DEPOCEN

Working Paper Series No. 2007/10

East Asian Currency Area: A Fuzzy Clustering Analysis of Homogeneity

Toan Nguyen *

* Room 1, Engineering Building No. 4 Yoshida Honmachi Sakyo-ku, Kyoto Japan

East Asian Currency Area: A Fuzzy Clustering Analysis of Homogeneity*

Toan Nguyen
Room 1, Engineering Building No. 4
Yoshida Honmachi
Sakyo-ku, Kyoto
Japan
Tel: 075-753-7197
Email: toanjp@economics.mbox.media.kyoto-u.ac.jp

* We thank Tamas Kenesei, Balazs Balasko and Janos Abonyi at the Department of Process Engineering, University of Veszprem, Hungary for their Matlab-based Clustering Toolbox, which we use to perform fuzzy clustering analysis in this paper.

Abstract

This paper attempts to examine the degree of homogeneity and the plausibility of a currency union in East Asia from the perspective of multiple OCA criteria, using the technique of fuzzy clustering analysis. The question of homogeneity is obviously of importance to the smooth formation and operation of the prospective currency union. We find that East Asia has not been sufficiently homogeneous and can be divided into about four groups with significant degree of fuzziness. We find no notable trend of convergence from the data. In fact, East Asian has appeared to be more diverged since the onset of the regional financial crisis. Thus, we suspect the possibility of forming a currency union in East Asia in the near future.

Keywords: Fuzzy Clustering Analysis, East Asia, Currency Area

East Asian Currency Area: A Fuzzy Clustering Analysis of Homogeneity

Toan Nguyen
Graduate School of Economics
Kyoto University

1. Introduction:

There has been a resurgence of interest in a concerted monetary arrangement and currency union in East Asia in the aftermath of the regional crisis. In both academia and policy circle, the issue of establishing a regional currency area has attracted increasing attention (see for example, Kwan (1998), Kuroda (2004)). Indeed, as an initial step, the ASEAN+3 (ASEAN plus Japan, Korea and China) has agreed, in the so-called Chiang Mai Initiative, upon a network of bilateral swap agreements which allow East Asian countries to borrow funds from each other. The issuance of Asia regional accounting currency (ACU) has been also put forward.

It is, however, suspect that East Asian economies are very different in the level of development that makes them hardly possible to constitute a currency union. Chow and Kim (2003) investigate the symmetry of shocks using a structural VAR framework and find that East Asia countries are structurally different from each other and thus likely to be subject to asymmetric shocks. Sato *et al* (2003), based on their analysis of structural shocks, suggest that there are two groups of East Asian countries, of which one is more synchronized and might form a currency union in the first place. These studies, however, analyzes each type of shock separately and do not consider other criteria in the Optimum Currency Area (OCA) theory. While shock symmetry is important, other criteria come into play as well.

This paper attempts to examine the degree of homogeneity and the plausibility of a currency union in East Asia from the perspective of multiple OCA criteria, using the technique of fuzzy clustering analysis. In this paper, East Asia refers to ten countries and territories in the region: Japan, Korea, China, Hong Kong, Taiwan, Singapore, Malaysia, Thailand, Indonesia and the Philippines. The question of homogeneity is obviously of importance to the smooth formation and operation of the prospective currency union. If the countries are homogeneous, a common monetary policy is probably sufficient. Heterogeneous countries would, however, face with dissimilar benefit – cost tradeoffs and thus prefer independent monetary policies to a currency union. The aim of fuzzy clustering analysis is to assign each East Asian country, with various degree of fuzziness, to a group to which it is most similar in terms of a chosen set of OCA criteria. The advantage of the method is that it can take into consideration not one but multiple criteria at the same time and thus, produce a more comprehensive picture of the degree of homogeneity across East Asia countries. To capture the evolution of convergence, we employ a dataset of four overlapping periods: 1990 – 1996, 1990 – 2000, 1999 – 2003 and 1990 - 2003.

To anticipate our results, we find that East Asia has not been much homogeneous and can be classified into about four groups with significant degree of fuzziness. The regional financial crisis has negative influence on the convergence of countries in the region. Our results indicate a divergence of East Asia in the aftermath of the crisis. Thus, we are unconvinced about the formation of a currency union in the area in the near future.

The rest of the paper is deployed as follow. Section 2 briefly describes the technique of fuzzy clustering analysis employed in our paper. In Section 3, we apply the technique to a

set of selected OCA criteria to partition East Asian countries into different groups. The final section is as usual, conclusion.

