Synchronization in Business Cycle of East Asian Economy: Evidence from Time Varying Coherence Study

Jean-Pierre Allegret [*], Essahbi ESSAADI [†]

Submission at the 13^{th} International Conference on Macroeconomic Analysis and International Finance-May 28-30, 2009

First draft: December 2008
This draft: February 2009

Abstract

This paper analyses the dynamic synchronization process in East Asia. Our main purpose is to study the feasibility of a monetary union in this group. To this end, we examine business cycle synchronization in the region. We propose a new empirical methodology based on frequency domain. Firstly, we apply a new measure of comovement allowing us to distinguish period of synchronization and de-synchronization and to determine the cycle properties of it. Second, we compare the satisfaction degree of this criterion for the region. Analysis the degree of *cohesion* in the region gives us some recommendations about monetary union option in East Asia region. We are interested whether if business cycle in Asia would become more similar over time and if their similarities allow them to build a monetary union.

Key-words: Business Cycle Synchronisation, Spectral Analysis, Time Varying Coherence Function, Structural Change.
JEL Classification: C22, E32, E63, F42 and O47.

1 Introduction

Integration process in East Asia is based on two main phases. During the first, the main driver of integration has been the so-called global production sharing. Indeed, the dramatic increase of international trade under the form of trade in intermediate inputs led to the constitution of an intense trade network between East Asian countries. The striking characteristic of this first phase is the lack of an institutional framework to promote integration. The Asian financial crisis in 1997-98 radically changes this situation. Monetary and financial cooperation within the East Asian region has been

[*] GATE - CNRS - University of Lyon. allegret@gate.cnrs.fr
[†] **U**nité d'**A**nalyse **Qu**antitative **A**ppliquée (UAQUAP)-ISG Tunis and and GATE - CNRS - University of Lyon. essahbi.essaadi@univ-lyon2.fr

seen as the mean to protect countries against international turbulences. As stressed by Rana (2007), this second phase in the integration process rests on a formal institutional framework[1].

In this paper, considering the critical role of trade integration in the integration process, we study whether East Asian countries are characterized by business cycle synchronization. Monetary union implies the relinquishing of independent counter-cyclical monetary policy to stabilize cyclical fluctuations. The lower the business cycles synchronization between countries forming a monetary union, the higher the costs of this union. Frankel and Rose (1998) consider an endogenous approach of optimum currency area in which currency union affects the nature of domestic business cycles[2]. Currency union increases trade intensity that, in turn, leads to a rise in output correlation and, thus, to an increase in business cycle synchronization. The new economic geography stresses that trade integration may increase countries specialization leading to lower business cycles synchronization. Empirical studies dedicated to industrialized countries show that trade intensity increases the business cycle co-movement among them (Clark and van Wincoop, 2001). For emerging and developing countries, results are mixed (Calderón et al., 2007). Differences in the patterns of specialization and bilateral trade are the main explanation of this result. While trade among industrialized countries is based on intra-industry trade, in developing countries, inter-industry trade prevails. As a consequence, the relationship between trade intensity and correlation of business cycles is positive in the former case, negative in the latter.

Are Asian countries similar to other emerging and developing countries where regional integration tends to promote inter-industry trade? In order to assess the synchronization of business cycles in the area, different methodologies have been applied in the literature. A first strand uses correlation analysis to determine to what extent trade integration in East Asia has led to more business cycles synchronization (Crosby, 2003; Shin and Wang, 2003; Rana, 2007). Correlation analysis gets mixed results in the sense that there is no clear evidence that co-movements of GDP have increased. A second strand of literature applies the cointegration and common feature approaches (Sato and Zhang, 2005 and 2006; Sato, Allen, and Zhang, 2007). Cointegration allows to check whether there exist long-run co-movement of real output variables among the East Asian economies while the common cyclical feature analysis examines the short-run

[1]The main initiatives are the implementation of cooperation devises between East Asian countries such as the ASEAN Surveillance Process in October 1998 and the Economic Review and Policy Dialogue in May 2000. The Chiang Mai Initiative (May 2000) has established a regional financial arrangement under the form of bilateral swaps. The ERPD and the CMI include ASEAN countries (the members of the Association of Southeast Asian Nations are Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam), China, Japan, and Korea (the so-called ASEAN+3).

[2]The basic idea of this approach is that "a country is more likely to satisfy the criteria for entry into a currency union ex post than ex ante" (Frankel and Rose, 1998: 1024).

and long-run dynamics of real output. They find that some countries in the share both the long-run and short-run synchronous movements of the real outputs. A third group of literature includes different empirical methods to decompose cycles into specific and common components. Using panel data econometrics, Loayza and al. (1999) build an error components model to distinguish between country-specific factors and to common factors. For the period 1970-1994, they find that both for long run trends and short run fluctuations, sector-specific effects which are country-independent predominate in East Asia. Chow and Kim (2003) built VAR models to show to what extent country-specific, regional or world shocks most significantly affect output fluctuations in East Asia. Their main finding is the weak importance of regional shocks in East Asia relative to the country specific ones suggesting that a currency union would be costly. Lee et al. (2003), Moneta and Rüffer (2006), and Lee and Azali (2006) propose dynamic unobserved factor models to decompose output in world common, regional common and country specific components. Results are mixed: Lee et al. and Moneta and Rüffer find that the degree of business cycles synchronization has increased since 1990; Lee and Azali get opposite results in the sense that country-specific shocks remain the main driver of output fluctuations.

Overall, the empirical literature dedicated to business cycles synchronization in East Asia does not lead to firm conclusion. In this paper, we suggest a different empirical approach allowing, contrary to the previous studies, to detect endogenously structural changes in the co-movement process between outputs. We apply a new measure based on the time varying coherence function[3]. Such a measure not only detects co-movement dynamics in different cycles for East-Asian economies, but also it tests if these countries tend to be more synchronized or not. A high level or an increasing one of co-movement in long term cycle constitutes a solid argument in favor of the feasibility of a monetary union for this region. Our methodology outperforms existing literature in three points. Firstly, we decompose output in short and long cycle components. Secondly, we estimate the dynamic of the synchronization process in the East Asian region. Thirdly, the measure of countries integration is based on the whole Asian region and not to one country as a proxy. Our study extends also the related literature by using a much longer sample period spanning from 1975Q1 to 2007Q1 to study the ten Asian economies.

