Measuring Economic Integration in the Asia-Pacific Region: A Principal Components Approach*

Bo Chen
School of International Business Administration
Shanghai University of Finance and Economics
777 Guoding Rd., Yangpu District
Shanghai, China 200433
chen.bo@mail.shufe.edu.cn

Yuen Pau Woo
Asia Pacific Foundation of Canada
Suite 220, 890 West Pender Street
Vancouver, BC
Canada V6C 1J9
yuenpau.woo@asiapacific.ca

Abstract
This paper measures economic integration in the Asia-Pacific (AP) region using a composite index. The weights of the index are obtained from a two-stage principal component analysis. In the first stage, we obtain a convergence index to measure the extent of convergence among the main macroeconomic indicators of a sample of AP economies. In the second stage, we use indicators of trade, FDI, and tourism, as well as the convergence index, to compute the weights for the composite index. We found that economic convergence in the AP region increased until 1998 but has since fallen back. The integration of trade, investment, and people flows increased between 1990 and 2000, weakened slightly to 2003, and has since picked up again. Among the 17 sample economies, Singapore, Hong Kong, and Chinese Taipei are the most integrated with the AP region and Indonesia and China are the least integrated.

1. Introduction

The process of economic integration is commonly defined as the freer movement of goods, services, labor, and capital across borders. The degree of economic integration can be analyzed at a bilateral, regional, and global level. The

* Corresponding author: Bo Chen. This paper was originally commissioned by the Pacific Economic Cooperation Council's State of the Region Project. Chen also acknowledges the financial support from the "211 project" at Shanghai University of Finance and Economics. The authors thank Dr. Shinji Takagi for helpful comments. Participants at ADBI's 10th anniversary conference, SFU-UBC Economics Winter Workshop, the Pacific Economic Outlook panel, and the Asian Economic Panel meeting in September 2009 in Tokyo are gratefully acknowledged. All errors in this paper are ours.

trend toward regional trading arrangements (for instance, the European Union, ASEAN, and NAFTA) has created a need for measures of economic integration within that region, which in turn allows for comparisons across different regions. There are many single variable measures of regional economic integration, but relatively little work has been done in developing a composite index of economic integration.

The Asia-Pacific Economic Cooperation (APEC) forum of 21 economies consists of high-income economies such as the United States, Japan, Canada, Hong Kong (China), Australia, and Chinese Taipei; middle-income economies like Chile, Russia, and Malaysia, and low-income economies such as Papua New Guinea, Indonesia, and China. It is well known that parts of the region are already highly integrated through production networks that trade intermediate and finished goods across borders, often within the same firm. Since 1998, many economies in the Asia-Pacific (AP) region have negotiated bilateral and sub-regional free-trade agreements with partners in the region as well as with partners outside the region. APEC leaders have also endorsed a proposal to investigate the idea of a Free Trade Agreement of the Asia-Pacific, which, if successful, would constitute the largest regional trading bloc in the world. In 2010, APEC will be looking to measure progress against its Bogor Target of "free and open trade" in developed member economies. Although the goal of free and open trade will certainly not be met by 2010, it may be possible to argue that APEC has made progress toward its broader goal of deeper economic integration in the region. One of the purposes of our composite index, therefore, is to provide a measure of APEC's economic integration agenda and to track the progress of integration on an annual basis.

There have been many attempts to construct composite indices for measuring economic or sociological developments in a country or across a set of countries. Composite indices are constructed using either non-parametric or parametric methods.

Non-parametric approaches directly assign weights to the chosen indicators based on the researchers' prior beliefs about the relative importance of the indicators (i.e., higher weights are assigned to indicators that are more important). Examples include the Human Development Index (HDI) of the United Nations Development Program (UNDP), and the European Union's (EU) Lisbon Development Strategy Indices (LSI), which measure the level and pattern of development of EU member economies. The consulting firm A.T. Kearney (2002, 2003) has produced a composite globalization index based on measures of economics, technology, demography, and politics. The Kearney index has two forms—unweighted (where equal weights are applied to all indicators) and weighted (where the "more important" indicators are weighted more heavily). However, it is evident that indices are sensitive to the subjective weighting scheme (Lockwood 2004), which is often criticized for lack of scientific rigor.

On the other hand, parametric approaches assume there is some latent structure behind the variation of the indicators. The weights for these indicators can be determined objectively by measuring the co-variation between the indicators on each dimension of the structure. The most common parametric methods in use are common factor analysis (CFA) and principal components analysis (PCA). Andersen and Herbertsson (2003) attempt to measure globalization based on CFA. Cahill and Sanchez (2001) use PCA to construct an economic and social development index for Latin America and the United States. Heshmati (2006) uses PCA to construct a globalization index based on the same indicators as the Kearney index and he compares the results of the two methods. Dreher (2006) uses PCA to determine the weights of economic, political, and social factors in developing the KOF index of globalization. The KOF index is updated annually by using (comparable) time varying weights and adding new indicators or revising the existing ones. The United Nations Conference on Trade and Development (UNCTAD) has adopted the PCA approach to construct a trade and development index (TDI). TDI is designed to capture the complex interaction between trade and development to reflect the composite trade and development performance of countries.

This paper uses the PCA approach to construct a composite index of economic integration that will show the dynamic pattern of integration not only for the Asia-Pacific region as a whole, but also for individual economies within the region. This paper makes two major contributions. First, it is a pioneering attempt at measuring economic integration in the AP region. Although there has been some research on the integration of economies within a sub-regional unit such as ASEAN and its neighbors (Batra 2007), East Asia (Cheong 2003; Yung 2007), and NAFTA (Acharya, Rao, and Sawchuk 2002), much less attention has been paid to the economic integration of the AP region as a whole. Second, by employing the detailed economy–economy pair data in trade, FDI, and tourism, we filter out the effects of sub-regional integration that could distort the findings for integration of the AP region as a whole. Most attempts to measure integration across a large group of countries fail to take into account the effects of sub-regional agreements on an economy's broader integration with the world, and hence result in an inaccurate reading of globalization.

This paper is an improvement over an earlier study by us[1] in four ways. First, we have added Chinese Taipei and Chile to our list of economies, which makes the re-

1 Chen and Woo (2008) was commissioned by the Pacific Economic Cooperation Council (PECC) as an input to PECC's State of the Region project.

vised index more representative of APEC as a whole. Second, we have modified or replaced some of the original indicators with superior measures (see detailed comparison in section 5). Third, as a robustness check, we compare our results with commonly accepted priors and with the results of other indexing methods. Fourth, we have updated our index by including data for 2006, and demonstrated the use of time-varying weights and a chained index to ensure that the overall index time series is consistent.

This paper is organized as follows. Section 2 describes our methodology for constructing a composite index from multi-dimensional data. Section 3 provides a description of the data and the rationale for our chosen indicators as well as for the use of a sub-index that measures the convergence of sample economies. Section 4 presents the results of the sub-index as well as the composite index from 1990 to 2005. Section 5 discusses the robustness of our indices and updates the index with 2006 data, using time-varying chained weights. Section 6 concludes with the main results.

