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Energy Market Integration and Economic Convergence: Implications for East Asia*

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Abstract: Energy Market Integration (EMI) has been pursued by East Asian countries in recent years, but how it could play a role in facilitating economic growth of countries in the region remains to be an empirical question. This paper uses the economic convergence analysis (including both the σ-convergence and β-convergence approaches) to examine the impact of EMI — measured by two newly constructed indexes (namely, the energy trade index and the energy market competition index) — at the country level, on dynamic economic growth path across countries, with a special interest to inform policy makings related to promoting EMI among East Asian countries. The result shows that a more integrated energy market may significantly reduce income disparity across countries and thus help poor countries to catch up with rich countries in economic development. Moreover, a comparison among the three regions including EU, NAFTA and EAS shows that EAS countries are more likely to achieve economic convergence along with the construction of EMI process. An important policy implication is that less developed countries in the EAS region can increase benefits from actively participating into the EMI process.

Keywords: Economic convergence, energy market integration, principle component analysis, East Asia

JEL Classification: F43; O11; O19; R11

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1. Introduction

Beginning with ASEAN in the 1960s, East Asia has pursued a policy of economic integration. More recently, with the emergence of cooperation frameworks between the Association of Southeast Asian Nations (ASEAN) and its dialogue partners including Japan, South Korea, China, India, Australia and New Zealand[1] (Shi and Kimura, 2010), a policy of energy market integration (EMI) has been undertaken in East Asia. Although significant progress has been made implementing EMI, East Asian policy makers have little information regarding the context of regional EMI and its associated economic impacts.

Moreover, there is an accepted positive theoretical relationship between EMI and regional economic development, but few empirical studies have been carried out to date. The existing literature - although small – verifies this theoretical relationship. Bhattacharya and Kojima (2008, 2010) use a Computable General Equilibrium (CGE) model to analyze EMI (modeled as tariff reduction, investment reallocation and productivity improvement for energy production) and its economic effects among East Asian Summit (EAS) nations. They find the benefits from EMI have generally outweighed costs. More generally, Park (2000), followed by Lee *et al.* (2009) and Lee and Plummer (2010), also use a CGE model to examine economic impacts of regional trade integration on ASEAN and other ASEAN dialogue partners. By using tariff reductions as an indication of trade integration, these studies showed that free trade agreement (including energy products) may generally bring positive economic impact to member countries within the region. This literature has provided useful evidence on the positive economic effects of EMI in East Asia; however, there are three key limitations. First, most analysis has been carried out basing on the CGE models, which cannot examine the direct channels through which positive effects of EMI have been generated. Second, the measurement of EMI has been restricted to tariff cutting, which neglects

[1] The 10 ASEAN member countries, i.e. Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Vietnam, and 6 ASEAN dialogue partner countries, i.e. Australia, China, India, Japan, Republic of Korea and New Zealand are collectively group as East Asia Summit (EAS), which was established in 2005. The US and Russia will join the EAS in 2011. For the current paper, we are still focusing on the 16 countries. In this paper, EAS and East Asia are interchangeable.

changes in real trade of energy products across countries due to other components of EMI such as non-tariff barrier elimination, improvements in market accessibility and market deregulation. Finally, these studies focus on the aggregate impact of EMI and ignore the uneven distribution of EMI's benefits across countries. In particular, these studies cannot inform policy makers on how EMI may play a role in narrowing development gaps (NDG) across countries and thus facilitate economic integration within a region. These shortcomings in the existing literature need to be addressed.

Further exploring the role of EMI in NDG also has important policy implications for boosting economic integration and encouraging member countries' participation, particularly from ASEAN nations. The integration of the EAS region depends on member countries' willingness to participate and on efforts towards forming a unified market, which is determined by the benefits obtained from the integration. NDG allows Less Developed Countries (LDCs) to gain substantial benefits from EMI, to participate in regional cooperation, and ultimately to support economic integration. Full regional economic integration cannot be achieved without the participation of Cambodia, Laos, Myanmar and Vietnam (CLMV), which have a central location in South East Asia and thus are an indispensable part of East Asia. These nations are the poorest in the EAS region and the progress of energy sector reform in CLMV lags behind other EAS countries. NDG can provide additional incentive for the participation of CLMV. Ultimately, the CLMV countries' participation in regional integration will affect the speed, and roadmap of achieving full EMI, and NDG should be given extra attention.

This paper aims to inform policy makers of the potential benefits of EMI from reducing income disparity within the East Asian region. To do so, we use economic convergence analysis to examine the impact of EMI on economic convergence across countries between 1960 and 2008. Contributing to previous literature, we construct two new indexes: the energy trade index and the energy market competition index, to analyze multiple aspects of the EMI process and directly link EMI to regional economic growth. We aggregate bilateral trade flow of energy products adjusted with trade distance to construct the energy trade index and use the Principle Component Analysis (PCA) approach to extract information from a group of different variables to construct the energy market competition index. The research provides useful information on the dynamic path of income disparity across countries resulting from EMI, in particular, the impact of EMI on LDCs' catch-up.

The remainder of the paper is arranged as follows. Section II briefly discusses the progress that EMI has made in the East Asian region and its impact on regional economic development. The channels through which EMI may impose its impact on regional disparity in economic growth are highlighted. Section III presents the methodology, empirical specifications and data. Section IV describes measurement of EMI and two indexes have been created to represent EMI from trade facilitation and energy consumption perspectives. Section V reports the regression results and is followed by discussions and policy implications. In the last section, we make the conclusion.

