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Business Cycle Synchronization  
in the East Asian Economies

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Business Cycle Synchronization  
in the East Asian Economies †

by

Xulan Yu\* and Yoshihiko Tsukuda\*\*

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**Abstract:**

The paper examines the possibility of financial cooperation by investigating the business cycle synchronization among the eight core East Asian countries (China, Japan, Korea, Indonesia, Malaysia, the Philippines, Singapore, and Thailand) using the logarithm of per capita real GDP data from 1994Q1 to 2005Q3. The paper employs the model of multivariate time series analysis developed by Engle and Kozicki (1993) and Vahid and Engle (1993). The empirical study reveals that the per capita real GDP series in the region have 2 cointegration vectors in the long-run and 4 cofeature vectors in the short-run dynamics. In other words, the GDP series in the region share 6 common stochastic trends in the long run and 4 common business cycles in the short run. The result indicates that the East Asian countries satisfy an important precondition for creating the financial cooperation in the higher levels.

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JEL: C32, E32, F42

Key words: financial cooperation, common trend, common cycles.

## 1. Introduction

The importance of economic cooperation in the East Asian countries has been well recognized in accordance with rapid economic growth and close economic interdependence within the region. The Asian financial crisis of 1997 has made the East Asian countries acutely aware of the need to facilitate regional financial cooperation to forestall new financial crisis and to attain stable economic growth. The Asian crisis revealed that sound macroeconomic policies and large currency reserves may not be sufficient to enable a country to defend financial crisis successfully. The rapid development of financial liberalization and globalization increases the possibilities of individual and local financial crises transforming swiftly into regional and global ones. Due to the great damage and contagion of financial crisis, the prevention and solution of financial crisis has become a regional and global issue across boundaries. Wang (2002) pointed that financial cooperation is based on economic cooperation and will bring about great benefits for East Asia.

The purpose of this paper is to examine the possibility of financial cooperation by investigating business cycle synchronization among the East Asian countries<sup>1</sup>. While most studies on the East Asian financial cooperation are descriptive, there have been three different quantitative approaches in the literature that could be used to examine the business cycle synchronization among the countries.

The first one uses a stationary vector autoregressive (VAR) model. Bayoumi and Eichengreen (1994) provide a detailed analysis of asymmetric

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<sup>1</sup> The East Asian countries in the paper refer to the five major ASEAN (Indonesia, Malaysia, the Philippines, Singapore and Thailand) + 3 (China, Japan and Korea) countries.



disturbances, which they interpret as aggregate-demand and aggregate-supply shocks, using the structural VAR methodology of Blanchard and Quah (1989) to identify supply and demand disturbance underlying aggregate output and price. Eichengreen and Bayoumi (1999) discussed that the East Asian region as well as the Western Europe satisfy the standard optima currency area (OCA) criteria for the adoption of a common monetary policy.

The second one is principal component analysis to measure the degree of synchrony and interdependence for a group of nations. Goto (2002) used a principal component analysis to measure the degree of synchronization of real disturbances among six Asian countries and compare the degree of synchronization with that among the EU countries in terms of an investment equation. His study shows that real disturbances of Indonesia, Korea, Malaysia, the Philippines, Singapore, and Thailand are highly synchronized, and that the synchronization of the six countries with Japan increased in the 1990s.

The third one is to use recent common trend and common cycle theory to examine the business cycle synchronization. Most of empirical research in these issues has concentrated on the OECD countries and little attention was paid to the business cycle synchronization in East Asia. Selover (2004) uses the structured VARs to analyze international co-movements and business cycle transmission between Korea and Japan on industrial production, prices, interest rate, money supplies, and exchange rates. He found that there is no cointegration between the output of Korea and Japan, but business cycles in the two countries are moderately synchronized. Cheung and Yuen (2004) examined co-movement patterns of the outputs of China, Japan and Korea, and found that the three countries have common

synchronous business cycles in the sample period from 1993Q4 to 2001Q4.