2. Methodology

To include as much information as possible from a multi-dimensional data set into a composite index, the key task is to allocate reasonable weights to the chosen indicators or sub-indices. A good index should carry the essential information in all the indicators but not be biased toward one or more of the indicators.

As mentioned, there are non-parametric and parametric approaches to construct composite indices. Examples of non-parametric indices include the UNDP's HDI and EU's LSI. This approach directly assigns weights to the chosen indicators based on researchers' prior beliefs about the relative importance of the indicators. Non-parametric approaches have been criticized for subjectivity in the assignment of weights. Parametric approaches, on the other hand, determine the weights objectively by checking the co-variation between indicators. As noted earlier, the most commonly used parametric methods are CFA and PCA.

CFA attempts to simplify complex and diverse relationships by assuming that there exist some latent common variables in a set of observed variables. That is to say, CFA attempts to explain each of the original variables by the set of unobserved common factors (CF). The loadings of the original variables on each CF reveal their relative importance in the dimension represented by the corresponding CF.

Originally introduced by Pearson (1901) and independently developed by Hotelling (1933), PCA transforms the original set of variables into principal components (PC), which are orthogonal to each other. Each PC is a linear combination of all the included indicators. The first PC accounts for the largest amount of the total variation (information) in the original data, the second PC explains the second largest variation, and so on. The (normalized) loadings in a PC are the weights of the corresponding indicators in the dimension represented by that PC.[2]

The final weight assigned to each indicator in a composite index is its loading in each dimension of the selected CFs or PCs weighted by the relative importance of that factor or component.

Although non-parametric methods are simple to construct and allow for ease of comparison over time, they suffer from the subjective assignment of weights, which often lack a theoretical basis. Changing the weights on a non-parametric index even slightly can dramatically alter the final index. There is a further problem in reassigning weights when new indicators are added to an existing index.

Parametric methods, on the other hand, are statistically sound because the weights are determined by the sample indicators themselves. Furthermore, they are also robust to high dimensional data. From an empirical point of view, PCA is often preferred to CFA for two reasons. First, PCA is simpler to apply mathematically because no assumptions are attached to the raw data (i.e., the underlying common factors) (Stevens 1992); secondly, PCA does not have to account for factor indeterminacy, which is a troublesome feature of CFA (Steiger 1979). The advantage of PCA in empirical investigations makes it widely used in research on indices. Therefore, we choose PCA as our approach in constructing a composite index of economic integration in the AP region.

Our use of PCA is similar to the approach adopted by UNCTAD in its construction of the TDI 2005. The formal steps in this methodology are as follows: Suppose there is a multi-dimensional data $X_{T\times p}$,[3] where T is the total number of periods and p is the number of the indicators (dimensions). $R_{p\times p}$ is the correlation matrix of the p indicator series. Define $\lambda_i(i=1,\ldots,p)$ as the i^{th} eigenvalue and $\alpha^i_{p\times 1}(i=1,\ldots,p)$ as the i^{th} eigenvector of the correlation matrix $R_{p\times p}$ respectively, given the property of eigenvalue and eigenvector, we know, λ_i should be the solution of the determinant $|R-\lambda I|=0$ (where $\lambda=\lambda_1,\ldots,\lambda_p$), and I is the $p\times p$ identity matrix), and the corresponding (normalized) eigenvector α^i can be solved by

2 The normalization is to scale up or down the loadings of each indicator in a PC uniformly so that the sum of the square of them is unity.

3 In general, the components of matrix **X** are the normalized transformation of the raw data to avoid the problem of heterogeneous scales.

$$(R - \lambda_i \alpha^i) = 0$$
$$\text{subject to } \alpha_i' \bullet \alpha_i \text{ (normalization condition)}$$

Without loss of generality, assume

$$\lambda_1 > \lambda_2 > \ldots > \lambda_p$$

and denote the i^{th} principal component as PC_i, then

$$PC_i = X\alpha^i \tag{1}$$

and

$$\lambda_i = \text{var}(PC_i) \tag{2}$$

Therefore, the first principal component is the linear combination of the initial indicators that has the biggest variance. The second PC is another linear combination of the indicators, which is orthogonal to the first PC (since the eigenvectors are orthogonal to each other) and has the second biggest variance. Following this order, the p^{th} PC is a linear combination of the indicators, which is orthogonal to all the other PCs and has the smallest variance. In other words, the PCA is a method to represent a p-dimensional data by p orthogonal PCs, with the first i PCs carry the biggest i variances (information) of the initial data.

Thus, our index will be constructed by the PCs and their relative importance (accountability of the variance),

$$Ind = \frac{\sum_{i=1}^{p} \lambda_i PC_i}{\sum_{i=1}^{p} \lambda_i} = \frac{\sum_{i=1}^{p} \sum_{j=1}^{p} \lambda_i \alpha_j^i x_j}{\sum_{i=1}^{p} \lambda_i} = \sum_{j=1}^{p} w_j x_j \tag{3}$$

where x_j (j=1, . . . ,p) is the j^h column (indicator series) of the matrix **X,** and the final weight[4] of indicator j is given by,

$$w_j = \frac{\sum_{i=1}^{p} \lambda_i \alpha_j^i}{\sum_{i=1}^{p} \lambda_i} \tag{4}$$

4 In general, the sum of weights is not, but very close to, unity due to the fact that PCA normalizes the mode of each eigenvector to be unity.

We recognize that using PCA could result in bias toward the weights of indicators that are highly correlated with each other (Mishra 2007). To correct this problem, we adopt a two-stage PCA. That is, in the first stage, we group the highly correlated indicators together to construct a composite sub-index, and then use this sub-index with the remaining indicators to construct the final composite index.

3. Data and descriptive statistics

Most research on economic integration is based on the following four indicators: trade, FDI, portfolio capital flows, and international remittances of income payments and receipts (e.g., Keohane and Nye 2000; Shin and Wang 2004; Bhandari and Heshmati 2005; Wakasugi 2007). Other indicators that have been applied include the flow of people, for instance, international tourism (Acharya, Rao, and Sawchuk 2002), GDP per capita (Heshmati and Oh 2005), and the relative size of the agriculture sector to GDP (Cahill and Sanchez 2001).

Given data availability, we selected the following eight indicators: the absolute deviation of real GDP per capita, the non-agriculture sectoral share (to GDP), the urban resident ratio, life expectancy, and the education expense share (to GNI) (as a proxy for investment in human resource); the AP regional imports and exports share (to GDP); the intra-AP FDI interflow share (to gross capital formation); and the intra-AP tourist inflow (per one thousand people).[5] The data sources are listed in Table 1. These data are collected from 17 APEC member economies, namely, Japan, Republic of Korea, People's Republic of China, Hong Kong, and Chinese Taipei from East Asia; Vietnam, Thailand, the Philippines, Indonesia, Singapore, and Malaysia from Southeast Asia; the United States and Canada from North America; Chile and Mexico from Latin America; and Australia and New Zealand from Oceania. The data start from 1990 and end at 2005. Missing data were approximated using standard interpolation and extrapolation techniques.

