	0.0558
Δoil_t	0.248751	0.04363	5.70	0.0000
Δoil_{t-1}	0.147831	0.04448	3.32	0.0036
Δk_t	-0.0618633	0.04116	-1.50	0.1493
Δk_{t-1}	0.0416015	0.03752	1.11	0.2813
Δl_t	-0.0641715	0.05542	-1.16	0.2613
Δl_{t-1}	-0.238798	0.06924	-3.45	0.0027
$\Delta poil_t$	-0.0628948	0.02160	-2.91	0.0090
$\Delta poil_{t-1}$	0.0428981	0.02379	1.80	0.0872
$dummy97$	-0.0426946	0.01188	-3.60	0.0019
$dummy98$	-0.122912	0.01249	-9.84	0.0000
$ECM1_{t-1}$	-0.254349	0.05119	-4.97	0.0001

Sigma (σ)	0.00974756	RSS	0.00180528246
R^2	0.966596	F(12,19)	45.82 [0.000]**
log-likelihood	111.118	DW	2.04

Test Summary

AR 1-2 test:	F(2,17) = 0.28137 [0.7582]
ARCH 1-1 test:	F(1,17) = 0.065551 [0.8010]
Normality test:	$\chi^2(2)$ = 0.97952 [0.6128]
Hetero test:	$\chi^2(22)$ = 27.300 [0.2001]
RESET test:	F(1,18) = 0.59374 [0.4510]

*Notes: 1. ** and * denote 1% and 5% significance level respectively.*

Table A8: The Specific Model of Aggregate Output in first differences with one lag and ECM term

Modeling Δy_t by OLS

Variables	Coefficient	Standard error	t-value	P-value
Constant	1.85952	0.3825	4.86	0.0001
Δoil_t	0.217531	0.03753	5.80	0.0000
Δoil_{t-1}	0.173084	0.03594	4.82	0.0001
Δl_{t-1}	-0.150582	0.05608	-2.69	0.0129
$\Delta poil_t$	-0.0439835	0.01830	-2.40	0.0243
$dummy97$	-0.0485799	0.01219	-3.99	0.0005
$dummy98$	-0.130924	0.01242	-10.5	0.0000
$ECM1_{t-1}$	-0.208954	0.04419	-4.73	0.0001

Sigma (σ)	0.01048	RSS	0.00263594673
R^2	0.951226	F(7,24)	66.87 [0.000]**
log-likelihood	105.062	DW	1.5

Test Summary

AR 1-2 test:	F(2,22) = 2.0007 [0.1591]
ARCH 1-1 test:	F(1,22) = 0.064112 [0.8025]
Normality test:	$\chi^2(2)$ = 1.1346 [0.5671]
Hetero test:	F(12,11) = 0.19419 [0.9956]
RESET test:	F(1,23) = 6.0019 [0.0223]*

*Notes: 1. ** and * denote 1% and 5% significance level respectively.*

2. The automatic model selection (Autometrics) is a useful feature in PcGive often used to perform general-to-specific modeling approach by searching through many available reduction paths and selecting the best model that can pass a set of statistical criteria. In this study, the criteria assigning for Autometrics are target size: 0.05 and Outlier detection. For more details please consult Doornik and Hendry (2007).

Test for general restrictions:

H_0: $\beta(\Delta oil_t) = \beta(\Delta oil_{t-1})$

$\chi^2(1)$ = 0.49386 [0.4822]

The result suggests that the null hypothesis of coefficient equality cannot be rejected.

Table A9: The Specific Model of Aggregate Output in first differences with one lag and ECM term

Modeling Δy_t by OLS

Variables	**Coefficient**	**Standard error**	**t-value**	**P-value**
Constant	1.87646	0.3779	4.97	0.0000
$\Delta oilcmb_t$	0.194659	0.01850	10.5	0.0000
Δl_{t-1}	-0.158692	0.05432	-2.92	0.0073
$\Delta poil_t$	-0.0491024	0.01662	-2.96	0.0067
$dummy97$	-0.0499003	0.01192	-4.19	0.0003
$dummy98$	-0.132912	0.01197	-11.1	0.0000
$ECM1_{t-1}$	-0.210856	0.04366	-4.83	0.0001

Sigma (σ)	0.0103734	RSS	0.00269018825
R^2	0.950222	F(6,25)	79.54 [0.000]**
log-likelihood	104.736	DW	1.58

Test Summary

AR 1-2 test:	F(2,23) = 1.3360 [0.2825]
ARCH 1-1 test:	F(1,23) = 0.069815 [0.7940]
Normality test:	$\chi^2(2)$ = 2.3953 [0.3019]
Hetero test:	F(10,14) = 0.17635 [0.9955]
RESET test:	F(1,24) = 5.6718 [0.0255]*

*Notes: 1. ** and * denote 1% and 5% significance level respectively.*
2. The automatic model selection (Autometrics) is a useful feature in PcGive often used to perform general-to-specific modeling approach by searching through many available reduction paths and selecting the best model that can pass a set of statistical criteria. In this study, the criteria assigning for Autometrics are target size: 0.05 and Outlier detection. For more details please consult Doornik and Hendry (2007).

Table A10: The Specific Model of Aggregate Output in first differences with one lag and ECM term

Modeling Δy_t by OLS

Variables	Coefficient	Standard error	t-value	P-value
Constant	1.87484	0.3996	4.69	0.0001
$\Delta oilcmb_t$	0.194613	0.01911	10.2	0.0000
Δl_{t-1}	-0.158576	0.05595	-2.83	0.0092
$\Delta poilup_t$	-0.0488639	0.02294	-2.13	0.0436
$\Delta poildown_t$	-0.0500765	0.06532	-0.767	0.4508
$dummy97$	-0.0499014	0.01216	-4.10	0.0004
$dummy98$	-0.132923	0.01224	-10.9	0.0000
$ECM1_{t-1}$	-0.210673	0.04610	-4.57	0.0001

Sigma (σ)	0.0105873	RSS	0.00269016152
R^2	0.950223	F(7,24)	65.45 [0.000]**
log-likelihood	104.736	DW	1.58

Test Summary

AR 1-2 test:	F(2,22) = 1.2937 [0.2943]
ARCH 1-1 test:	F(1,22) = 0.067922 [0.7968]
Normality test:	$\chi^2(2)$ = 2.3941 [0.3021]
Hetero test:	F(12,11) = 0.22885 [0.9913]
RESET test:	F(1,23) = 5.4244 [0.0290]*

*Notes: 1. ** and * denote 1% and 5% significance level respectively.*

2. The automatic model selection (Autometrics) is a useful feature in PcGive often used to perform general-to-specific modeling approach by searching through many available reduction paths and selecting the best model that can pass a set of statistical criteria. In this study, the criteria assigning for Autometrics are target size: 0.05 and Outlier detection. For more details please consult Doornik and Hendry (2007).

The System of two Equations Model

Table A11: The General Model of the System of two Equations in first differences with one lag and ECM term

Equation for Δy_t by OLS

Variables	**Coefficient**	**Standard error**	**t-value**	**P-value**
Constant	2.13202	0.4272	4.99	0.0001
Δy_{t-1}	0.110075	0.06543	1.68	0.1080
Δoil_t	0.232139	0.04081	5.69	0.0000
Δoil_{t-1}	0.159022	0.04333	3.67	0.0015
Δk_t	-0.0739203	0.04135	-1.79	0.0890
Δk_{t-1}	0.0473102	0.03786	1.25	0.2259
Δl_{t-1}	-0.202234	0.06201	-3.26	0.0039
$\Delta poil_t$	-0.0717925	0.02115	-3.40	0.0029
$\Delta poil_{t-1}$	0.0376522	0.02385	1.58	0.1301
$dummy97$	-0.0453893	0.01177	-3.86	0.0010
$dummy98$	-0.124686	0.01256	-9.92	0.0000
$ECM2_{t-1}$	-0.230078	0.04722	-4.87	0.0001
Sigma (σ)	0.00989528	RSS		0.001958331418