2. Fuzzy Clustering Analysis:

Clustering analysis is a well-known technique for finding groups in data. The method is employed to uncover the similarities across different objects and to identify homogeneous subgroups in a given dataset. While hard clustering analysis attempts to assign each object to one and only one cluster (group), fuzzy clustering analysis allows some ambiguity in the data by assigning each object to a cluster with a probability indicating the degree of belongingness of the object to that cluster. The probabilities are termed membership coefficients. An object is most likely to belong to the cluster with which it has the highest membership coefficient. In this paper, we apply the fuzzy C-mean (FCM) algorithm, the most popular fuzzy clustering technique which was first introduced by Dunn (1973) and generalized to final form by Bezdek (1973). The algorithm can be described briefly as follows. Assuming that our dataset contains *n* objects with *p* variables for each object. The objects are denoted $X_{np} = \{x_1, x_2, \ldots, x_n\}$, where x_i is the vector of variables for object i, $x_i = \{ x_{i1}, x_{i2}, \ldots, x_{ip}\}$. Suppose that we want to classify these objects into *c* clusters. Each cluster is represented by its center k_j (j=1, 2,.., *c*). The aim of the fuzzy C-mean algorithm is to minimize the objective function J

$$J = \sum_{i=1}^{n} \sum_{j=1}^{c} u_{i,j}^{m} d_{i,j}^{2}$$

subject to the probabilistic condition: $u_{i,j} \in [0,1]$ and $\sum_{j=1}^{c} u_{i,j} = 1$, where $u_{i,j}$ is the membership coefficient of object i to cluster j, m is a fuzzifier parameter (m>1) and $d_{i,j}$ is the dissimilarity between object i and the center k_j of cluster j, measured by the Euclidian distance between them.

$$d_{i,j} = \sqrt{\sum_{l=1}^{p} (x_{i,l} - k_{j,l})^2}$$

The center of cluster j associating with the minimized objective function J is identified by:

$$k_j = \frac{\sum_{i=1}^{n} u_{i,j}^m x_j}{\sum_{i=1}^{n} u_{i,j}^m}$$

The algorithm results in the matrix of membership coefficients $u_{i,j}$, whereby we can assign each object to a cluster to which it has highest membership. Details of the fuzzy C-mean algorithm and other clustering techniques are provided in, for example, Hoppner *et al* (1999).

The above algorithm is, however, based on the assumption that the number of cluster is already known. In reality, we have to choose the number of clusters so as to ensure that the clusters are as "crisp" as possible. To determine the optimal number of clusters, we rely on two popular validity tests which to us are most suitable for fuzzy clustering. The first test is the Xie and Beni (1991) index:

$$XB = \frac{1}{n} \frac{\sum_{i=1}^{n} \sum_{j=1}^{c} u_{i,j}^2 d_{i,j}^2}{\min\{(k_j - k_v)^2 \mid j, v = 1, 2, ..c; j \neq v\}}$$

where, k_j, k_v are the centers of cluster *j* and cluster *v* respectively. Smaller XB index indicates more compact and separated clusters.

Another useful statistics for validating a cluster partitioning is the silhouette width. The silhouette width of an individual object *i* is defined as:

$$s(i) = \frac{b_i - a_i}{max\{a_i, b_i\}}$$

where a_i is the average dissimilarity (distance) between object i and all other objects in the same cluster and $b_i = \min\{b_{i,j} \mid j = 1, 2, ..., c; j \neq i\}$; b_{ij} is the average distance from object *i* to all objects in cluster j. The value of silhouette width ranges from -1 to 1. A value close to 1 indicates that the object is well-clustered while a value near zero signals high degree of fuzziness and the object might be better classified to a neighboring cluster. A negative silhouette value indicates that the object is misspecified. The average silhouette of all objects is an indicator showing how well the entire dataset is partitioned. An optimal number of clusters must be associated with positive individual silhouettes and large average silhouette.

3. OCA Criteria and the Grouping of East Asian Economies:

3.1 The OCA Criteria

Traditional analyses of the OCA theory are typically conceived in terms of balancing the micro benefits gained by expanding the currency domain against the macroeconomic costs of giving up monetary autonomy and a separate exchange rate, which are important tools of macroeconomic adjustments. Monetary autonomy is not necessarily good, however, since it might be a destabilizing source once used improperly. The OCA theory outlines conditions or criteria with which a country can reap large benefit and/or substantially reduce the cost of joining a currency union. Talvas (1993) listed nine criteria from traditional literature: the similarity of inflation rates, the degree of factor mobility, the openness and size of the economy, the degree of industrial diversification, price and wage flexibility, the degree of goods market integration, fiscal integration, real exchange rate variability and political factors. Other criteria not listed in this survey but can be easily found in many other surveys of OCA literature such as Masson and Taylor (1993, 1994) are the synchronization of