The first five deviation indicators are grouped together because they may be highly inter-correlated macroeconomic variables. We have labeled the sub-index of these five indicators as a "convergence index" (CI) since the dispersion in these five indicators is expected to narrow over time if economies are integrating. In particular, the absolute deviation of real GDP per capita measures dispersion of overall welfare of the sample economies. The dispersion of industrialization levels is indicated by the

5 We want to emphasize the fact that no indicators can sufficiently reflect economic integration individually. And neither do ours. However, the process of integration, if any, must be reflected from various macroeconomic aspects, which are (theoretically, at least) captured by our selected indicators. And that is the reason why we try to measure integration from various dimensions rather than a single aspect.

Table 1. Data category and source

Category	Sub-category	Source
Economic convergence	Real GDP per capita	World Development Indicator 2007 and Statistical Yearbook 2007 (Chinese Taipei)
	Agriculture sectoral share Urban residents Total population Life expectancy Education expense ratio (to GNI)	
Trade share	Nominal GDP	United Nations Common Database and Statistical Yearbook 2007 (Chinese Taipei)
	Exports Imports	World Trade Analyzer
FDI flow share	Gross capital formation	United Nations Common Database and Statistical Yearbook 2007 (Chinese Taipei)
	FDI flow	1. United States Census Bureau for U.S. data 2. CANSIM for Canadian data 3. ASEAN Statistical Yearbooks for the ASEAN-6 4. Economy-specific statistical yearbooks
International tourists share	Total international tourists inflow and intra-AP inflow	Same as above

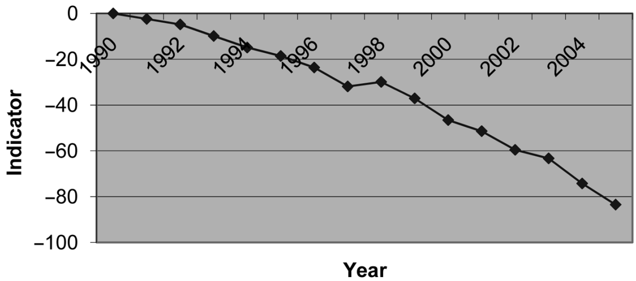
absolute deviation of the non-agriculture sectoral share. The absolute deviation of urban residents' ratio measures the dispersion of modernization levels (since most industrial and business activities occur in urban areas). Finally, the absolute deviation of the life expectancy and education expenses approximate the dispersion of health status and the investment in human capital (which is believed to be a key factor in long run economic growth), respectively. Figure 1 illustrates the aggregate performance of the indicators respectively using 1990 as the base year. The indicators are obtained as follows,

$$Dev.\,Indicator_t = 100 - \frac{Abs.Dev._t}{Abs.Dev._{1990}} * 100 \qquad t = 1990, \ldots 2005. \tag{5}$$

Compared to the base year (1990) indicator, which is normalized to zero, a positive indicator means that the absolute deviation of that year is smaller than that of the base year, that is, there has been convergence compared to 1990; a negative number would imply the opposite, which is greater divergence. A higher score implies a higher level of convergence, while lower means the opposite.

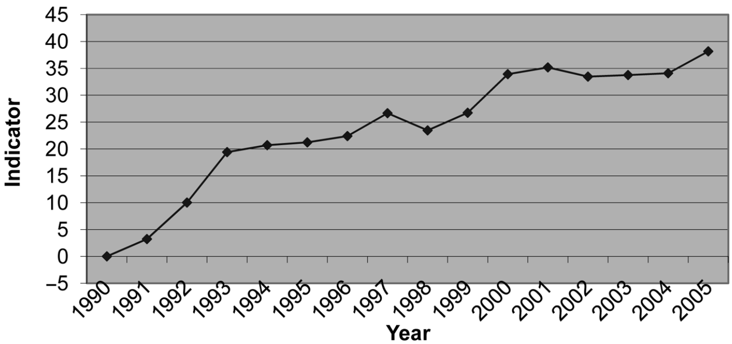
Figure 1a, the indicator of real GDP, reveals that the gap in real income among sample economies has been getting wider over time, suggesting economic divergence. On the other hand, Figures 1b and 1c clearly show that the indicators of non-agriculture sectoral share and urban resident share are consistently converging across the sample economies over time. Figures 1d and 1e show that the life expectancy and the education expense ratios are both volatile.

Figure 1a. The absolute deviation indicator of real GDP per capita



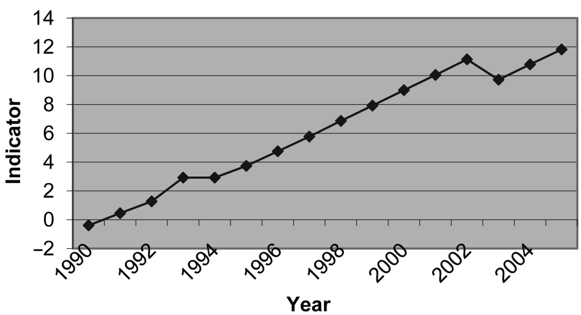
Source: *Please refer to Table 1 for the source of the raw data and the text for authors' calculations.*

Figure 1b. The absolute deviation indicator of non-agriculture sectoral share



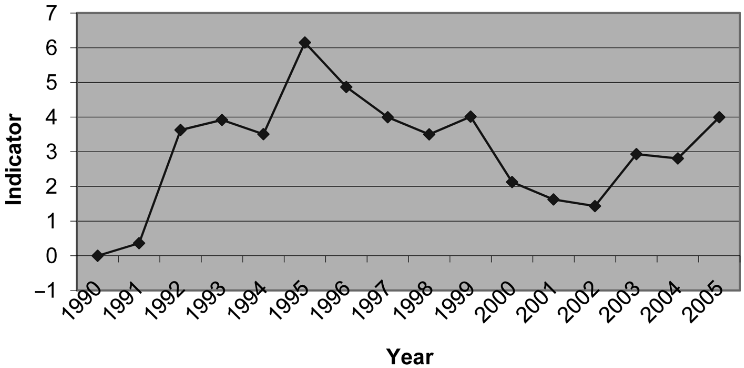
Source: *Please refer to Table 1 for the source of the raw data and the text for authors' calculations.*

Figure 1c. The absolute deviation indicator of urban resident ratio



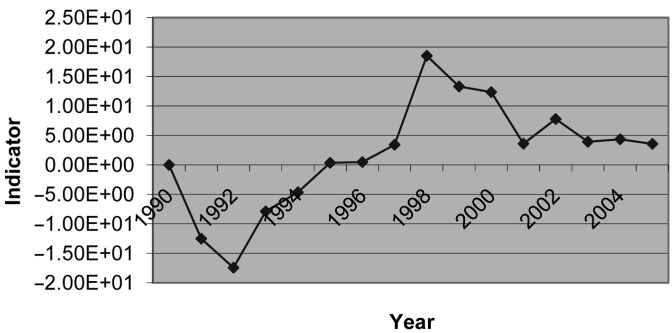
Source: *Please refer to Table 1 for the source of the raw data and the text for authors' calculations.*