Equation for Δl_t by OLS

Constant	3.79937	1.697	2.24	0.0367
Δy_{t-1}	0.377934	0.2599	1.45	0.1615
Δoil_t	0.322411	0.1621	1.99	0.0606
Δoil_{t-1}	-0.222186	0.1721	-1.29	0.2115
Δk_t	0.0690958	0.1643	0.421	0.6786
Δk_{t-1}	-0.0728377	0.1504	-0.484	0.6335
Δl_{t-1}	-0.607902	0.2464	-2.47	0.0228
$\Delta poil_t$	0.0993570	0.08401	1.18	0.2508
$\Delta poil_{t-1}$	0.0482171	0.09476	0.509	0.6164
$dummy97$	0.0525905	0.04675	1.13	0.2739
$dummy98$	0.0382017	0.04992	0.765	0.4530
$ECM2_{t-1}$	-0.417990	0.1876	-2.23	0.0375
Sigma (σ)	0.0393116	RSS		0.03090804687

Test Summary

Vector Portmanteau(4):	6.78766
Vector AR 1-2 test:	F(8,30) = 0.60891 [0.7631]
Vector Normality test:	$\chi^2(4)$ = 7.1886 [0.1263]
Vector Hetero test:	$\chi^2(60)$ = 53.346 [0.7157]

Table A12: The Specific Model of the System of two Equations in first differences with one lag and ECM term

Equation for Δy_t by OLS

Variables	Coefficient	Standard error	t-value	P-value
Constant	2.03167	0.4045	5.02	0.0000
Δy_{t-1}	0.100179	0.06623	1.51	0.1440
Δoil_t	0.210459	0.03763	5.59	0.0000
Δoil_{t-1}	0.136684	0.04104	3.33	0.0029
Δl_{t-1}	-0.167926	0.05617	-2.99	0.0065
$\Delta poil_t$	-0.0465428	0.01791	-2.60	0.0161
$dummy97$	-0.0469753	0.01200	-3.91	0.0007
$dummy98$	-0.124806	0.01269	-9.83	0.0000
$ECM2_{t-1}$	-0.218937	0.04465	-4.90	0.0001
Sigma (σ)	0.0102522	RSS		0.002417458336

Equation for Δl_t by OLS

Variables	Coefficient	Standard error	t-value	P-value
Constant	3.26327	1.481	2.20	0.0378
Δy_{t-1}	0.431048	0.2425	1.78	0.0887
Δoil_t	0.266970	0.1378	1.94	0.0650
Δoil_{t-1}	-0.265338	0.1502	-1.77	0.0906
Δl_{t-1}	-0.519920	0.2056	-2.53	0.0188
$\Delta poil_t$	0.0978686	0.06556	1.49	0.1491
$dummy97$	0.0478161	0.04394	1.09	0.2878
$dummy98$	0.0285750	0.04646	0.615	0.5446
$ECM2_{t-1}$	-0.358732	0.1635	-2.19	0.0385
Sigma (σ)	0.0375287	RSS		0.03239330808

Test Summary

Vector Portmanteau(4):	12.5573
Vector AR 1-2 test:	F(8,36) = 1.1596 [0.3496]
Vector Normality test:	$\chi^2(4)$ = 6.9043 [0.1410]
Vector Hetero test:	F(42,18) = 0.24743 [0.9999]

Note: This specific model is obtained from applying Autometrics (significance level = 10%) with the general model presented in table A11.

Table A13: The Specific Model of the System of two Equations in first differences with one lag and ECM term

Equation for Δy_t by OLS

Variables	Coefficient	Standard error	t-value	P-value
Constant	1.99368	0.4144	4.81	0.0001
Δoil_t	0.221858	0.03785	5.86	0.0000
Δoil_{t-1}	0.169194	0.03589	4.71	0.0001
Δl_{t-1}	-0.156498	0.05713	-2.74	0.0114
$\Delta poil_t$	-0.0451743	0.01836	-2.46	0.0215
$dummy97$	-0.0479661	0.01230	-3.90	0.0007
$dummy98$	-0.129858	0.01257	-10.3	0.0000
$ECM2_{t-1}$	-0.214372	0.04573	-4.69	0.0001
Sigma (σ)	0.0105236	RSS	0.00265791146	

Equation for Δl_t by OLS

Variables	Coefficient	Standard error	t-value	P-value
Constant	3.09982	1.543	2.01	0.0559
Δoil_t	0.316015	0.1409	2.24	0.0344
Δoil_{t-1}	-0.125459	0.1336	-0.939	0.3571
Δl_{t-1}	-0.470745	0.2127	-2.21	0.0366
$\Delta poil_t$	0.103757	0.06836	1.52	0.1422
$dummy97$	0.0435530	0.04581	0.951	0.3512
$dummy98$	0.00683692	0.04680	0.146	0.8851
$ECM2_{t-1}$	-0.339090	0.1703	-1.99	0.0579
Sigma (σ)	0.0391817	RSS	0.03684499283	

Test Summary

Vector Portmanteau(4):	11.532
Vector AR 1-2 test:	F(8,38) = 0.87528 [0.5456]
Vector Normality test:	$\chi^2(4)$ = 5.3984 [0.2488]
Vector Hetero test:	F(36,27) = 0.35469 [0.9980]

Note: This specific model is obtained from applying Autometrics (significance level = 5%) with the general model presented in table A11.