business cycles, the degree of currency substitution and the credibility of monetary policy. In this paper, we apply fuzzy clustering analysis to East Asian countries with a set of selected variables inspired by the OCA criteria. The countries are treated as objects in fuzzy clustering analysis. The purpose is to uncover the similarities across East Asian countries in respect of those variables so as to assign the countries into groups which are internally homogeneous. We select five important variables of which the data are within our reach: 1) the synchronization of business cycles; 2) the volatility of real exchange rates against US dollar; 3) the degree of openness to regional trade; 4) inflation differentials against the regional average and 5) the degree of export diversification. These variables are briefly defined below:

(1) *Synchronization of business cycles*: one of the most important OCA criteria is the synchronization of business cycles. If business cycles are highly synchronized, the cost of foregoing independent monetary policy is reduced since a common monetary policy can serve all countries well. A simple measure of the degree of synchronization is the simple cross-correlation coefficient between the cyclical components of each country with that of the centered country chosen to represent the region. Bayoumi and Eichengreen (1994) suggest a similar but more complicated measure: the cross-correlation coefficients of output shocks identified through a structural VAR framework *à la* Blanchard and Quad (1989). Pivotal in these approaches are the choice of the centered country. For EU or Northern America, finding a centered country is fairly easy since Germany and the United States are respectively the natural leaders in their regions. Yet, it is not the case in East Asia. Japan is the biggest economy in this area but its business cycle is significantly different from those of

the rest of the region[1]. No other countries are qualified as the regional center. To get around this issue, we employ the tool of factor analysis to construct the regional business cycle as the (unobserved) common cycle shared across East Asia. We assume that the business cycle in each country consists of two parts: a common part called the common factor, which is also the regional business cycle; and an idiosyncratic part that is unique in the country. The factor model is as follows:

$$y_i = \alpha_i F + \varepsilon_i$$

where y_i is the cyclical component of country i output, α_i is the correlation coefficient measuring the degree of synchronization, F is the unobserved common factor and ε_i is the idiosyncratic part of the business cycle in country i. The model is estimated using maximum likelihood. More complicated versions of factor analysis has been used in, among others, Gregory *et al* (1997) and Kose *et al* (2002) to derive international business cycle.

Annual GDP data are used as the proxy of aggregate outputs. To segregate the cyclical components from GDP, we take log and first difference the series. Since estimation results might be sensitive to the choice of detrending methods, we also attempt another well-known detrending technique, the Hodrik – Prescott (1980) filter with dampening parameter of 100.

(2) *Volatility of real exchange rates*: the cost of a currency union is associated with the abandonment of an independent monetary policy and a separate exchange rate as a shock absorber. In the presence of adverse shocks, a central banker can adjust its monetary policy so as to affect the nominal exchange rate, expecting this would change the real exchange rate. If there has been little cause for real exchange rate volatility, the cost of abandoning a

[1] See Sato *et al* (2003) and Chow and Kim (2003), for instance.

separate exchange rate would be presumably small. We measure real exchange rate variations as standard deviations of the log-difference of the quarterly real bilateral exchange rates *vis à vis* US dollar[2].

(3) *Openness to Trade*: openness to regional trade involves both the benefit and the cost of joining a currency union. A more open country is likely to reap greater benefits from the expansion of currency domain thank to reduced transaction costs and risks. On the other hand, the value of a separate exchange rate is relatively lower in the country due to high ratio of traded goods to non-traded goods. A change in nominal exchange rate is likely to be followed by a change in domestic price and wage rather than a change in real exchange rate, reducing the effectiveness of exchange rate as a tool of trade balance adjustment. Thus, the more open a country, the less the usefulness of domestic currency and the value of a separate exchange rate and the greater the benefit of a currency union. In this paper, we measure openness to trade as the ratio of trade with East Asian countries to total trade: Openness = $(x_{i,EA}+ m_{i,EA})/(x_i + m_i)$, where x_i and m_i are annual total export and total import of country i, $x_{i,EA}$ and $m_{i,EA}$ are country i's annual export to and import from other East Asian countries.

(4) *Inflation differentials*: while traditional OCA criteria involve only real variables, recent developments have put a nominal variable to the list of criteria: inflation differentials across countries. When inflation rates are similar over time, the terms of trade will be fairly stable, underplaying the need for a separate exchange rate. Also, since similar inflation rates result from similarities in monetary and fiscal stance and economic structures, the cost of joining a currency union is presumably low. In this paper, inflation rates are computed from annual consumer price indices except for China, where inflation rate is reported directly.