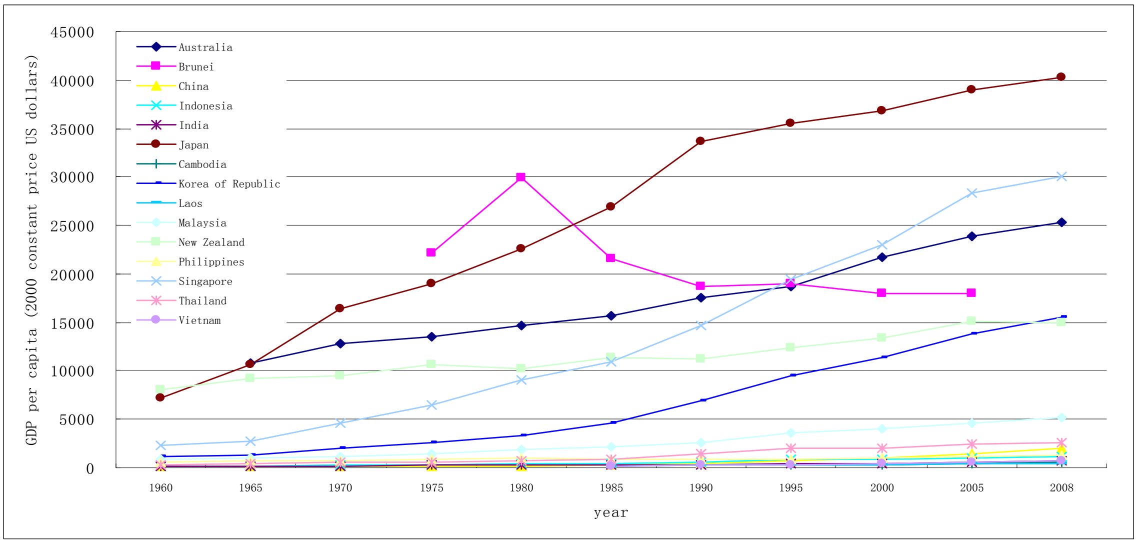
2. Energy Market Integration and Economic Divergence in East Asia

The impressive economic performance of many economies in East Asia over the past few decades had been widely observed and led the world economy. The growth of per capital GDP averaged over 4.0 percent in the major East Asian economies between 1960 and 2008, compared with less than 2 percent in other developing economies and 2.7 percent among the industrial countries (IMF, 2009). East Asia stands out as the only region where living standards are catching up with those in industrial countries, while other parts of the developing world seem to be struggling either to tread water or to fall further behind.

Despite their high rates of economic growth with rapid capital accumulation, the EAS countries have shown huge differences in development level with the CLMV countries at the bottom. In 2008, the current value of Gross National Income (GNI) per capita in Cambodia, Laos, and Vietnam in US$ were 630, 750, 910, respectively, while that in developed EAS countries, Australia, Japan, South Korea and New Zealand in US$ were 41890, 37930, 21570, 26830, respectively (World Bank, 2010). The difference between the richest and the poorest is more than 60 times (See Figure 1).

The CLMV countries are also not industrialized. In 2005, agriculture accounted for 34 per cent of GDP in Cambodia and 19.6 per cent in Vietnam (Kimura, 2010).

Figure 1. GDP per Capita in Real Term across Countries in EAS Region: 1960-2008



Source: World Development Indicator Database (World Bank, 2010).

Using the Human Development Index (HDI) as another measure of relative economic development levels across countries, one can also find that there are huge development gaps in the EAS region. Among 169 countries throughout the world, Australia and New Zealand ranked second and third according to the HDI index, while the CLMV countries ranked below the 110th country. As for education, the average years of schooling in the six countries with the lowest income are less than 6, which is less than half of that in Australia (12.0) and New Zealand (12.5) (Table 1).

Since NDGs across countries is a pre-requisite condition for achieving regional integration, it is therefore important to study how this disparity between EAS nations has developed. Given the relationship between EMI and growth, it is important to examine how EMI may affect economic convergence.

EMI may help LDCs to catch up with rich countries and thus reduce disparity in economic growth across EAS countries through three channels. First, EMI may transform many resource advantages in the LDCs into real economic benefits and thus increase income of LDCs. Energy resources in LDCs are usually abundant but not well explored. This is due in part to a lack of trade opportunities, poor infrastructure, weak national governance and a lack of capital. For example, only 3 per cent of Laos' 23 Giga-watts hydropower potential had been exploited by 2007 and only 20 mega-watts (MW) of Cambodia's 10,000 MW of hydropower potential had been utilized by 2009 (Kimura, 2010). Local demand for this energy supply is high: many newly industrialized countries, mainly China and India, are short of energy supply. Therefore, the integration of regional energy markets can benefit Laos and Cambodia in achieving economic growth through developing their under-exploited resources for both domestic use and exports.

Table 1. HDI and Its Components in EAS countries

HDI Rank	Country	HDI Index	Life expectancy (years)	Ave. years of schooling	Exp. years of schooling	GNI per capita (PPP 2008 US$)
2	Australia	0.937	81.9	12	20.5	38,692
3	New Zealand	0.907	80.6	12.5	19.7	25,438
11	Japan	0.884	83.2	11.5	15.1	34,692
12	South Korea	0.877	79.8	11.6	16.8	29,518
27	Singapore	0.846	80.7	8.8	14.4	48,893
37	Brunei	0.805	77.4	7.5	14	49,915
57	Malaysia	0.744	74.7	9.5	12.5	13,927
89	China	0.663	73.5	7.5	11.4	7,258
92	Thailand	0.654	69.3	6.6	13.5	8,001
97	Philippines	0.638	72.3	8.7	11.5	4,002
108	Indonesia	0.6	71.5	5.7	12.7	3,957
113	Viet Nam	0.572	74.9	5.5	10.4	2,995
119	India	0.519	64.4	4.4	10.3	3,337
122	Lao PDR	0.497	65.9	4.6	9.2	2,321
124	Cambodia	0.494	62.2	5.8	9.8	1,868
132	Myanmar	0.451	62.7	4	9.2	1,596

Source: UNDP (2010).

Second, EMI may improve domestic energy efficiency in member countries, especially LDCs. This could occur through strengthening market competition and increasing investment in both infrastructure and more efficient appliances. EMI may help to eliminate monopolies and promote competition in domestic energy markets by facilitating the entrance of new competitors. Open access to energy infrastructure is a prerequisite for efficient energy use as otherwise competition will be restricted and new investors cannot enter the energy market. Energy infrastructure is often in shortage and often restricted to the third party access. A better use of energy infrastructure (based on competition) resulted from the EMI will reduce domestic energy supply costs and final user prices in LDCs, which in turn promote their economic growth. For example, Cambodia currently has high prices of electricity because it is generated by oil fired power plants that are fully dependent on imported oil. Since electricity from oil is much more expensive than that from gas and coal, Cambodia will benefit from cheaper imported electricity.

Finally, EMI may also encourage the free flow of foreign direct investment across countries within the region, and thus provide more energy infrastructure to boost economic development. Because of low per capita incomes, LDCs are usually short of investment in the energy production sector. In turn, low investment may restrict the supply of energy products and thus economic development. EMI in EAS region has the potential to encourage the cross-border investment in the energy production sector, and help LDCs to overcome bottle-necks in energy supply, lowering energy prices and promoting their economic convergence.

