



Received: 22 May 2014

Received in revised form: 19 November 2014

Accepted: 22 December 2014

Exploring long-run relationship and error correction of Thai output and price

Kanokwan Chanchaoenchai*

Faculty of Economics, Kasetsart University

As the Thai economy has integrated into the world system, it increasingly endures not only internal circumstances, but also external turmoils. Stabilizing the country's growth and inflation from macroeconomic shocks has then become a challenge to policymakers. This study thus concentrates on investigating the long-run relationship and the adjustment process towards the equilibrium of output and price of Thailand from 2001 to 2014. For this purpose, the dynamic relationship, cointegration property, and error correction term are explored by DOLS, various cointegration tests, and ECM. The cointegration test also remarks the possibility of monetary policymakers to surprise the market in order to expect the increase in output. It also reconfirms that the interest rate tends to be a passive monetary instrument in curbing inflationary. Moreover, the adjustment process to the long-run of both output and price is found to have a symmetric cointegration property which implies the systematic ECM. The symmetric error correction test presents the significantly negative elimination in the next quarter towards long term equilibrium. The monetary policymakers thus seem to react to the rise in inflation uncertainty by keeping down inflation. Meanwhile, the output level tends to have faster adjustment speed than that of the price level.

Keywords: dynamic OLS, cointegration, asymmetric cointegration, error correction test

Introduction

Under the economic link with globalization, the Thai economy has to endure not only the country's macroeconomic shock, but also the impact of turmoils in other countries, which can bring about the uncertainty in economic growth and inflation. This uncertain

* Kanokwan Chanchaoenchai, Department of Economics, Faculty of Economics, Kasetsart University, Bangkok, Thailand, E-mail: fecokwo@ku.ac.th

situation effects passing through the living standard, social welfare cost and economic efficiency catch both academic and non-academic interest. For example, in the case of the impact of globalization on growth, the subprime crisis in the US causes the decline in economic growth in Thailand from 2.5 to -2.3 percent in 2009, (Bank of Thailand, 2014). Moreover, even though Thai monetary policymaker has reset its inflation target, headline inflation tends to be uncertain due to macro shocks both internally and externally. One reason could be the inflation target that is indicated by core inflation, which does not reflect people's purchasing power and the cost of doing business. This could bring the mismanagement and wider credibility gap of policymakers in stabilizing inflation. Consequently, the analysis on equilibrium correction of output and price has recently challenged macroeconomic researchers and policymakers.

To address this issue, there are various approaches introduced to explain the relation between output and macroeconomic variables, and also the price level. The deviation from equilibrium of output and price is also investigated. Grier, Henry, Olekalns, and Shields (2004), Blackburn and Pelloni (2005), and Karanasos and Schurer (2008), for instance, propose GARCH-type models to capture the effect of output growth and inflation volatility, and macro shocks on economic growth and inflation. Ibrahim and Chanchaoenchai (2014) employ dynamic OLS (DOLS) to examine the long-run cointegration, and asymmetric error correction model and measure the speed of adjustment of both aggregate and disaggregate inflation of Thailand related to changes in oil prices. Meanwhile Escribano (2004) suggests the non-linear error correction function in the form of cubic and rational polynomial, at least in the case of the UK money demand. Balke and Fomby (1994) argue that linear error correction could be rejected because of the failure to account for conditional heteroskedasticity. Besides the alternate empirical approaches, the findings of long-run relation and adjustment process are still inconclusive as demonstrated by the work of Cukierman (1992), Grier, Henry, et al. (2004), Blackburn and Pelloni (2005), and Bloom, et al. (2012), for example. This study thus initially tests for the asymmetric hypothesis by applying ARCH-type techniques to model an error correction equation.

In order to present empirical evidence and provide more understanding on the interaction between price levels and output in Thailand, the investigation of the dynamic behavior, testing for the long-run relationship and exploring the property of adjustment process are undertaken. The estimated equations of price and output are developed based upon the theoretical framework of money quantity and new growth. The asymmetric cointegration property is tested before the DOLS and error correction model are applied. To avoid the misspecification, the ARCH-type family is further employed to capture the time-varying variance effect in conditional mean and variance.

The rest of the paper is organized into 6 sections as follows. Theoretical background and related literature review are given in detail in section 2, while an empirical approach is described in section 3. Section 4 provides data description. The following section reports empirical results, which are divided into 3 discussions; preliminary statistic findings, the implementation of cointegration, and the intuition of error correction model. The final section is a brief summary and concluding remarks.

Theoretical background and related literature review

The stabilization of economic growth rate and inflation rate has recently captured the interest of both academics and non-academics since it tends to have a large impact on continuous growth path, living standard and social welfare cost, especially. There are rich literatures that show related evidences from the various approaches of empirical techniques. However, the conclusion is still ambiguous due to the differences in economic environment and degree of global integration, which initiate various risk factors and adjustment process.

To abstract the macroeconomic picture of long-run relationship and the equilibrium correction as well as to draft the estimated framework, a number of relevant researches are discussed to explore their main findings and empirical models. For instance, Bloom (2009) uses market volatility as a measure of uncertainty while the study of Bloom, et al. (2012) provides the confirmation for the empirical work of the former. Bloom, et al. (2012) also contributes the evidence of theoretical general equilibrium model to explore the effects of uncertainty on economic activities, showing that firms, industries and macroeconomic variables are countercyclical. Moreover, Barro (1991) finds the negative correlation between growth and political instability, and Koren and Tenreyro (2007) whose results are

in line with that of Barro. They find the strong relation between growth and internal shocks. Other investigations related to volatility and growth are Karanasos and Schurer (2008) that study the correlation between growth and volatility of country level macro shocks in the case of Italy using Parametric Power ARCH Model (PARCH Model). They find bilateral relation among those variables, which supports Blackburn and Pelloni (2005). However, their findings are contrary to the common belief of macroeconomics theory that growth volatility itself tends to expect a negative effect on economic growth in the next period.

According to the work of Grier, Henry, Olekalns, and Shields (2004), it shows the conflicting result to standard business cycle models, assuming output growth uncertainty and its average growth to be independent. One explanation is irreversible investment and the option value of waiting predicts. They conclude the negative relationship which is in line with Ramey and Ramey (1995), while Black (1987) and Grier, and Tullock (1989) find the positive effect among those two factors. On the other hand, Dawson and Stephenson, (1997) and Grier and Perry (2000) find no effect.

