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Abstract

The East Asian region has experienced astonishing economic growth and integration over the past few decades. It is generally believed that high degree of integration in the region would greatly shape the economic structure of each individual economy and has direct implications for the effectiveness of domestic stabilization policy and policy coordination. This paper empirically examines the feasibility of forming a monetary union in East Asia by assessing the real output co-movements among these economies. As suggested by the optimum currency area (OCA) theory that losing monetary independence would be the major cost for adopting a common currency, it would be less costly for the economies to form a monetary union if the business cycles are synchronized across countries. Cointegration test and the Vahid and Engle (1993) test for common business cycles are conducted to examine their long-run relationship and short-run interactions in real outputs, respectively. Our study found that some pair countries in the region share both the long-run and short-run synchronous movements of the real outputs. In particular, the short-run common business cycles are found in some pairs of ASEAN economies consisting of Singapore, Thailand and Indonesia, and in the Northeast Asian region consisting of Hong Kong, Korea and Mainland China, as well as between Japan and Taiwan. These findings have important implications for the economies in terms of adjustment costs when considering the adoption of a monetary union.

JEL classification: E32; F36; F41
Keywords: Monetary union; Cointegration; Common feature business cycle; East Asia

1. Introduction

Over the past three decades, at least well before the Asian financial crisis in 1997, the East Asian region has recorded astonishing economic growth and was widely cited as an exemplar of sustained economic growth. Accompanying and fostering the region's remarkable economic dynamism have been the outward looking, export-oriented development strategy and its spontaneous and rapid regional integration. However, compared to the European experience, regional integration in East Asia has occurred in the absence of a formal institutional framework, and is more market-driven. It is the international firms that are creating linkages across borders in their search for profitable opportunities through trade, foreign direct investment (FDI), technology contracts, and other arrangements in accordance with changes in comparative advantage and industrial upgrading in these economies. Such a trend towards spontaneous regional integration is a result of progressive outward orientation of individual economies' trade and investment policies, and the unilateral liberalization of goods and capital markets (Dobson 1997, Zhang 2003).

It is believed that high degree of integration in the East Asian region would greatly shape the economic structure of each individual economy and has direct implications for the effectiveness of domestic stabilization policy and policy coordination. It is indeed true that, for the purpose of establishing a well-coordinated economic and financial monitoring system in the region, monetary co-operation and foreign exchange arrangements among the East Asian economies have been often conducted since 1977 when the ASEAN Swap Arrangement was established. The more recent calls among politicians for greater monetary integration and regional exchange rate stability in East Asia following the 1997 financial crisis have attracted the attention of academics to empirically study the feasibility of establishing a monetary union in the region.

Given the deepening integration process among the East Asian economies, the objective of the present paper is to empirically analyze how feasible to establish a monetary union in this region by a rigorous examination of the business cycle co-movements between the regional economies. Co-movements of real outputs reflect the degree of similarity in the economic structure and/or symmetry of the fundamental shocks among the concerned countries. Assessing the business cycle co-movements will allow us to evaluate the costs and benefits of forming an optimum currency area (OCA) when a member country has to give up its monetary independence (see Kawai, 1987; Tavlas, 1993; De Grauwe, 2003).

In recent years, there has been a number of studies empirically assessing the feasibility of forming a monetary union in the East Asian region from a symmetric shock perspective (see Bayoumi and Eichengreen, 1994; Bayoumi, Eichengreen and Mauro, 2000; Zhang, Sato and McAleer, 2004). The Blanchard and Quah (1989) structural decomposition technique is generally used in these studies to identify the fundamental supply and demand shocks. The analysis of correlation in supply and demand shocks per se, however, does not necessarily reveal a feasibility of forming a monetary union, because the degree (or pattern) of shock correlation is not necessarily identical to that of short-run output co-movements. Even in the case of low correlation in supply shocks, for example, there is still a possibility that the countries in question might share a common business cycle where common monetary and exchange rate policy is effective.[1] If real output variables are found cointegrated, that is, the stochastic trends that drive output variable to wander randomly over time are common

[1] Cheung and Yuen (2003) apply the cointegration approach to examining this issue.

to the economies concerned, it may be viewed as a necessary condition for forming a monetary union. The short-run cyclical variation of real output variables is a crucial issue when a common stabilization policy has to be adopted in the union. Thus, only if the East Asian economies have both synchronous long-run output co-movements and short-run common business cycles, a monetary union can be viewed feasible in the region.

The present paper adopts the Johansen (1991) maximum-likelihood procedure to examine the co-movements of real outputs among the East Asian economies from 1978Q1 through 2004Q4.[2] In particular, we perform the bivariate cointegration test for each pair of the East Asian economies to determine the long-run (cointegrating) relationship of the real output variables. This will allow us to specify the appropriate model to estimate the short-run dynamics, the contemporaneous correlation and the cyclical co-movement of the variables. Following Vahid and Engle (1993) and Engle and Kozicki (1993), we conduct a common feature test to detect the presence of common business cycles among the paired economies in the presence of cointegrating relationship.

The remainder of this paper is organized as follows. Section 2 presents the analytical framework. Section 3 describes the data and the result of preliminary analysis. Section 4 discusses the results of estimations for both long-run and short-run real output co-movements. Section 5 concludes the paper.

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[2] By far few studies have applied this method to studying the co-movements of the real output in East Asia. Cheung and Yuen (2003) examine the cointegrating relationship of real outputs among China, Japan and Korea using the quarterly series of real per capita GDP ranging from 1993Q4 to 2001Q4. Ogawa and Kawasaki (2004) also conduct the cointegration test to investigate a long-run sustainability of a common currency basket in East Asia by applying the Generalized Purchasing Power approach.