Although we have good theoretical reasons to believe that EMI will help countries within the EAS region to achieve economic convergence, the empirical relationship between EMI and income disparity across countries ought to be examined before any conclusive policy implications can be drawn. If there is significant impact on NDGs, EMI will be further justified and the policy makers can more confidently promote EMI. If there is significant loss, policy measures should be proposed to avoid such kinds of negative impacts. It is only through this way that a better EMI for the EAS countries can proceed.

3. Methodology, Model Specification and Data

To examine changes in cross-country income disparity and EMI, we adopt convergence analysis based on the panel data regressions (the so-called 'Barro regressions')[2]. There are two concepts of convergence employed in the analysis, namely σ-convergence and β-convergence (Barro and Sala-i-Martin, 1995).

σ-convergence indicates that the dispersion of real per capita income across countries tends to fall over time. Dispersion is measured by the variance of the logarithm of per capita income or product across regions. Let σ^2 be the cross-country variance of log (y_{it}) at time t. Equation (1) and the assumed properties of u_{it} imply that σ^2 evolves over time in accordance with the first-order difference equation.

$$\delta_t^2 = e^{-2}\beta\delta_{t-1}^2 + \delta_{ut}^2 \tag{1}$$

where it is assumed that the cross-section is large enough so that the sample variance of $\log(y_{it})$ corresponds to the population variance. If the variance of the disturbance, σ_{ut}^2, is constant over time such that $\sigma = \sigma_u^2$ for all t, then the solution of the first-order difference equation (1) is

$$\sigma_t^2 = \left(\frac{\sigma_t^2}{1-e^{-2}\beta}\right) + [\sigma_0^2 - \left(\frac{\sigma_u^2}{1-e^{-2}\beta}\right)] \tag{2}$$

Equation (2) implies that income per capita (σ_t^2) monotonically approaches its steady-state value, $\sigma^2 = \left(\frac{\sigma_u^2}{1-e^{1}-\beta}\right)$, which rises with σ_u^2 but declines with the convergence speed.

β-convergence applies if a poor country or region tends to grow faster than a rich one. Under such a context, the poor country or region will 'catch up' with the rich one in terms of per capita income. This phenomenon is often described as 'regression towards the mean'.

$$\ln\left({y_{i,t}}/{y_{i,t-1}}\right) = \alpha - (1 - e^{-\beta}) \times \ln(y_{i,t-1}) + u_{it} \tag{3}$$

where y_{it} is the real per capita income, the subscript t denotes the year, and i denotes the country or region. The left-hand side of the equation is the logarithm of the annual growth rate of the real per capita income. The disturbance term (u_{it}) is assumed to have

[2] Incorporating EMI into the economic convergence analysis as a controlled condition is justifiable since moving towards an integrated energy market by a country can be treated as improvement in institutional arrangement, which may have a similar role as capital accumulation and technology progress in promoting economic growth.

zero mean, the same variance σ_{ut}^2 for all regions, and is independent over time and across regions. β is the convergence coefficient. If the intercept, a, is the same in all regions and β>0, then the equation (3) implies that poor regions tend to growth faster than rich ones and convergence takes place. In contrast, a 0 or negative value for β means that no convergence takes place. β can be calculated based on the coefficient estimation of $\ln(y_{i,t-1})$.

σ-convergence is designed to examine the absolute convergence of income level while β-convergence examines relative convergence of income level. More importantly, the former approach is a more strict condition than the latter. Over time, income per capita of a country (σ_t^2) falls (or rises) if its initial value σ_0^2 is greater than (or less than) the steady-state value, σ^2 . However, a positive coefficient β (β-convergence) does not imply a falling σ_t^2 (σ-convergence). Thus, β-convergence is a necessary but not a sufficient condition for σ-convergence (Barro and Sala-i-Martin, 1995).

Both measures provide useful indications as to whether economic convergence (or divergence) has taken place over time, but they do not reveal why convergence or divergence has occurred. To find out the major determinants of changing economic growth across countries and the role that EMI has played in affecting the process, a series of factors such as the use of capital per worker, the technology progress index and the index for EMI have been incorporated into β-convergence analysis to test how important they are in contributing to the convergence process across countries. Thus, Equation (3) can be re-written as

$$\ln\left({y_{i,t}}/{y_{i,t-1}}\right) = \alpha - \left(1 - e^{-\beta}\right) \times \ln\left(y_{i,t-1}\right) + \gamma_1 KL_{it} + \gamma_2 TEC_{it} + u_{it} \quad (4)$$

$$\ln\left({y_{i,t}}/{y_{i,t-1}}\right) = \alpha - \left(1 - e^{-\beta'}\right) \times \ln\left(y_{i,t-1}\right) + \gamma_1 KL_{it} + \gamma_2 TEC_{it} + \gamma_3 EMI_{it} + u_{it} \quad (5)$$

where $y_{i,t}$ and $y_{i,t-1}$ are real per capita income of country i at time t and t-1. To capture the lag effect, we use a 5-year span to estimate equations (4) and (5). KL_{it}, TEC_{it} and EMI_{it} are the per capita use of capital, technology progress index and the EMI index respectively. The use of per capita capital (KL) and technology progress index (TEC) here, is relevant since both the effectiveness of labour and technology progress (or human capital) are important for promoting economic growth (Romer, 2001).

Based on Equations (4) and (5), a two-step procedure is to be used to examine the contribution of EMI to economic convergence in the East Asia region. Specifically, we first run the β-convergence regression with Equation (4) (excluding the EMI index), and then run the β-convergence regression with Equation (5) (including the EMI index). There are in general three situations that may occur, each of which corresponding to a specific result. First, if γ3 is positive and significant and β'>β, we have evidence that EMI contributes to economic converge across countries. Second, if γ3 is negative and significant and β'<β, we have evidence that EMI contributes to economic divergence across countries. Third, if γ_3 is insignificant and β' are similar as β, we have no evidence that EMI has an impact on dynamic path of economic growth across countries.

Finally, as a robustness check, the similar regression procedure has been carried out with data for different regions (or country groups) including the 12 old EU countries[3], NAFTA countries (USA, Canada and Mexico) and over a different time period.