Another macroeconomic concern is to stabilize inflation in order to keeping the cost of living and social welfare at their proper levels. Even though inflation targeting has been applied in many countries, including Thailand, the introduction of inflation targeting does not immediately reduce inflation uncertainty in the market place at least in the case of UK monetary policy as suggested by Shen (1998). His finding is basically in line with the general view that inflation targeting takes time to gain credibility with the public. Meanwhile this uncertainty and the credibility of policymakers are taken as the indicator of macroeconomic stability in the marketplace. Meanwhile, Grier, et al. (2004) explore the relationship between inflation and real activity using the bivariate GARCH in mean model to capture effect among those variables and its volatility for post-war US data. According to the variance-covariance coefficients, they reflect asymmetric response of growth and inflation to shock at the same magnitude. Their results also show negatively significant correlation growth uncertainty and average growth itself. The inflation uncertainty, at the same time, significantly reduces growth and average inflation. This finding reaches the same result as that of Holland (1995), and Bernanke, et al. (1997), which show that the Federal Reserve reacts to increased inflation uncertainty by lowering inflation. On the other hand, Cukierman

and Meltzer (1986), and Cukierman (1992), for example, find opposite relation between inflation uncertainty and inflation due to the implicitly uncertain component in the money supply process and the lack of predictability of monetary policy's objective. Policymakers will then react to that increase in inflation uncertainty by raising inflation rate. With the unpredictability of real shocks as a consequence of stochastic component to the money supply, Deveraux (1989) shows the support to the conclusion of the positive effect of increased inflation uncertainty on average inflation. Based on the framework of Phillips Curve and the motive of Federal Reserve to increase output, this unpredictability would tend to shorten labor contracts, so that surprised inflation would then drive up the output.

Alternatively, Enders and Granger (1998), and Enders and Siklos (2001) provide threshold autoregressive (TAR) model which has extended by Enders and Dibooglu (2001), so called momentum threshold autoregressive (M-TAR) model to capture the asymmetric cointegration against the symmetric hypothesis. This property tests are alternatively employed to reassure the proper adjustment process towards the equilibrium whether that specific series is a linear or non-linear error correction, so called symmetric or asymmetric error correction model, respectively. Ibrahim and Chanchaoenchai (2014), for instance, investigate the long-run relation of aggregated and disaggregated price levels for Thailand using the framework of Enders and Granger, Enders and Siklos, and error-correction modeling approaches. Their findings are supportive of asymmetric cointegration, and asymmetric error correction model. Furthermore, Escribano (2004) also introduces the non-linear error correction model as the cubic and rational polynomial error correction function. His work explores the UK money demand from 1878 to 1970 which gives the strong evidence of non-linear equilibrium correction process. However, Balke and Fomby (1994) argue that linear error correction could be rejected because of the failure to account for conditional heteroskedasticity. This study thus provides the contribution on that area by first tests for the asymmetric hypothesis. The ARCH-type techniques are later employed to model the error correction equation.

Given the inclusiveness of empirical approach and evidence on various issues related to the economic growth and inflation dynamic, the areas of study remain fertile for further research. The conflicting results on the exact relationship among the economic

growth rate are one of main issues to be addressed. The response to the uncertainty of countries' macroeconomic shock also needs to be explored, especially for such a developing country as Thailand. This would confirm the direction of dynamic relation and adjustment process after deviating from equilibrium. The cointegration and adjustment process of economic growth and inflation are worth exploring in order to provide useful information to policymakers and businesses.

To address the long-run relation and error correction of output, the framework of growth model is employed to form estimated equations. According to Romer (1996), Crespo (2005), and Chanchaoenchai (2011) among others, there are several debates among economists over the sources and specification of growth. Most of investigations have built upon the work of Solow (1956). Those works continually provide alternative paths of analyzing the effect of explanatory factors in the form of updated neoclassical endogenous growth models as Romer (1986) and Lucas (1988) initially introduced. Underlying the theoretical framework of money quantity, the price equation is thus based on the quantity equation consisting of money supply, interest rate, and output to capture the cointegration relation and speed of adjustment. The cointegration relation is further taken in this investigation using the dynamic OLS, originally introduced by Stock and Watson (1993), and suggested by Maddala and Kim (1998).

Empirical approach

Production:

The Cobb-Douglas production is not only the most widely used form of production function, but it also provides a relatively accurate description of the economy. Moreover, it is very easy to work with algebraically. To simplify the model, this study thus assumes production function taking a Cobb-Douglas form. In order to capture the production phenomena, the two standard production factors, namely gross private investment expenditure¹ (K), labor (L), the ratio of the number of labor graduated above the high school to the lower level (SL) to capture labor skill, and imports of capital goods (ICG) to account direct technological diffusion are included to explain the production of Thailand, which is

¹ Gross private investment expenditure is a proxy for capital stock which is not available in quarterly frequency.

proxied by gross domestic product (GDP). Again, the Cobb-Douglas equation of production function must be taken into natural logarithmic linear form without the SL series, and let L be logarithmic value as follows:

Conditional Mean Equation: ARMA (p,q)

$$LGDP_t = \phi + \beta_K LK_t + \beta_L LL_t + \beta_N LICG_t + \beta_S SL_t + \sum_{i=1}^p \alpha_i LGDP_{t-i} + \sum_{i=1}^q \rho_i \varepsilon_{t-i} + \varepsilon_t$$

$$\text{Conditional Variance Equation: ARCH}(s); \varepsilon_t^2 = \gamma_0 + \sum_{i=1}^s \gamma_i \varepsilon_{t-i}^2 + v_t$$

where $LGDP_{t-p}$ and ε_{t-q} are the previous LGDP and moving average, respectively, to take the time-series effect into account if it presents the autoregressive process, specified as ARMA (p,q). Notably, the ARCH-type models could be extended from Engle (1982) as suggested by Bollerslev (1986), and Engle, Lilien and Robin (1987).