[2] We use real effective exchange rate and real exchange rate data published in IMF International Financial Statistics. When these data are not available, we compute real exchange rate from nominal exchange rates and consumer price indices.

(5) *Diversification of export*: one of the original OCA criteria is the diversification of economic structure suggested by Kenen (1969). In a diversified economy, each of its sectors might be subject to shocks but if shocks are independent and the country produces a sufficiently large variety of different goods, the law of large numbers will come into play and total production will not suffer much from shocks. Moreover, the changes in real exchange rate needed for adjustment to a single shock will be less in a diversified economy. Since we do not have data on economic structures in East Asia, export diversification is used as a proxy. To measure the degree of export diversification, we resort to the inverse of the period average of the annual Herfindahl indices, a popular indicator of the degree of specialization. Herfindahl index is computed as $H = \sum_{i=1}^{n} s_i^2$, where s_i is share of the export of product i, n is the number of products exported. As we do not have data on the export of individual products, we use annual export data broken down into ten first-digit sub-industries of the United Nation's Standard International Trade Classification (SITC), revision 2: 0 - Food and live animals; 1 - Beverages and tobacco; 2 - Crude materials, inedible, except fuels; 3 - Mineral fuels, lubricants and related materials; 4 - Animal and vegetable oils, fats and waxes; 5 - Chemicals and related products, n.e.s.; 6 - Manufactured goods classified chiefly by material; 7 - Machinery and transport equipment; 8 - Miscellaneous manufactured articles; 9 - Commodities and transactions not classified elsewhere in the SITC.

3.2 Results:

We perform the fuzzy clustering exercises on four overlapping periods: 1990-1996, 1990-2000, 1990-2003 and 1999-2003. Details of data sources are given in the Appendix. The OCA criteria for the four periods are presented in tables from Table 1.1 to Table 1.4.

Before analyzing the results of clustering partition, we first identify the optimal number of clusters based on two validity tests: the Xie - Beni index and the silhouette statistics. For each period, we run the validity tests with increasing number of clusters, from two clusters to six clusters. Since we have only ten countries, it seems fair to limit the maximum number of clusters to six. The results of the validity tests are reported in Table 2 (we do not report individual silhouette width here). A well-clustered scheme is the one which has small Xie – Beni index, positive individual silhouettes and large average silhouette. Once the number of clusters is selected, we perform fuzzy clustering analysis using the FCM algorithm in the Matlab-based Clustering Toolbox by Tamas Kenesei, Balazs Balasko and Janos Abonyi at the Department of Process Engineering, University of Veszprem, Hungary. (http://www.fmt.vein.hu/softcomp/). The results of fuzzy clustering analysis are presented in Table 3, where we report membership coefficients and individual silhouette width. For the purpose of this paper, we set the fuzziness parameter m = 2 as usual. For all periods, we find significant degree of fuzziness as indicated by small silhouette width in many countries.

Table 1.1: OCA Variables in East Asian Countries (1990 – 1996)

Countries	Business cycles synchronization	Exchange rate volatility	Trade openness	Inflation differentials	Export diversification
Japan	0.293	0.059	0.348	-4.728	1.918
Korea	0.742	0.016	0.408	0.211	3.399
China	-0.527	0.040	0.544	4.838	3.483
Hong Kong	-0.574	0.021	0.661	2.993	3.194
Taiwan	-0.407	0.072	0.467	-2.447	3.365
Singapore	0.449	0.010	0.520	-3.640	2.640
Malaysia	-0.021	0.026	0.573	-2.454	3.803
Thailand	0.760	0.011	0.498	-1.040	4.385
Indonesia	0.596	0.012	0.552	2.463	5.043
Philippines	0.237	0.042	0.446	3.804	4.172

1990 -1996 is the period prior to the East Asian financial crisis when the region experienced high economic growth coined by the World Bank as “East Asian miracle”

(World Bank, 1993). The variables for East Asia countries in this period are reported in Table 1.1. The Xie – Beni index is lowest at two clusters. However, some of the individual silhouette statistics are negative and the average silhouette is low, indicating misspecification. The highest average silhouette statistics is found at three clusters, which also corresponds to the second lowest Xie – Beni index. Therefore, we opt to classify East Asian countries into three groups. Fuzzy clustering results in Table 3 show that the biggest group includes the ASEAN 5 of Indonesia, Malaysia, Philippines, Singapore and Thailand plus Korea. The characteristics of these countries were greater synchronization with the regional business cycle, low exchange rate variations and diversified export. The second group comprises two manufacturing – intensive countries, Japan and Taiwan province of China. These countries had business cycles that were less correlated with the regional one, low rates of inflation, not very open to regional trade and less diversified export. The last group is Mainland China and Hong Kong; both were not very synchronized with the regional cycle, experienced high inflation and quite open to regional trade.