Data used in this study come from four major sources including the World Development Indicator (WDI) Database, the cross-country historical adoption of technology (CHAT) dataset, the UN Comtrade Database and Subramanian and Wei (2007). The dependent variable, income per capita for each country, is defined as GDP per capita at the constant price of 2000 US dollars. The use of capital per capita, as a controlled variable for capital-labour ratio, is defined as the ratio of gross capital formation to total population. Data used for constructing the two variables are extracted from the WDI Database. As another controlled variable representing technology difference across countries, a technological progress index is also used in our regression. The index is defined as the percentage of population with age being 15 years and older who are able to read and write in the total population and comes from the CHAT database (Comin and Hobijn, 2009).

[3] Due to data constraints, this study used the 12 old EU countries (that is, UK, Germany, France, Spain, Portugal, Italy, Turkey, Ireland, Iceland, Austria, Hungary and Greek) rather than 27 EU countries as a subset for the regression. Since the 12 old EU countries accounted for most EU production and trade, the results from this subset would not be significantly different from that with 27 EU countries.

Based on the above discussion on variable definition and data collection, the total sample used in this paper covers 49 countries in 1960, 118 countries in 2008 and we have 1017 total observations. Between 1960 and 2008, the average GDP per capita across countries has been increasing with the annual growth rate of 2.1 per cent a year. Yet, the variance of GDP per capita also increased suggesting that economic growth has been achieved unevenly across countries with different capital accumulation process and technology progress.

4. Measurement of Energy Market Integration

As for the measure of EMI within the neighborhood, we define two types of indexes in this paper: one for energy trade and the other for domestic energy market competition.

It is widely argued that bilateral trade of fossil fuel may provide useful information on EMI. There are two arguments for this belief. Firstly, bilateral trade in fossil fuel products and transnational investment in energy production sectors is more likely to take place between countries with more integrated energy market if the initial endowment difference in endowments can be well controlled. Secondly, bilateral trade not only reflects the degree of resistance between countries for free flow of energy products across countries but also implies their mutual demand for energy from (or dependency on) each other.

In this paper, we construct an EMI index for energy trade by using bilateral trade of fossil fuel products, geographical distance between each trading partners and each country's production of fossil fuel products. The index (as is shown in Equation (6)) is defined as the relative imports of fossil fuel products, which is equal to the average imports of a country's fossil fuel products from its trading partner over domestic production. To account for the impact of geographical vicinity, we define the average imports of a country's fossil fuel products as the weighted average of the country's import of fossil fuel products from each trading partner with the weights being geographical distance between the two countries (obtained from Subramanian and Wei

(2007)). Since the index generally increases as the country imports more fossil fuel from neighborhood countries and deceases as domestic production (consumption) of fossil fuel products increase (decrease), it can be used to reflect the extent to which the country is integrated in neighborhood EMI.[4]

$$EMI\_TRADE_{it} = sum_j (energy\_trade_{ijt} / distance_{ij}) / n_j \times 1 / PROD_{it} \quad (6)$$

where EMI_TRADE_{it} is the energy trade index, $energy\_trade_{ijt}$ is the imports of fossil fuel in country *i* from country *j*, $distance_{ij}$ is the economic distance between country *i* and *j* and $PROD_{it}$ is the total amount of consumption of fossil fuels in country *i*. The index has been calculated for each country in each specific year.

We also measure the progress of energy market competition in each country. In addition to trade and investment liberalization, EMI is also expected to be associated with energy market liberalization and thus competition (Shi and Kimura, 2010). Therefore, an energy market competition index was proposed to capture this domestic effect of EMI. Three indicators have been employed in this paper including energy productivity (defined as millions of 2000 US dollar GDP generated per unit of energy consumption), the share of electricity consumption in total energy consumption. This indicator is closely related to the level of economic development, which is further related to competition since energy markets are often more liberalized in developed countries than in developing countries. Finally, we also use a measure of road sector energy use efficiency, which is defined as the thousand tones of energy use in the road sector for a given amount of CO2 emissions.

These three indicators are all expected to be positive correlated with the level of market competition. Energy productivity will be increased in a more competitive market according to standard economic theory. The share of electricity consumption in total energy consumption represents the quality of life resulting from using the clean energy. The higher the quality of life within a country, the higher the demand of competition, as it has been shown that developed countries generally have more

[4] Although oil is often imported from non-neighbor countries such as Middle East countries, the index for energy trade is still valid since the weighting system used here has accounted for each bilateral trading pair in fossil fuel and thus filter the potential bias due to resource abundance.

competitive markets than less developed ones. The supply of petrol oil, the dominant energy product used in the road sector, is usually subject to global market forces. Therefore, the efficiency of domestic consumption is determined by the competitiveness level of domestic oil market. Generally, the more efficient the energy used in road sector (fewer CO2 emissions), the more competitive the domestic energy market would be.

We combine all these factors using PCA approach to construct our measurement for energy market competition. PCA approach is a powerful tool for analyzing data to form a comparable index across countries when no explicit weighting is available, since the PCA approach is able to find an appropriate weight for each component (Song and Sheng, 2008). The PCA approach can refine common information from a few variables each of which contains some common information and many different noises. These variables form a space that can be expressed by an orthogonal coordinate system, the dimensions of which is the number of variables. When those variables are projected to individual coordinate, the information and noises are very likely be separated. The coordinate capturing the most variance, the principle component, will carry the common information if the variables are chosen appropriately.

In this paper, we use the first component (around 50 per cent of information) as an index in the regression (See Appendix A for more detailed discussion on the PCA method).

$$EMI\_MKT_{it} = PCA(Energy\_\mathrm{int}_{it}, Electricity\_cons_{it}, Energy\_road_{it}) \tag{7}$$

where $Energy\_\mathrm{int}_{it}$ is the energy productivity, $Electricity\_cons_{it}$ the share of electricity consumption in total energy consumption and $Energy\_road_{it}$ the energy use for road sector per tonne of CO2 emission.

As for the EMI indexes, the average trade index for EMI across all countries has increased from 3.89 in 1960 to 5.44 in 2008, showing that bilateral trade in energy products among countries in neighborhood has been strengthened due to regional integration over time. The low value of EMI indices in 2000 for most countries can be explained by the fact that Asian Financial Crisis (AFC) in 1997 significantly damaged global trade flow and thus imposed a negative impact on our estimation for 2000.