2. Analytical Framework

To investigate whether there exists a stable linear steady-state relationship between the interested variables, we need to conduct unit-root and cointegration tests for the variables. Unit-root tests show if a time-series variable is stationary. Cointegration analysis determines the long-run (cointegrating) relationship between the variables when all the variables are found non-stationary (i.e., have unit roots). If all variables studied are I(1), we then use the Johansen maximum likelihood (ML) method (Johansen, 1991) to test whether these variables are cointegrated. The Johansen approach allows testing the long run relationship between variables in a multivariate framework, and considers the error structure of the data processes and the interactions in the determination of the relevant economic variables. If the variables are cointegrated, the real output series share synchronous long-run movements, implying a common stochastic trend driving the output series among the economies. It would therefore be possible to use one common monetary policy and a common currency to effectively manage the economies should a monetary union be formed.

The Johansen cointegration technique is based on the maximum likelihood estimation of the vector error-correction model. Let X_t be an $(n \times 1)$ vector of I(1) variables. Then, it is possible to specify the following unrestricted vector autoregression (VAR) involving up to *k*-lags of X_t:

$$X_t = \mu + A_1 X_{t-1} + \ldots + A_k X_{t-k} + \varepsilon_t \qquad (1)$$

where A_i is an $(n \times n)$ matrix of parameters and ε_t are a Gaussian error term. The above equation can be expressed as a vector error-correction form:

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + ... + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \varepsilon_t \quad (2)$$

where $\Gamma_1 = -(I - A_1 - ... - A_i)$, ($i$ = 1, … , $k-1$), and $\Pi = -(I - A_1 - ... - A_k)$. Our major interest is in the matrix $\Pi = \alpha\beta'$, where α represents the speed of adjustment to disequilibrium, while β is a matrix of long-run coefficients such that the term $\beta' X_{t-k}$ represents up to $(n-1)$ cointegration relationship in the multivariate model. Thus, the test for cointegration is to determine how many $r \le (n-1)$ cointegration vectors exist in β, which amounts to testing whether $\Pi = \alpha\beta'$ has reduced rank.

We use the trace statistic and the maximum eigenvalue statistic. The null hypothesis that there are at most r cointegrating vectors ($0 \le r \le n$) can be tested by the trace statistic:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \quad (3)$$

where $\hat{\lambda}_i$'s are the $(n-r)$ smallest squared canonical correlations of X_{t-1} with respect to ΔX_t corrected for lagged differences and T is the sample size used for estimation. Another test of the significance of the largest λ_r is to use the maximum eigenvalue statistic:

$$\lambda_{\max} = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (4)$$

This is to test that there are r cointegrating vectors against the alternative that r + 1 exist. Rejection of this hypothesis suggests the existence of the maximum r cointegrating vectors. Asymptotic critical values are shown in Osterwald-Lenum

(1992).

Even though cointegrating relationship in real output is found among the economies, short-run output fluctuations might not be synchronous. Such an asynchronous business cycle will have to be attended by an individual monetary policy, which would suggest a low feasibility for forming a monetary union.

Test for common business cycles will be a test for a serial correlation common feature in the difference of the variables. Engle and Kozicki (1993) devise the test for a serial correlation common feature for stationary variables based on two-stage least square regression using the lagged value of all variables as the instruments. If there exists a linear combination of variables that eliminates all correlation with the past and is not correlated with past information set, we then conclude that the set of variables shares a common cycles. Vahid and Engle (1993) extend the Engle and Kozicki test to propose test procedure for common serial correlation cycles given the presence of cointegration. The test procedure is to find a sample canonical correlation between ΔX_t and $W(p) \equiv (\Delta X'_{t-1},...,\Delta X'_{t-p}, Z'_{t-1})'$ where Z_{t-1} is the error-correction term. Under the null hypothesis that there exist s linearly independent common feature vectors, the test statistic is given by:

$$C(p,s) = -(T-p-1)\sum_{j=1}^{s} \ln(1-\lambda_j^2) \qquad (5)$$

where λ_j^2 (j = 1,…, s) is the s smallest squared canonical correlations between ΔX_t and $W(p)$. Under the null hypothesis, the statistic $C(p,s)$ has a χ^2 distribution with ($s^2 + snp + sr - sn$) degrees of freedom, where n is the number of endogenous variables, p is the lag order of the differenced variables in the error-correction model, and r is the number of cointegrating vectors.

3. Data and Preliminary Analysis

We use real GDP series as a proxy for real outputs. All data are quarterly, expressed in natural logarithms and seasonally adjusted using the Census X-12. Eleven economies are taken up in this paper, including the four Asian NIEs (Korea, Taiwan, Hong Kong and Singapore), ASEAN4 (Malaysia, Indonesia, Thailand and the Philippines), China, Japan and the United States. The sample period covers 1978Q1-2004Q4 for all economies. The data for real GDP are obtained from the websites of the statistic authorities in the respective economies and the NUS ESU databank.

We first check the stationarity of the real GDP series using the ADF (Augmented Dickey-Fuller) tests. The test statistics show that for the levels of all the series, the null hypothesis that a unit root exists cannot be rejected. The unit root tests of the first difference of the variables reject the null hypothesis. These findings suggest that each series contains one unit root and thus I(1) (the results are not reported in the paper but available upon request). Then we proceed to the cointegration analysis in the next section.