We employ the analysis by a multivariate time series model with both cointegration and common cycle after preliminary investigating the correlations between the pair of each country. The correlation analysis offers a quick and rough measure for co-movements of outputs between the two countries in the region. We utilize a VAR model with both common trends and common cycles relying on the recent developments of common feature literature originated from Engle and Kozicki (1993) and Vahid and Engle (1993). Using the log real per capita GDP from 1994Q1 to 2005Q3, our study reveals that there exist a strong evidence for common stochastic trends across the East Asian countries in the long-run, and a significant evidence for the cofeature vector. In other words, the core ASEAN+3 countries do share both common trends in the long run and synchronous business cycles in the short run. The East Asian countries satisfy an important precondition for creating the higher levels of financial cooperation such as common currency area in the region.

This paper is organized as follows. Section 2 briefly states an economic background of regional financial cooperation. Section 3 describes an econometric model for investigating common trends and common cycles. Section 4 presents the empirical results. Section 5 gives some concluding remarks.

## **2. Economic Background for Examining Business Cycle Synchronization**

This section briefly explains an economic background why investigation of business cycle synchronization is useful to discuss the possibility of financial cooperation. Because the financial cooperation is indispensable to achieve the common interests of the East Asian countries, the regional

financial cooperation has become a hot issue in recent years. The regional financial cooperation has a wide range of scope from loose information exchange to the most rigid common currency area. It is often classified into the four stratified different categories from loose to rigid levels: (i) policy dialogue, (ii) system of regional lender of the last resort, (iii) exchange rate policy cooperation, and (iv) common currency area<sup>2</sup>.

The optimal currency area (OCA) theory of Mundell (1961) and Mckinnon (1963) made an epoch making contribution to discuss the financial cooperation among the countries. The OCA theory is mainly based upon a cost-benefit analysis to monetary union. The benefits from a common currency area are mainly related to the reduction of transaction costs and predictability of exchange rate. Higher levels of openness and integration are associated with larger benefits for the participating countries. The costs of joining a common currency area are mainly related to the loss of independence for monetary policy as a tool of stabilizing external shocks. If all the participating countries are faced with a common business cycle, the costs of losing independent monetary policy may be bearable. Business cycle synchronization is one of the major criteria to evaluate the possibility of a common currency area<sup>3</sup>. The degree of business cycle synchronization is important because it provides information on the necessity of independent fiscal and monetary policy. If the business cycles across countries are synchronous and shocks are common, then a coordination of macro policies can become desirable. On the other hand, common currency area may not be

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<sup>2</sup> See Yu (2006) for more detailed analyses.

<sup>3</sup> The theory of optimum currency area gives criteria to constitute a common currency area. The criteria include (i) openness of economies in the area, (ii) degree of trade integration among the countries in the region, (iii) similarity of trade patterns, (iv) business cycle synchronization, and (v) mobility of labors in the area.



desirable if the countries display asynchronous business cycles.

Much empirical studies on business cycles mainly focused on identifying and explaining fluctuations of aggregate economic time series. In this paper, the term of business cycle synchronization refers to the existence of common short-run cycles and common long-run trends in the aggregate economic variables across the countries. The tendency of fluctuations in economic activity to synchronize internationally is analyzed by testing whether these trends and cycles are common across countries. The theory of cointegration is an appropriate way of simultaneously modeling long-run persistence and co-movement, which provides a natural setting for testing whether a set of economic variables move together. Common trends and common cycles theory in Engle and Kozicki (1993) usually advocate the use of the common feature test to detect common serial correlations. Vahid and Engle (1993) developed a procedure for testing common cycle given the existence of common trends to be known and fixed.

### 3. An Econometric Model for Testing Business Cycle Synchronization

#### 3.1 The model

Let us consider a Gaussian vector autoregressive model with finite order  $p$  (VAR( $p$ )) for an  $n$ -vector time series  $\{Y_t, t = 1, \dots, T\}$ ,

$$Y_t = A_0 + \sum_{i=1}^p A_i Y_{t-i} + \varepsilon_t \quad (3.1)$$

for fixed values of  $Y_{-p+1}, \dots, Y_{-1}$  and  $Y_0$ , and  $\varepsilon_t$  is an  $n$ -dimensional Gaussian mean zero white noise process with nonsingular covariance matrix  $\Omega$ . Let  $L$

denote the lag operator and define  $\Phi(L) = I_n - \sum_{i=1}^p A_i L^i$ . We make the following

assumption.

