Chapter 4

Methodology and Econometric Methods

Chapter 4 will be including the research methodology and econometric methods that use in this thesis. The research methodology will consider theoretical model, econometric model, hypothesis in this study, and data description. The econometric methods will explain the co-integration and error-correction model.

4.1 Research Methodology

Since equilibrium real exchange rate is positive relationship with the relative price of non-tradable good at equilibrium level. When the relative price of non-tradable adjusted to steady state , the real exchange rate also adjust to steady state. The theoretical model of R_n and R are evaluated in term of exogenous variables T, s, r' and y. The equations R_n and R captures something close to the total effects. The direct effects may be quite different from the indirect effects. The theoretical model of a change in Z is

$$dR_n/dZ = \partial R_n/\partial Z + [(\partial R_n/\partial k)\, dk^*/dZ + (\partial R_n/\partial F)\, dF^* / dZ]$$

$$dR/dZ = \partial R_n/\partial Z + [(\partial R_n/\partial k)\, dk^*/dZ + (\partial R_n/\partial F)\, dF^* / dZ]$$

where Z = (T, s, y, r');

when R_n = the relative price of non-tradable.

R = the real exchange rate

T = term of trade

s = social thrift

y = the parameter of productivity u that proxy by GDP per workers

r' = the world real long term interest rate

The objective of equation non-tradable relative price and real exchange rate find out long-run relationship that are determined by fundamental variables. The econometric method will be use co-integration and error-correction model base on Johansen method which will explain in above.

4.2 Econometric model

The econometric model that capture the total effect of R_n and R can shows the following reduced equations.

$$\mathbf{R}_{nt} = \alpha_0 + \alpha_1 \mathbf{y}_t + \alpha_2 \mathbf{s}_t + \alpha_3 \mathbf{T}_t + \alpha_4 \mathbf{r}_t' + \varepsilon_{1t}$$

$$\mathbf{R}_t = \beta_0 + \beta_1 \mathbf{y}_t + \beta_2 \mathbf{s}_t + \beta_3 \mathbf{T}_t + \beta_4 \mathbf{r}_t' + \varepsilon_{2t}$$

where $\mathbf{R}_{nt}$= the relative price of non-tradable.

$\mathbf{R}_t$ = the real exchange rate

$\mathbf{T}_t$ = term of trade

$\mathbf{s}_t$ = social thrift

$\mathbf{y}_t$ = the parameter of productivity u that proxy by GDP per workers

$\mathbf{r}_t'$ = the world real long term interest rate

ε_{it}= disturbance terms.

4.3 Hypothesis

From the theoretical framework in chapter 3 we can expect the relationship in non-tradable relative price depend on the fundamental variables. Since the real exchange rate model related non-tradable relative in positive way hence we can assign the real exchange rate model also depend on the fundamental variables. Therefore we can explain the effect of fundamental variables to non-tradable relative price and real exchange rate in same direction. The relation of fundamental variables and non-tradable relative price and real exchange rate can expect the following.

(1) Productivity (y): the direction of productivity can effect in positive and negative relation. In positive effects, it means direct effect more than indirect effect. Hence non-tradable relative price and real exchange rate will appreciate when the productivity rise. On the other hand, negative direction means the direct effect less than indirect effect. Non-tradable relative price and real exchange rate will depreciate.

(2) Thrift (s): it can relate with non-tradable relative price and real exchange rate in positive and negative direction. The positive direction imply direct effect more than indirect effect. The opposite way, if indirect effect more than direct effect it imply that when thrift increase then non-tradable relative price and real exchange rate depreciate.

(3) Term of trade (T): this variable will effect to non-tradable relative price and real exchange rate in positive and negative direction. The positive direction indicate that indirect effect more than direct effect.

(4) Foreign real long term interest rate (r'): it has negative effect upon non-tradable relative price and real exchange rate. It indicate that the direct effect and indirect effect are same direction. Non-tradable relative price and real exchange rate will depreciate when real long term interest rate increase.

In sum, it can show the expected sign of fundamental variables are following

$$R^{*}_{n} = R_{n}(\overset{(+,-)}{y}, \overset{(+,-)}{s}, \overset{(+,-)}{T}, \overset{(-)}{r'})$$

$$R^{*} = R^{*}(\overset{(+,-)}{y}, \overset{(+,-)}{s}, \overset{(+,-)}{T}, \overset{(-)}{r'})$$

4.4 Data description

In this study, data is quarterly data 1980.1 until 1997.4 period. Almost series are adjusted to 1988 as based year, except the real long term foreign interest rate. The data are collected from the Quarterly Bulletin (BOT) , NESDB and International Financial Statistics (IMF).