Figure 1d. The absolute deviation indicator of life expectancy



Source: *Please refer to Table 1 for the source of the raw data and the text for authors' calculations.*

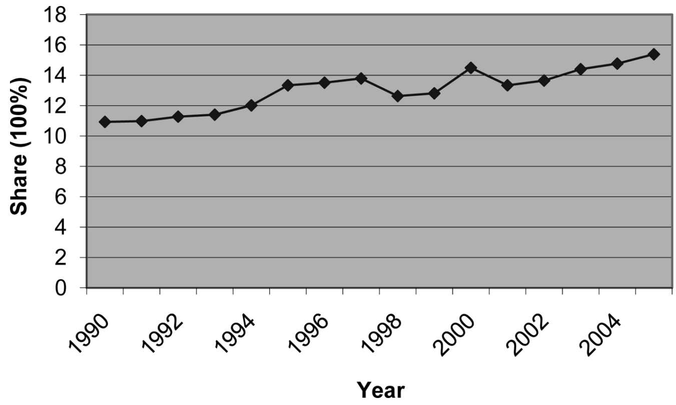
Figure 1e. The absolute deviation indicator of education expense ratio



Source: *Please refer to Table 1 for the source of the raw data and the text for authors' calculations.*

The second part of our index construction involves the collection of economic integration indicators. We have chosen commonly used indicators that measure flows of goods (trade), capital (FDI), and people (tourists) in a region. To avoid bias, we have netted outflows among AP economies that are part of a sub-regional unit. In particular, the sub-regional units we exclude are the so-called "Greater China" region (including Chinese Taipei, Hong Kong, and the People's Republic of China), ASEAN, NAFTA, and the Australia/New Zealand Closer Economic Relations Grouping. Accordingly, the trade and FDI data are calculated as the total of intra-AP flows net of flows among members of the sub-regional units. For instance, we ex-

Figure 2. Trade share in Asia-Pacific region

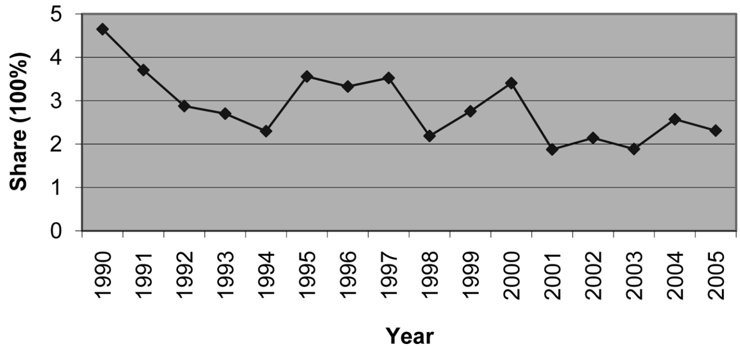


Source: *Please refer to Table 1 for the source of the raw data and the text for authors' calculations.*

clude China's FDI flows with Hong Kong and Chinese Taipei when we calculate the total AP regional FDI inflows to and outflows from China. Ignoring the effects of sub-regional agreements may seriously overstate the level of integration in the AP region. For example, Mexican trade and FDI inflow increased rapidly after it became a member of NAFTA in 1992. However, most of the growth was due to increasing business with the United States and Canada rather than with the economies outside of NAFTA. A global economic integration index for Mexico that does not exclude the effects of NAFTA would provide a false reading of Mexico's integration with the world.

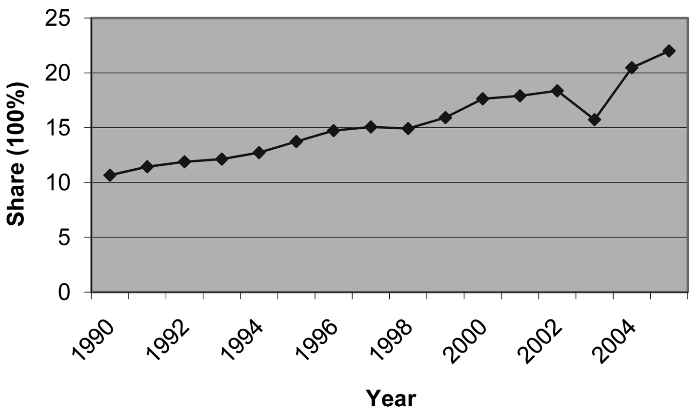
Figures 2 to 4 show, respectively, the share of AP intra-regional imports and exports (to regional GDP), intra-regional FDI share (to regional gross capital formation), and the intra-regional tourist share (to total annual international tourists hosted by all AP sample economies). As illustrated in Figures 2 and 4, the trade share and tourist share have both increased steadily over time, implying stronger links in goods and demographic flows in the AP region. On the other hand, the FDI measure has been volatile, with a decreasing trend. There are two reasons that may account for the declining FDI share. First, even though there has been a large increase in FDI in many AP economies, much of the increase has been due to investment among economies belonging to the same sub-regional trade agreement, for example, NAFTA. Another factor worth noting is the growing volume of FDI inflow from the tax havens such as the Cayman Islands and the British Virgin Islands. Although much of this inflow

Figure 3. Intra-AP FDI share within Asia-Pacific region



Source: *Please refer to Table 1 for the source of the raw data and the text for authors' calculations.*

Figure 4. Share of intra-AP tourists inflow



Source: *Please refer to Table 1 for the source of the raw data and the text for authors' calculations.*

may in fact originate from AP economies, we are unable to make this determination based on the available data. It is likely, therefore, that the investment measure of AP integration is understated.

4. The convergence index and composite index

We believe a good composite index of economic integration should exhibit two fundamental properties. First, the index should not exhibit a high degree of volatility. Because economic integration is usually a gradual process, a representative index should reflect a modest pace of change as economies become tied to each other. Sec-

Table 2. Summary of principal component analysis for convergence index, n = 272

Indicator	Eigenvector PC1	PC2	PC3	PC4	PC5	Final weight (normalized)
gdp	0.4056	−0.5334	0.5168	−0.0355	0.5316	0.1744
nagri	0.5299	−0.0822	−0.2401	0.7838	−0.2012	0.2150
urb	0.4494	0.1272	−0.6757	−0.3909	0.4154	0.0910
life	0.5552	0.0497	0.2479	−0.4598	−0.6453	0.1844
edu	0.2109	0.8307	0.3967	0.1422	0.2965	0.3352
Eigenvalue	2.2146	1.0468	0.8650	0.4980	0.3756	

Source: *Authors' calculations.*

Note: *Weights are normalized such that the sum of them is unity. Abbreviations: the absolute deviation of real GDP per capita (gdp), of the non-agriculture sectoral share (nagri), of the urban resident ratio (urb), of lifetime expectancy (life), and of the education expense ratio (edu).*

ond, the weight of any one indicator should not be so high that it dominates the overall index. We assess our composite index against these two properties.