Figure 1

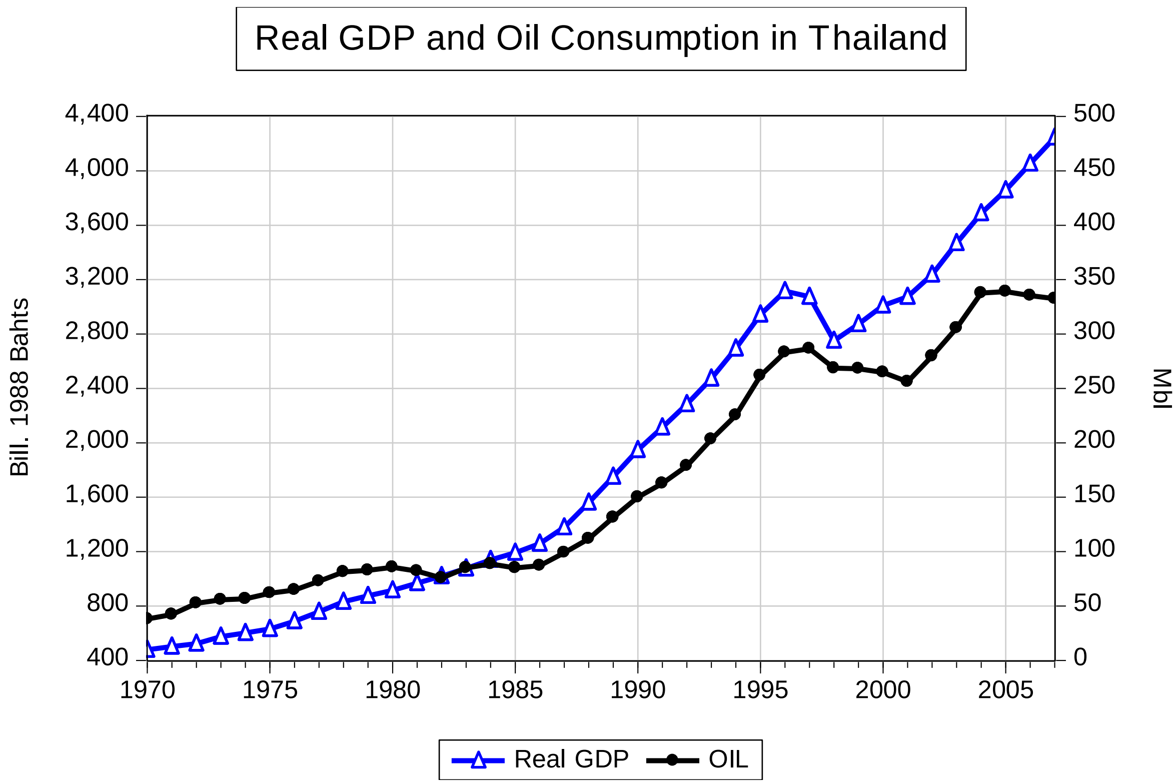


Figure 2

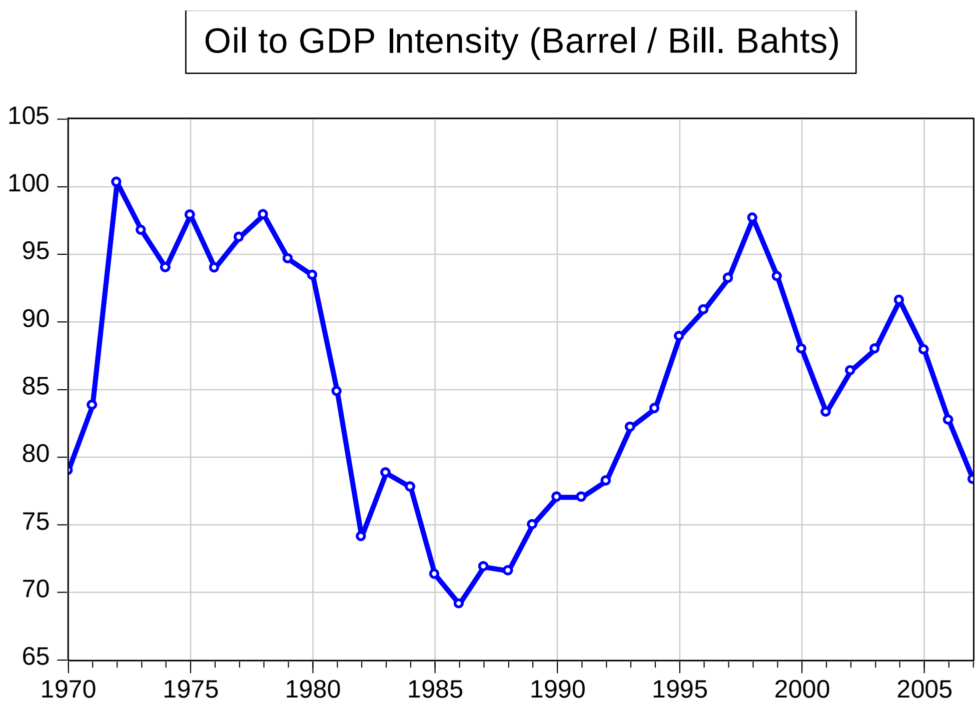
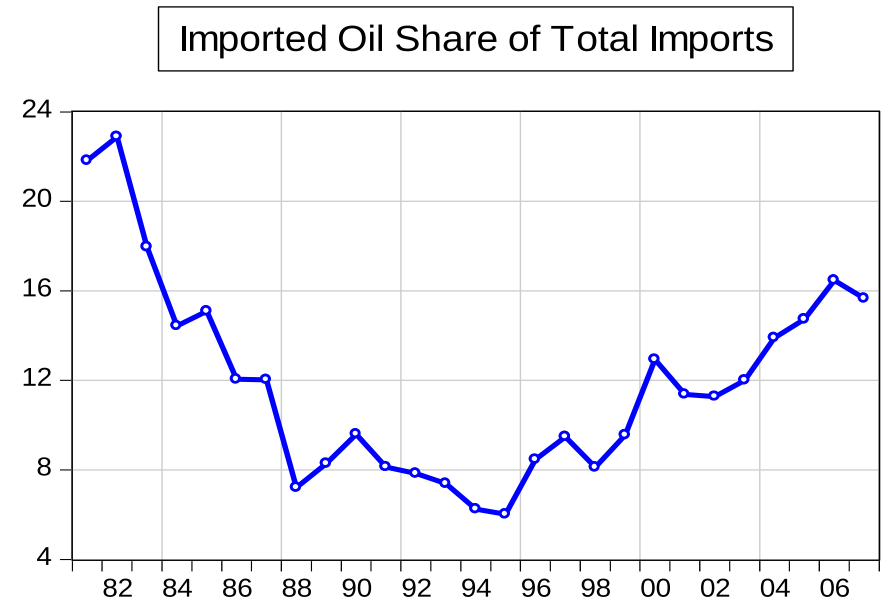


Figure 3


Imported Oil Share of Total Imports
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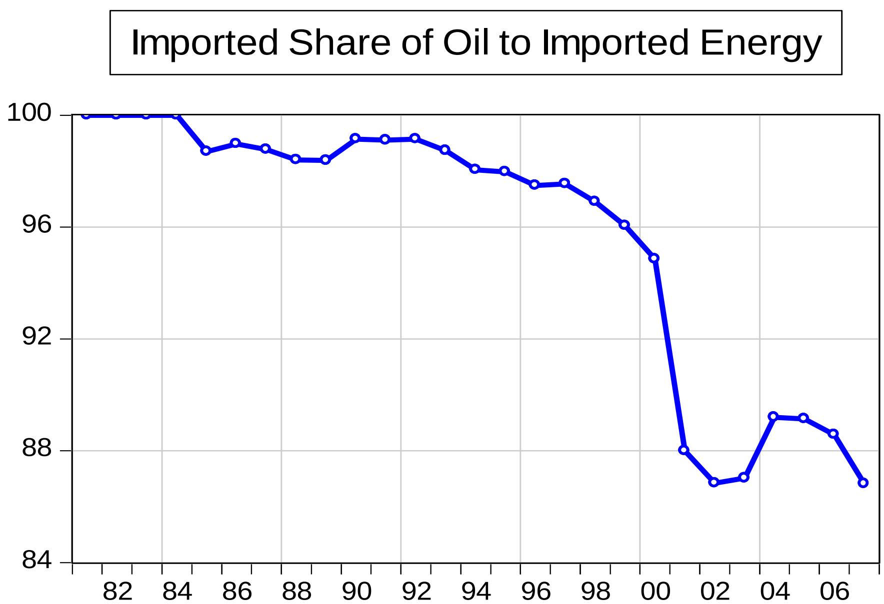
16
12
8
4
82
84
86
88
90
92
94
96
98
00
02
04
06


Imported Share of Oil to Imported Energy
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92
88
84
82
84
86
88
90
92
94
96
98
00
02
04
06