The real exchange rate is bilateral real exchange rate of Thailand and US (CPIs use to calculate). The relation between the real exchange rate R and the relative price of non-tradable R_n is R =NP/ P' = T R^a_n that is RN =R / T = R^a_n (when N is nominal exchange rate). We can not measure R_n directly, so we measure R_n by the ratio R/T of the real exchange rate to the terms of trade.

The productivity series are proxies by GDP per workers. However the quarterly real GDP came from the regression model (see appendix B). This series are adjusted to the US currency.

As the social thrift is (saving / real GDP). Because saving data does not correct in the quarterly I will proxy by PII (private investment index). The procedure of calculating quarterly real GDP and saving are explained in appendix B, and appendix C.

The US real long term interest rate measure of the world real rate of interest r'. I will use the bond yield (10 year) in case US and Thailand. The different real long term interest rate is Thai real interest rate (1 year) less US real interest rate (1 year).

4.5 Econometric Methods

Chapter 4 will explain the econometric methods based on NATREX in case Thailand by used the co-integration that find the long run equilibrium and will be used the error correction explained the shot-run adjustment. Why we must used these econometric method, since the variables in economic often are the non-stationary series. If we used the traditional econometric that the variables are non-stationary the results is the spurious. It mean the results is not correct may show the results very well but the truth is not correct. The indication may be show we have the R^2 very high value but the Durbin Watson statistics is very low value.

The co-integration will used to solve the spurious by detrend the series by difference series and find the linear combination in movement of those variables. If they have the long run relationship model have the co-integration. However the co-integrating methods they have many method that used to the equilibrium long run relationship such as the Engle Granger methods, Johansen and Juselius method, and Hendry methods and error-correction will be used to confirm the long run equilibrium exits which each methods would have the ECM model does not similar. However, in this thesis will estimate the long run relationship by the Johansen and Juselius methods.

The procedure in co-integration and error-correction can be use the following four steps when implementing the Johansen procedure.

First, pretest the unit roots in each variables.

Second, consider vector autoregressive (VAR) to select appropriate lag length.

Third run co-integration that selected appropriate lag in step 2.

Finally, estimate error-correction that is the speed of adjustment.

4.6 Unit Root Test

In time series analysis, it is important to determine whether the nature of the long run movements of the variable is stationary or non-stationary before carrying out any estimation. Since we need to avoid spurious problem. The non-stationary time series means the mean and/or variance of a non-stationary series are time-dependent. Augmented Dickey and Fuller (ADF) is a criterion testing between stationary and non-stationary time series.

The procedure of ADF test begin with considering the higher-order autoregressive process of real exchange rate, non-tradable relative price, thrift, productivity, term of trade, foreign real long term interest rate and different of real long term of interest rate. The variable y_t represent the variables that used to testing in stationary series.

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + a_3 y_{t-3} + \ldots + a_{p-2} y_{t-p+2} + a_{p-1} y_{t-p+1} + a_p y_{t-p} + \varepsilon_t \quad (4.1)$$

It can be rewritten by add and subtract $a_p y_{t-p}$, $a_{p-2} y_{t-p+2}$,... to obtain

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \; \Delta y_{t-i+1} + \varepsilon_t \quad (4.2)$$

where $\gamma = -\left[1 - \sum_{i=1}^{p} a_i \right]$

$$\beta_i = \sum_{j=1}^{p} a_j$$

The coefficient of interest is γ ; if $\gamma = 0$, the equation is entirely in first differences and so has a unit root. We can test for the presence of a unit root using the ADF statistics to determine whether to accept or reject the null hypothesis $\gamma = 0$.

The problem is to select the appropriate lag length. Because the model that include too many lags will reduces the power of the test to reject the null of a unit root since the increased number of lags necessitates the estimation of addition parameter and a loss of degrees of freedom. On the other hand, too few lags will not appropriately capture the actual error process, so that γ and its standard error will not be well estimated.

One approach is to start with a relatively long lag length and pare down the model by the usual t-test and/or F-test.[1] If the t-statistic on the lag n* is insignificant at some specified critical value, re-estimate the regression using a lag length of n*- 1. Repeating the process until the lag is significantly different from zero. Alternative approach can be use AIC, SBC, $\bar{R}^2$, and LM to justify the appropriate lag length.