In the first stage, we compute the weights for the five deviation indicators and calculate the CI. Table 2 reports the summary of PCA for CI indicators. The weights of the five deviation indicators are derived by equation (4) and normalized such that the sum of them is unity. The deviation indicator of education expense ratio is assigned the highest weight (0.34), followed by non-agriculture share (0.22), with the weights for life expectancy and real GDP per capita roughly the same, at 0.18 and 0.17, respectively. The urban resident ratio is assigned the lowest weight at 0.09.

Using the weights, we can compute the CI for the AP region as well as for each economy in the sample. Due to space limitations, we only provide the CI for the AP region as a whole in Figure 5.[6] Starting from 1990 as the base year with CI normalized to zero, the CI series fluctuates over time, peaking at 7.31 in 1998 and falling to −3.35 in 2005.

In the second stage, we use PCA again to compute the weights for the other three indicators (trade, FDI, and tourists) with the CI. The summary of the second stage PCA is reported in Table 3. PCA assigns the biggest weight to CI (0.36), followed by tourist inflows (0.29) and trade flows (0.24), and the smallest weight (0.10) to FDI. Though the weights are not evenly distributed, none of the indicators is dominant. We show in Figure 6 the movement of the composite index for the AP region from 1990 to 2005. This figure shows the composite index is upward sloping (albeit with modest volatility). The fluctuations in the index are relatively modest, which satisfies the property of an index that is not highly volatile.

6 The detailed CI of each sample country can be provided upon request.

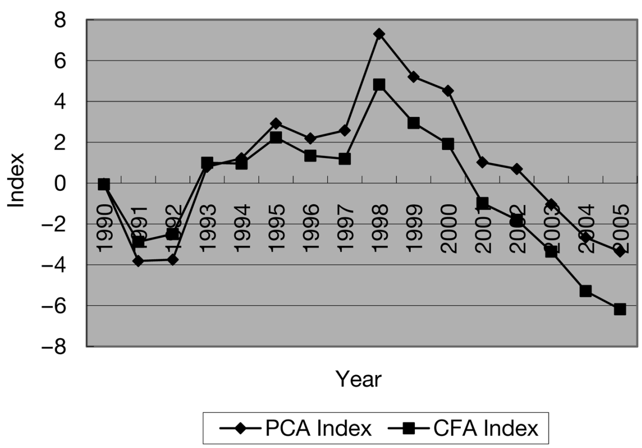
Table 3. Summary of the principal component analysis for composite index, n = 272

Indicator	Eigenvector PC1	PC2	PC3	PC4	Weight (normalized)
ci	0.0465	0.7305	0.6771	0.0754	0.3596
trade	0.7036	−0.0187	0.0507	−0.7086	0.2432
fdi	0.1931	0.6482	−0.7262	0.1228	0.1027
tour	0.6823	−0.2141	0.1072	0.6908	0.2945
Eigenvalue	1.7132	1.0973	0.8921	0.2974	

Source: Authors' calculations.

Note: Weights are normalized such that the sum of them is unity. Abbreviations: the Convergence Index (ci), the in-AP regional imports and exports share (trade), the in-AP regional FDI inflow share (fdi), and the in-AP regional tourists share (tour).

Figure 5. Convergence index of Asia-Pacific region

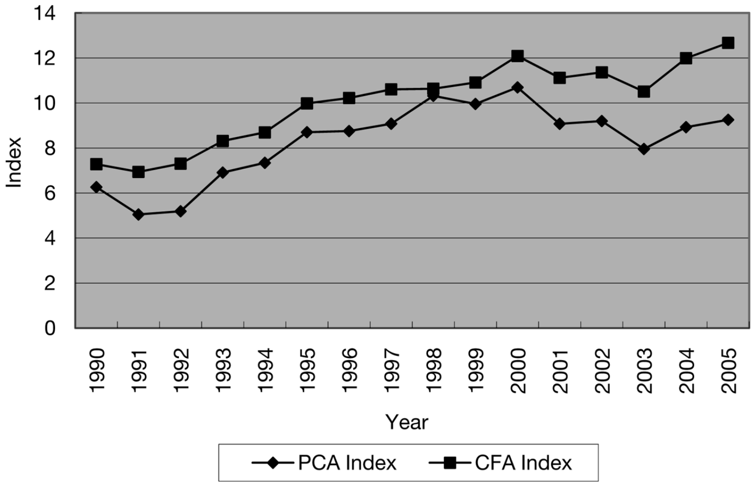


Source: Authors' calculations.

The sample economies' integration indexes are shown in Table 4. Due to space limitations, only six sample economies are reported (the United States, Canada, China, Japan, Thailand, and Australia).

According to the integration index reported in Table 4, Australia and Thailand were the most integrated of the six economies throughout the period 1990 to 2005. Japan's integration level has fluctuated through the period but seems to have picked up since 2003. China is consistently below the average level of integration for the region as a whole, which may reflect the country's more intensive ties with Hong Kong and Chinese Taipei, as well as China's substantial trade and investment links with the EU. NAFTA economies are the least integrated in the AP region, likely because of the bias toward trade and investment within North America. Interestingly, the U.S.

Figure 6. Composite index of Asia-Pacific economic integration



Source: *Authors' calculations.*

Table 4. Integration index of representative economies and the AP region

	United States	Canada	PRC	Japan	Thailand	Australia	AP region
1990	5.92	−8.81	−9.62	10.89	29.62	18.35	6.26
1991	5.00	−11.81	−9.13	12.09	27.22	24.61	5.05
1992	2.55	−11.71	−8.68	13.87	28.82	28.71	5.19
1993	4.73	−6.75	−6.08	16.18	32.69	26.47	6.91
1994	4.04	−2.27	−3.81	15.03	30.64	31.55	7.34
1995	9.35	0.58	−5.51	13.18	33.41	35.69	8.70
1996	9.20	3.01	−6.55	12.50	35.65	41.88	8.75
1997	10.08	1.64	−6.58	12.87	35.43	37.66	9.08
1998	7.53	5.98	−5.53	12.00	35.47	36.83	10.32
1999	6.95	5.84	−6.69	13.03	35.32	36.97	9.96
2000	8.84	8.25	−5.96	13.39	38.62	43.21	10.69
2001	8.93	11.80	−6.09	12.63	37.26	41.95	9.08
2002	6.69	11.64	−4.96	14.31	36.07	42.30	9.20
2003	6.87	9.04	−3.93	13.84	36.06	39.15	7.96
2004	6.88	12.14	−3.50	15.48	38.56	39.85	8.93
2005	5.97	11.94	−2.44	16.69	39.37	40.10	9.26

Source: *Authors' calculations.*

integration level reached a high in 1997, coinciding with the Asian financial crisis, and has been falling since.