Figure 4

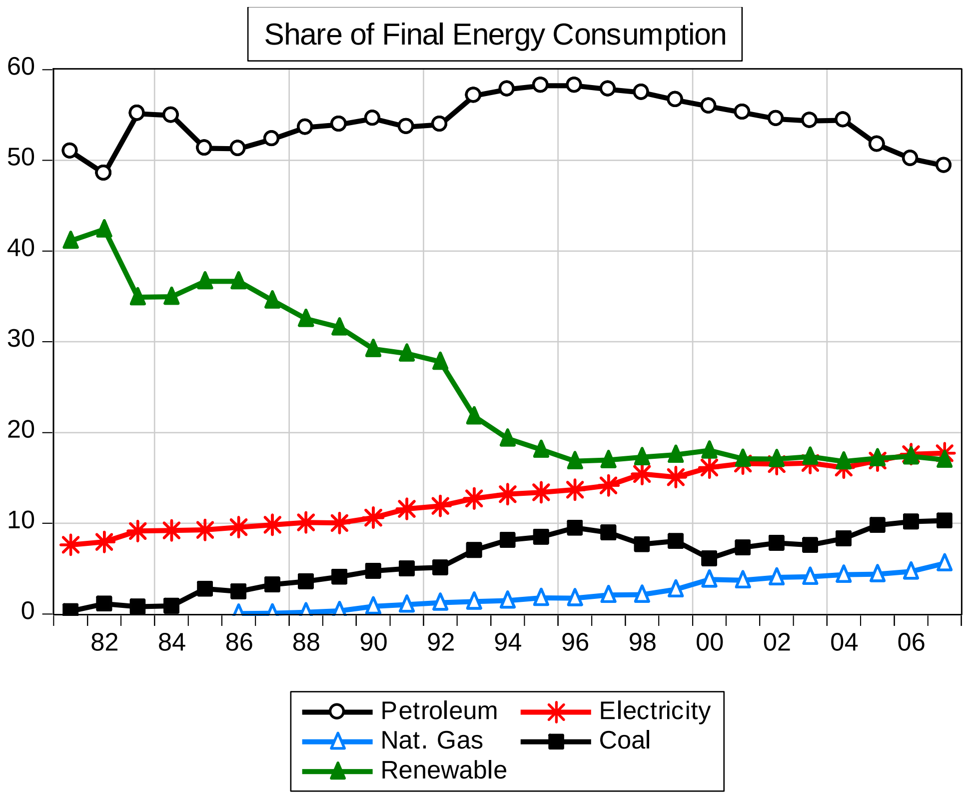

Figure 5

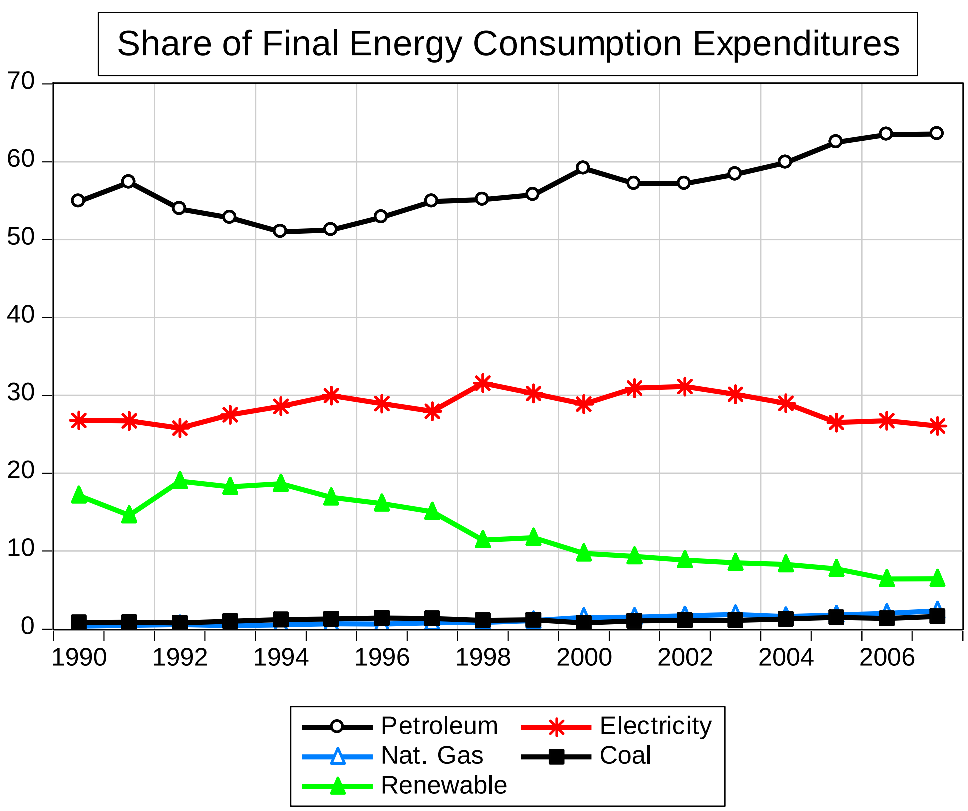

Figure 6

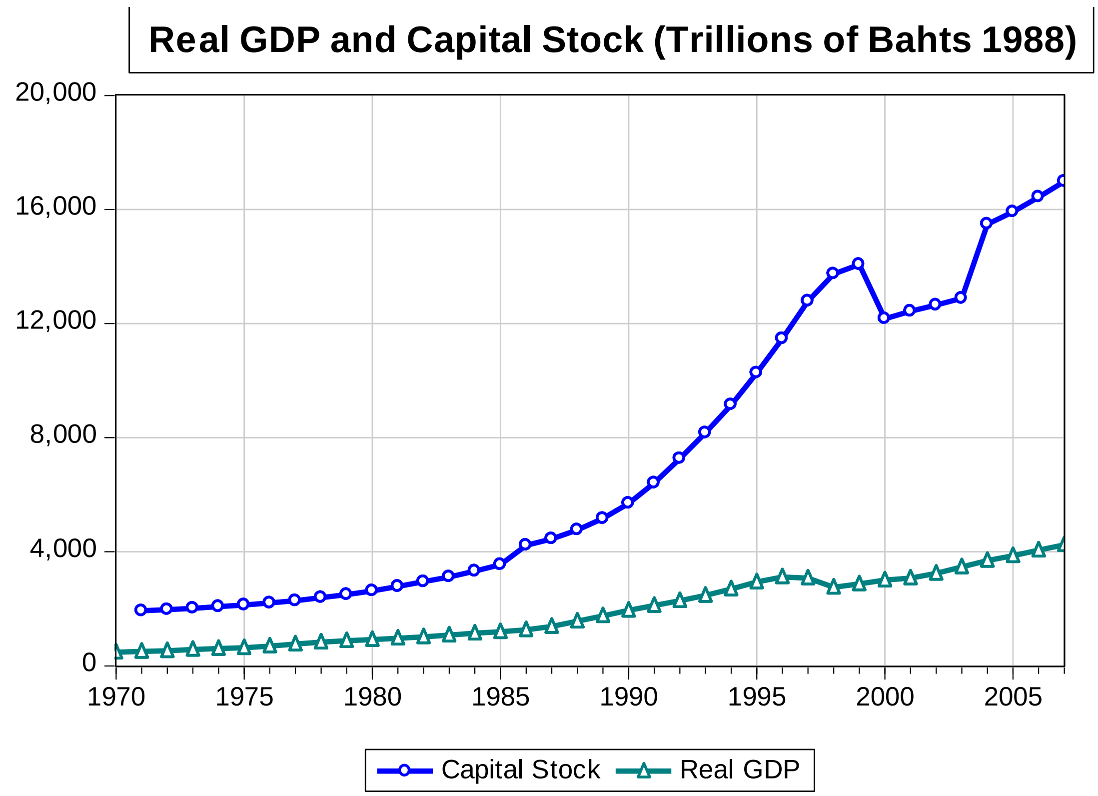

Figure 7

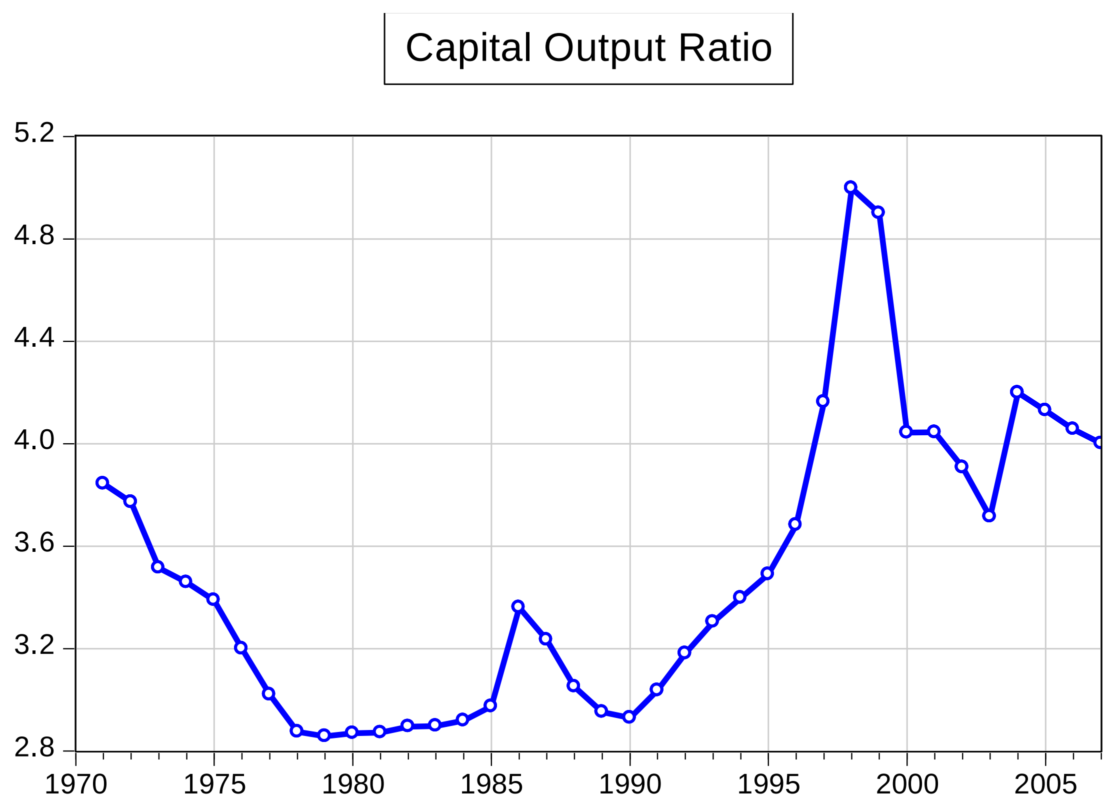

Figure 8

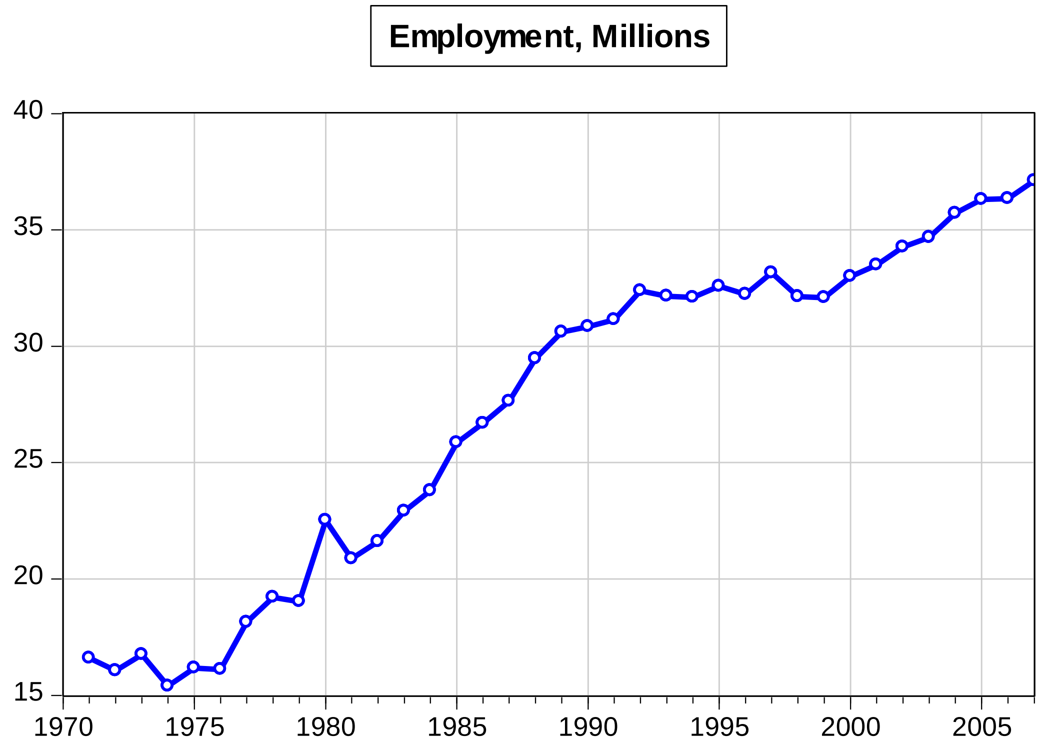

Figure 9