The remainder of this paper is organized as follows. Section 2 explains the methodology adopted in this paper. Section 3 presents the empirical results. Section 4 concludes.

[3] See Essaadi and Boutahar (2008) for a technical analysis.

2 Empirical Methodology

2.1 Overview of the method

Two methods allow analysing time series: the spectral approach (frequency approach) on the one hand, and the time approach (dynamic approach) on the other hand. The advantage of the spectral approach rests on the fact that -contrary to the time approach- an upstream treatment, based on the verification of the stationarity of series, is not required to identify periodicity within the series. Frequency domain defines correlation between two components in frequency as the coherence interpreted as the squared linear correlation coefficient for each frequency of the spectra of two series. If time approach gives the instantaneous coherent peaks between two series and describes their patterns over time, its main drawback is that it does not assess whether coherence increases or not between the cycles of countries. On this point, the main advantage of the use of frequency approach is to detect changes in synchronisation process in different frequencies. With this additional information, we can know which cycles are more synchronized than other. It's a critical point to know to what extent countries are suitable to form a monetary union.

From this perspective, the frequency domain approach improves previous analysis in six points. First, it does not depend on any particular detrending technique. Second, as frequency approach identifies both short-run and long-run changes, their respective importance relative to business cycle frequencies (short vs long cycles) remains clear. Third, coherence measure generalizes on simple correlation. Fourth, convergence or divergence periods are detected endogenously. In addition, frequency approach specifies if convergence or divergence belong to short-term or long-term cycles. Fifth, this approach is relevant for both stationary and non stationary cases. Finally, the frequency domain performs our time-varying analysis at different frequencies simultaneously. Indeed, we obtain the short, medium and long run behaviors of the generating process of the co-movement series.

Essaadi and Boutahar (2008) introduce a new method to estimate Time Varying Coherence Functions (thereafter TVCF) for economics series[4]. This method offers a more illuminating interpretation of coherence and develops a well-suited procedure to estimate the time-varying coherence of non-stationary time series. The choice of the TVCF analysis for the dynamic in synchronization process is motivated by the presence of crisis and their important impact in the East Asian economies (Asian crisis of 1997, the ICT bubble 2000-2001).

Our goal is to pinpoint dates of changes in co-movements between two series in two dimensions: time and frequency. In time domain, dynamic correlation can give us some responses to this issue, but the choice of window can affect seriously the dynamic correlation pattern (Essaadi et al, 2007). To overcome this limit we propose a TVCF

[4]See Mathematical Appendix A for technical details.

as a measure of co-movement variability by the frequency approach. Time varying coherence function estimates not only a degree of co-movement over time but also their behavior in each frequency. Such methodology is critical if we consider the specificity of the integration process in East Asia. Relative to the European experience, regional integration in East Asia has occurred in a shorter period, and is more market-driven. Stimulated by the expansion of bilateral trade, integration in Asia seems to follow a fast trajectory relatively to other regional integration experiences. For this reason, employing the same empirical methodology as European case -such as VAR approaches- seems to be inappropriate. We need a measurement of synchronization that take in evidence the nonlinearity of the integration process. The TVCF not only answers to this requirement, but enriches our study with the short and long run dimension of this integration.

2.2 Time Varying Coherence Function stability test

Some techniques have been developed to test multiple structural breaks. We adopt Bai and Perron (1998, 2001) tests to detect a mean-shift in TVCF. Using GAUSS software, we obtain estimates by running the Bai and Perron's codes. The choice of this type of model is motivated by the TVCF characteristics. Indeed, the analysis of the graphical pattern of these statistics (see Appendix B) shows that it is affected only by breaks in mean. Using Bai and Perron test (1998) allows us to determine endogenously break dates when the change in coherence between series is significant. We are interested in break point in the coherence between two economies. Break point is defined as changes in the underlying relationship of the two economies that occur as a response to an exogenous event or a change in economic policy.

2.2.1 The model and estimators

We consider the following mean-shift model with m breaks, $(T_1, ..., T_m)$:

$$\begin{aligned} TCVF_{w_j,t} &= \mu_1 + u_t, \quad t = 1, ..., T_1, \\ TCVF_{w_j,t} &= \mu_2 + u_t, \quad t = T_1 + 1, ..., T_2, \\ &\vdots \\ TCVF_{w_j,t} &= \mu_{m+1} + u_t, \quad t = T_m + 1, ..., T. \end{aligned} \tag{1}$$

for $i = 1, 2, ..., m+1$, $T_0 = 0$ and $T_{m+1} = T$, where T is the sample size. $TCVF_{w_j,t}$ is the time varying coherence function in the neighbourhood of the w_j frequency. μ_i are the means, and u_t is the disturbance at time t. The break points $(T_1, ..., T_m)$ are explicitly treated as unknown. Based on the ordinary least-squares (OLS) principle Bai and Perron (1998) estimate the vector of the regressors coefficients μ_j $(1 \leq j \leq m+1)$

by minimising the sum of squared residuals $\sum_{i=1}^{m+1}\sum_{t=T_{i-1}+1}^{T_i}(TCVF_{w_j,t}-\mu_i)^2$. Let $\widehat{TCVF}_{w_j,t}(\{T_j\})$ denote the resulting estimate. Substituting it in the objective function and denoting the resulting sum of squared residuals as $S_T(T_1,\ldots,T_m)$, the estimated break dates $\left(\hat{T}_1,\ldots,\hat{T}_m\right)$ are such that

$$\left(\hat{T}_1,\ldots,\hat{T}_m\right)=\arg\min_{(T_1,\ldots,T_m)} S_T(T_1,\ldots,T_m), \tag{2}$$

where the minimization is taken over all partitions $(T_1,\ldots,T_m)$ such that $T_i-T_{i-1}\geq[\varepsilon T]$.[5]

2.2.2 The test statistic and the model selection criteria

This test locates multiple breaks without imposing any prior expectations on the data. The procedure estimates unknown regression coefficients together with the break points when T quarters are available. In order to determine the number of break points, we use Bayesian Information Criterion (BIC) as suggested by Yao (1988) and defined as follows:

$$BIC(m)=(T^{-1}S_T(\widehat{T}_1,...,\widehat{T}_m))+p^*T^{-1}ln(T), \tag{3}$$

where $p^*=(m+1)q+m$ is the number of unknown parameters. The author demonstrates that, for normal sequence of random variables with shifts in mean, the number of breaks can be consistently estimated.