Although there are many statistics that to consider the appropriate lag, the two most commonly used model selection criteria are the Akaike information criterion (AIC) and Schwartz Bayesian criterion (SBC)[2], they calculated as

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[1]Enders Walter, Applied Econometric Time Series (New york: John Wiley & Sons, 1995), p. 227.

[2]Ibid., p.88.

AIC = T ln (residual sum of squares) + 2n

SBC = T ln(residual sum of squares) + n ln(T)

Where n = number of parameters estimated (p + q + possible constant term)

T = number of usable observations.

Because we want the results that solve problem non-stationary data. It necessary to take first difference in each variable to estimate co-integration and error-correction, or the series of data must be difference more than once, if that series still is non-stationary. ADF test will be use again. Repeating process used select appropriate model and test ADF-statistic.

4.7 Co-integration and Error-correction

Second step, before to estimate all co-integration, the important condition will test the lag length in unrestricted VAR. Begin with the longest lag length that deemed reasonable and test whether the lag length can be shortened. The criteria that can be use to select lag length[3] are Likelihood Ratio test (LR test), AIC or SBC. Again testing in vector autoregressive (VAR), these thesis will be use AIC and SBC select appropriate lag lenght. However Johansen test can detect differing order of integration.

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[3]Ibid., pp. 315,397.

The procedure of LR test estimates a vector autoregressive using the undifferenced data. Begin with the longest lag length deemed reasonable and test whether the lag length can be shortened. The likelihood ratio test statistic recommended by Sims is

$$(T - c)(\log \left| \Sigma_r \right| - \log \left| \Sigma_u \right|)$$

Where T = number of observations

c = number of parameters in the unrestricted system

$\log \left| \Sigma_i \right|$ = natural logarithm of the determinant of log Σ_i

The degree of freedom χ^2 distribution with degrees of freedom equal to the number of coefficient restriction.

Before present the results the co-integration and error-correction model. We shall consider the methodology of these tools. The Ordinary Least Square method may be have nonsensical (or spurious) results, the estimated model containing non-stationary variables at best ignores important information about the underlying (statistic and economic) processes generating the data. For this reason, it is important to test for presence of units roots and if they are present to use appropriate model procedures. Co-integration method developed to use in non-stationary series . There have been many methods in co-integration analysis; one of all is maximum likelihood methods(or Johansen Method).

There are two reasons that Johansen procedure better than Engle and Granger' two step methods. First, these methods can be used to estimate all the co-integrating vectors that exist within a vector of variables. Second, it also provides tests for the number of co-integrating of co-integration vectors.[4]

Before we will explain the procedure of Johansen methods, we will introduce the VAR that include the all variables in the VAR model. This thesis will be test the validity of long-run relationship two model; non-tradable relative price model and real exchange rate model.

In case of non-tradable relative price model: A 5-equation VAR can be represented by

$$\begin{bmatrix} R_{nt} \\ y_t \\ s_t \\ T_t \\ r_t' \end{bmatrix} = \begin{bmatrix} A_{10} \\ A_{20} \\ A_{30} \\ A_{40} \\ A_{50} \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{13}(L) & A_{14}(L) & A_{15}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) & A_{24}(L) & A_{25}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) & A_{34}(L) & A_{35}(L) \\ A_{41}(L) & A_{42}(L) & A_{43}(L) & A_{44}(L) & A_{45}(L) \\ A_{51}(L) & A_{52}(L) & A_{53}(L) & A_{54}(L) & A_{55}(L) \end{bmatrix} \begin{bmatrix} R_{nt-1} \\ y_{t-1} \\ s_{t-1} \\ T_{t-1} \\ r'_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix}$$

where A_{i0} = the parameters representing intercept terms

$A_{ij}(L)$ = the polynomials in the lag operator L.

In the case of real exchange rate model we can show the same the VAR model by change R_{nt} to R_t.

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[4]Rungsun Hataiseree," Vector Autoregression, Unit Roots, Cointegration and Error-correction Mechanisms: A General Overview," Chulalongkorn Journal of Economics 8 No. 2 (May 1996): 284-285.

Procedure of Johansen method, beginning the n variables case is possibility of multiple co-integration vectors

$$x_t = A_1 x_{t-1} + \varepsilon_t \qquad (4.3)$$

Where x_t = the (n x 1) vector $(x_{1t}, x_{2t}, \ldots, x_{nt})'$

A_t = the (n x n) matrix of long-run coefficient whose rank determines the number of distinct co-integrating vectors which exist between the variables in x_t.