Inflation:

According to Cosimano and Jansen (1988), and Ouellette and Paquet (2001), the standard price model can be specified in the form of expectation as

$$\Pi = \Pi_t^e + \varepsilon_t, \quad \text{or } \Pi^e = E(\Pi_t | \Omega_{t-1}) = Z_t' \phi,$$

Where Π_t is the price and Π_t^e is the expected price. The ε_t is the error terms or unexpected price component and Z_{t-1} is the information available to economic agents at time t-1, which is a subset of Ω_{t-1} , i.e. $Z_{t-1} \in \Omega_{t-1}$.

Based on the quantity theory of money, the common quantity equation can be rewritten in logarithmic form of price level as $p = m + v(i) - y$, where p is price level, v(i) stands for the velocity to interest rate, and m and y denotes the money supply and output. The information set of Z_t hence contains the narrow money supply (M1), the government bond yield (INT), and the GDP. If it behaves autoregressive, the previous price level (Π_{t-n}) and moving average (ε_{t-m}) up to order n and m are added in the model to capture its time-series effect, so-called ARMA (n,m). If the error terms ε_t are serially uncorrelated with the zero mean, but they exhibit heteroskedastic process in variance, the ARCH-type models are then necessary. With the underlying of classical assumption, the price equation is thus in the form of natural logarithmic linearity which is written as

$$\text{Conditional Mean Equation: ARMA (n,m); } \Pi_t = \omega_0 + \sum_{g=1}^3 \omega_g Z_{g,t} + \sum_{i=1}^n \kappa_i \Pi_{t-i} + \sum_{i=1}^m \phi_i \varepsilon_{t-i} + \varepsilon_t$$

$$\text{Conditional Variance Equation: ARCH(s); } \varepsilon_t^2 = \gamma_0 + \sum_{i=1}^s \gamma_i \varepsilon_{t-i}^2 + v_t$$

Cointegration:

Before estimating the long-run relation and adjustment speed, the augmented Dickey-Fuller (ADF)² unit root test and KPSS³ stationary test are first employed to test the stationary or no integrated property of each variable. Given the non-stationary variables that are integrated at the same order, the long-run relation is then examined using Engle and Granger (1987), the VAR-based test by Johansen (1998), and Johansen and Juselius (1990). To circumvent the assumption of symmetry in the adjustment process to the long-run of both tests in which causes the notoriously low power, the asymmetric cointegration tests are applied by Ender and Granger (1998), and Ender and Siklos (2001) as estimating equations are presented below.

1) The asymmetric cointegration tests equation: LGDP;

$$\Delta \eta_t = c_1 I_t \eta_t + c_2 (1 - I_t) \eta_{t-1} + \sum_{i=1}^h d_i \Delta \eta_{t-i} + \psi_t$$

2) The asymmetric cointegration tests equation: LCPI;

$$\Delta \delta_t = c_1 I_t \delta_t + c_2 (1 - I_t) \delta_{t-1} + \sum_{i=1}^h d_i \Delta \delta_{t-i} + \vartheta_t$$

Where η_t and δ_t are the error terms received from estimating the long-run equation of LGDP and LCPI that are $\eta_t = \beta_0 + \beta_K LK_t + \beta_L LL_t + \beta_N LICG_t + \beta_S SL_t$ and $\delta_t = \omega_0 + \omega_1 LGDP_t + \omega_2 LMI_t + \omega_3 IN_t$ respectively. h is the optimal lag order to render the disturbance term serially uncorrelated. I_t is the Heaviside Indicator, which is just the dichotomous variable. It is specified by the sign of error term. If the value is less than zero (negative), it would be marked as zero. On the other hand, if the value is equal and greater than zero (positive), it would be marked as one. This study also allows testing the cointegration either at the level or the change of the error term.

² The Schwartz Bayesian Criterion (SBC) is used to select the appropriate lag length in the augmented Dickey-Fuller regression equation, proposed by Dickey and Fuller (1979).

³ The Schwartz Bayesian Criterion (SBC) is used to select the appropriate lag length in the augmented Dickey-Fuller regression equation, proposed by Dickey and Fuller (1979).

If the cointegration test is a function of the error term in level or threshold autoregressive (TAR) model, Heaviside Indicator is specified as:

$$I_t = \begin{cases} 1 & \text{if } \eta_{t-1} \geq 0 \quad \text{or} \quad \text{if } \delta_{t-1} \geq 0 \\ 0 & \text{if } \eta_{t-1} < 0 \quad \text{or} \quad \text{if } \delta_{t-1} < 0 \end{cases}$$

Alternatively, if the error term or shock tends to exhibit momentum in moving in one direction, Heaviside Indicator is a function of the change in the error term that is more appropriate as suggested by Enders and Dibooglu (2001). This cointegration function is called momentum threshold autoregressive (M-TAR) model, where the specification of Heaviside Indicator is as follows;

$$I_t = \begin{cases} 1 & \text{if } \Delta\eta_{t-1} \geq 0 \quad \text{or} \quad \text{if } \Delta\delta_{t-1} \geq 0 \\ 0 & \text{if } \Delta\eta_{t-1} < 0 \quad \text{or} \quad \text{if } \Delta\delta_{t-1} < 0 \end{cases}$$

The error term η_t and δ_t are said to have stationary property when c_1 and c_2 are in the range of value -2 and 0. The procedure to derive test statistics for the null hypothesis of no cointegration is either c_1 or c_2 , or both of them indifferent from zero; $H_0 = c_1 = c_2 = 0$. The test statistics for such a hypothesis are referred to the critical values as tabulated in Ender and Siklos (2001) instead of non-standard distribution F-statistics. The error data is stationary; the null hypothesis of no cointegration then cannot be rejected as well. Given the presence of cointegration of LGDP and LCPI, the next step is thus to test whether adjustment process is asymmetric. The null hypothesis of symmetric adjustment is c_1 indifferent from c_2 ; $H_0 = c_1 = c_2$ against the alternative hypothesis of asymmetric adjustment, that is, $H_a = c_1 \neq c_2$ using the standard F-statistics. Consequently, if null hypothesis of no cointegration and symmetric adjustment are rejected, the adjustment to equilibrium is asymmetric process.