Bai and Perron (1998) introduces some asymptotic critical values for the arbitrary small positive number (ε) and the maximum possible number of breaks (M): ($\varepsilon=0.10,\ M=8$), ($\varepsilon=0.15,\ M=5$), ($\varepsilon=0.20,\ M=3$) and ($\varepsilon=0.25,\ M=2$). For our empirical computation, we choose ($\varepsilon=0.15,\ M=5$) and we use Bai and Perron (1998, 2001) algorithm to obtain global minimisers of the squared residuals.

3 Empirical Results

3.1 The Data

This section focuses on the synchronization nonlinearity. We choose real GDP quarterly frequency in order to disentangle more clearly common shocks from spill-over effects as source of synchronization. From an economic standpoint, detrending with non-parametric filters such as the Hodrick-Prescott (HP) filter is more appropriate to proxy business cycle than growth rate. We use the conventional HP filter with the *lambda*(λ) value of 1600 for quarterly frequency data.

[5] $[\varepsilon T]$ is interpreted as the minimal number of observations in each segment. where ε is an arbitrary small positive number and [.] denotes integer part of argument.

Our sample includes ten Asian countries (Japan, China, Singapore, Hong Kong, Taiwan, South Korea, Thailand, Malaysia, Indonesia and the Philippines)[6] spanning the period 1975:Q1 - 2007:Q1. All data have been seasonally adjusted using the X12ARIMA method. The main source of real GDP is the websites of the statistic authorities in the respective economies and the NUS ESU databank. Note that for the evolutionary spectral estimation necessity, we loose ten observations at the beginning and ten at the end. So we apply the different test to T-20 (yielding 167 observations)[7]. Synchronization nonlinearity is inspected for the following frequencies: $\pi/20$, $4\pi/20$, $7\pi/20$, $10\pi/20$, $13\pi/20$, $16\pi/20$ and $19\pi/20$.

3.2 The Cohesion in East Asia

To better measure integration in Asia, a measure of business cycle synchronization is calculated. We extend the Croux et al (2001)'s measure by including the time dimension of this measure and by allowing it to be appropriate for co-nonstationary process. The measure is defined in the frequency domain. Let us consider a vector of $n \geq 2$ variables $X_t = (X_{1t}, ..., X_{nt})'$ and attach to them a nonnormalized positive weights $\beta = (\beta_{1t}, ..., \beta_{nt})'$. This weighted average will be called *cohesion* for the group X noted Coh_X and defined as follows:

$$Coh_X(w,t) = \frac{\sum_{i \neq j} \beta_i(t)\beta_j(t) TVCF_{X_i X_j}(w,t)}{\sum_{i \neq j} \beta_i(t)\beta_j(t)}. \quad (4)$$

$Coh_X(w,t)$ measures the degree of the synchronization of countries X with the region at the time t, the frequency w gives the type of cycle. For example, when $w = \pi/20$, we estimate the variability of the synchronization between the Juglar cycle (40 quarters) of countries X with the East Asian region.

In order to estimate cohesion for each East Asian country relative to the whole region, heterogeneity across countries must be considered. As suggested by the endogenous OCA approach, trade integration may lead to higher degree of business cycle synchronization. But the economic significance of synchronization between countries depends on their respective influence in the region. We approximate this importance by the bilateral trade. More precisely, cohesion in equation (4) is estimated for each country by weighting it with its bilateral trade (Exports plus Imports) in order to take into account the fact that some countries represent a higher share of bilateral trade in the region than others[8]. As a result, in our estimates, China and Japan have a greater weight than Thailand and Indonesia. In other words, by estimating the cohesion of

[6]Recall that Indonesia, Malaysia, the Philippines, Thailand and Singapore are members of the ASEAN.

[7]For both spectral and cross spectra density estimation we loose 10+10 observations.

[8]Data on bilateral trade are available to the authors upon request.

South Korea, we give higher weights to the formers countries that to the latters. The choice of the bilateral trade as a proxy of economic significance of a country is motivated by the fact that GDP could lead to an underestimation of the role of Hong-Kong in the region.

Clearly, $Coh_X \leq 1$ and $Coh_X(w,t) = 1$ if and only if all of the cycles in the group X co-move perfectly in the frequency w at the instant t. So the equation will be defined as follows:

$$Coh_{Asia}(w,t) = \frac{\sum\limits_{i \neq j} \beta_{ij}(t)\beta_{ji}(t) TVCF_{X_i X_j}(w,t)}{\sum\limits_{i \neq j} \beta_{ij}(t)\beta_{ji}(t)}, \tag{5}$$

where $\beta_{ij}(t)$ is the export of the country i to the country j at the period of t. We estimate cohesion to explore the dynamic properties of cyclical component of the coherence series. This statistics will provide a measure of persistence of co-movement in the region. We also investigate whether the Asian financial crisis has had any impact on the degree of business cycle convergence by testing break dates endogenously through Bai and Perron test.

3.3 Results

We focus on two frequencies: $\frac{\pi}{20}$ and $\frac{4\pi}{20}$. The former frequency refers to the Juglar fixed investment cycle (7-11 years) and the latter to Kitchin inventory cycle (3-5 years).

Graphical patterns of evolutionary spectral analysis of the East Asian business cycle (appendix B) show that cycles between them are very similar. Shocks affect essentially the long cycle with two structural changes (represented by peaks on the graphics). The second structural change point is the most important in amplitude for all countries except Japan where they have the same amplitude. These similarities of reaction to shocks led us to predict a strong synchronization of the business cycles. As expected, business cycle varies in time. The observed similarities of cyclical components suggest the presence of common business cycle in the region.

Estimates of time varying cohesion (see equation (4) and appendix C) exhibit the degree of business cycle synchronization in the East Asian region. We find that increasing bilateral trade in Asia leads to more synchronization of business cycles, especially after the 1997 crisis. These estimates contradict previous studies on several points. First, while Moneta and Rüffer (2006) do not identify a significant increase in the degree of synchronization and Shin and Wang (2004) find only weak evidence of increasing co-movement of business cycle, cohesion estimates for the East Asia as a whole exhibit a clear pattern of increase in synchronization. Second, China and Hong Kong represent the group of the most integrated countries with the rest of Asia in the last ten years. Our results differ from those of Moneta and Rüffer (2006) -who find that China and Japan do not have common movements with the rest of Asian countries- and from those of

Bayoumi and Eichengreen (1994) who show that different groups of countries share different degrees of co-movements[9]. In addition, while Shin and Wang (2004) -considering the lower increase in intra-industry trade for Hong Kong, China, and South Korea-stress that these countries may face more asymmetric shocks, our cohesion graphics do not confirm such prediction.

