Chapter 10

Enhanced Measurement of Energy Market Integration in East Asia: An Application of Dynamic Principal Component Analysis

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CHAPTER 10

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As a part of the initiatives to enhance cooperation between ASEAN and its dialogue partners, the energy market integration (EMI) in East Asia has been under way for over a decade. Despite the efforts exerted by countries in the East Asia Summit (EAS) region, little research has been done to measure the extent of the EMI's progress. This paper innovatively applies the dynamic principal component analysis to measure EMI and its evolution in the EAS region between 1995 and 2011. The EMI is measured from all the five dimensions that have been identified in literature: (1) energy trade liberalisation; (2) investment liberalisation; (3) energy infrastructure development; (4) domestic market openness; and (5) energy pricing liberalisation. Results show that significant progress has been made for the EMI in the EAS region, although there are cross-country disparities in different aspects. According to the level of progress made in the past, further efforts towards EMI in general should focus on liberalising national markets, then phasing out fossil fuel subsidies and finally, liberalising investment regime. Some mechanisms have to be developed to keep national level market liberalisation under monitoring. Certain countries that lagged behind in EMI may have to catch up and learn from either their past experiences or from other nations as well as focus their efforts on their relatively weak dimensions.

Key Words: Dynamic Factor Analysis, Energy Market Integration, East Asia
JEL Classification : C1, Q4, R1

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Introduction

Most countries in the East Asia Summit (EAS) region have long been cooperating on energy endeavors to sustain their economic growth. For example, even before the first ASEAN Declaration in August 1967, Thailand and Lao PDR had already signed their own energy agreement. Since 1990, the scope of the regional energy integration has broadened to cover all energy products and went from bilateral to multilateral cooperation. Beyond ASEAN, many institutional cooperation frameworks have emerged in East Asia under the principle of ASEAN centrality in the past decades such as the ASEAN Plus One, ASEAN Plus Three (ASEAN plus China, Japan, and South Korea), and EAS. Considerable progress in the areas of energy security, oil markets, renewable energy, and energy efficiency and conservation has been made as a result of the cooperation through the ASEAN plus Three process and more recently, the EAS process (Shi and Kimura, 2010, 2014; Shi and Malik, 2013).

To further enhance cooperation between ASEAN and its dialogue partners, the implementation of the energy market integration (EMI) in East Asia has been undertaken for over a decade. Energy market integration in the EAS region moved ahead in five areas: (a) trade liberalisation; (b) investment liberalisation; (c) development of regional energy infrastructure and institutions; (d) liberalisation of domestic energy markets; and (e) energy pricing reform---in particular, the removal of fossil fuel subsidies (Shi and Kimura, 2010; 2014).

So that governments can be guided on the right policies on EMI, there is a need to measure how individual countries are aligned with the EMI dimensions. Despite the efforts already made by countries in the EAS region, little research has been carried out on how to measure the EMI's progress.

Needless to say, there were previous studies that attempted to look at how the EMI fared (Sheng and Shi, 2011, 2013; Yu, 2011). The measure by Yu (2011) is cross-sectional and thus has not demonstrated the dynamics. Without such dynamics, the measurement cannot shed light on what policy initiatives to prioritise. Sheng and Shi (2011, 2013) have succeeded in

measuring the dynamics of EMI, but their studies only focus on two dimensions: trade liberalisation and competitiveness in the domestic markets. Other dimensions of EMI have not been measured. Neither are the dynamics of these dimensions explored because these studies do not concentrate on the involvement of EMI itself.

This paper attempts to use some newly developed statistical methods---namely, the dynamic principle component analysis (dynamic PCA) and the information tree technique---to analyse the progress of EMI across countries and over time. The study aims to build an index system by using the principal component analysis approach to measure the status of the EMI process of each EAS country without knowing the weights for each dimension.

To contribute to the existing literature, this study aims to enhance the measurement of each dimension of the EMI and, for the first time, provide a comprehensive measurement of such integration in East Asia. Breaking down the EMI into such areas as institutional arrangement, physical infrastructure, and energy pricing, etc. helps identify the appropriate policy initiatives to take in the EAS region as well as aids each country's policymakers in determining how they must prioritise their own EMI efforts.