**Assumption 1:** In the VAR model of (3.1), we assume that

- (i)  $\text{rank } \Phi(1) = r$ ,  $0 < r < n$ , so that  $\Phi(1)$  can be expressed as  
 $\Phi(1) = -\alpha\beta'$  with  $\alpha$  and  $\beta$  both  $n \times r$  matrices of full column rank  $r$ ;
- (ii) the characteristic equation  $|\Phi(\xi)| = 0$  has  $n - r$  roots equal to 1 and all other roots outside the unit circle.

Assumption 1 implies that the process  $Y_t$  is a cointegrated I(1) process. The columns of  $\beta$  span the space of cointegrating vectors, and the elements of  $\alpha$  denote the corresponding adjustment coefficients. Defining  $\Delta = 1 - L$ , we have the vector error correction model (VECM):

$$\Delta Y_t = \mu + \alpha\beta' Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (3.2)$$

where  $\Gamma_i = -\sum_{j=i+1}^p A_j$  ( $i = 1, \dots, p-1$ ). Under Assumption 1, the equation (3.2)

is expressed as:

$$\Delta Y_t = \mu + BW_t + \varepsilon_t, \quad (3.3)$$

where  $B = (\Gamma_1, \dots, \Gamma_{p-1}, \alpha) : n \times (n(p-1) + r)$ ,

$W_t = (\Delta Y_{t-1}, \dots, \Delta Y_{t-(p-1)}, Z_{t-1}) : (n(p-1) + r) \times 1$ , and  $Z_{t-1} = \beta' Y_{t-1} : r \times 1$ . The  $r$ -dimensional cointegration vector ( $Z_t$ ) represents a deviation from the long run equilibrium among the level vector of  $Y_t$ .

The serial correlation common feature (SCCF) defined by Engle and Kozicki (1993) holds for the VECM in (3.2), if there exists an  $n \times s$  matrix  $\tilde{\beta}$ , whose columns span the cofeature space such that

$$\tilde{\beta}' \Delta Y_t = \tilde{\beta}' \varepsilon_t \quad (3.4)$$

is an  $s$ -dimensional vector mean zero innovation process. The serial correlation common features arise if there exists a cofeature matrix  $\tilde{\beta}$  such that the following condition is satisfied:

**Assumption 2:** There exists an  $n \times s$  matrix  $\tilde{\beta}$  with full column rank such that

$$\tilde{\beta}' \Gamma_j = 0 ; s \times n, j = 1, \dots, p-1, \quad (3.5)$$

and

$$\tilde{\beta}' \Phi(1) = -\tilde{\beta}' \alpha \beta' = 0 ; s \times n. \quad (3.6)$$

Assumption 2 implies that the  $n \times (n(p-1)+r)$  coefficient matrix (B) has  $\text{rank}(B) = n - s$ . In other words, the short-run dynamics among the variables in  $\Delta Y_t$  includes common cycles in the sense that a linear combination of  $\Delta Y_t$  degenerates to the white noise innovation process. The rank of B ( $= n - s$ ) represents the number of common cycles.

Assumptions 1 and 2 imply that the time series of  $Y_t$  exhibits both  $r$  cointegration relations in the long-run and  $s$  cofeature vectors in the short run. The  $n$ -dimensional vector  $Y_t$  can be decomposed to the sum of a random walk part and a stationary part. More precisely, the time series of  $Y_t$  has the following representation:

$$Y_t = G \tau_t + F c_t \quad (3.7)$$

where  $G: n \times (n-r)$ ,  $F: n \times (n-s)$  matrices,  $\tau_t: (n-r) \times 1$  vector of random walk process, and  $c_t: (n-s) \times 1$  vector of stationary process. The first term in the right hand side of (3.7) is a linear estimation of a  $(n-r) \times 1$  random walk vector, which represents a stochastic common trend. The second term is a linear estimation of a  $(n-s) \times 1$  stationary vector, which denote a common cycle. If there exist  $r \times 1$  cointegration vector and  $s \times 1$  cofeature vector of the elements of a set of  $I(1)$  variables, then those variables must share  $n-r$



common trends and  $n - s$  common cycles. In this case, the process has to satisfy the condition  $s \leq n - r$ .