Table 1.2: OCA Variables in East Asian Countries (1990 – 2000)

Countries	Business cycles synchronization	Exchange rate volatility	Trade openness	Inflation differentials	Export diversification
Japan	0.612	0.058	0.357	-4.398	1.935
Korea	0.908	0.064	0.409	-0.015	3.221
China	0.219	0.033	0.527	1.637	3.399
Hong Kong	0.804	0.020	0.665	0.477	3.106
Taiwan	0.676	0.057	0.474	-2.707	3.101
Singapore	0.875	0.014	0.521	-3.548	2.476
Malaysia	0.989	0.040	0.565	-1.966	3.325
Thailand	0.951	0.062	0.494	-0.764	4.217
Indonesia	0.980	0.140	0.537	8.127	5.538
Philippines	0.428	0.050	0.459	3.156	3.363

The East Asia miracle has been somewhat marred since the outbreak of the regional financial crisis, following by substantial exchange rate depreciation and high inflation in

many countries, especially in the badly-hit Korea, Thailand and Indonesia. Instead of three groups when not include the years of crisis, for the period of 1990 – 2000, both the Xie – Beni index and the silhouette statistics suggest the optimal number of four groups. The average silhouette is highest at six groups but there we witness the existence of negative individual silhouettes. The highest average silhouette with positive individual silhouettes is found at four clusters. Fuzzy clustering analysis with four groups is reported in Table 3. The first group consists of Hong Kong, Singapore, Malaysia and Thailand. The financial crisis had driven Hong Kong's business cycle and its rate of inflation close to the regional ones and thus brings the territory to the same group with major Southeast Asian countries. This group features high degree of openness to trade, highly synchronized business cycles with the regional cycle and fairly low rates of inflation. The fact that the hard-hit Korea experienced rapid exchange rate depreciation and lower inflation following the crisis make it no longer in the same group with the Southeast Asian nations. The manufacturing-intensive countries of Japan, Korea and Taiwan preferably constitute the second group of which the main characteristics are low inflation rates, low degree of openness to regional trade and higher exchange rate volatility. China and the Philippines form the third group since they both had high inflation rates, average degree of export diversification and low degree of business cycle synchronization. The worst victim of the East Asian financial crisis is probably Indonesia. The country suffered from the extremely deep depreciation of the Rupiah and from very high inflation. Indonesia was also very open to regional trade and had highly diversified export structure as well. It is no surprise that the country constitutes its own group.

Many believe that the regional crisis has driven East Asia towards greater regional integration and bilateral cooperation (see, for instance, Plummer (2007)) and one might

expect a trend of convergence in East Asia. We conduct the fuzzy clustering analysis on the period of 1999 – 2003 to investigate whether the degree of convergence in these recent years is different from the previous ones. The minimum Xie – Beni index is found at four clusters. The largest average silhouette is, however, corresponding to two clusters. The second largest average silhouette is at four clusters and this value is still fairly high (0.5). It turns out that Indonesia is the single outlier if we divide East Asia into two groups. Is East Asia so converged that every country falls into one group except Indonesia? We are less convinced that East Asia has such degree of homogeneity. We decided to follow the Xie – Beni index to work with four groups. The result of fuzzy clustering analysis with four groups is reported in Table 3. The first group contains Hong Kong, Singapore and Malaysia. These countries feature high degree of business cycle synchronization, low exchange rate variations and high openness to trade. The second group is comprised of the manufacturing-intensive countries of Japan, Korea, Taiwan and Thailand and Philippines. These countries are less open to regional trade and have high degree of exchange rate volatility. China stays alone in the third group with low level of business cycle synchronization, stable exchange rate and quite diversified export structure. Indonesia again constitutes the last group of its own. The country suffered from very high inflation and volatile exchange rate, became less synchronized with the regional cycle and had very diversified export.