The next section of this study introduces the complexity of the EMI, which underscores the need for concise and clear indicators of its progress. The third section explains the methodology and data, followed by the presentation of the empirical results in Section 4. Section 5 discusses the results and policy implications. The last section provides the conclusions.

Energy Market Integration in the EAS Region

Following a conceptual framework for studying EMI in East Asia as proposed by Shi and Kimura (2010, 2014), this study tries to measure EMI in five areas: (1) trade liberalisation; (2) investment liberalisation; (3) development of regional energy infrastructure and institutions; (4) liberalisation of domestic energy markets; and (5) energy pricing reform (in particular, the removal of fossil fuel subsidies). Shi and Kimura's recent review (2014) finds that a large number of attempts for policy reforms for bilateral/multilateral

trade and investment liberalisation have been made. However, energy trade continues to be restricted by both trade and non-trade barriers. These barriers should be removed so as to achieve freer trade in the EAS region. In particular, investment is restricted in many EAS countries.

Ongoing and proposed energy infrastructure projects have been limited to the ASEAN and China, while institutional arrangements related to energy trade have not been well developed. Also, national leaders still have to resolve major challenges, such as the need to further liberalise the domestic energy market and remove fossil fuel subsidies.

Given the above framework, this section next summarises the latest developments on EMI in East Asia.

To start with, trade liberalisation has been strongly promoted in East Asia, with the ASEAN playing a leading role. By 2010, more than 99 percent of the tariff lines had been eliminated in the ASEAN-6 members; namely, Brunei, Indonesia, Malaysia, the Philippines, Singapore, and Thailand, and reduced steadily in the newer members Cambodia, Laos, Myanmar, and Viet Nam. As for energy trade, tariffs in mineral fuels were reduced dramatically between 1993 and 2010 (Okabe and Urata, 2012). The ASEAN has also entered into free trade agreements (FTAs) or economic partnership agreements (EPAs) with countries outside ASEAN, and has established FTAs with the Plus Six countries (Australia, China, India, Japan, South Korea, and New Zealand) (ASEAN, 2012). The ASEAN is also working towards the Regional Comprehensive Economic Partnership (RCEP), also known as ASEAN++ FTA. In East Asia as a whole, while trade in energy remains restricted by tariffs, the levels of tariffs substantially declined in the period 1995-2010 (Shi and Kimura, 2014).

A recent study on investment liberalisation in ASEAN countries (Intal *et al*., 2011) shows that the foreign investment regime on the overall is relatively open, with five ASEAN members-states (AMSs) having overall liberalisation rates between 88 percent and 92 percent; three AMSs with a liberalisation rate of around 85 percent; and two others hovering around the 80 percent rate. Of the ASEAN countries, Malaysia, Cambodia, and the Philippines boast the most open foreign investment regime, followed closely by Thailand

and Brunei, while Viet Nam and Indonesia have the most restrictive regimes. The restrictions on investment are often embedded in domestic regulations and thus cannot be resolved by international agreements alone (Shi and Kimura, 2014).

Proposed energy infrastructure projects are concentrated within the ASEAN region plus China, partly because the other Plus Six countries of the ASEAN, excluding India, are somewhat physically disconnected. However, with the development of more infrastructure such as marine transportation and liquefied natural gas (LNG) terminals, networks of energy infrastructure may be expanded to other countries, such as the Philippines and Australia in the case of LNG.

In general, there is still a long way to go in terms of interconnectivity and trade in the EAS electricity sector. The EAS lags behind Europe, where physical cross-border exchanges of electricity reached 10.3 percent of consumption in 2005 (Wu, 2012). Very little progress has been made towards harmonising technical specifications for the electricity trade, including design and construction standards, system operation and maintenance codes and guidelines, safety, environment, and measurement standards (Shi and Kimura, 2010, 2014).

Energy market liberalisation has been implemented in Australia, Japan, India, New Zealand, the Philippines, and Singapore. Meanwhile, in other countries, energy markets remain more or less restricted (Shi and Kimura, 2014). In terms of market integration, most EAS members are yet to develop a national electricity market. Meanwhile, when viewed in terms of their integration and unbundling of business activities, one end of the spectrum has Australia, New Zealand, and Singapore, where generation, transmission, distribution, and retailing operations have been fully disaggregated. The other end of the spectrum has Brunei, which has a fully integrated and stated-owned electricity sector. Meanwhile, China and India have kept the retailing and distribution operations integrated but separated the generation and transmission operations (Wu, 2012).