ε_t = the (n x1) vector $(\varepsilon_{1t}, \varepsilon_{2t}, \ldots, \varepsilon_{nt})'$

Subtracting x_{t-1} from each side and let I be an (n x n) identity matrix, we obtain

$$\Delta x_t = A_1 x_{t-1} - x_{t-1} + \varepsilon_t$$

$$\Delta x_t = -(I - A_1) x_{t-1} + \varepsilon_t$$

$$= \Pi x_{t-1} + \varepsilon_t \qquad (4.4)$$

where Π is the (n x n) matrix $-(I - A_1)$ and Π_{ij} denotes the element in row i and column j of Π.

Π concern the rank of matrix (n x n). If the rank of this matrix is zero, each element of Π must equal zero. Equation (4.4) is equivalent to an n-variable VAR in first differences:

$$\Delta x_t = \varepsilon_t$$

each $\Delta x_{it} = \varepsilon_{it}$, is the first difference of each variable in vector x_t is I(0). Therefore, each $x_{it} = x_{it-1} + \varepsilon_{it}$, all the $\{x_{it}\}$ sequences are unit root processes and there is no linear combination of the variables that is stationary.

At the other extreme, suppose that Π is of full rank. The long-run solution to (4.4) is given by the n independent equations:

$$\Pi_{11}x_{1t} + \Pi_{12}x_{2t} + \Pi_{13}x_{3t} + \ldots + \Pi_{1n}x_{nt} = 0$$

$$\Pi_{21}x_{1t} + \Pi_{22}x_{2t} + \Pi_{23}x_{3t} + \ldots + \Pi_{2n}x_{nt} = 0$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (4.5)$$

$$\Pi_{n1}x_{1t} + \Pi_{n2}x_{2t} + \Pi_{n3}x_{3t} + \ldots + \Pi_{nn}x_{nt} = 0$$

Each of these n equations is an independent restriction on the long-run solution of the variables; the n variables in the system face n long-run constraints. In this case, each of the n variables contained in the vector x_t must be stationary with the long-run values given by (4.5).

In intermediate cases, in which rank of Π is equal to r, there are r co-integrating vector. If r = 1, there is a single co-integrating vector given by any row of matrix Π. Each $\{ x_{it} \}$ sequence can be written in error-correction form. For example, we can write Δx_{it} as

$$\Delta x_{1t} = \Pi_{11}x_{1t-1} + \Pi_{12}x_{2t-1} + \ldots + \Pi_{1n}x_{nt-1} + \varepsilon_{1t}$$

or, normalizing with respect to x_{1t-1}, we can set $\alpha_1 = \Pi_{11}$ and $\beta_{ij} = \Pi_{ij}/\Pi_{11}$ to obtain

$$\Delta x_{1t} = \alpha_1(x_{1t-1} - \beta_{12}x_{2t-1} + \ldots + \beta_{1n}x_{t-1}) + \varepsilon_{1t}$$

In the long-run, the $\{x_{it}\}$ will satisfy the relationship:

$$(x_{1t} + \beta_{12}x_{2t} + \ldots + \beta_{1n}x_{nt}) = 0$$

the normalized co-integrating vector is ($1, \beta_{12}, \beta_{13}, \ldots, \beta_{1n}$) and the speed of adjustment parameter α_1. In the same way, with two co-integration vectors the long-run values of the variables will satisfy the two relationships:

$$\Pi_{11}x_{1t} + \Pi_{12}x_{2t} + \Pi_{13}x_{3t} + \ldots + \Pi_{1n}x_{nt} = 0$$

$$\Pi_{21}x_{1t} + \Pi_{22}x_{2t} + \Pi_{23}x_{3t} + \ldots + \Pi_{2n}x_{nt} = 0$$

which can be appropriately normalized.

As with the ADF test, the multivariate model can also be generalized to allow for a higher-order autoregressive process.

$$x_t = A_1x_{t-1} + A_2x_{t-2} + A_3x_{t-3} + \ldots + A_px_{t-p} + \varepsilon_t \qquad (4.6)$$

where x_t = the (n x 1) vector ($x_{1t}, x_{t-2}, \ldots, x_{nt}$)'

ε_t = is an independently and identically distributed n-dimensional vector with zero mean and variance matrix.