Table 5 reports on the composite index and its sub-indicators for a single economy, using Canada as an example. Canada's economic integration with the AP region increased from a level of −8.81 in 1990 to 11.94 in 2005, albeit with some volatility. The rise in Canada's integration index can be mainly attributed to a convergence of key

Table 5. The economic integration index of Canada

	Convergence index (0.36)								
Year	gdp (0.17)	nagi (0.22)	urb (0.09)	life (0.18)	edu (0.34)	Trade (0.24)	FDI (0.10)	Tour (0.29)	CEII
1990	−47.45	4.77	37.54	−29.60	−138.5	5.37	1.84	33.07	−8.81
1991	−37.85	6.07	38.49	−25.34	−169.1	5.37	1.07	32.21	−11.81
1992	−35.70	12.69	39.41	−14.87	−180.8	5.70	0.67	32.54	−11.71
1993	−36.95	22.95	39.29	−16.61	−145.4	5.79	2.34	32.22	−6.75
1994	−45.50	25.03	41.27	−13.52	−121.3	6.06	2.32	37.69	−2.27
1995	−49.08	28.29	42.19	−12.59	−120.7	6.91	2.16	46.09	0.58
1996	−46.47	33.48	42.49	−10.13	−117.8	6.09	1.23	51.61	3.01
1997	−50.15	34.19	42.79	−8.16	−115.6	6.39	0.88	46.08	1.64
1998	−73.19	33.87	43.16	−5.31	−45.53	6.03	2.40	36.23	5.98
1999	−87.5	35.25	43.5	−5.89	−42.37	5.83	0.56	38.04	5.84
2000	−96.02	39.60	43.85	−3.12	−28.48	6.07	1.05	40.17	8.25
2001	−107.0	41.35	44.98	−2.23	12.83	5.64	2.66	36.67	11.80
2002	−112.4	41.05	46.15	−0.75	12.30	5.81	3.82	36.57	11.64
2003	−115.3	41.43	44.96	1.08	17.77	5.51	0.15	27.24	9.04
2004	−115.9	41.7	46.1	3.67	14.9	6.72	1.85	36.71	12.14
2005	−125.0	45.48	47.22	4.67	12.68	6.91	0.19	37.94	11.94

Source: *Authors' calculations.*
Note: *The values in parentheses are the indicator weights of the CI or CEII. Please refer to Tables 2 and 3 for the abbreviations of the indicators. CEII denotes the Composite Integration Index (CEII).*

indicators with the AP average (except real GDP per capital), and to the recent rise in the AP region's share of Canada's trade and investment.

Table 6 reports the ranking of AP economic integration for the 17 AP sample economies. The relative ranking of AP economies has not changed significantly over time. Singapore, Hong Kong, and Chinese Taipei are consistently ranked as the economies most closely integrated with the AP region and Indonesia and China are among the least. Table 6 also shows that the top five economies that have integrated most rapidly with the AP region between 1990 and 2005 are Hong Kong, New Zealand, Vietnam, Korea, and Australia, whereas the bottom five are Chinese Taipei, Chile, Indonesia, Mexico, and Singapore. Vietnam's ranking has risen consistently over the period. Even though Singapore is at the bottom in terms of its pace of integration with the region, it is still the economy most integrated with the AP. The table shows that only 5 out of 17 economies were less integrated with the AP region in 2005 than in 1990.

5. Discussion

5.1 Robustness

We test the robustness of our index by re-computing the index using CFA. Using the software program SAS 9.1, we select the two "common factors" that capture most of the variations in the observed indicator set. The overall loadings of each indicator in

Table 6. Ranking of the economic integration with the Asia-Pacific market

Asia-Pacific economies	1990 CEII	1990 Ranking	1997 CEII	1997 Ranking	2005 CEII	2005 Ranking	1990–2005 Integration improvement	1990–2005 Ranking
Hong Kong, China	56.11	3	69.03	3	114.85	2	58.74	1
New Zealand	29.32	7	47.6	5	61.1	5	31.78	2
Vietnam	−19.44	17	−5.07	15	8.58	14	28.02	3
Republic of Korea	41.42	5	43.73	6	63.69	4	22.27	4
Australia	18.35	9	37.66	7	40.1	7	21.75	5
Canada	−8.81	14	1.64	14	11.94	11	20.75	6
Thailand	29.62	6	35.43	8	39.37	8	9.75	7
P.R. China	−9.62	15	−6.58	16	−2.44	16	7.18	8
Japan	10.89	11	12.87	12	16.69	10	5.8	9
The Philippines	8.35	12	15.34	11	11.65	12	3.3	10
Malaysia	45.93	4	55.16	4	48.55	6	2.62	11
United States	5.92	13	10.08	13	5.97	15	0.05	12
Chinese Taipei	75.58	2	89.91	2	74.95	3	−0.63	13
Chile	25.76	8	29.15	9	25.07	9	−0.69	14
Indonesia	−15.69	16	−16.55	17	−21.35	17	−5.66	15
Mexico	17.78	10	17.37	10	11.22	13	−6.56	16
Singapore	307.45	1	255.77	1	265.51	1	−41.94	17

Source: *Authors' calculations.*

Note: *CEII means Composite Integration Index.*

the convergence and composite indices are given by the final communality estimates, which are the proportion of variance of the variables, accounted for by the common factors. To make the CFA indices comparable to the PCA indices, the weights are calculated by normalizing the loadings such that the sum of the weights in CFA is also unity as is in PCA. The weights of convergence indicators are 0.2031, 0.1927, 0.1423, 0.2101, 0.2517 for real GDP per capita, the non-agriculture sectoral share (to GDP), the urban resident ratio, the life expectancy, and the education expense share (to GNI), respectively; and the weights in final composite index are 0.2302, 0.3026, 0.1643, 0.3029 for convergence index, trade share, FDI share, and tourism share, respectively. The weights derived by CFA are not significantly different from those using PCA. Figures 5 and 6 also plot the convergence and composite index obtained from CFA. Both convergence index and composite integration index obtained from CFA largely resemble the two indices obtained from PCA. The overall similarity reveals that our indices are stable in terms of their dynamic pattern under the alternative methodologies of CFA and PCA.

Compared to the original version of the AP economic integration index first published in Chen and Woo (2008), this paper introduces two improvements. First, we removed from the convergence index one of the original measures (gross capital formation ratio) and replaced it with two other indicators (life expectancy and education expense ratio). We had originally included the gross capital formation ratio (to GDP) because of the role that investment plays in (potential) GDP growth. How-

Table 7. Comparison of the weights in previous and current work

Convergence index			Composite integration index		
Indicator	**Weight (p)**	**Weight (c)**	**Indicator**	**Weight (p)**	**Weight (c)**
gdp	0.1621	0.1744			
nagri	0.1415	0.2150	ci	0.1686	0.3596
gcf	0.4325	—	trade	0.2650	0.2432
urb	0.2639	0.0910	fdi	0.3144	0.1027
life	—	0.1844	tour	0.2519	0.2945
edu	—	0.3352			
nobs	240	272	nobs	240	272