4. Empirical Results

4.1. Bivariate Cointegration test

We investigate the bivariate relations of real output co-movements between the East Asian economies, Japan and the United States. The Johansen (1991) cointegration test is employed to test whether the I(1) non-stationary output series move together in the long-run. In conducting the Johansen test, we follow the Hendry approach of general-to-specific modeling. We initially estimate vector autoregressions (VAR) with eight lags and then reduce the longest lag if none is specifically significant for the *F*-test of the overall significance in the system of each regressor.[3] Once the common lag length is determined, we perform the test for reduced rank.

The result of the Johansen test is very sensitive to the assumption that errors are independently normal (Maddala and Kim, 1998, Chapter 5). Doornik, Hendry and Nielsen (1999) propose to include impulse dummies that take account of outliers in the data so that residuals from a VAR estimation may be normally distributed, even though the inclusion of a dummy-type variable may affect the underlying distribution of the test statistics.[4] Including dummies appears to be necessary to allow for an impact of the Asian currency crisis. In our VAR estimations, we have checked the distribution of VAR residuals and allowed for extreme outliers by including impulse dummies.[5]

We conducted the Johansen cointegration test for fifty-four pairs of economies and the results are reported in Tables 1 and 2. Panels A and B of Table 1 show the results for East Asian economies with respect to the United States and Japan, respectively. We have found that the hypothesis of no cointegration is rejected by either trace or maximum eigenvalue test at least at the 10 percent level in five out of nine

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[3] We estimate a VAR with a linear trend restricted to the cointegration space and an unrestricted constant, which is proposed by Doornik, Hendry and Nielsen (1999). The trend is excluded if the *F*-test shows it is insignificant in the system. We use PcGive version 10.1 for the Johansen cointegration test.

[4] Doornik, Hendry and Nielsen (1999) argue that impulse dummies should be included unrestrictedly based on their Monte Carlo study.

[5] We attempted to minimize the number of impulse dummies included in VAR estimation. The dummies are included when the following economies are included in the VAR: Japan (1993Q2), Korea (1980Q4, 1981Q1, 1988Q1, 1998Q1), Taiwan (2003Q3), Malaysia (1985Q1, 1998Q1), Indonesia (1998Q1, 1998Q2), Thailand (1994Q4, 1997Q4).

cases with respect to the United States and in four out of nine cases with respect to Japan. The null hypothesis of at most one cointegrating relationship is not rejected in all cases. Table 2 reports the results of cointegration test for the possible pairs of nine East Asian economies. The null hypothesis of no cointegration is rejected by either trace or maximum eigenvalue test at least at the 10 percent level in twelve out of thirty-six cases. The null hypothesis of at most one cointegrating relationship is again not rejected in all cases.

For the country pairs with one cointegrating relationship, we impose certain restrictions on the cointegrating vectors to determine the unique cointegration relations. We first conduct the likelihood ratio (LR) test for restrictions that each cointegrating vector is zero, i.e., H0: $\beta_k = 0$ where $k = i, j$. The results are reported in Table 3. It is interesting to note that, for the pairs between East Asian economies and the United States, only the coefficient of the US real output is statistically significant (Panel A of Table 3), which implies that the US real output series are individually stationary. Insignificant coefficients are also found in the Hong Kong-Taiwan and Taiwan-China pairs. On the other hand, for the pairs between the Philippines and four economies (i.e., Japan, Taiwan, Hong Kong and Singapore), the estimated β-coefficients indicate the real outputs move in the opposite direction (Table 3). As with an insignificant coefficient the cointegrating relationship between two real output series is unlikely to occur, we then proceed to the error-correction estimations for the pair-countries where they have a statistically significant estimate of the real output.[6]

Table 4 reports the summary of the estimated bilateral cointegrating

[6] We have also performed the LR test for the restrictions that two cointegrating vectors are equal, i.e., H0: $\beta_i - \beta_j = 0$. The last column in Table 3 shows that the hypothesis is accepted for only three pairs, i.e., Hong Kong-Japan, Taiwan-Korea and Singapore-Indonesia, implying the real outputs between the pair countries tend to move together over time.

relationship for the concerned economies. It is interesting to note that the cointegration relationship of the real output variables tends to be "cluster" based, related to the development level of an economy. Among the Asian NIEs and Japan with the exclusion of Singapore, real output variables are found to be cointegrated, and the same for the ASEAN countries as well as between China and Hong Kong.

4.2. Error-Correction Estimation

Once the cointegrating relationship of the variables is identified, we then perform the error-correction estimation to investigate the short-run interactions of the real output variations. In estimating the error-correction model, we first conduct the weakly exogenous test, i.e., the LR test for the significance of the α coefficients. If the null hypothesis of $\alpha_k = 0$ is not rejected where *k* represents the country *i* or *j*, we condition on the weakly exogenous variable and its short-run behavior is not modeled. It is found that, in six out of twenty cases in our estimations, the hypothesis of $\alpha_k = 0$ is not rejected, which implies that this variable can enter on the right-hand side of the vector error-correction model (see the second and the third columns of Table 5).