When we check the stability of the bilateral synchronization for the Juglar ($\frac{\pi}{20}$) and the Kitchin ($\frac{4\pi}{20}$) cycles, we observe two common results (Appendix D): on the one hand, the higher degree of synchronization especially after 1996 for all pairs of countries, and, on the other hand, the presence of two significant dates -1996Q3 and 2000Q3- for the most of pairs. These results support that common shocks (Asian crisis in 1997 and the ICT bubble in 2000-2001 over the studied period) lead to more synchronous business cycles in the region. This finding supports the feasibility of a monetary union in the region.

4 Conclusion

In this paper, we proposed a new measure of business cycle synchronization to assess the feasibility of a monetary union in East Asia. Our main finding is the presence of an Asian common cycle, especially after the crisis of 1997. The strong synchronization of shocks suggests the presence of common cycle so that members' countries may constitute an optimal currency area. However, our results must to be interpreted with cautious for two main reasons. On the one hand, as suggested by the recent world economic crisis, business cycle synchronization in East Asia seems still driven by external factors rather than by an autonomous regional process. Even if trade linkages with the Group of Three countries are less important today, emerging Asia remains vulnerable to economic fluctuations in industrialized countries[10]. On the other hand, countries may have different initial responses to shocks and react symmetrically to shocks with one or two period lag(s). For this purpose, it's recommended to complete the business cycle synchronization studies by testing the reaction of each country for different shocks to affirm the feasibility of a monetary union in the region.

[9]More precisely, the authors identify two blocks forming an optimal currency area: a Northeast Asian block (Japan, Korea and Taiwan) and a Southeast Asian block (Hong Kong, Indonesia, Malaysia, Singapore and Thailand).

[10]On this point, see Haltmaier, Ahmed, Coulibaly, Knippenberg, Leduc, Marazzi and Wilson (2007), and Pula and Peltonen (2009).

Appendices

A Mathematical Appendix

A.1 The Evolutionary Spectral Analysis : Definition (Priestley, 1965-1996)

The evolutionary aspect of the spectrum is related to the nonstationarity in series which follows an oscillatory process.

$$X_t = \int_{-\pi}^{\pi} A_{x,t}(w) e^{iwt} dZ_X(w). \tag{6}$$

Where for each $'w'$, the sequence $\{A_t(w)\}$, as it is according to t admits a maximum Fourier transform (in module) in zero with $\{Z_X(w)\}$ an orthogonal process on$[-\pi, \pi]$, $E[dZ_X(w)] = 0$, $E[|dZ_X(w)|^2] = d\mu_X(w)$ and $\mu_X(w)$ a measurement. We conclude that the evolutionary spectral density of $\{X_t\}$ is the function $S_X(w,t)$ defined as follows:

$$S_X(w,t) = \frac{dH_X(w,t)}{dw}, -\pi \leq w \leq \pi. \tag{7}$$

Where $dH_X(w,t) = |A_X(w,t)|^2 d\mu_X(w)$. The variance of $\{X_t\}$ at t is:

$$\sigma^2_{X,t} = Var(X_t) = \int_{-\pi}^{\pi} S_X(w,t) dw \tag{8}$$

Let we suppose a two zero-mean real stochastic process $(X_t; Y_t)$, consider $S_X(w)$ and $S_Y(w)$, $-\pi \leq w < \pi$, be the spectral density functions and $S_{XY}(w)$ be the cospectrum. Each of the two series can be written as

$$X_t = \int_{-\pi}^{\pi} A_X(w) e^{iwt} dZ_X(w), \qquad Y_t = \int_{-\pi}^{\pi} A_Y(w) e^{iwt} dZ_Y(w). \tag{9}$$

where

$$\begin{aligned} E[dZ_X(w_1)\overline{dZ_Y(w_2)}] &= 0 \quad w_1 \neq w_2 \\ &= S_{XY}(w)dw \quad w_1 = w_2 = w. \end{aligned} \tag{10}$$

where the overline indicates complex conjugation. As is well known, we have

$$S_{XY}(w) = C_{XY}(w) - iQ_{XY}(w) \tag{11}$$

Eq(11) verify this inequality coherence, $C^2_{XY} + Q^2_{XY} \leq S_X(w)S_Y$.
$\mathcal{K}_{XY}(w)$ is the coherence in the neighborhood of w

$$\mathcal{K}^2_{XY}(w) = \frac{C^2_{XY} + Q^2_{XY}}{S_X(w)S_Y(w)} \tag{12}$$

$\mathcal{K}_{XY}$ is analogue to the coefficient of the correlation between two sample and interpreted as it.

A.1.1 Evolutionary cross-spectra ($S_{XY}(w,t)$)

Priestley (1988) extend the theory of evolutionary spectra to the case of bivariate non-stationary processes. Consider now two oscillatory component process, $(X_t; Y_t)$, we can write

$$X_t = \int_{-\pi}^{\pi} A_{X,t}(w) e^{iwt} dZ_X(w), \quad Y_t = \int_{-\pi}^{\pi} A_{Y,t}(w) e^{iwt} dZ_Y(w), \tag{13}$$

where:

$$\begin{aligned} E[dZ_X(w_1)\overline{dZ_X(w_2)}] &= E[dZ_Y(w_1)\overline{dZ_Y(w_2)}] \\ &= E[dZ_X(w_1)\overline{dZ_Y(w_2)}] = 0 \quad when \;\; w_1 \neq w_2. \\ E[|dZ_X(w_1)|^2] &= d\mu_X(w),\; E[|dZ_Y(w_1)|^2] = d\mu_Y(w) \;\; and \\ E[dZ_X(w_1)\overline{dZ_Y(w_1)}] &= d\mu_{XY}(w). \end{aligned} \tag{14}$$

According to Priestley (1988), in the non-stationary case cross spectrum is time varying and is define as $dH_{XY,t}(w)$. In virtue of the Cauchy-Schwarz inequality, we have

$$|dH_{XY,t}(w)|^2 \leq dH_{X,t}(w) dH_{Y,t}(w), \quad at\ all\ t\ and\ w. \tag{15}$$

We can write now

$$dH_{XY,t}(w) = S_{XY,t}(w)\ dw. \tag{16}$$

where $S_{XY,t}(w)$ is the evolutionary cross-spectrum density function.

$$\begin{aligned} S_{XY}(w_j,t) &= E[U^X_{j,t}(\overline{U^Y_{j,t}})] \\ &= C_{XY}(w_j,t) - iQ_{XY}(w_j,t), \end{aligned} \tag{17}$$

Where

$$\begin{aligned} C_{XY}(w_j,t) &= \Re\{S_{XY}(w_j,t)\}\ and \\ Q_{XY}(w_j,t) &= -\Im\{S_{XY}(w_j,t)\} \end{aligned} \tag{18}$$

are the Real Time Varying Cospectrum (the gain) and the Time Varying Quadrature Spectrum (the phase) respectively. $\Re$ and $\Im$ meaning the real and the imaginary part of the time varying cross spectrum.