Figure 10: Thailand's Weighted Nominal Oil Price from Seven Oil Products

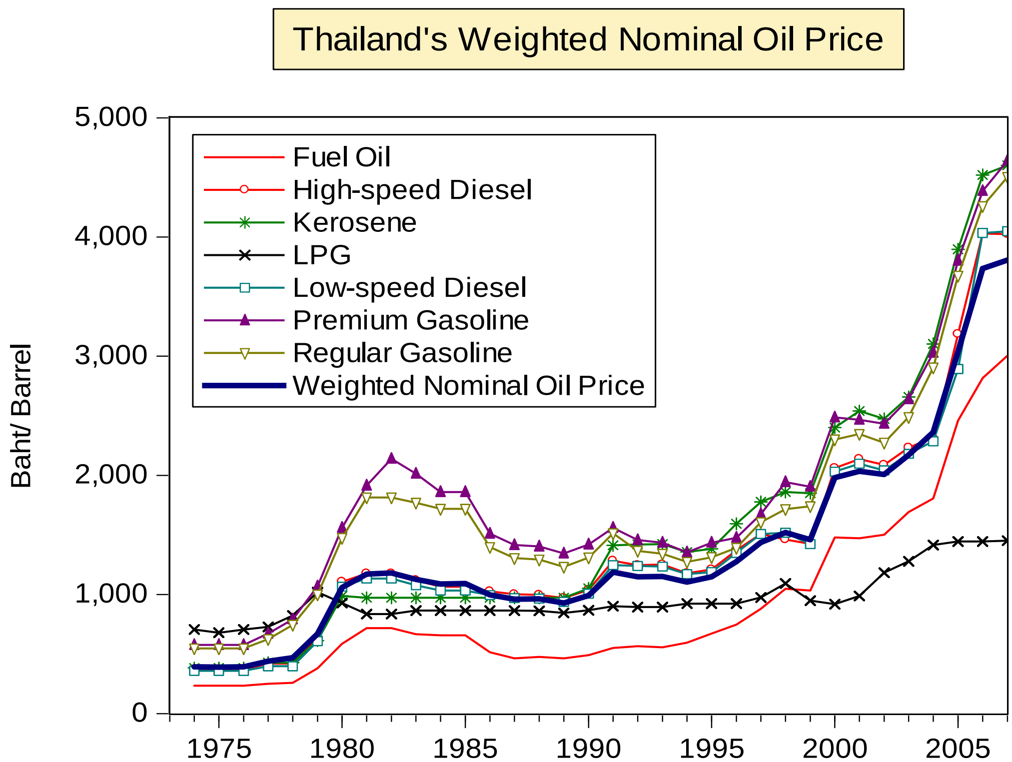

Figure 11: Weighted Nominal and Real Oil Price
1988 Bahts per Barrel

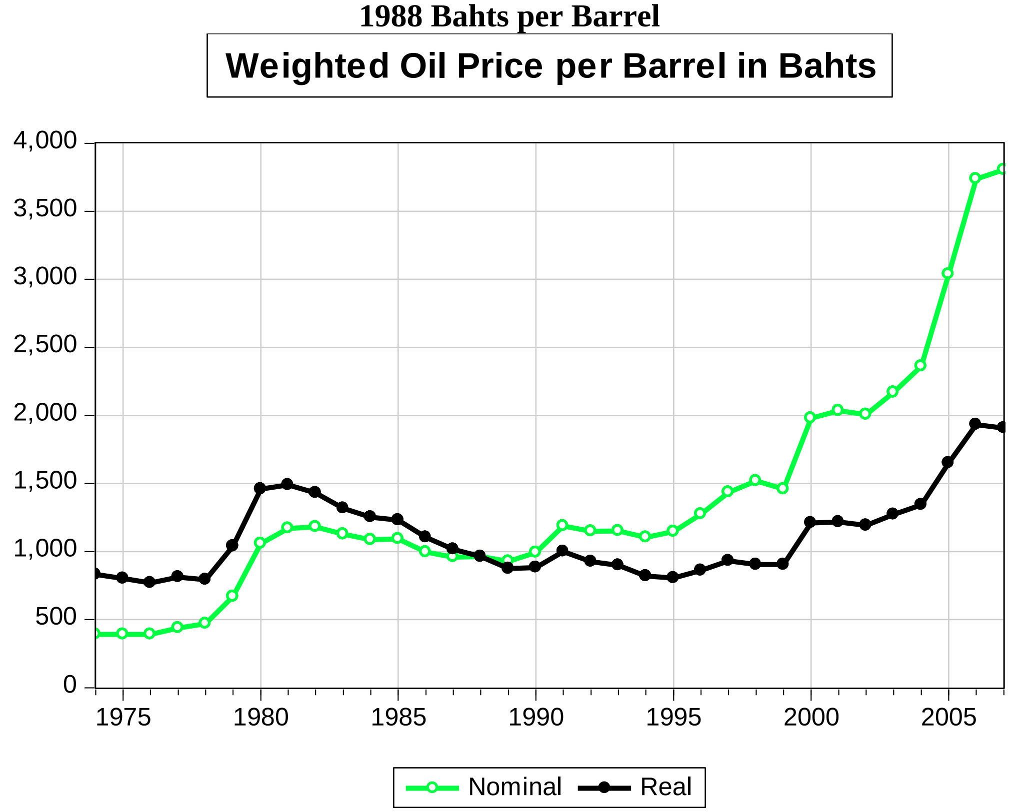

Figure 7: Graphical Analysis: Residual Diagnostic and Chow Tests of VAR(2)