Based on the results of the weakly exogenous tests, we then estimated the error-correction model. Table 6 reports part of the results of estimating the error-correction model. As it is seen from Panel A of Table 6, all the error-correction terms for the Northeast Asian countries are significant and show the correct signs, which implies that a divergence from the long-term relationship of the real output is short-lived and the real output rapidly converges towards its long-term level. In Panel B, the error-correction term does not show a correct sign in the real output growth equations for the pair-country of Singapore-Thailand and Malaysia-Thailand. We have also conducted the Granger-causality test on the joint significance of the lagged output growth variables for each pair country to determine the short-run interaction of the output variables. The results are reported in panel B of Table 5. As it can be seen, the null hypothesis that the lagged real output growth of one country does not Granger-cause the output growth of the other country is not rejected only in four out of twenty cases. In addition, the two-way Granger causality is found in seven out of ten pairs, which implies the existence of short-run interactions of output growth between the countries.

4.3. Test for Common Feature Business Cycle

Synchronous long-term co-movement per se does not necessarily guarantee a monetary union, especially when the short-run business cycles are found asynchronous. It is therefore crucial also to determine the commonality of the cyclical behaviour and business cycle synchronization before moving towards a monetary union. The short-run cyclical behaviour of the output growth is often represented by the common serial correlation. To incorporate this issue in the analysis, we conducted the Vahid and Engle (1993) procedure to test for common serial correlation of the business cycles in the presence of cointegrating relationship.[7] The test results using equation (5) are reported in Table 7. If the null hypothesis of $s = 1$ is not rejected, this means that there exists a linearly independent common feature vector, i.e., we have found a linear independent combination of real output growth which has no correlation with the relevant past. Then, we can say that besides the cointegrating relationship of real outputs, the concerned countries share common short-term business cycles.

As it can be seen from Table 7, the hypothesis that $s = 1$ is not rejected in six

[7] Cheung and Yuen (2003) employ the Vahid and Engle (1993) test to examine the prospect of creating a currency union in the North East Asian region that consists of China, Japan and Korea.

out of ten pairs while the null that s = 2 is rejected in all pairs. The results for the presence of one common feature vector indicate there exists a linear combination of the output growth series in the Northeast Asian region as well as ASEAN economies that display no significant serial correlation. Thus, we can conclude that these economies share common business cycles and react symmetrically to shocks. In particular, the short-run common business cycles are found in some pairs of ASEAN economies consisting of Singapore, Thailand and Indonesia, and in the Northeast Asian region consisting of Hong Kong, Korea and Mainland China, as well as between Japan and Taiwan. A monetary union will be considered feasible in these pair countries as they share both long-run output co-movements as well as common short-run business cycles. The results contrast with the finding in some of the existing studies on East Asia, such as Bayoumi, Eichengreen and Mauro (2000) and Zhang, Sato and McAleer (2004), where a significant correlation in supply shocks is normally found between Taiwan, Hong Kong and Singapore in the Asian NIEs and no significant correlation is detected between Japan and the Asian NIEs. The finding that the concerned economies share common long-run and short-run cyclical behaviours is believed the important economic evidence to assess the feasibility of forming a monetary union in the East Asian region.

5. Concluding Remarks

This paper examines the feasibility of forming a monetary union in East Asia by applying both the Johansen (1991) cointegration technique and Vahid and Engle (1993) test for common serial correlation cycles to assessing the long-run and short-run real output co-movements among these economies. The East Asian region has experienced astonishing economic growth and rapid integration over the past few decades. Our study found that some pair countries in the region share both the long-run and short-run synchronous movements of the real outputs. In particular, the short-run common business cycles are found in some pairs of ASEAN economies consisting of Singapore, Thailand and Indonesia, and in the Northeast Asian region consisting of Hong Kong, Korea and Mainland China, as well as between Japan and Taiwan. A monetary union will be considered feasible in these pair countries as they share both long-run output co-movements as well as common short-run business cycles. These results suggest that the high degree of integration through the flows of trade and capital in the East Asian region has greatly shaped the economic structure of each individual economy and contributed to the business cycle synchronization and co-movements of real output variables in both the short run and the long run. This has important implications for the economies concerned when considering the adoption of a monetary union and a common currency. As the losing of monetary independence would be the major cost for adopting a common currency, it is therefore less costly for the economies to form a monetary union when the business cycles are synchronized across countries.

This paper focuses on the bivariate cointegration tests in determining the long-run (cointegrating) relationship of the real output variables. It is still possible to conduct a multivariate cointegration test, although the three-variable system or more is inherently atheoretical. We have assessed the impacts of the recent financial crisis on the co-movements of output by including the dummy variables in the empirical study. Some further measures would be necessary to deal with possible structural break especially when we adopt a longer time span. These certainly reward a further study.

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Table 1. Tests for Cointegration Rank: Comparisons with the United States and Japan