Across the three regions, the average index for the EAS countries (Table 2A) has increased from 4.33 in 1960 to 6.22 in 2008 with the annual growth rate of 0.8 per cent a year, which is much higher than those for EU countries (0.6 per cent a year) and the NAFTA countries (0.4 per cent a year). This result suggests that energy market in the EAS region has integrated more quickly than that in the EU and the NAFTA regions in recent years. Similar trends are also found from the energy market competition index (Table 2B).

Table 2(A). The Estimation of Energy Trade Index for EAS Countries: 1960-2008

Country Name	1960	1970	1980	1990	2000	2008
Australia	4.15	4.22	6.56	5.61	4.65	6.95
New Zealand	-	3.93	5.52	4.46	3.48	4.48
Japan	4.71	5.08	7.80	7.71	7.35	8.65
South Korea	-	-	6.54	7.21	7.14	7.03
Singapore	4.62	4.72	7.04	7.81	6.95	7.26
Brunei	-	-	-	-	-	-
Malaysia	-	4.32	6.16	5.12	5.36	5.22
China, P.R.: Mainland	-	-	-	5.97	7.53	8.59
Thailand	3.93	4. 77	6.84	5.55	5.40	6.59
Philippines	4.23	5.23	6.96	6.14	6.09	5.76
Indonesia	3.26	4.20	5.04	5.56	4.66	5.68
Vietnam	-	-	4.66	7.52	-	-
India	4.27	5.53	7.75	6.29	5.53	8.23
Lao	-	-	-	-	-	-
Cambodia	-	-	-	-	3.81	5.01
Myanmar	-	4.70	-	-	-	-
EAS	4.33	4.51	6.44	6.25	5.66	6.62
EU-15	5.41	5.90	8.02	7.54	7.05	7.40
NAFTA	4.61	4.79	6.53	6.14	5.91	5.49
All World	3.89	4.19	5.50	5.50	4.80	5.44

Note: For simplicity, the estimation of energy trade index reported here only covers the EAS countries and major regions between 1960 and 2008. The estimated index for other countries is available upon request.

Source: Authors' own estimation.

Table 2(B). The Estimation of Energy Market Competition Index for EAS Countries: 1960-2008

Country Name	1960	1970	1980	1990	2000	2008
Australia	1.16	2.12	2.26	2.76	2.84	2.90
New Zealand	1.10	2.26	3.36	2.87	3.11	3.99
Japan	1.08	1.68	2.26	2.83	2.86	2.95
South Korea	-	1.05	1.37	2.01	2.63	2.61
Singapore	1.15	1.98	2.16	2.59	2.87	2.80
Brunei	-	-	-	-	-	-
Malaysia			0.24	0.41	0.69	0.83
China, P.R.: Mainland	-	-	-	0.21	0.54	0.93
Thailand	0.31	0.47	0.59	1.46	1.42	1.27
Philippines	0.60	0.70	0.65	0.75	1.14	1.39
Indonesia	-	-	-	-	-	-
Vietnam	-	-	-	-	0.64	0.74
India	0.04	0.05	0.06	0.47	0.66	0.86
Lao	-	-	-	-	-	-
Cambodia	-	0.03	0.06	0.19	0.31	0.34
Myanmar	-	-	-	-	-	-
EAS	1.08	1.22	1.30	1.50	1.64	1.80
EU-15	1.32	2.17	2.46	3.03	3.53	3.73
NAFTA	2.83	3.88	4.17	1.73	1.91	2.09
All World	1.52	1.71	1.87	1.96	1.96	2.34

Note: For simplicity, the estimation of energy trade index reported here only covers the EAS countries and major regions between 1960 and 2008. The estimated index for other countries is available upon request.

Source: Authors' own estimation.

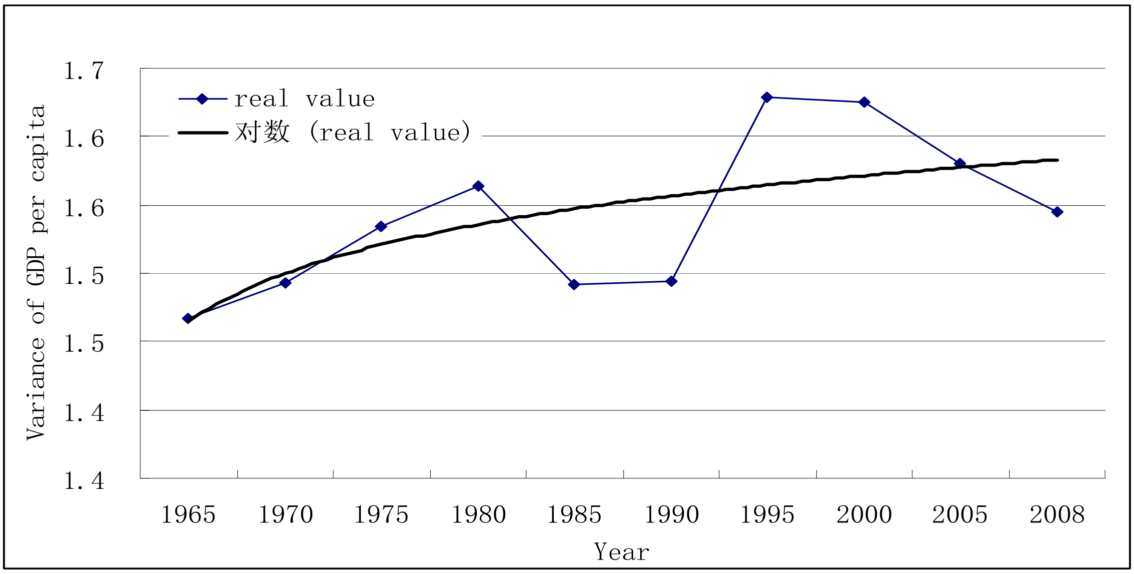
5. Estimation Results

Based on the methodology and data mentioned above, this section presents empirical findings on the relationship between EMI (measured by using the trade index and the energy market competition index) and economic convergence across countries (in particular, for countries in the EAS region) between 1960 and 2008.