Within the ASEAN, the only country with a competitive electricity market is Singapore. Countries such as Malaysia and Thailand have deregulated the

supply side but without a power purchase pool, while the Philippines has power pools in certain parts of the electricity network. Others such as Brunei and Lao PDR have strong stated-owned utility companies. In the gas sector, the transmission pipeline is usually owned and regulated by state-owned companies (Sahid *et al*, 2013).

Pricing reforms---in particular, the removal of energy subsidies---have been supported by policymakers and attempted by some countries. Energy prices are now broadly liberalised in Australia, Japan, South Korea, New Zealand, and the Philippines. The APEC leaders have declared that they would rationalise and phase out fossil fuel subsidies over the medium term (APEC, 2009).

Nations such as China, India, Indonesia, Malaysia, and Viet Nam have either planned or taken the initial steps to liberalise energy prices and remove subsidies for fossil energy. In China, its government is currently cutting the energy subsidies and promoting market-determined energy prices. In fact, China has implemented a market-based pricing for coal for the past few years (Yu, 2008). Malaysia plans to cut its fuel subsidies under a proposed five-year plan starting from 2010 (*The Straits Times*, 2010). In Viet Nam, although a road map for energy price increases has been formulated, the implementation has so far lagged behind (Kimura, 2011). Meanwhile, the Indonesian government planned a gradual reduction of total subsidies by an average of 10 percent to 15 percent per year from 2011 to 2014 (Mourougane, 2010), but the first attempt in March 2012 failed. In general, the removal of fossil fuel subsidies is a politically sensitive topic, as Indonesia and Malaysia had learned (*The Straits Times*, 2010). Therefore, the pricing reform has to be carefully planned and managed.

Due to economic development disparities, energy resource endowment, government regime and tradition, different countries have different situations for each dimension of the EMI. Furthermore, given the number of dimensions and diversification in each dimension, it is difficult for policymakers to comprehend what have been done and what still has to be done. The development of a quantitative assessment methodology will be useful for policymakers to monitor the progress of the EMI.

The next section of this paper proposes a methodology for quantifying the progress of EMI. These quantitative scores can then be used by policymakers as an indicator to measure their own work against and to identify leading policies that can be implemented in their own countries.

Methodology: Dynamic Principal Component Analysis

The principal component analysis (PCA) is a method to identify patterns in data and to express the data in a way that highlights their similarities and differences. The method seeks the linear combinations of the original variables such that the derived variables capture maximal variance. In particular, as highlighted by Shlens (2005), it can be completed via singular value decomposition (SVD) of the data matrix. Since patterns can be hard to find in data of high dimension (i.e., where the luxury of graphical representation is not available), the PCA is a powerful analytical tool that allows one to form a comparable index across countries under the condition that there is no explicit weight available. Detailed mathematical derivations on this can be read from previous papers of Sheng and Shi (2011, 2013), and Song and Sheng (2007). Meanwhile, this section will proceed to explain how a dynamic PCA analysis can be applied to measure the EMI process in the EAS region.

The Basic Model: A Dynamic PCA Analysis

To date, the static PCA method has been widely used in policy analysis (Shlens, 2005). Examples can be seen in Sheng and Shi (2011, 2013), Song and Sheng (2007) and Yu (2011). However, there are some difficulties in applying the method to measure the EMI's process in the EAS region from the empirical perspective. This is partly because the concept of EMI may involve too much information originating from different dimensions, plus the unknown potential effects on the final measurement can continue to change over time.