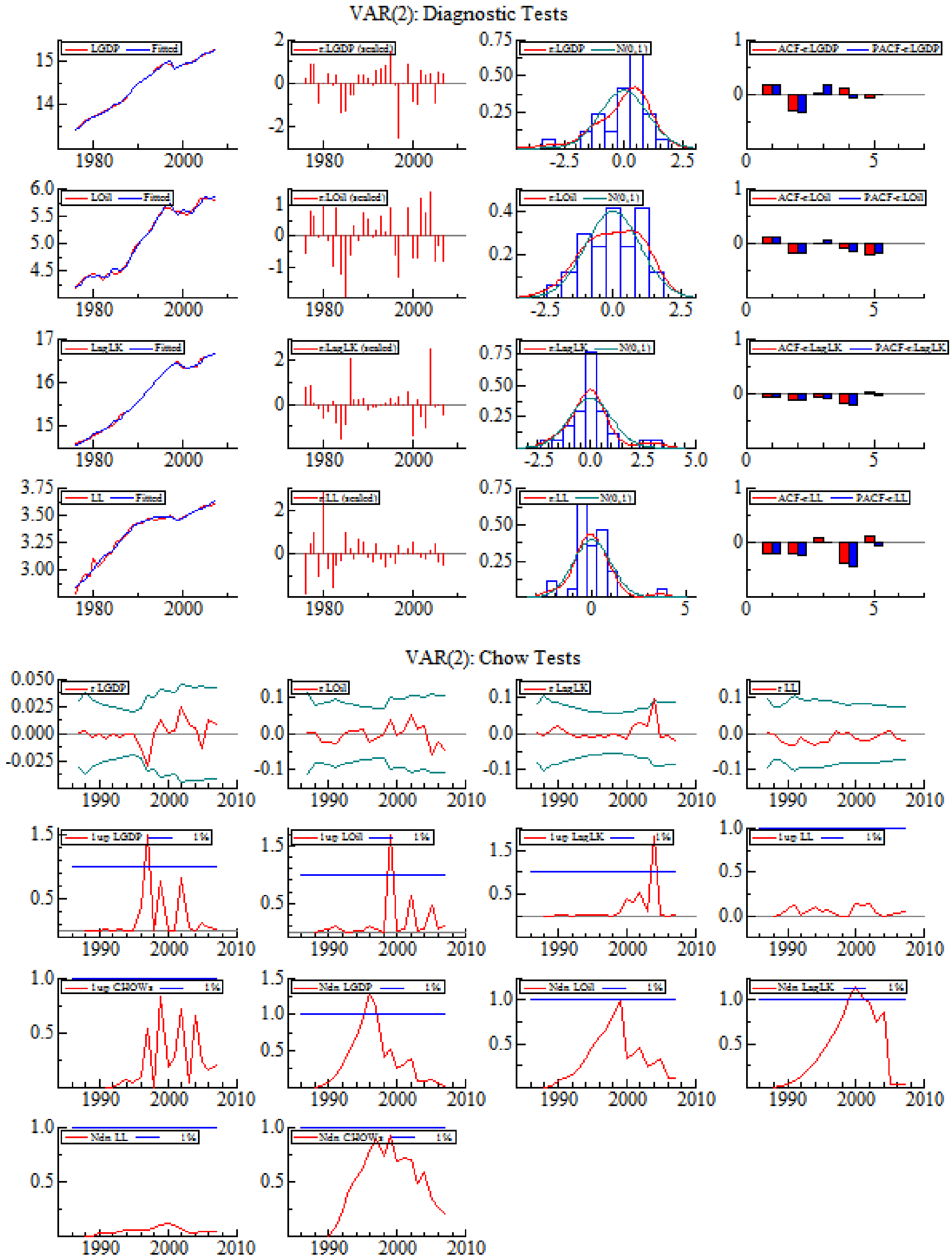

Figure 8: Graphical Analysis for General Model of Aggregate Output (VECM of Single Equation)

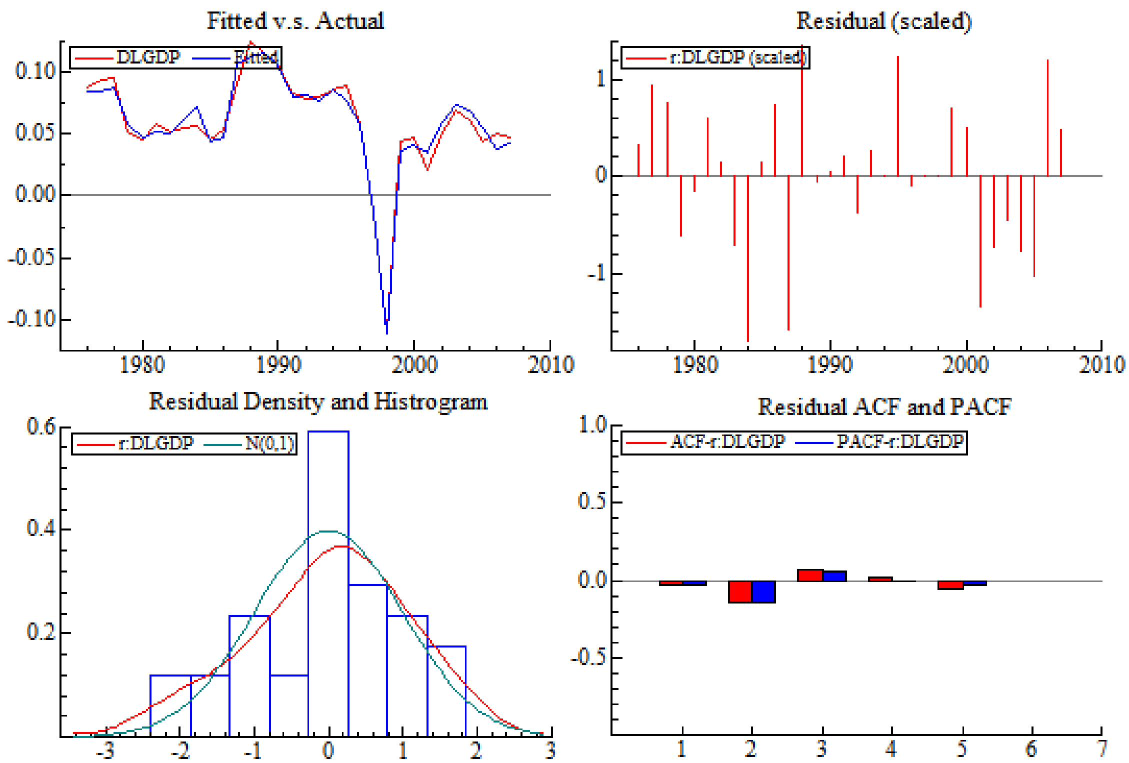

Figure 9: Recursive Graphics for General Model of Aggregate Output (VECM of Single Equation)