5.1. Economic Convergence and its Conditions: a Baseline Model

To better understand cross-country disparity in economic development and its changing trend over time, we first use σ-convergence analysis to examine the variance of real income per capita across countries. Figure 2 shows the logarithm of the standard deviation of GDP per capita of all countries in our sample over the period of 1960 to 2008. Although there were significant fluctuations, the time trend of the variable has been increasing.[5] A further regression of the logged variance of real GDP per capita on the time tend (based on Equations (1) and (2)) showed that the estimated coefficient (0.004) in front of time trend was positive and significant at 1 per cent level.[6] Both the regression and the trend change analysis suggest that the disparity in real income per capita across countries has been enlarging over time throughout the world during the past four decades. This finding is consistent with our expectation that unbalanced economic growth has taken place in different countries, in particular in the EAS region.

Figure 2. Variance of Real GDP across Countries throughout the World: 1960-2008



Source: Authors' own calculation.

Although σ-convergence analysis has shown income per capita diverged across countries, it could not tell whether it is possible for poor countries to catch up with rich countries in terms of economic growth and the factors affecting the catch-up if it could. To solve this problem, we further use the β-convergence analysis to re-examine cross-country economic growth and its determinants. Table 3 shows the regression results

5 Between 1960 and 2008, the standard deviation of real GDP per capita in logarithm across 114 countries has increased from 1.37 to 1.54, with the annual growth rate of 0.24 per cent a year.
6 The Durbin-Watson statistics is 1.44, which is far less than 2.00, suggests that the regression results may not suffer from the time-series problem.

based on Equations (3) and (4) by using both Pooled ordinary least square (OLS) and controlling for country-fixed effects (FE). In particular, columns (1) and (2) of Table 3 shows the unconditional convergence results and columns (3) and (4) of Table 3 shows the conditional convergence results when the capital-labor ratio and the technical progress index has been well controlled.

Table 3. The Regression Result from the β-convergence Analysis

	Model I		Model II	
	OLS	Panel (FE)	OLS	Panel (FE)
Dependent variable: Difference in Logged GDP (constant 2000 USD) (dlncgdp2000)				
Lagged Logged GDP (constant 2000 USD) (lncgdp2000)	-0.008*	-0.022***	-0.096***	-0.074**
	(0.004)	(0.007)	(0.029)	(0.032)
Lagged capital-labor ratio	-	-	0.059**	0.026***
	-	-	(0.027)	(0.009)
Lagged literacy proportion	-	-	0.001***	0.001***
	-	-	(0.000)	(0.000)
Constant	0.181***	0.308***	0.301***	0.323***
	(0.040)	(0.061)	(0.059)	(0.070)
Number of observations	264	264	264	264
Adjusted R-squared	0.005	0.009	0.108	0.107

Note: For the OLS regression, country-specific effects have been controlled. "***", "**" and "*" represent the estimated coefficients are significant at 1 percent, 5 percent and 10 percent level.

Source: Authors' own estimation.

Without controlling for any other variables, the OLS regression (in Column (1)) may be biased due to the potential endogeneity problem. This would occur where there are unobserved country-specific factors in the residual that are correlated to the lagged income per capita, which is likely. This source of endogeneity can be removed by controlling for country fixed effects. Column (2) presents these results, which shows that the negative relationship between changes in logarithm of income per capita and the lagged logarithm of income per capita became more significant (with the estimated coefficient being -0.022 and significant at 1 per cent level). The result suggests that levels of economic growth across countries are likely to converge unconditionally despite of the enlarging disparity in income per capita level. In other words, poor countries are catching up with rich countries in terms of economic growth, reducing the income gap in the long run.

Moreover, we added two controlled variables, the capital-labor ratio (for investment per capita) and literacy proportion (for technical progress), into the β-convergence analysis to identify whether those factors may contribute to economic convergence across countries. As is shown in Columns (3) and (4) of Table 3, the estimated coefficients in front of lagged logarithm of income per capita obtained from the new regressions were -0.096 (for the OLS regression) and -0.074 (for the panel data regression) and significant at 5 per cent and 1 per cent level respectively. Comparing with those obtained from the unconditional analysis, the newly estimated coefficients were more negative. This finding, combined with the positive and significant coefficients in front of capital-labor ratio and literacy proportion, suggests that increasing capital-labor ratio and literacy proportion may help to facilitate the catch-up of poor countries with rich countries in economic growth and promote economic convergence across countries (Barro and Sala-i-Martin, 1995).

5.2. Energy Market Integration and Economic Convergence

Based on the baseline model for economic convergence, the next step is to examine the impact of EMI on the path and speed of economic convergence across countries. We use Equation (5) as a benchmark model and incorporate two indexes for EMI, including the energy trade index and the energy market competition index, into the regression. Each index is designed to capture EMI from a different perspective: the energy trade index is used to capture relative importance of energy trade within neighborhood and the energy market competition index is used to capture the domestic market distortion. The results are shown in Table 4, where Columns (1) and (3) presents the results by using pooled OLS and Columns (2) and (4) presents the results using country fixed effects. Compared between Tables 3 and 4, there are three findings that we wish to highlight.

Second, when we control for EMI, the estimated elasticities of economic growth of a country to its initial economic development level are more negative than those obtained from the baseline model. On one hand, when the energy trade index is controlled, the estimated coefficients in front of the lagged logarithm of real GDP per capita (from the panel data regression with the fixed effects) become -0.084. On the other hand, when the energy market competition index is controlled, the estimated coefficients in front of the lagged logarithm of real GDP per capita (from the panel data regression with the fixed effects) become -0.252. Both estimated elasticities are significantly smaller than that obtained from the regression without control of energy trade index (-0.074). This is strong evidence that EMI within a country's neighborhood, either through promoting trade facilitation or promoting competition in the domestic energy market, may help to improve the ability of poor countries to catch up with and overtake rich countries in economic growth. In other words, poor countries tend to grow faster than rich countries with EMI.

Table 4. Economic Convergence: 1960-2008

	EMI Model I		EMI Model II	
	OLS	Panel (FE)	OLS	Panel (FE)
Dependent variable: dlncgdp2000				
Lagged lncgdp2000	-0.103***	-0.084**	-0.098***	-0.252***
	(0.030)	(0.033)	(0.033)	(0.101)
Lagged capital-labor ratio	0.061**	0.030***	0.059*	0.053*
	(0.027)	(0.003)	(0.033)	(0.033)
Lagged literacy proportion	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Lagged energy trade index	0.017***	0.018***	-	-
	(0.001)	(0.002)	-	-
Lagged energy market competition index	-	-	0.026***	0.051**
	-	-	(0.001)	(0.022)
Constant	0.277***	0.298***	0.208***	1.207***
	(0.059)	(0.072)	(0.073)	(0.524)
Number of observations	264	264	193	193
Adjusted R-squared	0.110	0.113	0.193	0.09

Note: For the OLS regression, country-specific effects have been controlled. "***", "**" and "*" represent the estimated coefficients are significant at 1 percent, 5 percent and 10 percent level. The low value of adjusted R-squared results from the control of country fixed effects in OLS and panel data regressions.