Country pair: (country i & j)	Number of lag:	Deterministic components	Trace test H0: r =0	λmax test H0: r =0	Trace test H0: $r \leq 1$	λmax test H0: $r \leq 1$
Panel A: Comparisons with the United States						
Kr - US	3	Trend	20.94	18.53 #	2.41	2.41
			[0.185]	[0.064]	[0.923]	[0.924]
Tw - US	2	Trend	24.54 #	15.67	8.87	8.87
			[0.071]	[0.164]	[0.194]	[0.194]
HK - US	8	Trend	24.81 #	20.38 *	4.43	4.43
			[0.066]	[0.033]	[0.683]	[0.685]
Si - US	7	Trend	19.02	13.89	5.13	5.13
			[0.285]	[0.271]	[0.585]	[0.587]
Ml - US	2	Trend	11.93	11.45	0.48	0.48
			[0.815]	[0.481]	[1.000]	[1.000]
Id - US	7	Trend	17.55	17.47 #	0.08	0.08
			[0.383]	[0.092]	[1.000]	[1.000]
Th - US	2	Trend	12.07	9.97	2.1	2.1
			[0.806]	[0.630]	[0.948]	[0.949]
Ph - US	6	Trend	24.87 #	15.86	9.01	9.01
			[0.065]	[0.154]	[0.185]	[0.184]
Ch - US	3	Trend	22.58	17.61 #	4.96	4.96
			[0.122]	[0.088]	[0.608]	[0.610]
Panel B: Comparisons with Japan						
Kr - Jp	3	Trend	24.96 #	16.44	8.52	8.52
			[0.063]	[0.129]	[0.218]	[0.218]
Tw - Jp	3	No Trend	15.39 #	14.61 *	0.78	0.78
			[0.050]	[0.042]	[0.377]	[0.377]
HK - Jp	4	Trend	26.4 *	21.83 *	4.58	4.58
			[0.041]	[0.019]	[0.662]	[0.664]
Si - Jp	7	Trend	18.04	16.76	1.28	1.28
			[0.349]	[0.117]	[0.988]	[0.989]
Ml - Jp	5	Trend	19.53	16.11	3.42	3.42
			[0.255]	[0.143]	[0.816]	[0.818]
Id - Jp	5	No Trend	8.31	7.83	0.47	0.47
			[0.440]	[0.404]	[0.491]	[0.491]
Th - Jp	5	Trend	16.55	10.82	5.73	5.73
			[0.457]	[0.543]	[0.505]	[0.506]
Ph - Jp	7	Trend	33.94 **	27.75 **	6.2	6.2
			[0.003]	[0.002]	[0.447]	[0.448]
Ch - Jp	5	Trend	19.27	12.33	6.94	6.94
			[0.271]	[0.398]	[0.361]	[0.362]

Notes: Sample period is 1978Q1-2004Q4. λmax test denotes the maximum eigenvalue test. "Trend" indicates that a VAR is estimated with a linear trend restricted to the cointegration space. "No Trend" represents that VAR estimation is performed with an unrestricted constant only. “r” represents the number of cointegrating vectors. Double asterisks (**), a single asterisk (*) and a sharp (#) denote the 1 percent, 5 percent and 10 percent significance, respectively. Figures in brackets indicate p-value.

Table 2. Tests for Cointegration Rank: among East Asian Economies

Country pair: (country i & j)	Number of lag:	Deterministic components	Trace test H0: r=0	λ_{max} test H0: r=0	Trace test H0: $r\leq1$	λ_{max} test H0: $r\leq1$
Tw - Kr	5	Trend	29.16 *	18.7 #	10.46	10.46
			[0.017]	[0.061]	[0.109]	[0.109]
HK - Kr	8	Trend	48.87 **	38.99 **	9.88	9.88
			[0.000]	[0.000]	[0.135]	[0.135]
Si - Kr	5	Trend	14.77	8.93	5.84	5.84
			[0.600]	[0.733]	[0.491]	[0.492]
Ml - Kr	3	Trend	10.13	8.73	1.4	1.4
			[0.913]	[0.752]	[0.985]	[0.985]
Id - Kr	3	Trend	8.53	7.19	1.34	1.34
			[0.966]	[0.878]	[0.987]	[0.987]
Th - Kr	5	Trend	14.73	12.61	2.12	2.12
			[0.603]	[0.372]	[0.946]	[0.947]
Ph - Kr	5	Trend	14.51	12.76	1.75	1.75
			[0.621]	[0.360]	[0.969]	[0.970]
Ch - Kr	5	Trend	12.01	9.32	2.69	2.69
			[0.809]	[0.695]	[0.898]	[0.900]
HK - Tw	6	Trend	32.35 **	21.67 *	10.68	10.68
			[0.006]	[0.020]	[0.100]	[0.100]
Si - Tw	2	Trend	17.16	14.17	3	3
			[0.411]	[0.252]	[0.866]	[0.867]
Ml - Tw	5	Trend	16.97	11.36	5.61	5.61
			[0.425]	[0.490]	[0.520]	[0.522]
Id - Tw	5	Trend	14.54	13.41	1.13	1.13
			[0.619]	[0.306]	[0.992]	[0.993]
Th - Tw	5	Trend	19.63	11.28	8.35	8.35
			[0.250]	[0.497]	[0.231]	[0.231]
Ph - Tw	6	Trend	39.48 **	31.66 **	7.82	7.82
			[0.000]	[0.000]	[0.275]	[0.275]
Tw - Ch	5	Trend	26.44 *	18.14 #	8.3	8.3
			[0.040]	[0.074]	[0.235]	[0.235]
HK - Si	8	Trend	22.89	12.89	10	10
			[0.112]	[0.349]	[0.129]	[0.129]
HK - Ml	5	Trend	11.99	9.94	2.05	2.05
			[0.811]	[0.633]	[0.951]	[0.952]
HK - Id	8	Trend	10.63	9.12	1.5	1.5
			[0.890]	[0.714]	[0.981]	[0.981]
HK - Th	5	Trend	24.96 #	18.71 #	6.25	6.25
			[0.063]	[0.060]	[0.439]	[0.440]
HK - Ph	7	Trend	52.94 **	42.9 **	10.04	10.04
			[0.000]	[0.000]	[0.127]	[0.127]
HK - Ch	8	Trend	24.43 #	14.75	9.68	9.68
			[0.073]	[0.214]	[0.145]	[0.145]

(continued on next page)