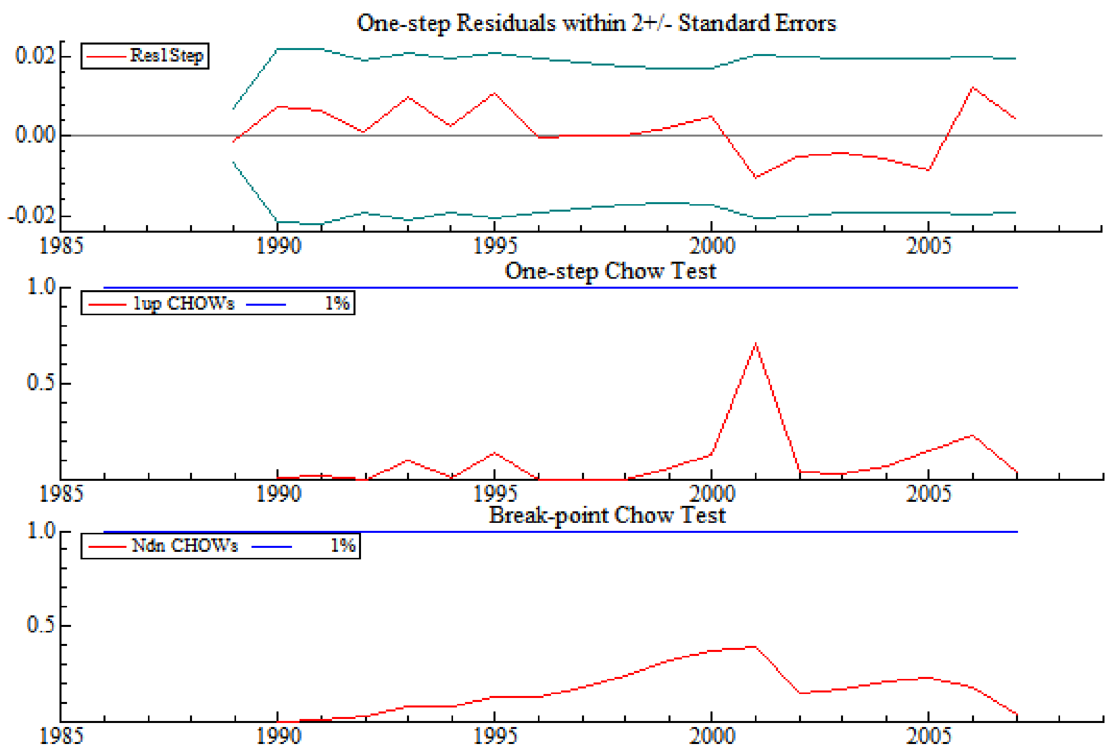

Figure 10: Graphical Analysis for Specific Model of Aggregate Output (VECM of Single Equation)

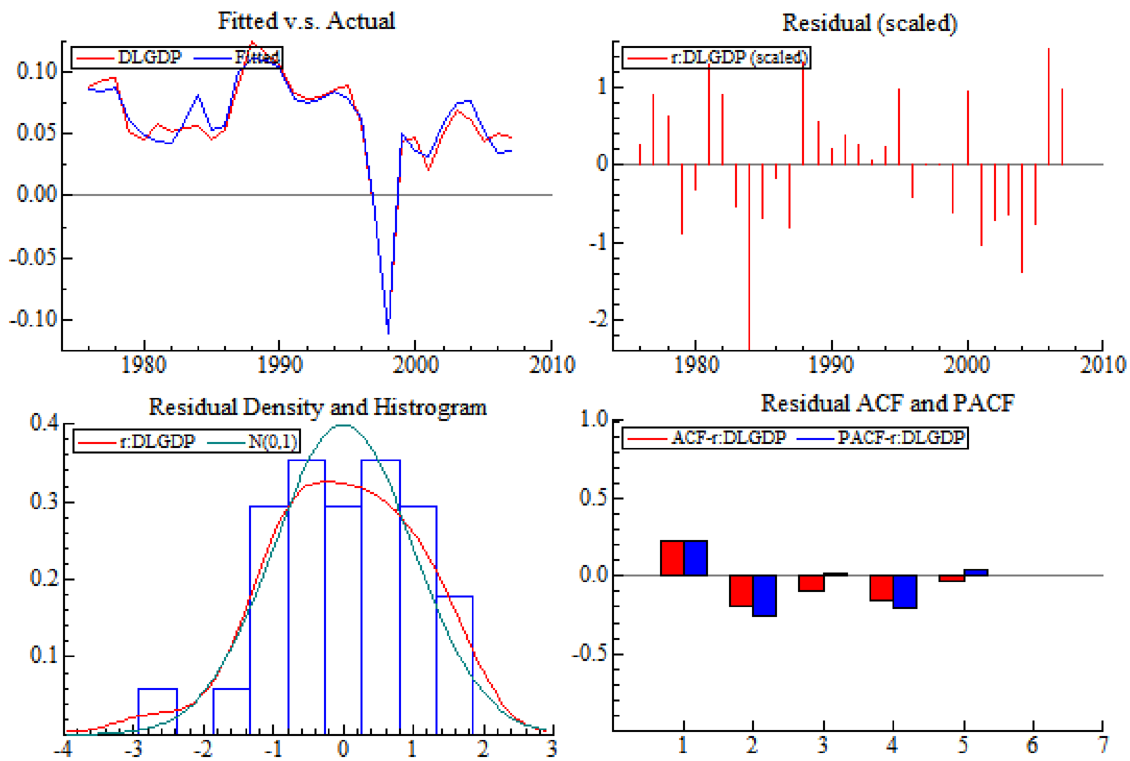

Figure 11: Recursive Graphics for Specific Model of Aggregate Output (VECM of Single Equation)

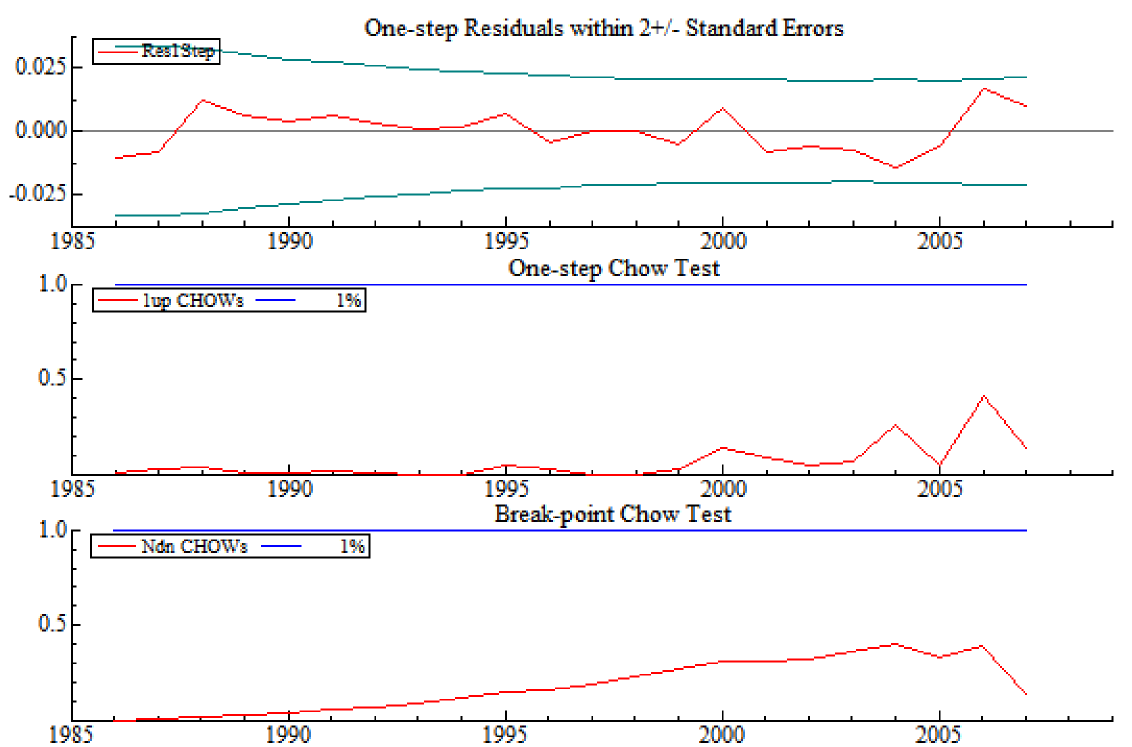

Figure 12: Graphical Analysis for General Model of Aggregate Output & Labor (VECM of the System of 2 Equations)