Source: Authors' own estimation.

Moreover, when the related coefficients obtained from the regressions are translated into the convergence ratios following the equation of $r = -1/\ln(1-\beta)$, it is estimated to take approximately 55 years (convergence rate 8.7 per cent) and 13 years (convergence rate 37.3 per cent) for the poor countries to catch up with rich countries in half of their income per capita when EMI has been implemented and the investment and technology progress are well controlled. The time line is shorter than that based on the baseline model without the consideration of EMI, where it may take more than 65 years for poor countries to catch up with their rich counterparts in half of their income per capita (convergence ratio 7.7 per cent). This suggests that EMI has significantly contributed to poor countries economic growth and can help to reduce the development gaps across countries.

Third, although EMI in general may help to reduce the economic development gap across countries, different policy instruments of EMI may play different roles. When the energy trade index and the energy market competition index are separately used in the β-convergence analysis (in different regressions) as controlled conditions, the role they each play in affecting economic convergence across countries are significantly different from each other. Table 4 shows the higher the energy trade index, the more likely economic convergence can be achieved across countries. The energy trade index's elasticity is positive, suggesting that trade policies aiming to further facilitate free movement of energy products within the region may help to narrow the development gap. Similarly, the higher the energy market competition index, the more likely economic convergence would be across countries. The elasticity of energy market competition is much larger, implying that eliminating obstacles and monopoly in domestic energy market seems to be a more important factor contributing to poor countries' catch-up with rich countries.

The above findings are based on the assumption that the energy trade index and the energy market competition index are good indicators for EMI within a country's neighborhood, from different perspectives. When more data becomes available, more accurate estimates could be made though the general finding would be similar.

5.3. Asymmetric Impact of EMI on Economic Convergence across Regions

How does EMI impose different impacts on economic convergence across countries in different regions? To answer this question, we split our sample into three country groups: namely, the EAS region, the European Union region (EU) and the North American Free Trade Area (NAFTA) and use a dummy variable for each region and its interaction term with the lagged real GDP per capita to account for regional specific effect in the β-convergence analysis. Based on Equation (5), three regressions thus have been made for the EAS region, the EU region and the NAFTA region respectively. The comparison of results obtained from different model specifications can be used to distinguish the asymmetric impact of EMI in different regions. Due to data constraint, only the energy trade index has been used for this exercise and the results are shown in Table 5.

Table 5. Different Impact of EMI on Economic Convergence across Regions: 1960-2008

	EAS	EU	NAFTA	All Countries
Dependent variable: dlncgdp2000				
lagged lncgdp2000	-0.065*	-0.093***	-0.084**	-0.077**
	(0.034)	(0.032)	(0.034)	(0.036)
lagged capital-labor ratio	0.020	0.029	0.030	0.017
	(0.029)	(0.028)	(0.029)	(0.029)
lagged literacy proportion	0.001***	0.001***	0.001***	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
lagged energy trade index	0.019*	0.022*	0.016*	0.021
	(0.010)	(0.012)	(0.011)	(0.014)
D_EAS	0.268**	-	-	0.191
	(0.125)	-	-	(0.146)
D_EAS X lagged lncgdp2000	-0.029**	-	-	-0.017
	(0.015)	-	-	(0.018)
D_EU	-	0.150	-	0.198
	-	(0.189)	-	(0.209)
D_EU X lagged lncgdp2000	-	-0.010	-	-0.014
	-	(0.020)	-	(0.023)
D_NAFTA	-	-	0.340	0.286
	-	-	(0.277)	(0.279)
D_NAFTA X lagged lncgdp2000	-	-	-0.034	-0.025
	-	-	(0.029)	(0.030)
Constant	0.220***	0.343***	0.303***	0.297***
	(0.082)	(0.080)	(0.075)	(0.111)
Number of observations	264	264	264	264
Adjusted R-squared	0.154	0.134	0.113	0.178

Note: The results are based on the panel data regression with the fixed effects. "***", "**" and "*" represent the estimated coefficients are significant at 1 percent, 5 percent and 10 percent level.

Source: Authors' own estimation.

When the capital-labor ratio and the literacy proportion are controlled, EAS countries have shown more rapid economic growth rates than the rest of the world and they are more likely to achieve economic convergence within the region. As is shown in Column (1) of Table 5, the coefficient in front of the EAS dummy is positive (0.268) and significant at 5 per cent level. This result suggests that: economic growth of EAS countries are on average stronger than rest of the world by 0.268 per cent over the period of 1960 to 2008. Moreover, the coefficient in front of the interaction term between the dummy for EAS countries and the lagged real GDP per capita is negative (-

0.029) and significant at 5 per cent level. This result implies that the elasticity of economic growth to initial real GDP per capita for the EAS countries are -0.094 (which is equal to -0.065+(-0.029)), which are much more smaller than that for the rest of the world (-0.065), suggesting that income per capita among EAS countries are more likely to converge to each other.

As a comparison, when the dummy variables for the EU and NAFTA countries are incorporated into the β-convergence analysis, similar results have not been found. As is shown in Columns (2) and (3) of Table 5, the coefficients in front of the dummy variables are positive and the coefficients in front of interaction terms between the dummy variables and the real GDP per capita are negative. This result is consistent with the estimation (in sign) obtained for the EAS countries. However, since all the coefficients are insignificant at 10 per cent level, this suggests that the EU countries and the NAFTA countries do not show different economic growth trend and convergence pattern comparing with the rest of the world over the past four decades.