Table 2. *(continued)*

Country pair: (country i & j)	Number of lag:	Deterministic components	Trace test H0: r=0	λmax test H0: r=0	Trace test H0: $r\leq1$	λmax test H0: $r\leq1$
Si - Ml	7	Trend	11.25	8.62	2.62	2.62
			[0.857]	[0.762]	[0.904]	[0.906]
Si - Id	7	Trend	18.33	17.63 #	0.71	0.71
			[0.329]	[0.088]	[0.998]	[0.998]
Si - Th	8	Trend	29.96 *	24.16 **	5.8	5.8
			[0.013]	[0.007]	[0.496]	[0.497]
Si - Ph	7	Trend	20.91	17.75 #	3.16	3.16
			[0.186]	[0.084]	[0.847]	[0.849]
Si - Ch	5	Trend	13.32	10.94	2.38	2.38
			[0.716]	[0.531]	[0.926]	[0.927]
Ml - Id	2	No Trend	7.24	6.13	1.11	1.11
			[0.557]	[0.603]	[0.292]	[0.292]
Ml - Th	7	Trend	26.54 *	20.81 *	5.74	5.74
			[0.039]	[0.028]	[0.505]	[0.506]
Ph - Ml	7	Trend	15	14.5	0.49	0.49
			[0.582]	[0.229]	[1.000]	[1.000]
Ml - Ch	3	Trend	5.04	4.83	0.21	0.21
			[0.999]	[0.981]	[1.000]	[1.000]
Th - Id	5	No Trend	12.24	10.38	1.86	1.86
			[0.147]	[0.191]	[0.173]	[0.173]
Ph - Id	5	Trend	11.5	9.57	1.94	1.94
			[0.841]	[0.670]	[0.959]	[0.959]
Id - Ch	3	Trend	8.1	7.56	0.54	0.54
			[0.975]	[0.852]	[0.999]	[0.999]
Ph - Th	8	Trend	17.33	14.43	2.9	2.9
			[0.399]	[0.234]	[0.877]	[0.878]
Th - Ch	5	Trend	12.41	10.8	1.62	1.62
			[0.782]	[0.546]	[0.976]	[0.976]
Ph - Ch	2	Trend	17.74	12.69	5.05	5.05
			[0.369]	[0.366]	[0.597]	[0.598]

Notes: Sample period is 1978Q1-2004Q4. λmax test denotes the maximum eigenvalue test. "Trend" indicates that a VAR is estimated with a linear trend restricted to the cointegration space. "No Trend" represents that VAR estimation is performed with an unrestricted constant only. “r” represents the number of cointegrating vectors. Double asterisks (**), a single asterisk (*) and a sharp (#) denote the 1 percent, 5 percent and 10 percent significance, respectively. Figures in brackets indicate p-value.

Table 3. Tests for Cointegrating Vectors

Country pair: (country i & j)	$\beta(i)$	$-\beta(j)$	$-\beta(t)$	H0: $\beta(i)=\beta(j)$
Panel A: Comparisons with the United States				
Kr - US	1.000	-40.417	0.31255	12.281 **
	(0.12389)	(13.607) **	(10.355) **	[0.0005]
Tw - US	1.000	1.0092	-0.034569	0.16137
	(0.81338)	(0.036510)	(0.76493)	[0.6879]
HK - US	1.000	-25.55	0.19494	11.288 **
	(0.40520)	(13.097) **	(10.661) **	[0.0008]
Id - US	1.000	41.948	-0.33979	13.24 **
	(0.13477)	(15.922) **	(11.839) **	[0.0003]
Ph - US	1.000	-5.2487	0.033233	2.0108
	(1.7026)	(3.6855) #	(2.0699)	[0.1562]
Ch - US	1.000	-9.8098	0.053561	11.911 **
	(0.68083)	(12.292) **	(3.8815) *	[0.0006]
Panel B: Comparisons with Japan				
Kr - Jp	1.000	-1.338	-0.00862	3.2068 #
	(7.915) **	(7.726) **	(6.727) **	[0.0733]
Tw - Jp	1.000	-2.0713	n.a.	2.9596 #
	(6.9082) **	(4.4238) *		[0.0854]
HK - Jp	1.000	-0.96358	-0.0068841	0.090726
	(17.122) **	(12.811) **	(17.122) **	[0.7633]
Ph - Jp	1.000	0.63877	-0.0099346	19.457 **
	(21.404) **	(10.378) **	(17.173) **	[0.0000]
Panel C: Among the East Asian Economies				
Tw - Kr	1.000	-0.89535	-0.0012694	0.7939
	(7.9155) **	(6.8028) **	(0.33156)	[0.3729]
Hk - Kr	1.000	-0.85067	0.0017477	6.4444 *
	(28.257) **	(28.253) **	(2.9840) #	[0.0111]
HK - Tw	1.000	-0.52171	-0.0059903	5.1460 *
	(3.3748) #	(1.2227)	(3.2218) #	[0.0233]
Ph - Tw	1.000	0.29380	-0.0098958	12.734 **
	(18.303) **	(3.0153) #	(6.4746) **	[0.0004]
Tw - Ch	1.000	-4.5899	0.093811	8.5192 **
	(1.4165)	(7.0946) **	(8.6058) **	[0.0035]
HK- Th	1.000	-0.49893	-0.0051074	8.6168 **
	(12.388) **	(9.9965) **	(6.6202) *	[0.0033]
HK - Ph	1.000	1.3149	-0.020710	32.816 **
	(30.252) **	(32.594) **	(32.865) **	[0.0000]
HK - Ch	1.000	-2.5142	0.046098	3.3364 #
	(4.1409) *	(4.8112) *	(4.4581) *	[0.0678]
Si - Id	1.000	-0.77605	-0.008062	1.4757
	(15.122) **	(13.354) **	(6.0079) *	[0.2244]
Si - Th	1.000	-0.41389	-0.010779	11.947 **
	(18.085) **	(12.863) **	(12.746) **	[0.0005]
Si - Ph	1.000	2.6862	-0.034183	14.521 **
	(2.7389) #	(12.246) **	(7.0586) **	[0.0001]
Ml - Th	1.000	-0.33777	-0.01005	10.67 **
	(14.816) **	(10.101) **	(10.504) **	[0.0011]