In further, the long-run coefficients for the cointegrated system is also tested in this study applying dynamic ordinary least square (DOLS) which is introduced by Stock and Watson (1993). As stated in Maddala and Kim (1998), this method is preferable to small sample size and superior to a multi-equation Johansen-Juselius estimator because the latter tends to have relatively large variation. DOLS also solves the simultaneity bias and takes effect of endogeneity regressor into account by allowing leads and lags of the first difference, $I(1)$ terms in the estimation. Letting the $-k$ and $+k$ denote the lags of order k and

leads of order k . The DOLS estimation of LGDP and LCPI are formulated as follows:

1) DOLS equation to test for long-run relation of LGDP:

$$\text{LGDP}_t = \phi + \beta_K \text{LK}_t + \beta_L \text{LL}_t + \beta_N \text{LICG}_t + \beta_S \text{SL}_t + \sum_{i=-h}^{+h} a_{1h} \text{GK}_{t-i} + \sum_{i=-h}^{+h} a_{2h} \text{GL}_{t-i} + \sum_{i=-h}^{+h} a_{3h} \text{GICG}_{t-i} + \sum_{i=-h}^{+h} a_{4h} \text{GSL}_{t-i} + \varepsilon_t$$

2) DOLS equation to test for long-run relation of LCPI:

$$\text{LCPI}_t = \phi + \omega_1 \text{LGDP}_t + \omega_2 \text{LMI}_t + \omega_3 \text{IN}_t + \sum_{i=-h}^{+h} b_{1h} \text{GGDP}_{t-i} + \sum_{i=-h}^{+h} b_{2h} \text{GMI}_{t-i} + \sum_{i=-h}^{+h} b_{3h} \text{GIN}_{t-i} + \theta_t$$

Finally, another examination of cointegration is presented by using the error correction model (ECM). It is a powerful technique since it combines both the short-run and long-run relation at the same time by allowing LGDP and LCPI to respond to other relevant variables. The error correction specification would be specified in three different models which are depended on the test of result of symmetric adjustment hypothesis. The alternative specifications are presented below.

1) Ender and Siklos cointegration test indicates no cointegration, that is

$H_0: c_1 = c_2 = 0$ cannot be rejected, the equation is then expressed as follows:

- The first difference of LGDP (GGDP) estimating equation:

$$\text{GGDP}_t = \lambda + \sum_{i=1}^m \alpha_i \text{GGDP}_{t-i} + \sum_{i=0}^{h1} \beta_K \text{GK}_{t-i} + \sum_{i=0}^{h2} \beta_L \text{GL}_{t-i} + \sum_{i=0}^{h3} \beta_N \text{GICG}_{t-i} + \sum_{i=0}^{h4} \beta_S \text{GSL}_{t-i} + \varepsilon_t$$

- The first difference of LCPI (INF) estimating equation:

$$\text{INF}_t = \lambda + \sum_{i=1}^n \eta_i \text{INF}_{t-i} + \sum_{i=0}^{h1} \omega_{1i} \text{GGDP}_{t-i} + \sum_{i=0}^{h2} \omega_{2i} \text{GMI}_{t-i} + \sum_{i=0}^{h3} \omega_{3i} \text{GIN}_{t-i} + \theta_t$$

2) Ender and Siklos cointegration test indicates cointegration with the symmetric

adjustment, that are $H_0: c_1 = c_2 = 0$ is rejected and, but $H_0: c_1 = c_2$ cannot be rejected, the equation is then formulated as follows:

- The first difference of LGDP (GGDP) estimating equation:

$$\text{GGDP}_t = \lambda + \sum_{i=1}^m \alpha_i \text{GGDP}_{t-i} + \sum_{i=0}^{h1} \beta_K \text{GK}_{t-i} + \sum_{i=0}^{h2} \beta_L \text{GL}_{t-i} + \sum_{i=0}^{h3} \beta_N \text{GICG}_{t-i} + \sum_{i=0}^{h4} \beta_S \text{GSL}_{t-i} + \phi \eta_{t-1} + \varepsilon_t$$

- The first difference of LCPI (INF) estimating equation:

$$\text{INF}_t = \lambda + \sum_{i=1}^n \eta_i \text{INF}_{t-i} + \sum_{i=0}^{h1} \omega_{1i} \text{GGDP}_{t-i} + \sum_{i=0}^{h2} \omega_{2i} \text{GMI}_{t-i} + \sum_{i=0}^{h3} \omega_{3i} \text{GIN}_{t-i} + \phi \delta_{t-1} + \theta_t$$

3) Ender and Siklos cointegration test indicates cointegration with the asymmetric

adjustment, that are $H_0: c_1 = c_2 = 0$ and $H_0: c_1 = c_2$ are rejected, the equation is then written as follows:

- The first difference of LGDP (GGDP) estimating equation:

$$\text{GGDP}_t = \lambda + \sum_{i=1}^m \alpha_i \text{GGDP}_{t-i} + \sum_{i=0}^{h1} \beta_K \text{GK}_{t-i} + \sum_{i=0}^{h2} \beta_L \text{GL}_{t-i} + \sum_{i=0}^{h3} \beta_N \text{GICG}_{t-i} + \sum_{i=0}^{h4} \beta_S \text{GSL}_{t-i} + \phi_1 \eta_{t-1}^+ + \phi_2 \eta_{t-1}^- + \varepsilon_t$$

- The first difference of LCPI (INF) estimating equation:

$$\text{INF}_t = \lambda + \sum_{i=1}^n \eta_i \text{INF}_{t-i} + \sum_{i=0}^{h_1} \omega_{1i} \text{GGDP}_{t-i} + \sum_{i=0}^{h_2} \omega_{2i} \text{GMI}_{t-i} + \sum_{i=0}^{h_3} \omega_{3i} \text{GIN}_{t-i} + \phi_1 \delta_{t-1}^+ + \phi_2 \delta_{t-1}^- + \theta_t$$

where G is denoted the first difference of logarithmic value and h_1, h_2, h_3 are the optimal lag orders. ϕ is the error correction term (ETC) coefficient which measures the adjustment speed of LGDP and LCPI is corrected the next period to get back on their long-run equilibrium path. ECT here represents the deviation of LGDP and LCPI from its long-run value which η_t and δ_t , respectively. The greater value of ϕ reveals the faster speed of adjustment. To be more specific, if the finding of specification 3) shows a significant $\phi_1 \neq \phi_2$, it would imply unequal two states of ECT adjustment process. Meanwhile, $|\phi_2| > |\phi_1|$ indicates the faster speed of adjustment to the long-run equilibrium path, and vice versa. It must be noted that the application of specification 1) provides only possible short-run relation between LGDP and LCPI and among their regressors since they are not cointegrated. Notably, the autocorrelation and heteroskedasticity property of residual data series must also be tested after each regression. If it exhibits a heteroskedastic process, the ARCH-type family will be employed to estimate the cointegration.