Considering the entire dataset from 1990 to 2003, the result is not very different from that of the period of 1990 – 2000. Both Xie – Beni and silhouette statistics indicate the optimal number of four clusters. Though the largest average silhouette is found at six clusters, the existence of negative individual silhouettes rules out this choice. Compared to the period of 1990 – 2000, the only difference is the move of Taiwan, from the second group of Japan

and Korea to the third group of China and Philippines due to the decrease of its degree of business cycle synchronization. Nevertheless, Taiwan's membership coefficient with the third group is just minimally higher than its membership with the second group. The silhouette width for Taiwan is merely 0.17, indicating high degree of fuzziness in its classification. Also note that although the membership coefficients of Thailand are the same in the first group and the second group, we put Thailand in the first group since this produces positive individual silhouette.

Table 1.3: OCA Variables in East Asian Countries (1999 – 2003)

Countries	Business cycles synchronization	Exchange rate volatility	Trade openness	Inflation differentials	Export diversification
Japan	0.652	0.040	0.402	-2.389	2.038
Korea	0.867	0.030	0.439	0.877	2.549
China	0.285	0.018	0.489	-1.867	3.427
Hong Kong	0.888	0.016	0.673	-4.791	3.238
Taiwan	0.947	0.041	0.539	-1.658	2.613
Singapore	0.984	0.012	0.565	-1.309	2.292
Malaysia	0.997	0.022	0.566	-0.095	2.521
Thailand	0.779	0.029	0.497	-0.621	4.003
Indonesia	0.141	0.072	0.539	9.029	6.143
Philippines	0.817	0.032	0.524	2.823	1.740

Table 1.4: OCA Variables in East Asian Countries (1990 – 2003)

Countries	Business cycles synchronization	Exchange rate volatility	Trade openness	Inflation differentials	Export diversification
Japan	0.637	0.053	0.369	-3.977	1.970
Korea	0.903	0.059	0.418	0.341	3.057
China	0.274	0.031	0.520	0.961	3.435
Hong Kong	0.823	0.020	0.665	-0.529	3.173
Taiwan	0.524	0.059	0.498	-2.562	3.013
Singapore	0.809	0.014	0.535	-3.094	2.451
Malaysia	0.987	0.037	0.566	-1.625	3.181
Thailand	0.932	0.056	0.496	-0.696	4.188
Indonesia	0.945	0.130	0.539	8.141	5.660
Philippines	0.389	0.047	0.477	3.041	3.011

If GDP data is detrended using Hodrik – Prescott filter with dampening parameter of 100, we find similar result when considering the entire sample. The results of sub-periods,

however, show greater heterogeneity that East Asia should better be divided into five or six groups.

Table 2: Validity Tests of Optimal Cluster Number

Number of clusters		2	3	4	5	6
1990 - 1996	Xie - Beni	0.9178	**1.0179**	1.1392	1.3586	1.3754
	Average Silhouette	0.2382	**0.4548**	0.407	0.3871	0.4428
1990 - 2000	Xie - Beni	1.2071	1.2884	**1.161**	1.2046	1.2497
	Average Silhouette	0.3456	0.399	**0.5036**	0.4131	0.5129
1999 - 2003	Xie - Beni	1.3595	1.3143	**1.287**	1.3036	1.49
	Average Silhouette	**0.8301**	0.4325	**0.5**	0.4082	0.4272
1990 - 2003	Xie - Beni	1.1771	1.2797	**1.0533**	1.1677	1.189
	Average Silhouette	-0.1317	0.4443	**0.511**	0.5181	0.5445

*Bold figures indicate Xie – Beni indices and average silhouette statistics possibly associated with optimal number of clusters.

All in all, it seems that East Asia countries have been fairly dispersed in terms of the OCA criteria. We find no clear trend of convergence through our fuzzy clustering analysis. Instead, the region has appeared even more diverged after the 1997 - 1998 financial crisis. The divergence can be seen clearly in the ASEAN countries, which were quite similar in the period before the crisis. Indonesia, in particular, has moved far apart other neighbors due to much higher inflation rate, highly volatile exchange rate and low degree of synchronization. Philippines have also fallen behind its neighbors. Thailand stays somewhere in between its ASEAN neighbors and the Northeast countries. Similarly, Taiwan's position is indeterminate between grouping with China and grouping with Japan. The only stable grouping is that of Singapore and Malaysia. In all periods, we witness the presence of high degree of fuzziness.