### 3.2 Test for business cycle synchronization

We want to test the existence of cointegration and common feature. Let us first assume that the cointegration rank  $r$  is known and fixed. For a given maintained reduced rank structure, we consider the sequence of hypotheses separately in order to test the hypothesis

$$H_0 : \text{rank}(B) \leq n - s \quad \text{vs.} \quad H_1 : \text{rank}(B) \geq n - s \quad (3.8)$$

or equivalently

$$H_0 : \text{rank}(\tilde{\beta}) \geq s \quad \text{vs.} \quad H_1 : \text{rank}(\tilde{\beta}) < s, \quad s = 1, \dots, n - r, \quad (3.9)$$

where the coefficient matrix  $B$  is defined in (3.3). Vahid and Engle (1993) proposed a test statistic for testing the hypothesis. The procedure utilizes the canonical correlations between  $\Delta Y_t$  and  $W_t$ . The test statistic is written as:

$$C(p, s) = -(T - (p - 1) - 1) \sum_{i=1}^s \ln(1 - \lambda_i), \quad s = 1, \dots, n - r, \quad (3.10)$$

where  $0 \leq \lambda_1 \leq \lambda_2 \leq \dots \leq \lambda_{n-r} < 1$  are the  $(n - r)$  smallest squared canonical correlations between  $\Delta Y_t$  and  $W_t$ . Under the null, this statistic has an asymptotic  $\chi^2$  distribution with  $s^2 + sn(p - 1) + sr - sn$  degrees of freedom. We sequentially test the hypothesis in (3.8) or (3.9) starting with  $s = 1$  until upto  $s = n - r$ .

Since we do not know the number of cointegration relations in practice, we have to estimate the number of cointegration relations and the cointegration vectors. The likelihood-based method of Johansen (1991, 1995) are used to test the null hypothesis of  $\text{rank}(\beta) = r$  where  $\beta$  is defined in (3.2). The trace statistic and the maximum eigenvalue statistic are respectively defined as:

$$Trace = T \sum_{i=r+1}^n \hat{\lambda}_i \approx -T \sum_{i=r+1}^n \ln(1 - \hat{\lambda}_i), \quad (3.11)$$

and

$$Max \text{ eigenvalue} = T \hat{\lambda}_{r+1} \approx -T \ln(1 - \hat{\lambda}_{r+1}). \quad (3.12)$$

where  $0 \leq \hat{\lambda}_1 \leq \hat{\lambda}_2 \leq \dots \leq \hat{\lambda}_n$  are the roots of a certain determinantal equation. The trace statistic tests the null of  $rank(\beta) = r$  against  $rank(\beta) = n$ , while the maximum eigenvalue statistic is against  $rank(\beta) = r + 1$ . Critical values for the asymptotic distributions of both statistics are tabulated in Mackinnon, Haug and Michelis (1999).

## 4. Empirical Studies

### 4.1 The data sources and preliminary analysis

In this section, we examine the existence of cofeatures among the logarithms of seasonally adjusted quarterly real per capita GDP for the five core ASEAN (Indonesia, Malaysia, Philippines, Singapore and Thailand) + 3 (China, Japan, Korea) countries. The local currency of each country is transformed into the US dollars in terms of the average nominal exchange rate for every period. The data are obtained from the International Financial Statistics (IFS), Singapore Department of Statistics (SDS) and National Bureau of Statistics of China (NBSC). The sample period is from the first quarter in 1994 to the third quarter in 2005 with the sample size of  $T = 47$ .