Data description

Based on the theoretical framework and related literature review, the variables used in this analysis are gathered from various sources to serve for both economic growth and inflation models. Gross domestic product (GDP) at 1988 prices and gross fixed capital formation (K) are drawn from the Office of National Economic and Social Development Board. The total labor force (L) and its classification by educational level are taken from the National Statistical Office. The Bank of Thailand provides the time-series data of narrow money supply (M1), Government Bond Yield at 5 years to maturity (IN), and headline consumption price index (CPI) while the Ministry of Commerce is the source of the import value of capital goods (ICG). The sample period covers from the first quarter of 2001 to the first quarter of 2014, totaling of 54 quarters. This is the period when the Thai economy recovered from the 1997 financial crisis with the application of inflation targeting and managed float exchange rate. This sample period also deals with the difficulty due to oil price surge and world economic slowdown. The economic environment is then framed which helps to

clarify the cause of deviation.

It must be noted that gross fixed capital formation is employed here as a proxy of capital stock which is not available on a quarterly basis. Government Bond Yield at 5 years to maturity and money supply are the proxy of monetary policy and banking system. To capture the contribution of human capital and direct channel of technological diffusion, the ratio of the number of labor graduated above the high school to the lower level (SL), and the import of capital goods (ICG) are included in growth model. Also, let's denote that the L and G stand for the logarithmic form as level, and percentage change as the growth rate, respectively. To be more specific, the percentage change is just the first difference of logarithmic form of those particular variable series. GDP measures the economic activity and the first difference form of logarithmic CPI and GDP are thus the proxy for the inflation rate and economic growth rate.

As for the various results of preliminary statistics, they illustrate the characteristic of economic growth and inflation rate during the sample period. The GGDP behaves kurtotic and right skewed which reveals the slowly continuous movement. This also could reflect the slow process of adjustment as the response to the deviation from its equilibrium. Meanwhile, inflation rate (INF) has leptokurtic and right skewed characteristic. This leptokurtic behavior shows the evidence of rapid change of consumption price in the response of any internal and external incidence, such as retail gasoline price ceiling and oil tax subsidy, minimum wage policy, Thai flood in 2011, terrorist attack in the US, violence in Iraq, world financial crisis. Therefore, the GGDP has normal distribution. On the other hand, according to Jarque-Bera test, the INF rejects the normal hypothesis.

Empirical results

Preliminary statistic results

Due to the limitation of space, the ADF and KPSS statistic test results are unreported. However, it can be summed up that the unreported ADF and KPSS reveal the stationary characteristic of each variable employed in this study. This alternative KPSS test for stationary is employed to reaffirm the robustness presented by ADF unit root test at the confidence level greater than 90%. They clearly point out that all variables in the first

difference form series are integrated of order 1, $I(1)$, with the exception of LM1. However, the KPSS strongly accepts the stationary hypothesis of GM1. The ADF gives also the opposite finding from KPSS in the test for the level value series which are LCPI, LICG and SL. The ADF reveals that LICG and SL have unit root, while the KPSS strongly rejects the hypothesis of stationarity. In contrast to LICG and SL, the KPSS cannot reject the null hypothesis of $I(0)$ of the LCPI series, while the ADF shows the opposite results. This study takes advantage of the inconclusive test results. Therefore, those macroeconomic variables are said to be integrated of order 1, $I(1)$, at level value, or integrated of order zero, $I(0)$, at first difference value. The long-run relation test is then constructed by employing the EG, JC and ES.

Table 1 EG and JC test results of symmetric cointegration property

Variables:	EG Test Statistic	Statistic	JC Test				
			Null hypothesis of no cointegration				
			$r=0$	$r\leq 1$	$r\leq 2$	$r\leq 3$	$r\leq 4$
LGDP	-2.384	Trace	100.758 ^{***}	58.626 ^{***}	32.650 ^{***}	14.163 ^{**}	3.323 [*]
		Max-Eigen	42.132 ^{***}	25.976 ^{**}	18.487 ^{**}	10.840 [*]	3.323 [*]
LCPI	-4.105	Trace	69.920 ^{***}	43.054 ^{***}	22.636 ^{**}	8.697 [*]	-
		Max-Eigen	26.866 [*]	20.418 [*]	13.939 [*]	8.6967 [*]	-

Note: EG Test is Engle-Granger Cointergartion Test with the inclusion of the 4 lag order for LGDP and 5 lag order for LCPI. JC is Johansen Cointegration Test. SIC is used to select the optimal lag order of 4 and 5 in the EG of LGDP and LCPI, respectively, meanwhile VAR lag order. ^asignificance at 1% level, ^bsignificance at 5% level, and ^csignificance at 10% level.
 * ** *** significance at 10%, 5% and 1% respectively

According to the EG and JC cointegration test in Table 1, the EG test cannot reject the null hypothesis of no cointegration for both IGDP and ICPI. In contrast, the JC test results present the evidence of cointegration for both cases. With the knowing of the EG and JC being under the condition of symmetric adjustment, the ES cointegration, TAR and M-TAR model, is then processed to relax this rigid condition by allowing the adjustment to be asymmetric process to assure the proper error correction model. The ES cointegration test results, presented in Table 2, clearly cannot reject the null hypothesis of all Heaviside indicator indifferent from zero, indicating the no cointergarion. The asymmetric adjustment

test using TAR and M-TAR model is thus not processed. Consequently, this finding tends to support the property of symmetric adjustment for both LGDP and LCPI. Based on the long-run relation test, the error correction model thus adopts the symmetrical cointegration for both economic growth (GGDP) and inflation rate (INF).

Table 2 ES test results for asymmetric cointegration property

Variables:	ES Test: F-statistic Test		Asymmetry Test: F-statistic Test	
	TAR	M-TAR	TAR	M-TAR
LGDP	0.6853	1.864	-	-
LCPI	1.8596	1.864	-	-

Note: ES Test is Enders-Siklos cointergartion test asymptotic to tabulance Ender and Siklos (2001) while the asymmetric adjustment property testis asymptotic to F-statistic. The SIC is used to select the optimal lag order of the test equation.