To solve this problem, statisticians developed a simple method called the dynamic PCA analysis or the dynamic factor analysis, to construct an index

with the unknown weights for aggregating various driving factors. Mathematically, such a measurement of the EMI can be simplified into the following two-equation model

$$EMI_t = \lambda(L)F_t + e_t \quad (1)$$

$$F_t = \Psi(L)F_{t\mathbf{1}} + \eta_t \quad (2)$$

where EMI_t represents the unique measure of (or an outcome index for) EMI at time t capturing all the potential determining factors; F_t is a vector of n variables ($f_{\mathbf{1}}, f_{\mathbf{2}}, \cdots, f_n$) representing various possible factors that could affect or determine the progress of EMI; z $\lambda(L)$ is a coefficient matrix that represents the potential contribution of various factors at different time period t to the EMI measure. The model defined by Equations (1) and (2) significantly differs from the previous studies in that it considers the fact that all the EMI determining factors are changing over time. Thus, these factors' changing pattern over time must be restricted. In doing so, $\Psi(L)$, the matrix used to define the trans-temporal movement of each determining factor, is specified. Finally, it is to be noted that both $\lambda(L)$ and $\Psi(L)$ are unknown and can change over time and thus, should be retrieved from the real data.

Applying the above model to practice may incur a problem called "curse of dimensionality". In other words, since there are two dimensions in the structure of determining factors ($f_{\mathbf{1}}, f_{\mathbf{2}}, \cdots, f_n$)---the cross-section dimension (i.e., $r_{\mathbf{1}}, r_{\mathbf{2}}, \cdots, r_n$) for different countries or regions, and the time series dimension (i.e., $t_{\mathbf{1}}, t_{\mathbf{2}}, \cdots, t_n$)---one cannot use the unconstraint entropy method to retrieve the weights for each determining factor along the two dimensions. Thus, two assumptions have to be made: (1) that each pair of cross-sectional observations is independent of each other; and (2) that the residual of the EMI measure is time contingent. The two assumptions can be further defined in two equations as
can be further defined in two equations as

$$E(e_t\eta'_{t-k}) = 0 \text{ for all } k \quad (3)$$

$$E(e_{it}e_{js}) = 0 \text{ for all } s \text{ if } i \neq j \quad (4)$$

Estimation of Equations (1) and (2) can be made either by using the maximum likelihood estimation combined with the Kalman Filter (Sargent and Sims, 1977) or by using the extraction of principal components (Stock and Watson, 2002). Recently, some studies (for example, Angelini et al., 2008) further suggest that the two methods be combined for a more efficient estimation---a process that is defined as the dynamic PCA or the dynamic factor analysis.

In the newly proposed estimation method, the fundamental difference is that determinant factors and their lags will be explicitly considered as the state vector such that the two-equation estimation system (i.e., Equations 1 and 2) is transformed into a three-equation system:

$$EMI_t = \mathbf{\Lambda} F_t + e_t \quad (5)$$

$$\mathbf{\Phi}(L)F_t = G\eta_t \quad (6)$$

$$d_i(L)e_t = v_{it} \quad (7)$$

where i refers to the i th determinant factor. Estimation of Equations (5) to (7) may take three steps.

First, one may apply the static PCA method to the panel data to estimate the biased contribution matrix $\mathbf{\Lambda}$. In doing so, all information from cross-sectional and trans-temporal dimensions is treated equally. The residual that contains information related to the time-series or trend change can be calculated by using the estimated EMI_t minus $\mathbf{\Lambda} F_t$.

Second, the obtained residuals are used as the dependent variable to regress with various determining factors, so as to identify the uni-variate auto-regressors. Specifically, the time-series analysis method (including the vector auto-regression estimation technique) should be used.

Third, the obtained uni-variate auto-regressors are implemented back to the first step to adjust the observations of all determinant factors and re-do the static PCA analysis. The results obtained would thus be reflecting the trans-temporal change in trend.

Estimation Strategy and Determinant Factors

Given the dynamic PCA method, the next step is to specify the estimation strategy and the determinant factors that should be used to measure the EMI and its changes across countries over time. Because information from different aspects may generate different impacts on the index aggregation process, this study has classified first all EMI determinant factors into different groups. Specifically, an EMI index was measured by aggregating a set of indices, each reflecting the five dimensions of EMI across the EAS countries.

Principal component analysis (PCA) was applied twice in the study:

- First, the PCA was applied to generate five indices for each of the five dimensions of EMI and then again to combine these indices into an overall index of EMI status. Under PCA, each index is a weighted linear combination of the input variables where optimal weights are selected to best account for the variation in the selected variables. This differs from previous studies measuring EMI status, wherein each type of factors is equally weighted in constructing the final index.
- Second, the aggregated index is further added up by using the same procedure to reflect the cross-country disparity in EMI level.. This will provide useful insights into the EMI's dynamic path.