Equation above can be put in a more usable form by subtracting x_{t-1} from each side to obtain

$$\Delta x_t = (A_1 - I)x_{t-1} + A_2x_{t-2} + A_3x_{t-3} + \ldots + A_px_{t-p} + \varepsilon_t \qquad (4.7)$$

add and subtract $(A_1 - I)x_{t-2}$ to obtain

$$\Delta x_t = (A_1 - I)x_{t-1} + (A_2 + A_1 - I)x_{t-2} + A_3x_{t-3} + \ldots + A_px_{t-p} + \varepsilon_t \qquad (4.8)$$

repeating this process to obtain

$$\Delta x_t = \sum_{i=1}^{p-1} \Pi_i \, \Delta x_{t-i} + \Pi x_{t-p} + \varepsilon_t$$

where $\Pi = -[\, I - \sum_{i=1}^{p-1} A_i \,]$

$$\Pi_i = -[\, I - \sum_{j=1}^{i} A_j \,]$$

Again, the key feature is the rank of matrix Π; the rank of Π is equal to the number of independent co-integrating vectors. If rank(Π) = 0, the matrix is null and the usual VAR model is first differences. Instead, if Π is of rank n, the vector process is stationary. Intermediate cases, if rank(Π) = 1, there is a single co-integrating vector and the expression Πx_{t-p} is the error-correction factor. For other cases in which $1 < \text{rank}(\Pi) < n$, there are multiple co-integrating vectors.

The number of distinct co-integrating vectors can be obtained by checking the significance of the characteristic roots of Π. We know that the rank of a matrix is equaL to the number of its characteristic roots that differ from zero. Suppose we obtained the matrix Π and ordered the n characteristic roots such that $\lambda_1 > \lambda_2 > ... > \lambda_n$. If the variables in x_t are not co-integrated, the rank of Π is zero and all these characteristic roots will equal zero. Since ln(1) = 0, each of the expressions $\ln(1 - \lambda_i)$ will equal zero if the variables are not co-integrated. Similarly, if the rank of Π is unity, $0 < \lambda_1 < 1$ so that the first expression $\ln(1 - \lambda_1)$ will be negative and all the other $\lambda_i = 0$ so that $\ln(1 - \lambda_2) = \ln(1 - \lambda_3) = ... = \ln(1 - \lambda_n) = 0$.

In practice, we can obtain only estimates of Π and the characteristic roots. The test for the number of characteristic roots that insignificantly different from unity can be conducted using the following two test statistics:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1-\lambda_i)$$

$$\lambda_{max}(r, r+1) = -T \ln(1-\lambda_{t+1})$$

where λ_i = the estimated values of the characteristic roots (also called eigenvalues) obtained from the estimated Π matrix.

T = the number of usable observations

When the appropriate values of r are clear, these statistics are simply referred to as λ_{trace} and λ_{max}.

The first statistics tests the null hypothesis that the number of distinct co-integrating vectors is less than or equal to r against a general alternative. It is clear that λ_{trace} equal s zero when all $\lambda_i = 0$. The further the estimated characteristic roots are from zero, the more negative is ln $(1- \lambda_i)$ and the larger the λ_{trace} statistics. The second statistic tests the null that the number of co-integrating vectors is r against the alternative of r + 1 co-integrating vectors. Again, if the estimated value of the characteristic root is close to zero, λ_{max} will be small.

Estimate the co-integration model in third step will specific the appropriate lag length. The co-integrating vector that the results for estimate, can be find the characteristic root. Since we want to test null hypothesis that the variables are not co-integrated against the alternative of on or more co-integrating vectors, we can calculate the λ_{trace} statistic compare the critical value. Alternative we can use the

λ_{max} statistic or eigenvalue static to test the null hypothesis of no co-integrating vector against the specific alternative hypothesis.

Forth step is the analyze the normalized co-integrating vector(s) and speed of coefficients or coefficient of the error-correction.

The real exchange rate model and the relative price of non-tradable model are estimated by error-correction and co-integration equations. Since the real exchange rate model depend on fundamental variables same as non-tradable relative price model, therefore the procedure that find co-integration will repeat two time. This study will examine order of integration by the Johansen maximum likelihood procedure, which tests for the number of co-integrating vectors. The procedure of Johansen methods assumed that all variables are endogenous variables that depends on lagged of each endogenous. The result of co-integration will show in unnormalize form. Since in this thesis will consider particularly non-tradable relative price model and real exchange rate model, I will adjust unnormalize equation to normalize equation.