Estimation of long-run equilibrium: Stock-Watson Dynamic OLS (DOLS)

Before estimating DOLS, the optimal lag order test equation is first selected based on the AIC and SIC. Since the AIC and SIC indicate different numbers of optimal lag order, the selection of optimal lag order of equation in this study is taken the SCI as suggested by Ender (2004). According to the SIC, it suggests the 1 lag order in the DOLS equation of LGDP while the LCPI equation processes with 2 lags order test equation. As for estimating results, the SL and LICG show insignificant predictability power on LGDP while LGDP has less explanatory power on LCPI. This statistical insignificance illustrates the less related power among dependent variables and those of independent variables in the long-run. However, they provide interesting information in terms of economic growth path during particular period of sample. SL has negatively and insignificantly explanatory power on LGDP while LICG positively relates to LGDP. This finding could reveal the imbalance of labor skill and technological improvement via the import of capital goods from developed countries. Moreover, it also presents evidence of the role of human capital and investment in the new growth framework on the economic growth.

Furthermore, LCPI highly relates to interest rate and money supply, but not LGDP. It does not show significant long-run relation with LCPI which is consistent with McCandless and Weber (1995). This finding remarks some insightful information about a mild association of average price and aggregate expenditure. On the other hand, average price level is more attached to government intervention, minimum wage and gasoline policy, for instance, and climate uncertainty, for example the wide spread drought among the agricultural dependence countries in 2010 and flood in Thailand in 2011.

Turning on to the long-run coefficients for the cointegrated system of LGDP, LL and LK productivity have significant effect on LGDP by 2.048 and 0.289, respectively. Intuitively, an increase in LL by 10 percent would possibly drive up LGDP by a roughly 20.48 percent while a 10 percent increase in LK could averagely expect an increase in LGDP by 2.89 percent. It is clear that employed labor and private investment productivity significantly capture the output deviation from its average level. The ten times larger of estimated coefficient for labor cointegrating with LGDP than capital perhaps points out that the Thai economy has been driven by the labor than capital. This could reflect that most industries are classified as the light industry whose productions are labor intensive. Thai output is thus unsurprisingly indicated by labor employment situation.

In the case of price level, the DOLS estimation shows the evidence of long-run cointegration that the change in money supply and interest rate significantly pass on through the price level in the long-run. The price level could be expected to increase by 2.77 percent and 0.17 percent if money supply and interest rate respectively rise by 10 percent. Their positive signs of relation are in line with the quantity theory of money and Fisher's real interest rate. The elasticity of price tends to depend on the expected increase in money supply more than interest rate. Therefore, the interest rate seems to be quite a passive monetary instrument compared to money supply (narrow definition) in curbing inflation as the consequences of welfare policy, such as grant for living expense, and financial aids for elderly, disable, and farmer's retirement pension. However, it must be noted that money supply is very vulnerable and lack of predictability due to an advance in information technology together with economic and financial integration as well as tendency of deregulation, which expedite all financial transactions and other economic activities. (Table 3)

Table 3 Stock-Watson Dynamic OLS (DOLS) test results of long-run relation

Dynamic Ordinary Least Squares (DOLS)			
LGDP		LCPI	
Independent Variables	Coefficient	Independent Variables	Coefficient
constant	-11.917 (-2.332)**	constant	-1.991 (-1.536)
LK	0.289 (2.603)***	LGDP	0.187 (1.307)
LL	2.048 (4.065)***	LM1	0.277 (3.476)***
LICG	0.700 (0.717)	IN	0.017 (1.848)*
SL	-1.806 (-0.975)	-	-

Note: ^a significance at 1% level, ^b significance at 5% level, and ^c significance at 10% level. The SIC is used to select the optimal lag order.

* ** *** significance at 10%, 5% and 1% respectively

Error Correction Model (ECM)

According to preliminary analyses of LGDP and LCPI series, they suggest that the economic growth rate (GGDP) and inflation rate (INF) present the symmetric adjustment. As a result, the error correction estimation is then symmetric ECM as illustrated in section 3 to test for the cointegration and the speed of adjustment process through long-run equilibrium. From the various test of statistics, they clearly agree with AR(2,3), and AR(1,3)-ARCH(1) as the appropriate specification to regressing GGDP and INF, respectively. Table 4 provides the estimated short-run coefficients associated with symmetric ECM for GGDP and INF. The estimation of GGDP and INF dynamics reports negative and significant relationship at higher than 99 percent confidence level of the error correction term (ETC) coefficient for both cases. This finding reaffirms the exhibition of cointegration. With the surprise of that, the error correction coefficient of GGDP is larger than coefficient of INF. Hence, the GGDP tends to adjust towards the long-run faster than INF once it deviates from its long-run value. The estimation results also suggest the corresponding adjustment for negative deviation of GGDP and INF by 23.0 percent and 18.7 percent in the next quarter, respectively. (Table 4)