Source: *Authors' calculations and Chen and Woo (2008).*

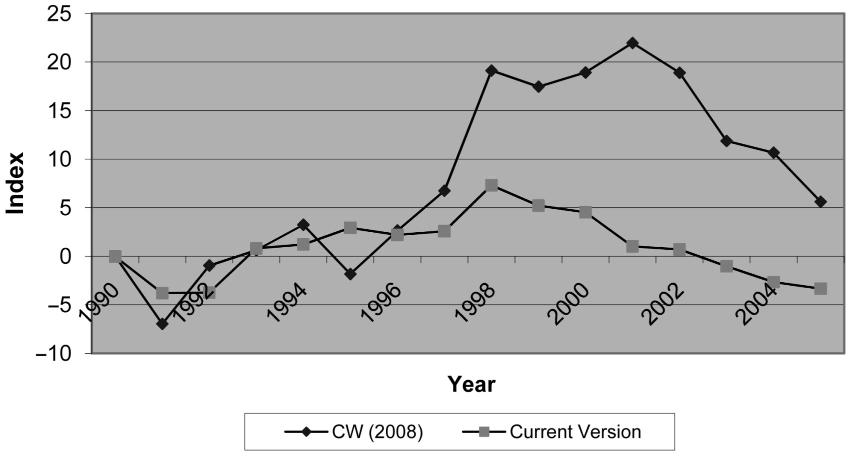
Note: *Weights are normalized such that the sum of them is unity. gcf = the absolute deviation of the gross capital formation ratio. Please refer to Tables 2 and 3 for the other abbreviations. p = previous version (Chen and Woo 2008); c = current version.*

ever, this indicator may seriously understate investment in developed countries due to the several reasons. The first is that the gross capital formation does not capture investment in human capital. The second reason is that gross domestic capital formation does not capture outward investment that can result in higher productivity for the economy as a whole.

We have also improved on Chen and Woo (2008) by adding two indicators that are more relevant to the convergence/divergence measure. The education expense share (to GNI) is a proxy for investment in human resources, which is an essential input to productivity enhancement and economic growth. We also include life expectancy, which captures overall population welfare. The left half of Table 7 compares the convergence weights in Chen and Woo (2008) with the current version. When the capital formation indicator is replaced by life expectancy and education expense, the education expense has the highest weight (33.52 percent) and the urban resident ratio weight drops from 26.39 percent to 9.10 percent. In Figure 7, we see that the original convergence index is insensitive to the Asian financial crisis of 1997–98 whereas the revised index takes a fall because of the growing divergence of economies in the AP region.

Second, we modify the FDI indicator in the composite integration index. Chen and Woo (2008) measures the FDI indicator by taking the ratio of FDI inflow with respect to GDP. This measure, however, suffers from measurement bias. Developed economies typically have a much higher FDI outflow than inflow (the United States, however, is a notable exception); hence regional integration may be understated if only FDI inflows to developed countries are considered. Furthermore, FDI, as a form of investment, should be compared to the gross capital formation (total physical investment). Therefore, in this paper we use the ratio of FDI inflow and outflow to the gross capital formation. The right half of Table 7 compares the index weights in

Figure 7. Comparison of the convergence index



Source: *Authors' calculations and Chen and Woo (2008).*

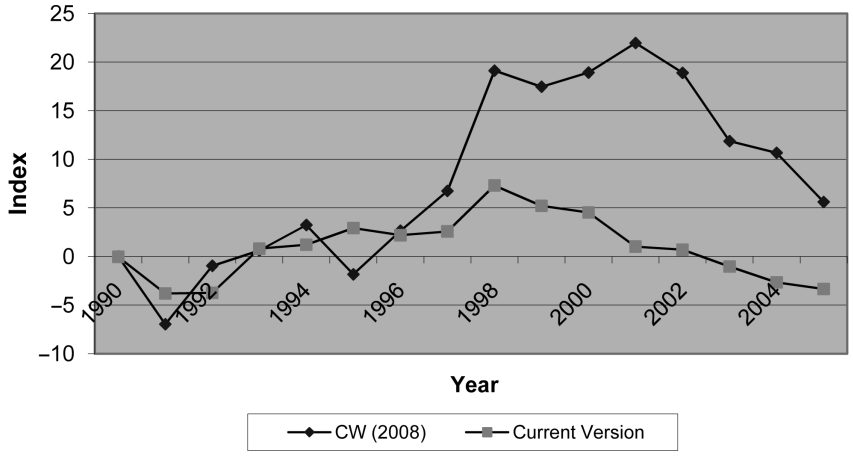
Chen and Woo (2008) with the weights used in this paper. The ranking of economies does not change much between the two indices. Indonesia, however, is an exception in that its ranking falls from the 10th (out of 15 economies) in Chen and Woo (2008) to 17th (out of 17 economies) in this paper. Finally, Figure 8 compares the composite indices in this paper and in Chen and Woo (2008).

5.2 Time-varying weights and the 2006 index

One of our goals in constructing an index of economic integration in the AP region is to create a measure that allows for periodic updates, as new data become available. Producing such an update usually results in time-varying weights of indicators as the relative importance of these indicators change over time. Time-varying weights are hard to adopt in the non-parametric approaches, but they are relatively easy to apply in parametric approaches. Of course, indices that are based on different weights are not directly comparable. Hence, there is a further need to create what is known as the "chained index." The chain index is widely applied in dynamic indices that involve time-varying weights.

We highlight the use of the chain index by updating observations for the eight indicators. To highlight the dynamic change in the index structure caused by more recent observations, we drop the 1990 data and focus on the period 1991 to 2006. Table 8 shows the new weights in comparison with the old weights. In the convergence index, the new weights on the non-agriculture sectoral share, the urban resi-

Figure 8. Comparison of the composite integration index



Source: *Authors' calculations and Chen and Woo (2008).*

dent ratio, and life expectancy are similar to the previously calculated weights. The weight on real GDP per capita has decreased, and that of the education expense share has risen by almost the same amount. In the composite index, the new weight for the convergence index drops more than 12 percent compared to the old calculation. As a result, the weights on the flow indicators (trade, FDI, and tourism) all increase.

The next step is to obtain the 2006 index, which is chained to the 2005 index. Specifically, our chained index is calculated by equation (6),

$$I_t = \sqrt{\left(\frac{\sum w_{t-1} v_t}{\sum w_{t-1} v_{t-1}}\right)\left(\frac{\sum w_t v_t}{\sum w_t v_{t-1}}\right)} \times I_{t-1} \tag{6}$$

where I is the index value, w and v refer to the weights and values of indicators, respectively, and the subscript t denotes the time (2006). Table 9 compares the 2006 chained convergence index and composite index with the 2005 values.