Table 3: Fuzzy Clustering Results

	1990 -1996				1990 - 2000					1999 - 2003					1990 - 2003				
	1	2	3	silhouette	1	2	3	4	silhouette	1	2	3	4	silhouette	1	2	3	4	silhouette
Japan	0.0579	**0.8958**	0.0463	0.539	0.1636	**0.6073**	0.1842	0.045	0.5764	0.1275	**0.6179**	0.2192	0.0354	0.2743	0.1348	**0.6535**	0.1751	0.0366	0.4307
Korea	**0.7216**	0.1573	0.1212	0.574	0.1358	**0.7322**	0.0964	0.0356	0.3916	0.0484	**0.8989**	0.0449	0.0078	0.6232	0.0907	**0.8061**	0.0784	0.0248	0.2788
China	0.0693	0.0473	**0.8834**	0.6998	0.0533	0.0606	**0.8687**	0.0173	0.813	0.0172	0.0244	**0.9532**	0.0052	1	0.0493	0.0511	**0.8857**	0.0139	0.7387
Hong Kong	0.1066	0.0617	**0.8317**	0.7426	**0.6443**	0.1413	0.1631	0.0514	0.4417	**0.604**	0.163	0.1869	0.046	0.6398	**0.7274**	0.1026	0.1293	0.0407	0.504
Taiwan	0.1673	**0.5829**	0.2499	0.3091	0.1112	**0.7939**	0.0817	0.0132	0.2914	0.4103	**0.4414**	0.1214	0.0269	0.1535	0.1941	0.3813	**0.3919**	0.0327	0.2411
Singapore	**0.4946**	0.2815	0.2239	0.3702	**0.6065**	0.2629	0.1049	0.0256	0.166	**0.8879**	0.0647	0.0407	0.0067	0.5652	**0.6516**	0.1982	0.1269	0.0232	0.3731
Malaysia	**0.4515**	0.1579	0.3906	0.0725	**0.9264**	0.0459	0.02	0.0078	0.6243	**0.9194**	0.0525	0.0235	0.0046	0.3425	**0.9085**	0.052	0.0295	0.01	0.7001
Thailand	**0.9258**	0.0316	0.0426	0.7055	**0.3896**	0.376	0.1501	0.0844	0.0377	0.2384	**0.4256**	0.2997	0.0363	0.0552	**0.3713**	0.3717	0.1741	0.0829	0.1673
Indonesia	**0.7166**	0.0804	0.203	0.4269	0.0002	0.0002	0.0002	**0.9995**	1	0	0	0.0001	**0.9999**	1	0.0001	0.0001	0.0001	**0.9996**	1
Philippines	**0.4755**	0.173	0.3515	0.1081	0.0464	0.0835	**0.8522**	0.0179	0.6941	0.2926	**0.5353**	0.1389	0.0332	0.346	0.0427	0.0701	**0.8717**	0.0155	0.676

Table 4: Grouping of East Asian Countries by OCA Criteria

	Business cycle synchronization	Exchange rate volatility	Openness to trade	Inflation	Export diversification
1990 - 1996					
1. Korea, Singapore, Malaysia, Thailand, Indonesia, Philippines	High	low	Mixed	mixed	High
2. Japan, Taiwan	low	High	Low	Low	Low
3. China, Hong Kong	low	Average	High	High	Average
1990-2000					
1. Hong Kong, Singapore, Malaysia, Thailand	high	Mixed	high	Low	Mixed
2. Japan, Korea, Taiwan	Mixed	high	low	Low	Low
3. China, Philippines	low	Mixed	Mixed	high	average
4. Indonesia	high	very high	High	very high	very high
1999-2003					
1. Hong Kong, Singapore, Malaysia	high	low	high	low	Mixed
2. Japan, Korea, Taiwan, Thailand, Philippines	Mixed	High	Low	mixed	Mixed
3. China	Low	Low	Low	average	high
4. Indonesia	Low	high	average	very high	very high
1990-2003					
1. Hong Kong, Singapore, Malaysia, Thailand	high	Mixed	high	low	mixed
2. Japan, Korea	Mixed	High	Low	Low	mixed
3. China, Taiwan, Philippines	Low	Mixed	Average	mixed	Average
4. Indonesia	high	very high	average	high	very high

4. Conclusion:

This paper seeks the empirical evidence on the readiness of East Asian countries for a currency union using data of four overlapping periods from 1990 to 2003. Applying the method of fuzzy clustering analysis, we attempt to examine the degree of homogeneity across the countries in terms of multiple OCA criteria by classifying them into groups within which they are at most similar. We find that East Asia has been fairly dispersed and can be divided

into about four groups with significant degree of fuzziness. We find no notable trend of convergence from the data. In fact, East Asian has appeared to be more diverged since the onset of the regional financial crisis. The only stable grouping that weathers all periods considered is the pair of Singapore and Malaysia. A currency union of the two is possible but hardly desirable, however, since a larger currency domain is necessary for a currency union to be meaningful to the region. Thus, we suspect the possibility of forming a currency union in East Asia in the near future.