Table 3. *(continued)*

Notes: The second and third columns report the cointegrating vectors of country pairs. The forth column indicates the coefficient of a linear trend that is found to exist in the cointegration space. Figures in parenthesis denote the likelihood ratio (LR) statistics for H0: $\beta_k = 0$ where $k = i, j$ or t. The fifth column shows the LR statistics for the null hypothesis of proportional co-movement of the respective countries. Double asterisks (**), a single asterisk (*) and a sharp (#) denote the 1 percent, 5 percent and 10 percent significance, respectively. Figures in brackets indicate *p*-value.

Table 4. Bilateral Cointegrating Relationship: 1978Q1-2004Q4

Panel A: Summary Result of Cointegration Test

	US	Jp	Kr	Tw	HK	Si	Ml	Id	Th	Ph	Ch
United States											
Japan	-										
Korea	β=0	**Coint**									
Taiwan	β=0	**Coint**	**Coint**								
Hong Kong	β=0	**Coint**	**Coint**	β=0							
Singapore	No	No	No	No	No						
Malaysia	No	No	No	No	No	No					
Indonesia	β=0	No	No	No	No	**Coint**	No				
Thailand	No	No	No	No	**Coint**	**Coint**	**Coint**	No			
Philippines	β=0	**Coint**	No	**Coint**	**Coint**	**Coint**	No	No	No		
China	β=0	No	No	β=0	**Coint**	No	No	No	No	No	

Panel B: Summary of Long-Run Relationship of Real Outputs

	US	Jp	Kr	Tw	HK	Si	Ml	Id	Th	Ph	Ch
United States											
Japan	-										
Korea	-	**Positive**									
Taiwan	-	**Positive**	**Positive**								
Hong Kong	-	**Positive**	**Positive**	-							
Singapore	-	-	-	-	-						
Malaysia	-	-	-	-	-	-					
Indonesia	-	-	-	-	-	**Positive**	-				
Thailand	-	-	-	-	**Positive**	**Positive**	**Positive**	-			
Philippines	-	Negative	-	Negative	Negative	Negative	-	-	-		
China	-	-	-	-	**Positive**	-	-	-	-	-	

Notes: "Coint" ("No") indicates that there is a (no) cointegration relationship. β=0 shows that a cointegration relationship is found but either (or both) of cointegrating vectors is not significantly different from zero. "Positive" indicates the co-movement of real outputs for the pair of countries. "Negative" shows that real outputs of the countries move in opposite directions.

Table 5. Restrictions on Short-run Dynamics

Country pair: (country i & j)	Weakly exogenous test		Granger causality test	
	H0: $\alpha(i)$=0	H0: $\alpha(j)$=0	Δy(i) → Δy(j)	Δy(j) → Δy(i)
Kr - Jp	5.6068 *	1.4283	5.8858 #	9.2552 **
	[0.0179]	[0.2320]	[0.0527]	[0.0098]
Tw - Jp	12.233 **	1.8604	12.648 **	1.9387
	[0.0005]	[0.1726]	[0.0018]	[0.3793]
HK - Jp	7.9562 **	5.9067 *	7.8844 *	8.913 *
	[0.0048]	[0.0151]	[0.0485]	[0.0305]
Tw - Kr	0.86673	9.1932 *	25.761 **	12.176 *
	[0.6483]	[0.0101]	[0.0000]	[0.0161]
HK - Kr	8.8924 **	13.744 **	49.658 **	24.304 **
	[0.0029]	[0.0002]	[0.0000]	[0.0010]
HK - Th	5.0276 *	5.3753 *	13.016 *	9.8065 *
	[0.0249]	[0.0204]	[0.0112]	[0.0438]
HK - Ch	0.44247	4.4852 *	3.3727	5.6808
	[0.5059]	[0.0342]	[0.8485]	[0.5775]
Si - Id	17.508 **	1.5064	9.1886	11.234 #
	[0.0002]	[0.4709]	[0.1632]	[0.0814]
Si - Th	14.681 **	5.4441 *	16.872 *	20.233 **
	[0.0001]	[0.0196]	[0.0182]	[0.0051]
Ml - Th	0.49778	15.065 **	29.947 **	15.074 *
	[0.4805]	[0.0001]	[0.0000]	[0.0197]

Notes: The figures reported in the second and third columns are the LR statistics for the null hypothesis of H0: $\alpha_k = 0$ where k = i or j. Those reported in the forth and fifth columns are the F-statistics for the null hypothesis that the lagged Δy(i) do not Granger-cause Δy(j) (Δy(i) →Δy(j)) or that the lagged Δy(j) do not Granger-cause Δy(i) (Δy(j) →Δy(i)). Double asterisks (**), a single asterisk (*) and a sharp (#) denote the 1 percent, 5 percent and 10 percent significance, respectively. Figures in brackets indicate p-value.