A.1.2 Estimation of the Coherence of the nonstationary spectra

Firstly, let the observable bivariate time series $(X_t; Y_t)$ which are not necessary stationary. Their time varying spectra can be defined via $S_X(w,t)$ and $S_Y(w,t)$ respectively. So the time-varying cross spectrum given by eq(17) have a polar representation

$$S_{XY}(w_j,t) = A_{XY}(w_j,t)exp\{i\theta_{XY}(w_j,t)\}, \tag{19}$$

This statistics allow us to compute the time varying cross amplitude in the following way

$$\begin{aligned} A_{XY}(w_j,t) &= |S_{XY}(w_j,t)| \\ &= [C^2_{XY}(w_j,t) + Q^2_{XY}(w_j,t)]^{1/2} \end{aligned} \tag{20}$$

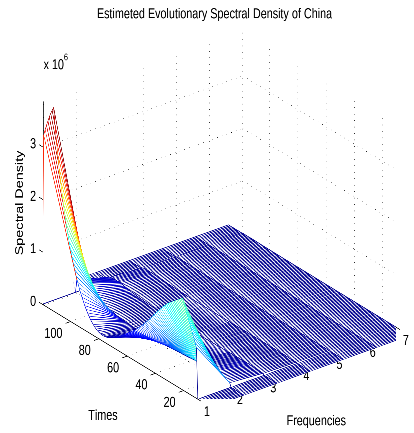
The Time Varying Magnitude Squared Coherence

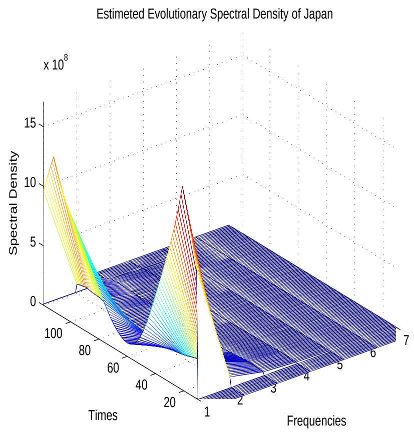
$$\mathcal{K}^2_{XY}(w_j,t) = \frac{A^2_{XY}(w_j,t)}{S_X(w_j,t)S_Y(w_j,t)} \tag{21}$$

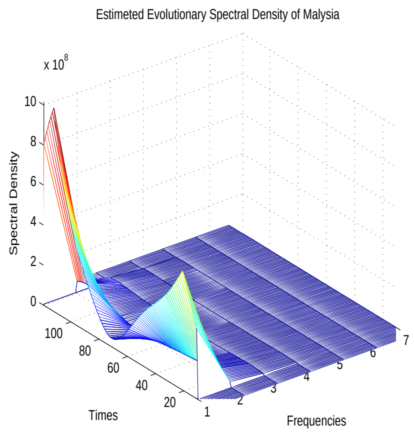
B Evolutionary Spectral Density of the East Asia business cycle

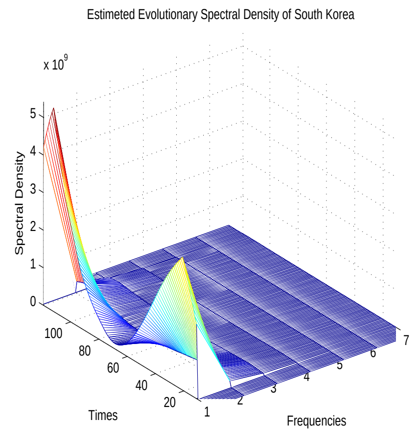
[11]

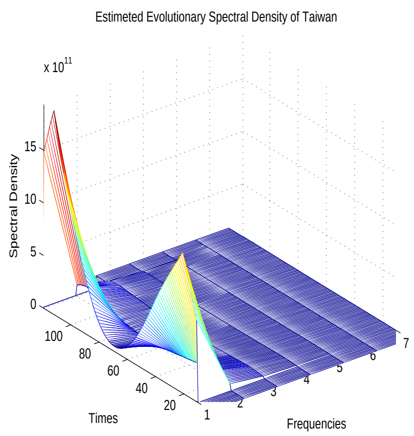
[11] Cycles are presented in X axis (which vary from 1 to 7); amplitude is presented in Z axis (spectral density) and the time is presented Y axis (Time) from 1977Q3 to 2004Q3.

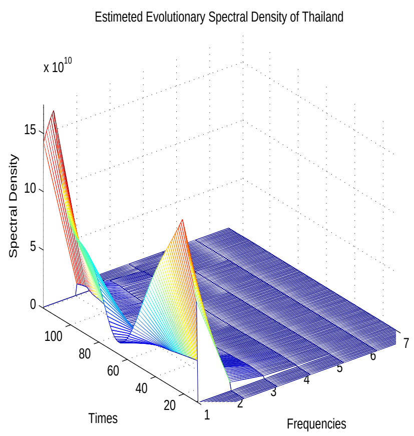

Estimeted Evolutionary Spectral Density of China
x 10^6
Spectral Density
Times
Frequencies


Estimeted Evolutionary Spectral Density of Japan
x 10^8
Spectral Density
Times
Frequencies