The logarithms of the GDP series for each country are shown in Figure 1. From visual investigation, we observe the following facts: (i) Most countries other than Japan have been enjoying economic developments over the past twelve years except the periods of the Asian Crisis of 1997-1998. Japan is an exception among these countries. Japan looks like indicating even a downward trend. (ii) All countries except China have experienced the

decreases of GDP at the time of the Asian Crisis. Only China has exhibited steady growth of DGP regardless of the Asian Crisis.

Figure 1. Per capita GDP

Table 1 shows average growth rates over the sample periods. Only Japan and Thailand indicate negative average growth rate. Thailand exhibits negative growth rates except for the Crisis periods in spite of negative average rate over the observed periods.

Table 1. Average growth rate

The growth rate of per capita GDP shown in Figure 2 demonstrates a similar pattern of fluctuation among the countries, which may suggest the existence of business cycle synchronization among the East Asian countries. The similarity of business cycles may also reflect the interdependence of the ASEAN+3 economies in terms of inter-regional trades and economic development strategies.

Figure 2. Growth rate of Per capita GDP

The correlation coefficients in Table 2 indicate quick and rough relationships about the business cycles in terms of the movements of growth rate among the eight countries over the sample periods from 1994Q1 to 2005Q3. The first important finding is that all countries have positive coefficients for each other. Second, the coefficients among the plus three countries are relatively small compared with those among the ASEAN

countries. Third, looking at the coefficients between the plus three and ASEAN countries, China and Japan have relatively small values while Korea has large values.

Table 2. Correlations of the growth rates
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In order to apply the VECM for the GDP time series data, we need to check the unit root of each series. Table 3 shows the Augmented Dickey-Fuller (ADF) test statistics for testing the unit root of log DGP series against the trend stationary process. The ADF test does not reject the null for any countries. The logarithm of GDP series for all countries may soundly be regarded as I(1) processes.

Table 3. Unit roots test
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#### 4.2 Cointegration rank tests

We first apply the VECM in (3.2) for determining the cointegration rank with ignoring the possible existence of serial correlation common feature (SCCF). The AIC chose  $p = 2$  for the VAR( $p$ ) model, which implies the order 1 for the vector of differenced variables appearing in the right hand side of the VECM representation. The procedure of Johansen (1991, 1995) is used for testing the order of cointegration. The asymptotic critical values are tabulated by Mackinnon, Haug, and Michelis (1999).

Table 4 shows the values for the trace and the maximum eigenvalue tests of (3.8) and (3.9) respectively.

Table 4. Cointegration rank tests
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The trace test suggests the existence of five cointegration relationships among the eight variables at 1% significance level while the maximum eigenvalue test suggests two cointegration relationships. The smallest AIC chooses two cointegration relationships. In this paper, we assume that there are two cointegration relations among the eight variables. In other words, we assume that the eight countries share the six common stochastic trends in the long-run. The estimated cointegrating relations with normalization are:

$$\begin{aligned}
Z_{1t} &= y_{1t} + 4.82y_{3t} - 8.78y_{4t} + 31.82y_{5t} + 2.68y_{6t} + 9.01y_{7t} - 23.51y_{8t} - 167.15 \\
&\quad (1.18) \quad (0.96) \quad (2.65) \quad (2.21) \quad (3.21) \quad (1.67) \\
Z_{2t} &= y_{2t} - 0.58y_{3t} - 0.22y_{4t} - 3.43y_{5t} + 0.29y_{6t} + 1.93y_{7t} + 0.68y_{8t} + 2.97 \quad (4.1) \\
&\quad (0.08) \quad (0.06) \quad (0.18) \quad (0.16) \quad (0.22) \quad (0.68)
\end{aligned}$$

where standard errors are in parentheses. Figure 3 exhibits the behaviors of two cointegration variables over the sample periods. Both of two variables move around zero level as we could expect since  $\{(Z_{1t}, Z_{2t}) : t = 1, \dots, T\}$  are stationary series. The values of  $(Z_{1t}, Z_{2t})$  are used as the data for the analysis of Section 4. 3.

Figure 2. Cointegration vectors

Despite the differences in output size, economic development level, and infrastructures, the output series of ASEAN+3 share six common stochastic trends and do not drift away in the long run. The presence of such common trends in the region could arise from the factors such as similar economic policy, large intra-regional, intra-industry trades, and large exposure to the

US or EU.