Table 6. The Results of Error-Correction Estimation

	Panel A: North East Asian Group								*Panel B: ASEAN plus Hong Kong*					
Country pair: (country *i* & *j*)	Kr - Jp	Tw - Jp	HK - Jp	HK - Jp	Tw - Kr	HK - Kr	HK - Kr	HK- Ch	Si - Id	Si - Th	Si - Th	Ml - Th	HK - Th	HK - Th
Dependent variable:	Kr	Tw	HK	Jp	Kr	HK	Kr	Ch	Si	Si	Th	Th	HK	Th
EC (-1)	-0.117	-0.031	-0.194	0.072	0.092	-0.243	0.156	0.049	-0.127	-0.198	-0.094	-0.150	-0.138	0.089
	(0.031) **	(0.009) **	(0.063) **	(0.027) **	(0.025) **	(0.078) **	(0.039) **	(0.014) **	(0.033) **	(0.048) **	(0.038) *	(0.035) **	(0.053) *	(0.033) **
Const	-0.529	-0.293	0.066	-0.018	-0.245	0.667	-0.406	0.253	-0.339	0.788	0.375	0.817	0.756	-0.474
	(0.144)	(0.085) **	(0.019) **	(0.008) *	(0.071) **	(0.211) **	(0.106) **	(0.068) **	(0.092) **	(0.188) **	(0.151) *	(0.189) **	(0.287) *	(0.178) **
Δ y(*i*)	0.144 [1]	0.378 [1]	0.221 [1]		0.280 [0]		-0.196 [2]		0.197 [1]	0.243 [1]	0.263 [7]	0.251 [2]	0.201 [3]	-0.156 [4]
	(0.063) *	(0.093) **	(0.104) *		(0.103) **		(0.058) **		(0.098) *	(0.102) *	(0.091) **	(0.094) **	(0.103) #	(0.063) *
	0.232 [2]		0.274 [3]		-0.231 [3]		-0.174 [3]		0.214 [2]	0.275 [2]		-0.213 [6]		
	(0.057) **		(0.105) **		(0.101) *		(0.055) **		(0.102) *	(0.104) *		(0.072) **		
					-0.238 [4]		-0.139 [4]		0.296 [6]	0.379 [6]				
					(0.099) *		(0.053) *		(0.102) **	(0.105) **				
							-0.210 [7]							
							(0.059) **							
Δy(*j*)	-0.185 [1]			0.200 [3]	0.192 [2]	0.218 [1]	0.139 [1]	0.178 [2]	-0.214 [6]	-0.351 [7]	0.302 [1]	-0.171 [2]		0.369 [1]
	(0.109) #			(0.088) *	(0.056) **	(0.122) #	(0.061) *	(0.102) #	(0.102) *	(0.117) **	(0.096) **	(0.096) #		(0.088) **
	-0.225 [2]					0.235 [2]	0.228 [2]	0.206 [3]			-0.173 [3]	-0.254 [3]		0.179 [2]
	(0.104) *					(0.115) *	(0.058) **	(0.106) #			(0.101) #	(0.094) **		(0.095) #
								0.250 [4]			-0.257 [7]			-0.209 [3]
								(0.110) *			(0.094) **			(0.095) *
														0.181 [4]
														(0.086) *

Notes: The result of error-correction estimation is reported. The third row shows which country's real output growth appears in the left-hand side of equations as a dependent variable. EC(-1) denotes the coefficient of the error-correction term. Figures in parenthesis are standard errors. Figures in brackets indicate the lag order for respective independent variables. The coefficients that are not statistically significant are not reported in this table. Double asterisks (**), a single asterisk (*) and a sharp (#) denote the 1 percent, 5 percent and 10 percent significance, respectively.

Table 7. Common Feature Test Results

Country pair: (*i* & *j*)		Degrees of Freedom	Squared Canonical Stat. (λs)	Common Feature Stat. C(p,s)		Critical Value (5% level)
Kr - Jp	S = 1	4	0.12	12.96	*	9.49
	S = 2	10	0.46	75.00	*	18.31
Tw - Jp	S = 1	4	0.08	8.24		9.49
	S = 2	10	0.75	150.22	*	18.31
HK - Jp	S = 1	6	0.17	19.00	*	12.59
	S = 2	14	0.38	66.26	*	23.68
Tw - Kr	S = 1	8	0.15	15.73	*	15.51
	S = 2	18	0.66	121.92	*	28.87
HK - Kr	S = 1	14	0.10	9.34		23.68
	S = 2	30	0.63	100.14	*	43.77
HK - Ch	S = 1	14	0.06	5.53		23.68
	S = 2	30	0.92	236.18	*	43.77
Si - Id	S = 1	12	0.10	10.05		21.03
	S = 2	26	0.65	109.30	*	38.89
Si - Th	S = 1	14	0.15	14.55		23.68
	S = 2	30	0.79	159.35	*	43.77
Ml - Th	S = 1	12	0.20	21.37	*	21.03
	S = 2	26	0.81	177.00	*	38.89
HK - Th	S = 1	8	0.09	9.23		15.51
	S = 2	18	0.66	114.94	*	28.87

Note: "S" denotes the number of common features. Under the null hypothesis, the common feature statistics, *C(p,s)* has an asymptotic chi-square distribution with $(s^2 + snp + sr - sn)$ degrees of freedom, where n is the number of endogenous variables, p is the lag order of the system in differences, and r is the number of cointegrating vectors. A single asterisk (*) indicates the 5% significance level.