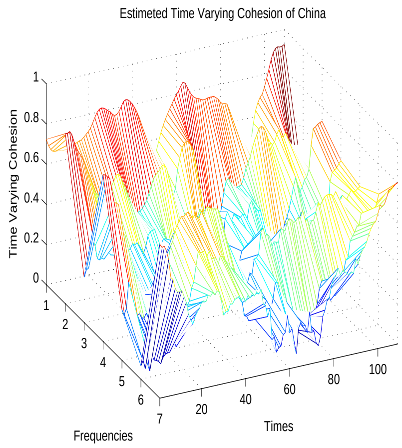

Estimeted Evolutionary Spectral Density of Malysia
x 10^8
Spectral Density
Times
Frequencies

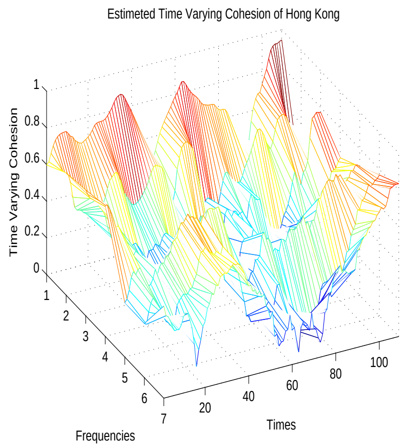

Estimeted Evolutionary Spectral Density of South Korea
x 10^9
Spectral Density
Times
Frequencies

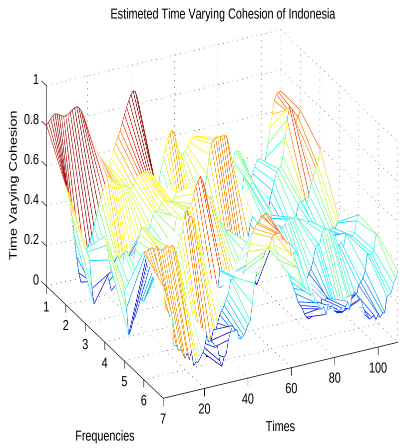

Estimeted Evolutionary Spectral Density of Taiwan
x 10^{11}
Spectral Density
Times
Frequencies

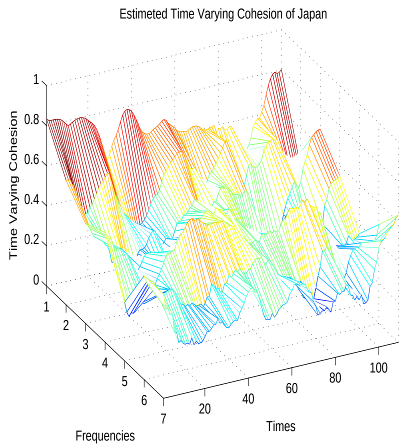

Estimeted Evolutionary Spectral Density of Thailand
x 10^{10}
Spectral Density
Times
Frequencies

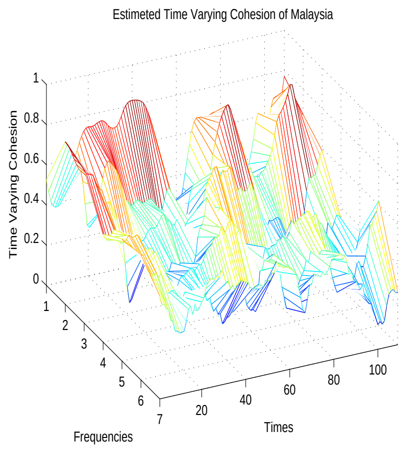
C Time Varying Cohesion of the East Asia countries

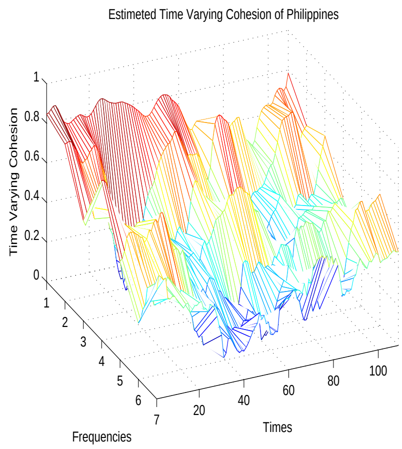


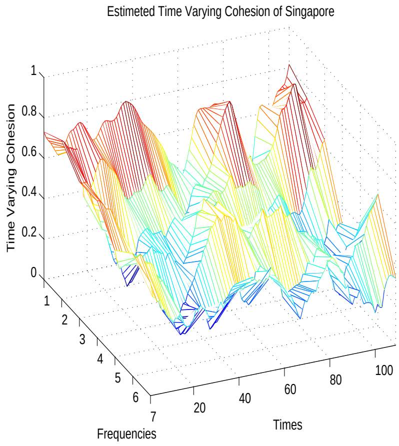


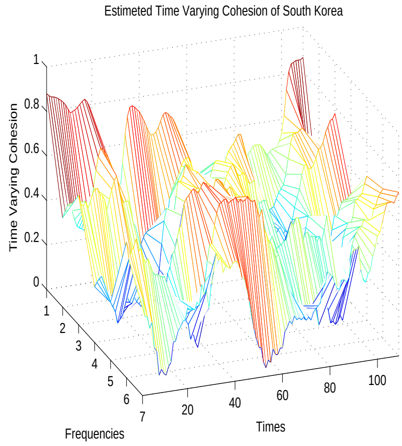


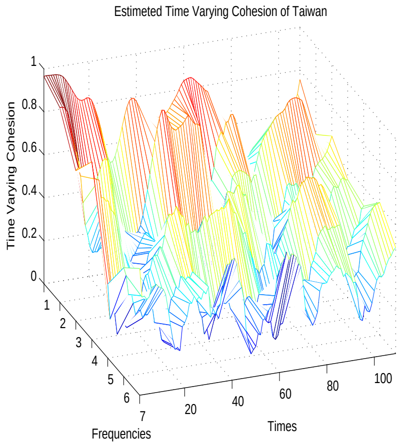


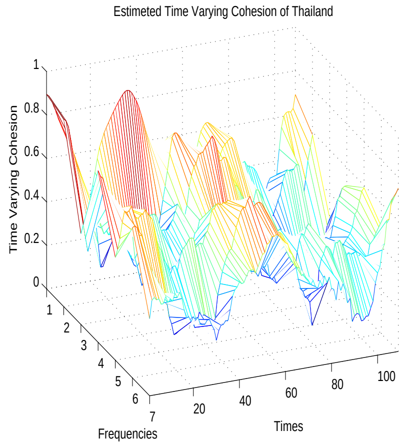


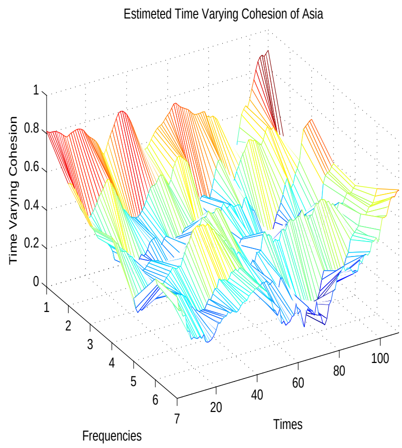



Estimeted Time Varying Cohesion of Singapore
Time Varying Cohesion
Frequencies
Times