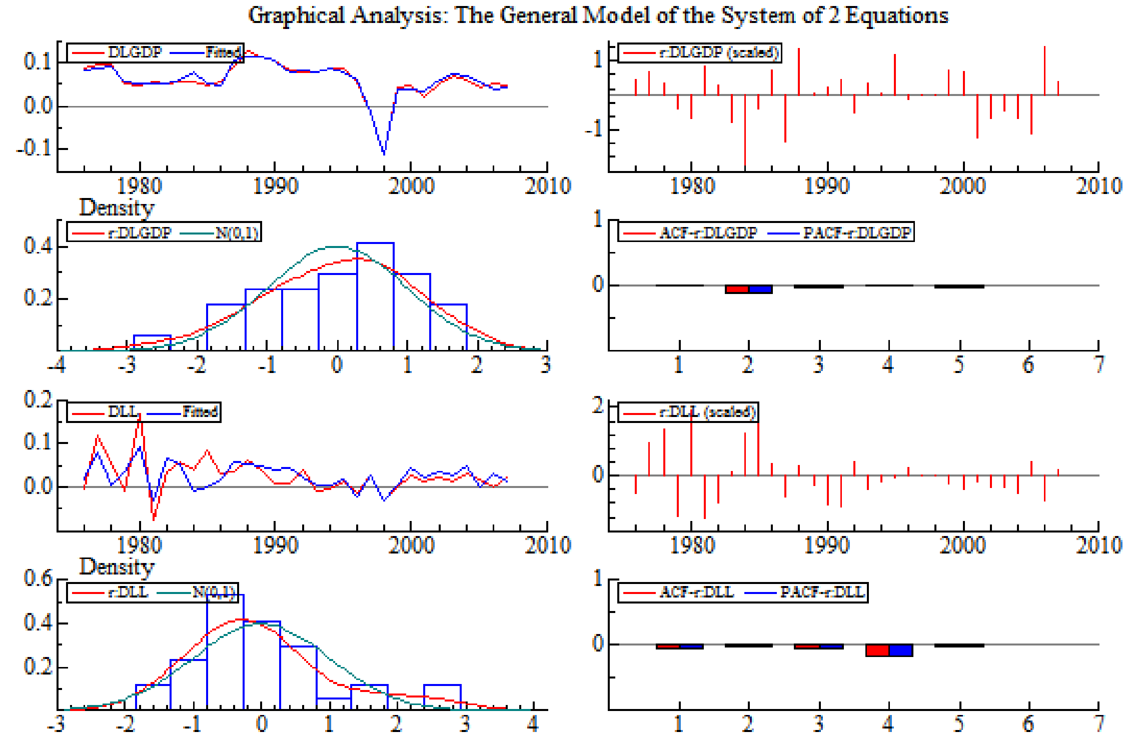

Figure 13: Recursive Graphics for General Model of Aggregate Output & Labor (VECM of the System of 2 Equations)

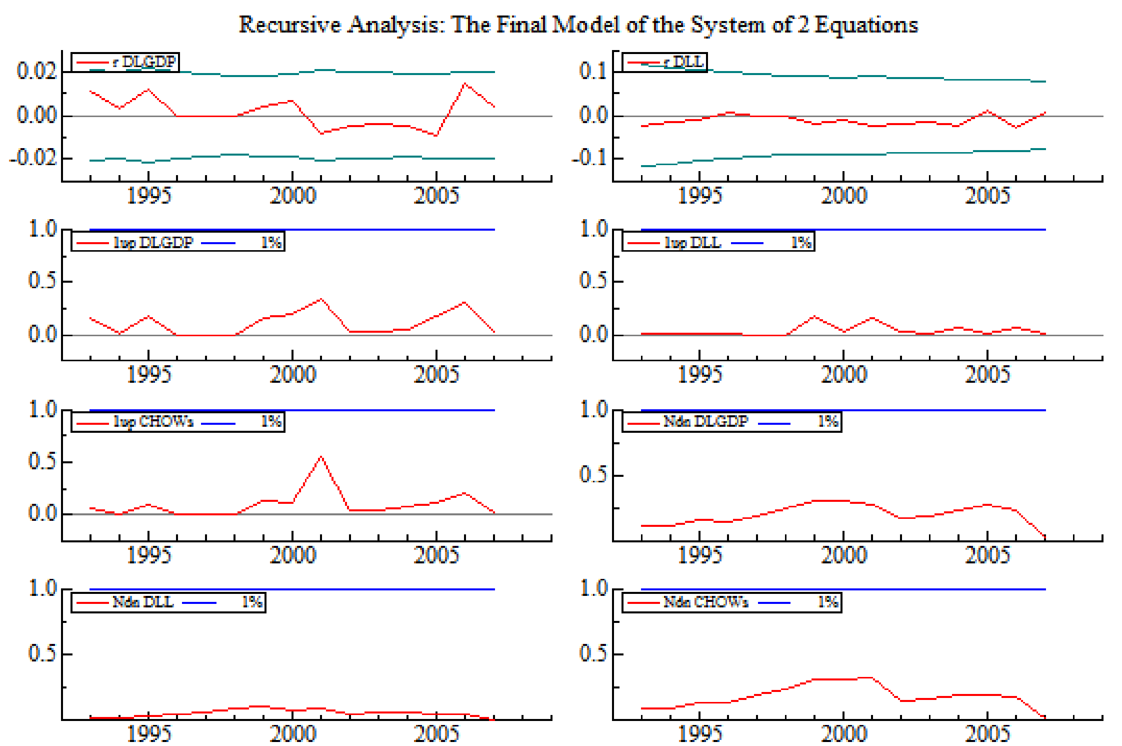

Figure 14: Graphical Analysis for Specific Model of Aggregate Output & Labor (VECM of the System of 2 Equations)

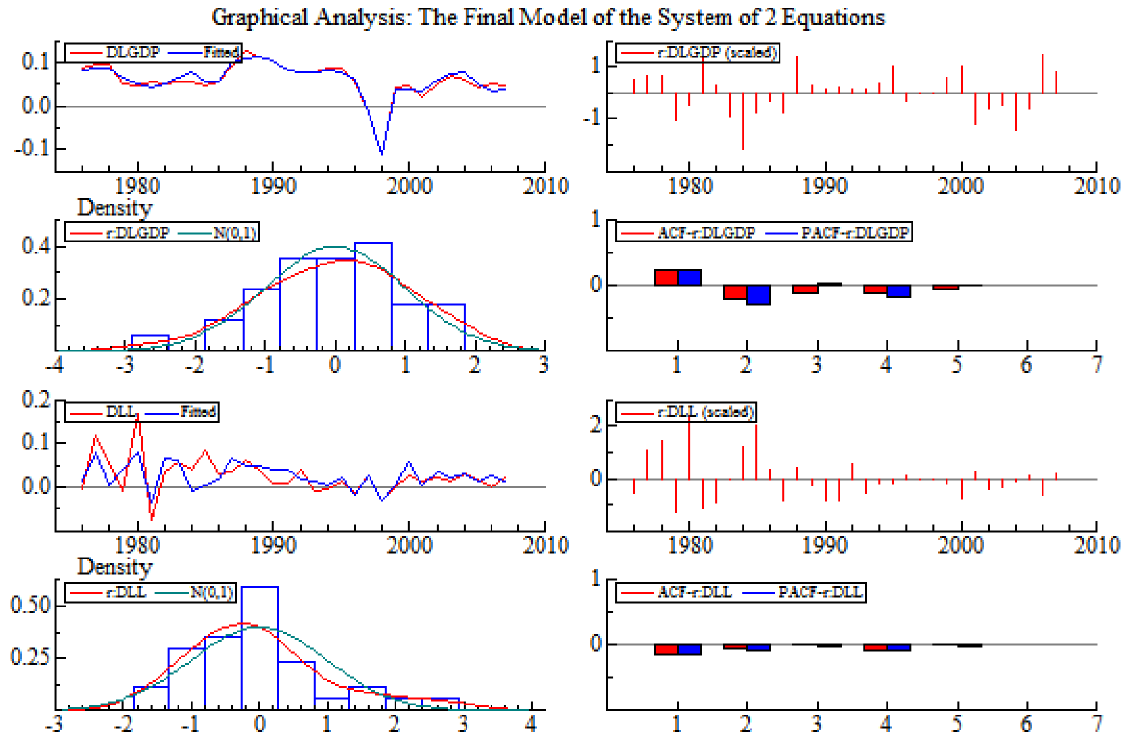

Figure 15: Recursive Graphics for Specific Model of Aggregate Output & Labor (VECM of the System of 2 Equations)