Table 4 Symmetric error correction model test results of cointegration

GGDP			INF		
Coefficient	OLS		Coefficient	AR(1, 3)	AR(1, 3)-ARCH(1)
Conditional Mean Equation:			Conditional Mean Equation:		
constant	0.022 (5.47)***		constant	0.010 (6.993)***	0.009 (20.726)***
ETC _{t-1}	-0.230 (-3.214)***		ETC _{t-1}	-0.160 (-3.127)***	-0.187 (-7433)***
GK _t	0.243 (3.686)***		GGDP _{t-1}	-0.053 (-2.405)**	-0.026 (-2.990)***
GK _{t-4}	-0.204 (-4.144)***		GIN _{t-1}	-0.005 (-2.591)***	-0.002 (-1.941)**
GL _{t-3}	-1.658 (-7.839)***		GIN _{t-3}	0.006 (3.060)***	0.006 (6.256)***
GL _{t-4}	-1.250 (-8221)***		GM1 _{t-3}	-0.103 (-2.921)***	-0.075 (-5.598)***
GICG _t	0.092 (2.734)***		INF _{t-1}	0.322 (2.673)***	-0.145 (-2.140)**
GICG _{t-3}	-0.072 (-2.883)***		INF _{t-3}	-0.528 (-4.475)***	-0.403 9-8626)***
GSL _{t-1}	-0.766 (-1.808)*		Conditional Variance Equation:		
GSL _{t-2}	0.917 (2.025)**		constant	-	2.16E ⁻⁰⁶ (0.696)
GSL _{t-3}	-1.763 (-4.080)***		ε_{t-1}^2	-	0.774 (2.937)***
GGDP _{t-2}	-0.242 (-1.840)*				
GGDP _{t-3}	0.640 (4.813)***				
Adj-R ²	0.922		Adj-R ²	0.551	0.323
Log(L)	133.099		Log(L)	166.380	176.290
JB	13.246***		JB	0.101	1.417
RESET Test: LR(2)	1.088		RESET Test: LR(2)	31.862***	[11.954***]*
			[wald test: $\chi^2(2)$]		
Autocorrelation Test:			Autocorrelation Test:		
Q(3)	0.575		Q(3)	2.092	2.711
Q(4)	0.739		Q(4)	2.527	2.789
Heteroskedastic Test:			Heteroskedastic Test:		
Q ² (2)	2.423		Q ² (2)	7.1331**	3.389
Q ² (4)	3.640		Q ² (4)	10.063**	4.194
ARCH-test:			ARCH-test:		
LR(2)	2.575		LR(2)	6.133**	3.183
LR(4)	4.001		LR(4)	8.020*	3.197

Note: Adj-R² = AdjustedR², Log (L) = log function likelihood. The numbers in the parentheses are t-statistics. Q and Q² are Ljung-Box Q-statistics for testing hypothesis of no autocorrelation and homoskedasticity, respectively. RESET Test is the Ramsey' misspecification test with the fitted terms set to 2 .ARCH test is the homoskedasticity process in conditional variance up to order 2 and 4. * indicates Wald test between AR(1,|3|) and AR(1,|3|)-ARCH(1).

* ** *** significance at 10%, 5% and 1% respectively

Moreover, the estimated results also present the short-run integration with other economic variables. Most of them seem to lead to oscillating fluctuation of GGDP and INF, with the exception of the change of employed labor whose two coefficients of the last two periods are negative for the GGDP. Again, in line with the long-run investigation using DOLS, labor tends to substantially affect the GGDP due to its specific property of the immediate adjustment depending on how well the economic performance is. However, error correction test gives the different sign of labor's coefficient from the DOLS estimation. This inconclusive sign of impact should somewhat be reemphasized. Nevertheless, this finding provides a supportive evidence to the common macroeconomics theory, but contrary to the standard business cycle model. Moreover, negative effect of ETC on GGDP is in line with the work of Grier, et al. (2004), and Ramey and Ramey (1995).

The similar technique is also used to estimate INF dynamic. According to the test results, they suggest the short-run causal influence of GGDP on INF while GM1 and GINT tend to have a long-run causal relation with INF. However, the results are still needed to be reemphasized across with the DOLS estimation since both seem to be counter intuitive. Interestingly, INF appears to have negatively significant long-run impact on itself and possesses positively significant time-varying variance due to the possibility of market's correction after receiving recent information. With negatively significant ETC, the Central Bank of Thailand seems to react to the rise in inflation uncertainty by keeping down inflation, which is in line with Bernanke, et al. (1997), and Holland (1995). Additionally, one lag ARCH coefficient is close to a unit, which is indicative of long-run adjustment process to get back on its average. The cointegration estimation of INF indicates the evidence of both mean and variance deviation that would take time to be corrected.

Conclusion

To understand more about economic phenomena under a rising connection of globalization, the investigation of macroeconomic factor dynamics and their adjustment process to its equilibrium after variation due to some macro shocks have been an increasingly critical issue. Nevertheless, this area of interest is still needed to be explored. In order to be part of contribution, this paper provides empirical evidence of the price levels and economic activities dynamics, covering period from the first quarter of 2001 to the first quarter of 2014 with the total of 54 quarters when the Thai economy recovered from the 1997 financial crisis with an adoption of inflation targeting and managed float exchange rate regime.

Various testes are employed in this study, including integration properties of the time series, long-run relation, cointegrated system, and error correction test. The ADF unit root test and alternative KPSS test clearly point out that all variables are integrated of order 1, $I(1)$. From the analysis of long-run relation and the cointegrated specification, the values of GDP (LGDP) and general price levels (LCPI) show a symmetric cointegration property. Therefore, the ECM model, which has been used for testing the short-run relationship, is then associated with a symmetric error correction model.

Before estimating the error correction models, the dynamic ordinary least square is employed to test cointegrated system, the findings provide the strong evidence of long-run relation between GDP, K and L. The findings reveal the imbalance of labor skill and technological improvement from the direct channel of diffusion, the import of capital goods. Moreover, the LCPI is also significantly affected by interest rate and money supply. This finding remarks the possibility of monetary policymaker to surprise the market in order to expect the increase in output. The interest rate also tends to be quite a passive monetary instrument compare to money supply in curbing inflationary.

Finally, an estimated ECM indicates that $AR(2,3)$ and $AR(1,3)$ -ARCH(1) are the most suitable model to estimate the economic growth rate and inflation rate, respectively. The estimations of coefficients for error correction term of both equations present the statistically and significantly negative relationship at a conventional confidence level. This shows that a speed of adjustment towards a long term equilibrium or the size of deviation

from equilibrium could be eliminated in the next quarter. When comparing the size of coefficients, it can be seen that the speed of adjustment of output level is faster than that of price level. Furthermore, ECM's results reveal short run effects among independent variables. Again, it must be noted that the ECM results are counter intuitive with dynamic ordinary least square; the cointegration might be needed to be reemphasized.

Acknowledgement

The author cordially owes thanks to Department of Economics, Faculty of Economics, Kasetsart University for its support of this research. All opinions and any remaining errors are those of author's responsibility.