### 4.3 Common cycles test

The main purpose of empirical study in this section is to examine whether the eight countries share common business cycles in addition to determine the cointegration rank. We employ the VECM in the form of (3.3) assuming that the order of lag is  $p = 2$ , the cointegration rank is  $r = 2$  and the cointegration vectors ( $\beta$ ) are correctly estimated, based on the analysis in Section 4.2. We apply the testing procedure stated in Section 3.2 which was originally developed by Engle and Kozicki (1993) and Vahid and Engle (1993). The test statistic in (3.10) runs  $s = 1$  through  $s = n - r (= 6)$ .

Table 5 shows that the null hypotheses are accepted if  $s \leq 4$  while they are rejected if  $s \geq 5$  at the 5 % level of significance.

Table 5. Common cycles test
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There exist the four cofeature vectors or equivalently the four common cycles in the eight countries. The results suggest the presence of common business cycles among the countries in the short run. In addition to the common long run movements, the ASEAN+ 3 countries also share the common short run business cycles.

## 5. Concluding Remarks

This paper examined the existence of cofeatures among the real per capita GDP for the five core ASEAN (Indonesia, Malaysia, Philippines, Singapore and Thailand) + 3 (China, Japan, Korea) countries. Motivated by the fact that all eight countries exhibit strongly positive correlation



coefficients for each other over the sample periods from 1994Q1 to 2005Q3, we analyzed business cycle synchronizations in this region using the VECM recently developed time series techniques.

The empirical study reveals that the per capita real GDP series in the region are cointegrated with order 2 and have 4 cofeature vectors in the short-run dynamics. In other words, it can be said that the GDP series in the region share the 6 common stochastic trends in the long run and the 4 common business cycles in the short run.

An important message of this paper to the East Asian economies is that they already possess an indispensable precondition for creating the common currency area in this region. It could be safely acknowledged that the East Asian countries are now well qualified as a candidate to establish higher level financial cooperation such as a fixed exchange rate regime or even a common currency area in the future.

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Table 1. Average annual growth rate of GDP in the ASEAN+3 countries  
(1994Q1-2005Q3)

China	Japan	Korea	Indonesia	Malaysia	Philippines	Singapore	Thailand
9.09	-2.11	3.19	1.05	1.48	0.66	0.55	-0.68

Source: IFS, SDS, and NBSC

Table 2. Correlation coefficients of the growth rate

	China	Japan	Korea	Indonesia	Malaysia	Philippines	Singapore	Thailand
China	1							
Japan	0.27	1						
Korea	0.24	0.33	1					
Indonesia	0.40	0.41	0.79	1				
Malaysia	0.40	0.35	0.78	0.78	1			
Philippines	0.28	0.17	0.72	0.71	0.79	1		
Singapore	0.49	0.48	0.62	0.66	0.82	0.62	1	
Thailand	0.37	0.34	0.68	0.73	0.74	0.78	0.65	1

Table 3. Augmented Dickey-Fuller test

	ADF	p-value
China	-0.59	0.98
Japan	-2.12	0.53
Korea	-1.99	0.60
Indonesia	-1.96	0.62
Malaysia	-1.50	0.83
Philippines	-2.20	0.49
Singapore	-1.41	0.86
Thailand	-1.08	0.93

Note: The ADF test is applied for the model,

$$\Delta y_t = \alpha_0 + \beta t + \delta y_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \varepsilon_t, \text{ with the null } H_0 : \delta = 0$$

against  $H_1 : \delta < 0$ . The length of lags (p) is determined by the Akaike information criterion (AIC).