6. Conclusion

This paper measures economic integration in the Asia-Pacific region with a composite index. The weights of the index are obtained from a two-stage PCA. In the first stage, we compute a convergence index to measure the dispersion of the main mac-

Table 8. Comparison of time-varying weights

Convergence index			Composite index		
Indicator	**Old weights**	**New weights**	**Indicator**	**Old weights**	**New weights**
gdp	0.1744	0.2175	ci	0.3596	0.2370
nagri	0.2150	0.2184	trade	0.2432	0.2951
urb	0.0910	0.1005	fdi	0.1027	0.1094
life	0.1844	0.1715	tour	0.2945	0.3585
edu	0.3352	0.2921			

Source: *Authors' calculations and Chen and Woo (2008).*

Note: *Old weights and new weights are derived from data during 1990–2005 and 1991–2006, respectively. Please refer to Tables 2 and 3 for the indicator abbreviations.*

Table 9. Comparison of 2005 and 2006 indices

Index	Convergence index		Composite index		
Economy	**2005**	**2006 (chained)**	**2005**	**2006 (chained)**	**Ranking**
Indonesia	−81.37	−76.08	−21.35	−20.22	17 (17)
Singapore	−12.68	−25.05	265.51	268.68	1 (1)
Thailand	−0.02	−0.49	39.37	37.56	8 (8)
Malaysia	13.09	17.97	48.55	49.08	6 (6)
Philippines	−24.14	−30.54	11.65	8.39	14 (12)
Vietnam	−53.75	−52.48	8.58	9.40	13 (14)
United States	−8.59	−4.51	5.97	6.03	15 (15)
Mexico	25.69	26.18	11.22	12.22	12 (13)
Canada	−2.61	−4.87	11.94	15.09	11 (11)
P.R. China	−35.03	−37.74	−2.44	−4.48	16 (16)
Hong Kong, China	−18.19	−24.94	114.85	118.51	2 (2)
Chinese Taipei	17.25	8.59	74.95	97.91	3 (3)
Rep. of Korea	68.14	72.06	63.69	66.97	5 (4)
Japan	5.61	9.61	16.69	19.39	10 (10)
Australia	9.82	13.08	40.10	43.76	7 (7)
New Zealand	−11.28	−3.27	61.10	70.58	4 (5)
Chile	51.19	49.90	25.07	26.18	9 (9)
AP Region	−3.35	−3.40	9.26	9.72	—

Source: *Authors' calculations and Chen and Woo (2008).*

Note: *In the last column, numbers outside (inside) parentheses refer to 2006 (2005) rankings.*

roeconomic indicators of a sample of AP economies. In the second stage, we combine the indicators of trade, FDI, and tourism with the convergence index to generate the composite index.

We find that economic convergence in the AP region was climbing until 1998 but has weakened in subsequent years. The broader economic integration index increased in the 1990–2000 period, fell in the 2000–03 period, and then increased from 2003 to 2006. Among the 17 sample economies, Singapore, Hong Kong, and Chinese Taipei are the most integrated economies with the AP region and Indonesia and China are the least integrated.

Caution should be exercised in the interpretation of these findings. The measures chosen for inclusion in the composite index are imperfect indicators of "convergence" and trade/investment integration. The rankings in turn should not be read normatively as "league tables" in the sense that a higher ranking is superior to a lower ranking. Indeed, a low ranking may simply indicate that an economy is more oriented globally than regionally, as is likely the case for China.

Nevertheless, the change in index value for a given economy over time can be read as a measure of its changing economic orientation. The index value for the region as a whole can also be seen as a measure of closer economic ties among AP economies and as one indicator of APEC's success.

References

Acharya, Ram C., Someshwar Rao, and Gary Sawchuk. 2002. Building a North American Integration Index: An Exploratory Analysis. Working paper. Washington, DC: Center for Strategic and International Studies.

Andersen, Torben M., and Tryggvi Thor Herbertsson. 2003. Measuring Globalization. IZA Discussion Paper No. 817. Bonn: Institute for the Study of Labor (IZA).

Batra, Amita. 2007. Asian Economic Integration: ASEAN+3+1 or ASEAN+1s? *ASEAN Economic Bulletin* V24 (2):181–204.

Bhandari, Amit K., and Almas Heshmati. 2005. Measurement of Globalization and Its Variations among Countries, Regions and over Time. IZA Discussion Paper No. 1578. Bonn: Institute for the Study of Labor (IZA).

Cahill, Miles B., and Nicolas Sanchez. 2001. Using Principal Components to Produce an Economic and Social Development Index: An Application to Latin America and the United States. *Atlanta Economic Journal* 29 (3):311–329.

Chen, Bo, and Yuen Pau Woo. 2008. A Composite Index of Economic Integration in the Asia-Pacific Region. In *A Decade of Developments,* edited by Masahiro Kawai and Susan F. Stone, pp. 163–181. Tokyo: Asian Development Bank Institute.

Cheong, Inkyo. 2003. Regionalism and Free Trade Agreements in East Asia. *Asian Economic Papers* 2 (2):145–180.

Dreher, Axel. 2006. Does Globalization Affect Growth? Evidence from a New Index of Globalization. *Applied Economics* 38 (10):1091–1110.

Heshmati, Almas. 2006. Measurement of a Multidimensional Index of Globalization. *Global Economy Journal* 6 (2):Article 1.

Heshmati, Almas, and Jong-Eun Oh. 2005. Alternative Composite Lisbon Development Strategy Indices. IZA Discussion Paper No. 1734. Bonn: Institute for the Study of Labor (IZA).

Hotelling, Harold. 1933. Analysis of a Complex Statistical Variables into Principal Components. *Journal of Educational Psychology* 24:417–441.

Kearney, A.T., Inc., and the Carnegie Endowment for International Peace. 2002. Globalization's Last Hurrah? *Foreign Policy* January/February:38–51.

Kearney, A.T., Inc., and the Carnegie Endowment for International Peace. 2003. Measuring Globalization: Who's Up, Who's Down? *Foreign Policy* January/February:60–72.

Keohane, Robert O., and Joseph S. Nye, Jr. 2000. *Governance in a Globalizing World* (Introduction), pp. 717–737. Washington, DC: Brookings Institution Press.

Lockwood, Benjamin. 2004. How Robust Is the Foreign Policy-Kearney Globalization Index? *The World Economy* 27:507–523.

Mishra, Sudhanshu Kumar. 2007. A Comparative Study of Various Inclusive Indices and the Index Constructed by the Principal Components Analysis. MPRA Paper No. 3377. University Library of Munich, Germany.

Pearson, Karl. 1901. On Lines and Planes of Closest Fit to Systems of Points in Spaces. *Philosophical Magazine* 2:559–572.

Shin, Kwanho, and Yunjong Wang. 2004. Trade Integration and Business Cycle Synchronization in East Asia. *Asian Economic Papers* 2 (3):1–20.

Steiger, James H. 1979. Factor Indeterminacy in the 1930s and the 1970s: Some Interesting Parallels. *Psychometrika* 44:157–167.

Stevens, James P. 1992. *Applied Multivariate Statistics for the Social Sciences* (2nd edition). Hillsdale, NJ: Erlbaum.

Wakasugi, Ryuhei. 2007. Vertical Intra-Industry Trade and Economic Integration in East Asia. *Asian Economic Papers* 6 (1):26–45.

Yung, Chul Park. 2007. Whither Financial and Monetary Integration in East Asia? *Asian Economic Papers* 6 (3):95–128.