Estimeted Time Varying Cohesion of South Korea
Time Varying Cohesion
Frequencies
Times


Estimeted Time Varying Cohesion of Taiwan
Time Varying Cohesion
Frequencies
Times


Estimeted Time Varying Cohesion of Thailand
Time Varying Cohesion
Frequencies
Times


Estimeted Time Varying Cohesion of Asia
Time Varying Cohesion
Frequencies
Times

D Variability in the bilateral Business Cycle Synchronisation

Table 1: Coherence of long and short business cycle between Singapore and Hong Kong in sub-period

Estimators	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	$\widehat{T}_5$	
Singapore-Hong Kong						
$\pi/20$						
Break dates	1981Q3	1986Q1	1992Q3	1996Q3	2000Q3	
Coefficients	0.5609	0.7285	0.4576	0.7264	0.3767	0.6035
Standard errors	0.0228	0.0221	0.0184	0.0235	0.0235	0.0235
$4\pi/20$						
Break dates	1993Q2	1994Q2	2000Q3			
Coefficients	0.6373	0.2244	0.5983	0.7805		
Standard errors	0.0167	0.0242	0.0227	0.0284		

Table 2: Coherence of long and short business cycle between Taiwan and China in sub-period

Estimators	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	$\widehat{T}_5$	
Taiwan-China						
$\pi/20$						
Break dates	1982Q1	1987Q3	1991Q3	1995Q3	1999Q3	
Coefficients	0.6615	0.9223	0.7090	0.8414	0.4759	0.8764
Standard errors	0.0201	0.0187	0.0219	0.0219	0.0219	0.0196
$4\pi/20$						
Break dates	1981Q2	1987Q3	1991Q3	1998Q3		
Coefficients	0.6564	0.4117	0.6325	0.3432	0.6512	
Standard errors	0.0213	0.0170	0.0213	0.0161	0.0174	

Table 3: Coherence of long and short business cycle between Taiwan and Japan in sub-period

Estimators	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	
Taiwan-Japan					
$\pi/20$					
Break dates	1982Q4	1990Q4	1995Q2	2000Q2	
Coefficients	0.9114	0.6811	0.8207	0.4001	0.5468
Standard errors	0.0164	0.0136	0.0182	0.0172	0.0187
$4\pi/20$					
Break dates	1983Q1	1987Q1	1996Q1	2000Q1	
Coefficients	0.6456	0.3152	0.7288	0.4741	0.7034
Standard errors	0.0272	0.0327	0.0218	0.0327	0.0308

Table 4: Coherence of long and short business cycle between Thailand and China in sub-period

Estimators	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	
Thailand-China				
$\pi/20$				
Break dates	1984Q3	1988Q3	1994Q3	
Coefficients	0.5243	0.8000	0.4609	0.7730
Standard errors	0.0250	0.0337	0.0275	0.0213
$4\pi/20$				
Break dates	1983Q2	1991Q2	1997Q3	
Coefficients	0.6920	0.3401	0.1812	0.4224
Standard errors	0.0182	0.0157	0.0178	0.0168

Table 5: Coherence of long and short business cycle between Hong Kong and China in sub-period

Estimators	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	$\widehat{T}_5$	
Hong Kong-China						
$\pi/20$						
Break dates	1983Q2	1987Q3	1991Q3	1996Q3	2000Q3	
Coefficients	0.7027	0.8356	0.5926	0.7758	0.4818	0.7927
Standard errors	0.0233	0.0277	0.0285	0.0255	0.0285	0.0285
$4\pi/20$						
Break dates	1982Q2	1992Q3	1997Q4			
Coefficients	0.3113	0.5238	0.3303	0.5263		
Standard errors	0.0264	0.0184	0.0257	0.0227		

Table 6: Coherence of long and short business cycle between Indonesia and Thailand in sub-period

Estimators	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	$\widehat{T}_5$	
Indonesia-Thailand						
$\pi/20$						
Break dates	1984Q3	1988Q3	1992Q3	1996Q3	2000Q3	
Coefficients	0.4884	0.8916	0.6659	0.8252	0.6264	0.7968
Standard errors	0.0184	0.0248	0.0248	0.0248	0.0248	0.0248
$4\pi/20$						
Break dates	1983Q2	1989Q1	1994Q1			
Coefficients	0.2776	0.6033	0.2299	0.6874		
Standard errors	0.0296	0.0303	0.0325	0.0224		

Table 7: Coherence of long and short business cycle between Malaysia and Hong Kong in sub-period

Estimators	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	
Malaysia-Hong Kong					
$\pi/20$					
Break dates	1982Q3	1990Q2	1996Q3	2000Q3	
Coefficients	0.5627	0.7068	0.5544	0.3452	0.6479
Standard errors	0.0303	0.0249	0.0278	0.0347	0.0347
$4\pi/20$					
Break dates	1981Q4	1987Q3	1993Q4		
Coefficients	0.4975	0.6840	0.4570	0.7173	
Standard errors	0.0345	0.0305	0.0292	0.0223	

Table 8: Coherence of long and short business cycle between Malaysia and South Korea in sub-period

Estimators	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	
Malaysia-South Korea				
$\pi/20$				
Break dates	1984Q4	1990Q1	2000Q1	
Coefficients	0.3142	0.6674	0.5394	0.8213
Standard errors	0.0217	0.0260	0.0188	0.0281
$4\pi/20$				
Break dates	1982Q4	1990Q3	1995Q1	
Coefficients	0.2766	0.5402	0.3846	0.7832
Standard errors	0.0197	0.0166	0.0218	0.0150

Table 9: Coherence of long and short business cycle between Japan and Philippines in sub-period