The EMI index scores for each country were standardised between zero and five. A higher overall ranking implies a higher capacity to adapt to change; hence, greater resilience in the face of external pressures. Conversely, regions with low overall scores are potentially more vulnerable to change.

In measuring the EMI index, the information tree technique will be applied to decompose the aggregate index into different components so as to identify the

role of different factors. The method uses a general non-linear function form (i.e., high-rank polynomial series) to build up the causal relationship between the EMI index and its potential determinants. This way, the drivers of EMI and the marginal contribution of each driver can then be identified.

Data and Estimation Strategy

The analytical framework proposed in Section 2 is consistent with that of previous studies (Sheng and Shi, 2011; Yu, 2011). Each of these five dimensions will be measured by at least three variables using dynamic PCA method. Data used for this study mainly comes from *World Development Indicators* (World Bank, 2013), UN Comtrade, and some other data sources. Variables were initially identified through a preliminary scoping study (See Song and Sheng, 2007) and selected based on the discussion on EMI process in Kimura and Shi (Shi and Kimura, 2010, 2014). These variables generally reflect the status of EMI in each country in the EAS region.

The different cross-country and time-series database come from a total of eight sources, including both censuses and surveys, collected from 1995 to 2011. Twenty variables are then selected based on their ability to intuitively inform one of the five dimensions. These variables, their expected relationship with the measured dimension, and data source are listed in Table 10.1.

Table 10.1: Variables Employed To Measure Each Dimension

Dimension	Variables To Be Used	Expected Sign	Source
Energy trade liberalisation	Mean of fuel trade	+	UN Comtrade
	Trade efficiency	+	Sheng & Shi, 2011
	MFN tariff	-	UN Comtrade
	Total energy self sufficiency (ESI, 1-1)	-	ERIA ESI
	Energy imports, net (% of energy use)	+	WDI
Investment liberalisation	Domestic credit to private sector (% of GDP)	+	WDI
	Interest rate spread (lending rate minus deposit rate, %)	-	WDI
	Market capitalisation of listed companies (% of GDP)	+	WDI
	Foreign direct investment, net inflows (% of GDP)	+	WDI
Energy Infrastructure (connectivity) development	Electric power transmission and distribution losses (% of output)	-	WDI
	Electric power consumption (kWh per capita)	+	WDI
	Commercial energy access ratio (ESI9-1)	+	ERIA ESI
	Rural population (% of total population)	+	WDI
National market openness	Trade (% of GDP)	+	WDI
	Net taxes on products (current US$)/*data174 GDP (current US$)	-	WDI
	Energy imports, net (% of energy use)	+	WDI
Price marketisation (no energy subsidy)	General government final consumption expenditure (% of GDP)	-	WDI
	Consumer price index (2005 = 100)	+	WDI
	Total natural resources rents (% of GDP)	-	WDI
	Energy use (kg of oil equivalent per capita)	-	WDI

Empirical Results: Measured EMI in the EAS Region

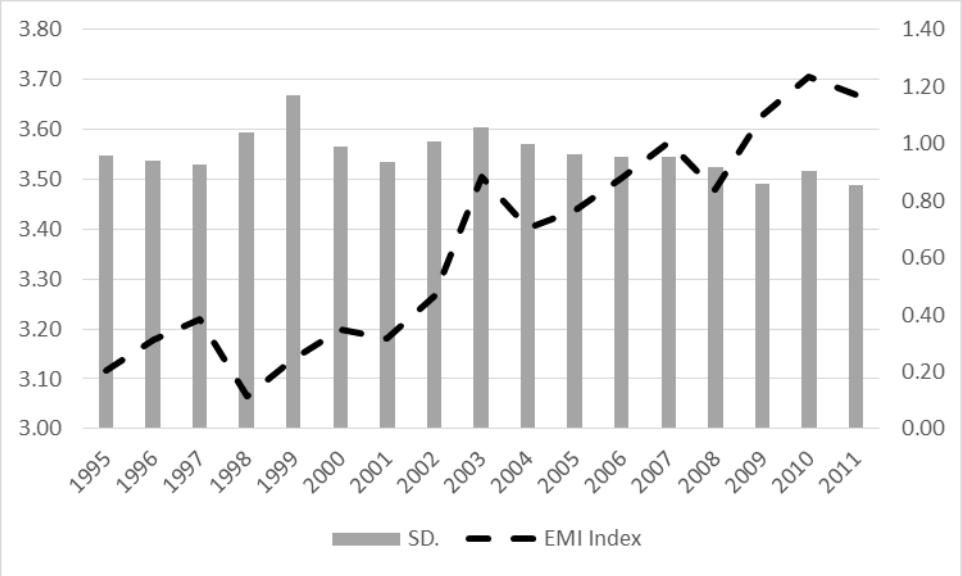
Using the dynamic PCA approach, the index for each EAS country involved in EMI is estimated by using the data from five dimensions (defined in the previous section) from 1995 to 2011. The empirical results on both the aggregate and country-specific measures are presented in Figures 10.1-10.3.