Table 4. Cointegration rank test

Null hypothesis (r)	Trace	Max-eigenvalue
0	287.77**	100.50**
1	187.27**	64.19**
2	123.08**	38.91
3	84.18**	27.42
4	56.76**	25.08
5	31.68	22.62
6	9.06	5.93
7	3.12	3.12

Note: The asterisk (\*\*) denotes significance at the 0.01 level

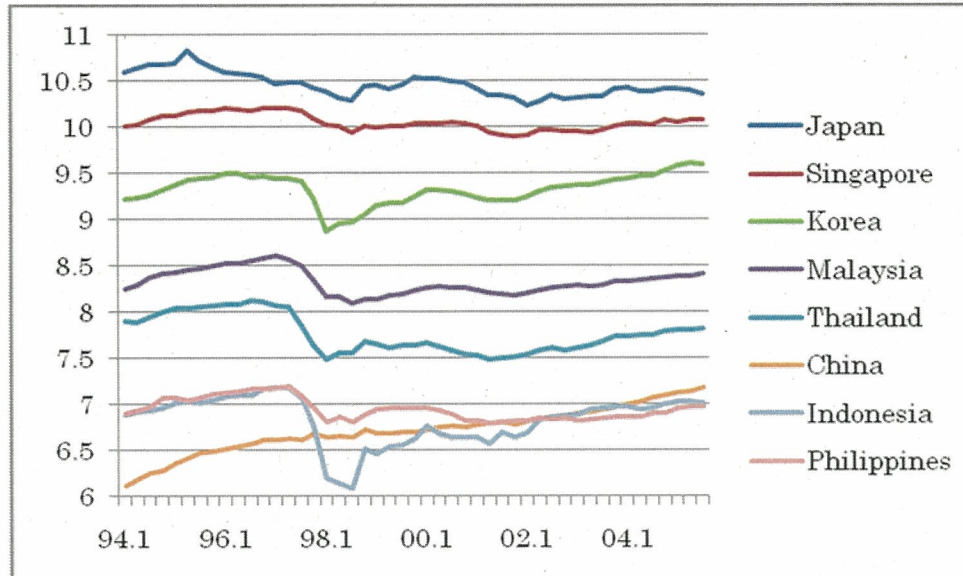
Table 5. Common cycles test

Null hypothesis (s)	$\lambda_i$	C(p,s)	Degree of Freedom	Critical value
1	0.0287	1.3	3	7.81
2	0.0586	4	8	15.51
3	0.1092	9.2	15	25
4	0.2685	23.3	24	36.4
5	0.4816	52.9*	35	49.8
6	0.6793	104*	48	65.2

Note: The asterisk (\*) denotes significance at the 0.05 level



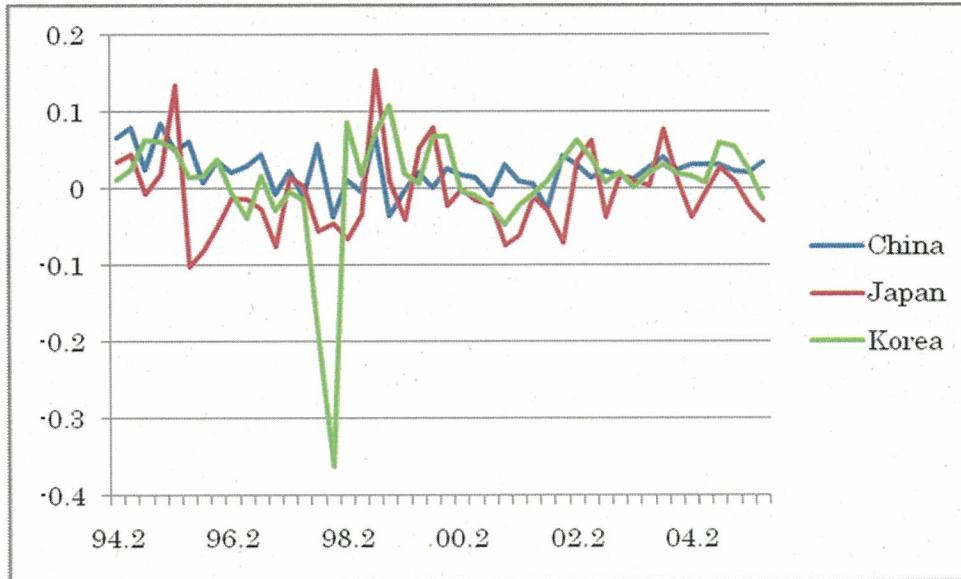
Figure 1. Per capita GDP in the core ASEAN + 3  
 (seasonally adjusted, US dollars in 2000 prices)



Source: The data are obtained from the International Financial Statistics (IFS), Singapore Department of Statistics (SDS) and National Bureau of Statistics of China (NBSC).