Estimators Philippines-Japan	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	
$\pi/20$					
Break dates	1992Q4	1997Q4			
Coefficients	0.8145	0.5214	0.6116		
Standard errors	0.0077	0.0136	0.0117		
$4\pi/20$					
Break dates	1982Q3	1986Q3	1996Q2	2000Q3	
Coefficients	0.7118	0.1802	0.6371	0.2182	0.5412
Standard errors	0.0223	0.0256	0.0164	0.0248	0.0256

Table 10: Coherence of long and short business cycle between South Korea and Philippines in sub-period

Estimators Philippines-South Korea	$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	$\widehat{T}_5$	
$\pi/20$						
Break dates	1982Q2	1987Q1	1991Q1	1996Q3	2000Q3	
Coefficients	0.7276	0.5579	0.6993	0.4571	0.5597	0.7458
Standard errors	0.0152	0.0156	0.0170	0.0145	0.0170	0.0170
$4\pi/20$						
Break dates	1981Q2	1985Q4	1993Q3			
Coefficients	0.6170	0.2967	0.1761	0.7388		
Standard errors	0.0284	0.0219	0.0242	0.0171		

References

[1] Bai J and Perron P. (2001), Multiple structural change models: a simulation analysis, unpublished manuscript, Department of Economics, Boston University.

[2] Bai J. and Perron P. (1998), Estimating and testing linear models withmultiple structural changes. Econometrica 66, 47-78.

[3] Bayoumi T. and Eichengreen B. (1994), One money or many? Analyzing the prospects for monetary unification in various parts of the world. Princeton Studies in International Finance, No.76.

[4] Calderón C., Chong A., and Stein E. (2007), Trade Intensity and Business Cycle Synchronization: Are Developing Countries any Different? Journal of International Economics, 71(1): 2-21.

[5] Chow H.K. and Kim Y. (2003), A common currency peg in East Asia? Perspectives from Western Europe. Journal of Macroeconomics, 25: 331-350.

[6] Clark T.E. and van Wincoop E. (2001), Borders and Business Cycles. Journal of International Economics 55(1): 59-85

[7] Crosby M. (2003), Business cycle correlations in Asia-Pacific. Economics Letters, 80, 35-44.

[8] Croux C. Forni M. and Reichlin L. (2001), A measure of comovement for economic variables: Theory and Empirics. The review of Economics and Statistics, 83(2):232-241.

[9] Essaadi E. and Boutahar M. (2008), A Measure of Variability in Comovement for Economic Variables: a Time-Varying Coherence Function Approach. GATE Working Paper No. 08-27.

[10] Essaadi E., Jouini J. and Khallouli W. (2007), The Asian Crisis Contagion: A Dynamic Correlation Approach Analysis. GATE Working Paper No. 07-25

[11] Frankel J. and Rose A.K. (1998), The endogeneity of the optimum currency area criteria. The Economic Journal, 108, 1009-1025.

[12] Haltmaier J. T, Ahmed, S., Coulibaly, B., Knippenberg, R., Leduc S., Marazzi M. and Wilson B.A (2007), The Role of China in Asia: Engine, Conduit, or Steamroller?, Board of Governors of the Federal Reserve System, International Finance Discussion Papers N°904, September.

[13] Lee G.H.Y. and Azali M. (2006), A currency union in East Asia: measuring the business cycle synchronization. 10^{th} International Conference on Macroeconomic Analysis and International Finance, University of Crete.

[14] Lee J.W., Park Y.C. and Shin K. (2003), A currency union in East Asia. ISER Discussion Paper, 571.

[15] Loayza N., Lopez H. and Ubide A. (2001), Sectorial Macroeconomic Interdependencies: Evidence from Latin America, East Asia and Europe. IMF Staff Paper, 48(2): 367-396.

[16] Moneta F. and Rüffer R. (2006), Business cycle synchronization in East Asia. European Central Bank Working paper, 671, August.

[17] Priestley M.B. (1965), Evolutionary Spectra and Non-Stationary Processes. Journal of the Royal Statistical Society. Series B (Methodological), Volume 27, Issue 2, 204-237.

[18] Priestley M.B. (1965), The Role of Bandwidth in Spectral Analysis. Applied Statistics, Volume 14, Issue 1, 33-47.

[19] Priestley M.B. (1966), Design Relations for Non-Stationary Processes. Journal of the Royal Statistical Society. Series B (Methodological), Volume 28, Issue 1, 228-240.

[20] Priestley M.B. (1978), Non-Linear Models in Time Series Analysis. The Statistician, Volume 27, Issue $\frac{3}{4}$, 159-176.

[21] Priestley M.B. (1988), Non-linear and non-stationary time series analysis, Academic press, London.

[22] Priestley M.B. (1996), Wavelets and Time-Dependent Spectral Analysis. J. Time Ser. Anal., vol.17, N°1.

[23] Priestley M.B. and Chao M.T. (1972), Non-Parametric Function Fitting. Journal of the Royal Statistical Society. Serie B (Methodological), Volume 34, Issue 3, 385-392.

[24] Priestley M.B. and Subba Rao T. (1968), A Test for Non-stationarity of Time-series. University of Manchester, Institute of Science and Technology.

[25] Pula G. and Peltonen T.A. (2009), Has Emerging Asia Decoupled? An Analysis of Production and Trade Linkages Using the Asian International Input-Output Table, European Central Bank, Working Paper Series, 993, January.

[26] Rana P.B. (2007), Economic integration and synchronization of business cycles in East Asia. Journal of Asian Economics, 18, 711-725.

[27] Sato K. and Zhang Z.Y. (2005), Real Output Co-movements in East Asia: A Cointegration Approach. In Zerger A. and Argent R.M. (eds), International Congress on Modelling and Simulation, 2869-2875.

[28] Sato K. and Zhang Z.Y. (2006), Real Output Co-movements in East Asia: Any Evidence for a Monetary Union?. The World Economy, 1671-1689.

[29] Sato K., Allen D. and Zhang Z.Y. (2007), A Monetary Union in East Asia: What does the Common Cycles Approach Tell? In Oxle, L. and Kulasiri D. (eds), International Congress on Modelling and Simulation, 1007-1013.

[30] Shin K. and Wang Y. (2003), Trade Integration and Business Cycle Synchronization in East Asia. Asian Economic Papers, 2 (3), 1-20.

[31] Yao Y-C. (1988), Estimating the number of change-points via Schwarz' criterion. Statistics and Probability Letters, 6, 181-189.