Energy Market Integration in the EAS Region: An Cross-country Overview

Over the past two decades, the energy market in the EAS region has become more and more integrated. The average EMI index (measured by DPCA) has increased from 3.12 in 1995 to 3.67 in 2011 while the standard deviation for the same periods declined from 0.96 to 0.85 (Figure 10.1). This suggests that the extent of integration has significantly improved.

Furthermore, since 2003, the standard deviation of the EMI index has reduced although the average EMI index continues to increase. This implies that member-countries have started to converge toward creating an integrated regional energy market. Incidentally, this was at a time when regional cooperation (in particular, economic and financial cooperation) was at its height following the Asia Financial Crisis. These seemingly related events imply that integration in the energy sector is coinciding with that of the whole regional integration.

Figure 10.1: Average Energy Market Integration in the EAS Region: 1995-2011

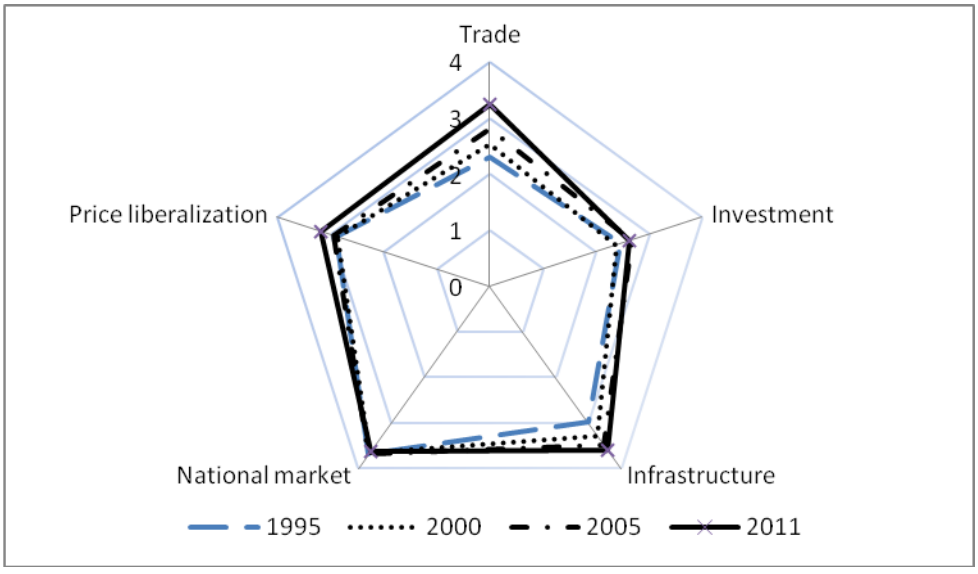


Note: The left axis is for DPCA and the right axis is for SD.

By further decomposing the average EMI index into the five dimensions: (1) energy trade liberalisation; (2) investment liberalisation; (3) domestic energy infrastructure development level; (4) national energy market liberalisation; (5) and price liberalisation level, one finds that the progress in the EMI in the EAS region came from improvements in all these aspects, although different dimensions might have played different roles over different periods of time.