Reference

- Baker, S.R., & Bloom, N. (2013). Does uncertainty reduce growth? using disasters as natural experiments. *National Bureau Economic Research*, Working Paper 19475. (Online). <http://www.nber.org/papers/w19475> (access 15 January 2014).
- Bank of Thailand. (2014). Thailand's economic conditions in 2014. *Year Report on Economic and Monetary Conditions*.
- Balke, N.S. & T.B. Fomby. (1994). Large shocks, small shocks and economic fluctuations: outliers in macroeconomic time series. *Journal of Applied Econometrics*, 9, 181-200.
- Barro, R.J. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics*, 106(2), 407-443.
- Bernanke, B.S., Gertler, M., & Watson, M. (1997). Systematic monetary policy and the effects of oil price shocks. C.V. Starr Center for Applied Economics, New York University.
- Black, F. (1987). *Business Cycles and Equilibrium*. Basil Blackwell: New York.
- Blackburn, K., & Pelloni, A. (2005). Growth, cycles and stabilisation policy. *Oxford Economic Papers*, 57, 262-282.
- Bloom, N. (2009). The impact of uncertainty shocks. *Econometrica*, 77, 623-685.
- _____, Floetotto, M., Jaimovich, N., Eksten, I.S. & Terry, S. (2012). Really uncertain business cycles. *National Bureau Economic Research*, Working Paper 18245. (Online). <http://ssrn.com/abstract=2114871> (access 15 January 2014).

- Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics*, 31, 307-327.
- Chancharoenchai, K.(2011). Study of economic growth in Thai economy. *Journal of International Development and Cooperation*, 17(2), 11-30.
- Cosimano, T.F. & Jansen, D.W. (1988). Estimates of the variance of U.S. inflation based upon the ARCH model: A comment by Thomas F. Cosimano and Dennis W. Jansen," *Journal of Money, Credit, and Banking*, 20(3), 409-423.
- Crespo, J.C. (2005). Total factor productivity: An unobserved components approach. Discussion Paper 05/579, Department of Economics, University of Bristol.
- Cukierman, A., & Meltzer, A.H. (1986). A theory of ambiguity, credibility, and inflation under discretion and asymmetric information. *Econometrica*, 54, 409–421.
- _____. (1992). *Central Bank Strategy, Credibility, and Independence*. MIT Press: Cambridge, MA.
- Dawson, J., & Stephenson, F. (1997). The link between volatility and growth: evidence from the States. *Economics Letters*, 55, 365–369.
- Deveraux, M. (1989). A positive theory of inflation and inflation variance. *Economic Inquiry*,27, 105–116.
- Dickey, D., & Fuller, W.A. (1979). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49, 1057–1072.
- Enders, W. (2004). *Applied Econometric Time Series*. 2nded. New York: Wiley.
- _____, & Granger, C.W.J. (1998). Unit-root tests and symmetric adjustment with an example using the term structure of interest rate. *Journal of Business & Economic Statistics*, 16, 304–311.
- _____, & P.L. Siklos. (2001). Cointegration and threshold adjustment. *Journal of Business & Economic Statistics*, 19 (2), 166–176.
- _____, W., & S. Dibooglu. (2001). Long-run purchasing power parity with asymmetric adjustment. *Southern Economic Journal*, 68 (2), 433–445.
- Engle, R.F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica*, 50(4), 987-1007.
- _____, D. Lilien & Robins, R. (1987). Estimating time varying risk premia in the term structure: The ARCH-M model," *Econometrica*, 55, 391-407.

- _____, & C.W.J. Granger. (1987). Cointegration and error-correction: representation, estimation and testing. *Econometrica*, 55, 251–276.
- Escribano, A. (2004). Nonlinear error correction: the case of money demand in the United Kingdom (1878-2000), *Macroeconomic Dynamics*, 8, 76-116.
- Grier K., & Perry M. (2000). The effects of uncertainty on macroeconomic performance: bivariate GARCH evidence. *Journal of Applied Econometrics*, 15, 45–58.
- _____, & Tullock, G. (1989). An empirical analysis of cross-national economic growth, 1951–1980. *Journal of Monetary Economics*, 24, 259–276.
- _____, Henry, O.T., Olekalns, N., & Shields, K. (2004). The asymmetric effects of uncertainty on inflation and output growth. *Journal of Applied Econometrics*, 19, 551-565.
- Holland, S. (1995). Inflation and uncertainty: tests for temporal ordering. *Journal of Money, Credit, and Banking*, 27, 827–837.
- Ibrahim, M. H., & Chanchaoenchai, K. (2014). How inflationary are oil price hikes? A disaggregated look at Thailand using symmetric and asymmetric cointegration models. *Journal of the Asia Pacific Economy*, 19(3), 409-422.
- Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, 12 (2–3), 231–254.
- _____, & Juselius, K. (1990). Maximum likelihood estimation and inferences on cointegration with application to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52 (2), 169–210.
- Karanasos, M., & Schurer, S. (2008). Is the reduction in output growth related to the increase in its uncertainty? the case of Italy. *WESAS Transactions in Business and Economics*, 2(3), 116-122.
- Koren, M., & Tenreiro, S. (2007). Volatility and development. *The Quarterly Journal of Economics*, 122 (1), 243-287.
- Kwiatowski, D., Phillips, P.C.B., Schmidt, P., & Shin, B. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: how sure are we that economic time series have a unit root? *Journal of Econometrics*, 54, 159–178.
- Lucas, R. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22, 3-42.

- Maddala, G., & I. Kim. (1998). *Unit Roots, Cointegration, and Structural Change*. Cambridge: Cambridge University Press.
- McCandless, G.T. & W.E. Weber.(1995). Some Monetary Facts. Quarterly Review, Federal Reserve Bank of Minneapolis.19(3), 2-11.
- Ouellette, P., & Paquet, A. (1999). Inflation uncertainty and the cost of inflation. *Canadian Journal of Economics*, 32(1), February, 95-214.
- Ramey, G., & Ramey V. (1995). Cross-country evidence on the link between volatility and growth. *American Economic Review*, 85, 1138–1151.
- Romer, D. (1996). *Advanced Macroeconomics*, MacGraw-Hill, USA.
- Romer, P.M. (1986). Increasing returns and long run growth. *Journal of Political Economy*, 94(5), 1002-1037.
- Shen, P. (Fourth Quarter 1998). How important is the inflation risk premium?. Economic Review, Federal Reserve Bank of Kansas City, 35-47.
- Solow, R. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, 70, 65-94.
- Stock, J.H., & Watson, M.W. (1993). A simple estimator of cointegration vectors in higher order integrated system. *Econometrica*, 61(4), 783-820.