Figure 2. Growth rate of per capita GDP

Panel (a) : China, Japan, Korea



Panel (b): The five core ASEAN countries

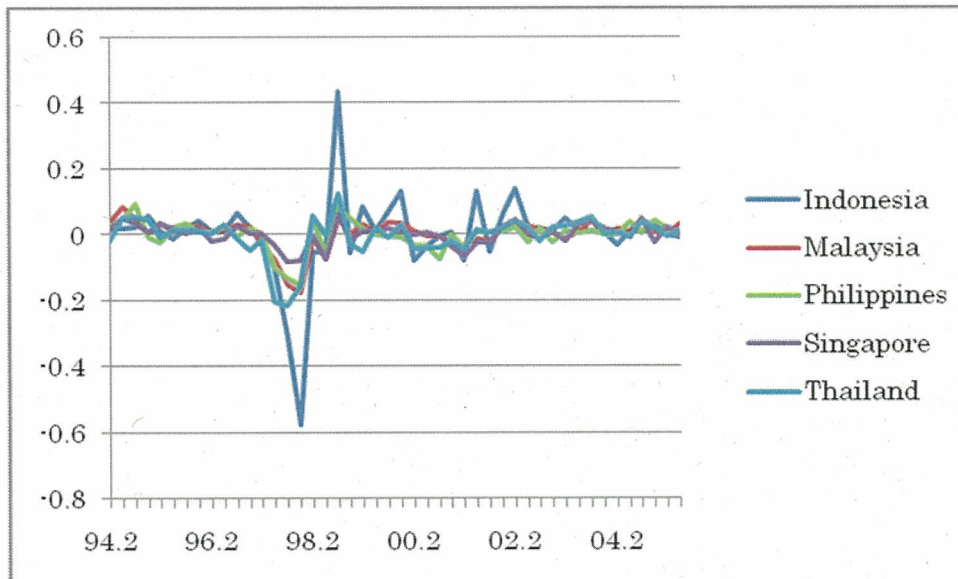
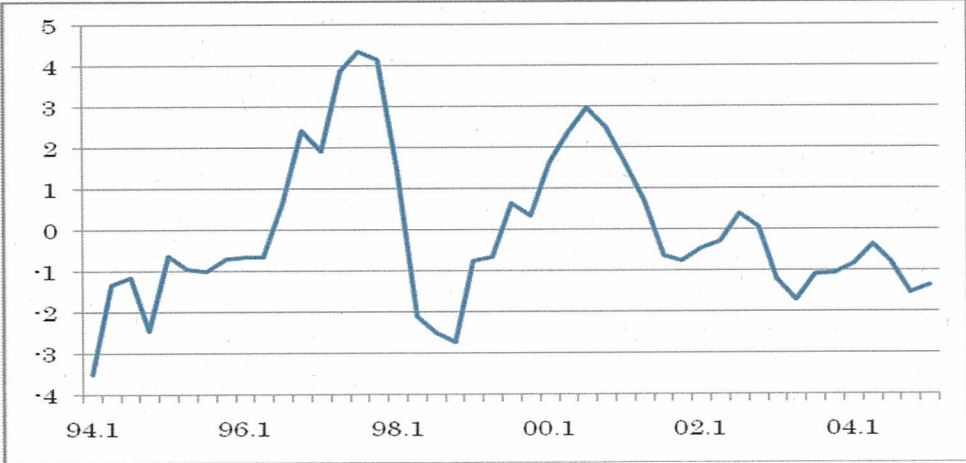


Figure 3. Cointegration vectors of  $(Z_{1t}, Z_{2t})$

Panel (a):  $Z_{1t}$



Panel (b):  $Z_{2t}$