A comparison among the EMI indexes from 1995 to 2011 shows that the EMI indexes for four dimensions (i.e., except national energy market liberalisation) have consistently risen over time (Figure 10.2). This implies that, in general, the improvement in EMI in the EAS region is following a relative balanced path. In particular, the EMI indexes for domestic energy infrastructure and energy trade exhibited a significant increase over time. Energy infrastructure experienced the largest progress from 2000 to 2005, while energy trade liberalisation significantly improved from 2005 to 2011. Meanwhile, price liberalisation and investment liberalisation had progressed during select years only. On the other hand, national energy market liberalisation made no progress during the period under study, which shows domestic market reforms are more challenging than the other four dimensions.

Figure 10.2: Relative Strength in Five Different Fields of Average EMI: 1995-2011



Trans-temporal Change in Country-specific EMI Levels

Given changes in the average EMI level, the next step is to investigate the contribution of each member-country in the regional integration of the energy market.

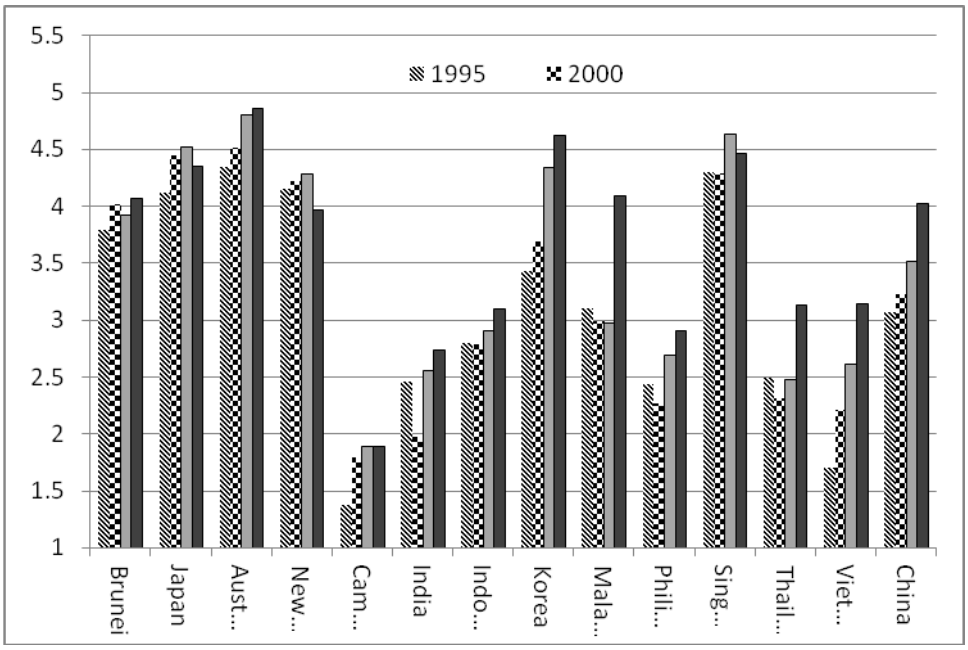
Figure 10.3 compares the EMI index for the 14 EAS countries (Lao PDR and Myanmar were not measured due to data limitations) from 1995 to 2011. Results show that most member-countries positively contributed to this process throughout the period.

In 13 countries (i.e., minus New Zealand), the aggregate EMI index increased during 1995-2011. Most also exhibit a monotonic increase in their EMI index, which means that that the integration has been progressing steadily among EAS member-countries. However, there are a few irregularities. India, Malaysia, the Philippines, and Thailand had a higher EMI index in 1995 that in 2000. Four ASEAN countries---Indonesia, Malaysia, Philippines, and Thailand---experienced a decline in their EMI index in 2000, which could be due to the Asia Financial Crisis.

New Zealand, too, experienced a decline in its EMI index during the sample period, although its 2011 index was higher than that of all ASEAN countries, except Singapore. This suggests that while New Zealand started with a high EMI index rating in 1995, it was not able to sustain its level over time.

Countries that are in the same economic development stages share a similar experience in their market integration efforts in the EAS region. High index levels were recorded in high-income countries（in terms of GDP per-capita）such as Australia, Brunei, Japan, South Korea, New Zealand, and Singapore. Nations that experienced rapid economic growth such as China, India, Thailand, and Viet Nam have also experienced quick improvements in their EMI index. Some ASEAN members such as Cambodia, Indonesia, and the Philippines showed little progress in their EMI index.