Reference

Bayoumi, Tamim and Eichengreen, Barry (1994), 'One Money or Many? Analyzing the Prospects for Monetary Unification in Various Parts of the Worlds', *Princeton Studies in International Finance,* 16.

Bezdek, J. C (1973), 'Fuzzy Mathematics in Pattern Classification', (Cornell University).

Blanchard, Oliver Jean and Quah, Danny (1989), 'The Dynamic Effects of Aggregate Demand and Supply Disturbances', *American Economic Review,* 79, 655-73.

Chow, Hwee Kwan and Kim, Yoobai (2003), 'A Common Currency Peg in East Asia? Perspectives from Western Europe', *Journal of Macroeconomics,* 25, 331-50.

Dunn, J. C (1973), 'A Fuzzy Relative of the ISODATA Process and Its Use in Detecting Compact, Well-separated Clusters', *Journal of Cybernetics,* 3, 32-57.

Gregory, Allan W., Head, Allen C., and Raynauld, Jacques (1997), 'Measuring World Business Cycles', *International Economic Review,* 38 (3), 677-701.

Hodrick, Robert and Prescott, Edward (1980), 'Postwar U.S. Business Cycle: An Empirical Investigation', *Discussion Paper* (No 451: Carnegie Mellon University).

Hoppner, Frank, et al. (1999), *Fuzzy Cluster Analysis: Methods for Classification, Data Analysis and Image Recognition* (Chichester: John Wiley & Son).

Kenen, Peter (1969), 'The Theory of Optimum Currency Areas: an Eclective View', in Robert Mundell and A.K. Swoboda (ed.), *Monetary Problems of the International Economy - Conference on International Monetary Problems* (Chicago: University of Chicago Press).

Kose, Ayhan M., Otrok, Christopher, and Whiteman, Charles H. (2002), 'International Business Cycles: World, Region and Country Specific Factors', *American Economic Review,* 93 (4), 1216-39.

Kuroda, Haruhiko (2004), 'Transitional Steps in the Road to a Single Currency in East Asia', paper given at A Single Currency for East Asia - Lessons from Europe, Jeju.

Kwan, C.H. (1998), 'The Theory of Optimum Currency Areas and the Possibility of Forming a Yen Bloc in Asia', *Journal of Asian Economics,* 9 (4), 555-80.

Masson, Paul and Taylor, Mark P. (1993), 'Currency Unions: A Survey of the Issues', in Paul Masson and Mark P. Taylor (eds.), *Policy Issues in the Operation of Currency Unions* (Cambridge: Cambridge University Press).

Masson, Paul and Taylor, Mark P. (1994), 'Optimal Currency Areas: A Fresh Look at the Traditional Criteria', in Pierre Siklos (ed.), *Varieties of Monetary Reform* (Boston, Massachusett: Kluwer), 23 - 44.

Plummer, Michael G. (2007), 'The Post-Crisis Sequencing of Economic Integration in Asia: Trade as a Complement to a Monetary Future', *ADB Working Paper Series on Regional Economic Integration No. 9.*

Tavlas, G.S. (1993), 'The "New" Theory of Optimum Currency Area', *The World Economy,* 16 (6), 663-385.

World Bank (1993), *East Asian Miracle* (New York: Oxford University Press).

Xie, X. L and Beni, G (1991), 'A Validity Measure for Fuzzy Clustering', *IEEE Transactions on Pattern Analysis and Machine Intelligence,* 13 (4).

Appendix: Data sources

Data	Sources
GDP data of East Asian countries except Taiwan	World Development Indicator 2006
GDP data of Taiwan	Taiwan Statistical Databook 2006
Exchange rate data of East Asian countries except Taiwan	IMF International Financial Statistics CD-Rom 2007
Exchange rate data of Taiwan	Taiwan Statistical Databook 2006
Trade data and data on export structure of East Asian countries except Taiwan	NBER World Trade Flows Database 1962 – 2000, IMF Direction of Trade Statistics Yearbook 2004 and International Trade Statistics, International Trade Centre UNCTAD/WTO website (2001-2003)
Trade data and data on export structure of Taiwan	NBER World Trade Flows Database 1962 – 2000, Taiwan Statistical Databook 2006 and International Trade Statistics, International Trade Centre UNCTAD/WTO website (2001-2003)
Consumer price index data of East Asian countries except Taiwan	World Development Indicator 2006
Annual consumer price index data of Taiwan	Taiwan Statistical Databook 2006