Figure 10.3: Comparison of the EMI Index across the EAS Countries in Selected Years



Different countries have achieved different improvements over time. Australia, Japan, and Singapore consistently remained in the Top 4 throughout the sample period. The largest jump in ranking was made by South Korea and Viet Nam, probably due to their more active contributions to regional market integration over the past two decades. On the contrary, New Zealand recorded the biggest decline in ranking. India and Indonesia also fell in ranking, which shows their failure to keep pace with the frontier countries. In comparison, China and Viet Nam managed a relatively higher rank in 2011 (Table 10.2).

Table 10.2: Ranking of EAS Countries, 1995 and 2011

1995 Rank	Country	Index	2011 Rank	Index		Change in Rank
1	Australia	4.350	1	Australia	4.862	
2	Singapore	4.308	2	South Korea	4.621	+4
3	New Zealand	4.151	3	Singapore	4.461	-1
4	Japan	4.128	4	Japan	4.356	
5	Brunei	3.799	5	Malaysia	4.095	+2
6	South Korea	3.434	6	Brunei	4.073	-1
7	Malaysia	3.109	7	China	4.024	+1
8	China	3.072	8	New Zealand	3.970	-5
9	Indonesia	2.806	9	Viet Nam	3.147	+4
10	Thailand	2.501	10	Thailand	3.129	
11	India	2.466	11	Indonesia	3.100	-2
12	Philippines	2.436	12	Philippines	2.908	
13	Viet Nam	1.703	13	India	2.736	-2
14	Cambodia	1.383	14	Cambodia	1.895	

Discussion and Policy Implications

Improvements were seen in all five dimensions of the EMI during the sample period. However, such progress is not balanced among the five dimensions. Trade and infrastructure have been advancing consistently and significant. This is no surprise as infrastructure development has always been aligned with economic development and improvement in quality of life. Infrastructure development is also less controversial than other dimensions of EMI. Trade liberalisation, too, has been progressing well in the EAS region due to the proliferation of free trade agreements.

On the other hand, price liberalisation and investment liberalisation saw little progress from 1995 to 2000 but improved after 2000. Price liberalisation gained some momentum after 2005, which could be due to an increasing awareness on the costs of fossil fuel subsidies and the related surging world oil prices. The political will to remove subsidies has slowly been gaining grounds over the past few years, as evident by APEC and G20 leaders' declarations to phase out fossil fuel subsidies. However, in practice, such fossil fuel subsidies persist, suggesting major challenges ahead.

National market liberalisation, however, saw no progress during the sample period. This means that EMI is mainly constrained by "behind-the-board"

barriers. A liberalised and open domestic market---a prerequisite towards deeper energy integration---is hindered by many domestic factors such as political environment, social acceptance, development level, and government's capability. All these need to be addressed if EMI is to be achieved. Efforts made towards achieving regional EMI will touch on these tough and sensitive issues nowadays. Despite the non-intervene principle of the ASEAN and EAS cooperation, some mechanisms have to be developed to keep national market liberalisation under monitoring.

Most EAS member-countries in the study exhibited a monotonic increase in their EMI index, although some ASEAN countries lagged behind their peers. The high correlation between the EMI index and economic development level suggests that there are significant potentials for regional cooperation among countries at different levels of development.

Conclusion

This paper uses the dynamic principal component analysis to measure the EMI and its change in the East Asia Submit region from 1995 to 2010from five different dimensions. Results show that significant progress has been made in all dimensions of the EMI in the EAS region, although there are cross-country disparities in different dimensions. Furthermore, between 1995 and 2011, the extent of the integration had significantly improved, with all member-countries positively contributing to this process throughout the period.

The study finds that trade liberalisation and infrastructure development have progressed quite well; thus, little extra attention is needed on these. Investment liberalisation, however, needs to gain further momentum, while price liberalisation needs concrete actions to continue the momentum gained after 2005. Thus, the removal of behind-the-board barriers need to be pushed by the regional block.

Areas for future EMI efforts, arranged by priority, are: national market, fossil fuel subsidies, and energy investment. Countries that have lagged behind can also learned from their peers in terms of improving their own EMI levels.

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