As for the impact of EMI from trade, the coefficients for the energy trade index throughout all regressions with the dummies for EAS, EU and NAFTA are all positive and significant at 10 per cent level. This suggests that EMI has played an important role in promoting economic convergence in all the three regions. Yet, the relative impact of EMI on economic convergence in the three regions is different from each other. As is shown in Table 5, the elasticity of the energy trade index for EAS, EU and NAFTA are 0.019, 0.022 and 0.016 respectively, implying that (after accounting for regional specific effects) a more integrated energy market within neighborhood is associated with a greater reduction in the development gap among EU countries than among EAS countries or NAFTA countries. Economic convergence took place more quickly among EU countries with the elasticity of real GDP per capita being -0.093 than those for the NAFTA countries (-0.084) and for the EAS countries (-0.065). This is partly because that the integrated market and international cooperation mechanism in EU helped enlarge the positive impact of EMI on balancing regional development gap across countries, setting a good example for EAS countries to follow.

6. Discussion and Policy Implications

Although EMI is shown to be beneficial to all countries in the region (Bhattacharya and Kojima, 2008, 2010), LDCs are often reluctant to play an active role in promoting the market integration process. For example, the CLMV countries often delayed their enforcement of existing trade and investment agreements. As a consequence, the ASEAN- China Free Trade Area gave five additional years preparation time to CLMV countries. Similarly, the ASEAN-Korea Free Trade Area also allowed six additional years to CLMV countries for preparation and the ASEAN-Australian-New Zealand Free Trade Area excluded Cambodia and Laos from their enforcement timetable (Shi and Kimura, 2010). Although these consensuses have been agreed by both developed countries and LDCs, the delayed participation of LDCs may do harm to further EMI process and its related effects on growth in the EAS region.

Since EMI appears to facilitate NDGs across countries and thus bring more benefits to member countries in particular to LDCs, it should be treated more confidently and positively in practice, which is consistent with findings from the previous study (Bhattacharya and Kojima, 2010). Considering the huge disparity in income per capita across EAS countries, the positive impact of EMI on economic convergence suggests that East Asia should promote EMI to achieve both sustainable and equal growth.

The comparison of EMI and economic convergence among the three regions shows that the deeper market integration can facilitate the faster economic convergence. Consequently, international cooperation towards a deeper integration of energy market should be advocated. In terms of economic convergence, EAS has overtaken NAFTA but still lags behind EU and thus there is still potential for further improvement.

Furthermore, greater participation of LDCs should be promoted. This analysis provides strong evidence of a positive impact on regional economic convergence, which implies that LDC would gain from active participation in EMI. From our calculations, participating in EMI on average may help to shorten the time period for LDCs catch-up with developed countries in economic growth by 50-75 years. Being aware of this potential benefit of EMI, LDCs in the EAS region should have more incentive to participate into regional cooperation and be actively involved into the construction of an integrated regional energy market.

Even though LDCs may need more preparation time, a workable roadmap toward EMI should be considered ahead of time to achieve the catch-up in economic development. The benefits of EMI to LDCs in terms of reducing economic development gaps across countries may only be achieved in the long run. However, as long as benefits to LDCs can be realized through the participation, more involvement from LDCs would come out and become the continuing driver of sustainable economic development and regional integration.

Developed countries can also play an important role in helping LDCs to build capacities in maintaining sustainable development when they pursue long-term goals for regional EMI. Since the study shows that increasing capital-labor ratio and literacy proportion may help to facilitate the catch-up of poorer countries with richer countries, investment and capacity building including for technology progress should be considered as a priority for LDCs since they are much weaker than developed countries in this field. This could involve providing development assistance and technology support to facilitate LDCs' participation into the construction of a unified energy market and eliminating domestic distortion. Currently, most EAS developed economies, including Australia, Japan, South Korea and New Zealand, are allocating a significant amount of official aid to ASEAN countries. The aim of this aid is to assist ASEAN nations economically integrate more fully in the region and EMI could be incorporated into these aid programs.

7. Concluding remarks

By using economic convergence analysis (including the σ-convergence and the β-convergence), this paper examines the impact of EMI on economic convergence across countries, with a particular focus on the EAS region, between 1960 and 2008.

The results show that in addition to trade, an integrated energy market may help to reduce economic development gaps among countries and accelerate the catch-up of

LDCs' income per capita. In particular, the positive impact of energy trade facilitation may play a more important role for the EU countries and the NAFTA countries than for the EAS countries. The study also finds that investment and capacity building may help to facilitate the catch-up and promote economic convergence across countries.

This paper suggests that EMI should be promoted more confidently and positively, not only among developed countries but also involving LDCs. Even though LDCs may need more time to make preparation, a workable roadmap toward EMI is valuable. Developed countries can also play an important role by helping LDCs to overcome the difficulty through capacity building programs.

Policy people may criticize the accuracy of trade data and thus the results because some countries may manipulate their trade data. However, as long as the manipulation is random while not systematic, the results should be still valid. Furthermore, we use the energy market competition index to check the robustness and the results are consistent and the conclusions remain unchanged.

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Appendix A. The Principle Component Analysis for EMI Market Competition Index

Principal component analysis (PCA) approach is a widely used method for identifying patterns in data. Since patterns can be hard to find in data of high dimensions, where the luxury of graphical representation is not available, the PCA allows us to form a comparable index across countries where there is no explicit weight available (Song and Sheng, 2008).

Mathematically, the PCA method seeks linear combinations of the original variables such that the derived variables capture maximal variance. It can be done via the singular value decomposition (SVD) of the data matrix. To see how we can use the method to measure EMI progress, we start with considering a m*n matrix Y=[y1, y2,…yn] with the mean of each vector is $\bar{Y} = [\bar{y}_1, \bar{y}_2, \ldots \bar{y}_n]$, one. One can demean the variable process by defining $X = [y_1 - \bar{y}_1, y_2 - \bar{y}_2, \ldots, y_n - \bar{y}_n]$. The covariance of this matrix X is as follows: $C_X = \frac{XX^T}{n-1}$, which is a squared symmetric □× □ matrix. To make the eigen-decomposition for the covariance matrix C_X, one may need to calculate m dimensional eigen-vector $E = [e_1, e_2, \ldots e_m]$ and their associated eigen-values $\lambda = [\lambda_1, \lambda_2, \ldots \lambda_m]$ such that $C_X E = [C_X e_1, C_X e_2, \ldots C_X e_m] = [\lambda_1 e_1, \lambda_1 e_2, \ldots \lambda_1 e_m]$, where the second equality follows the property of eigen-values and eigen-vectors. Thus, the initial matrix can be transformed as:

$$C_X E = [\lambda_1 e_1, \lambda_1 e_2, \ldots \lambda_1 e_m] = \begin{bmatrix} e_{11} & e_{21} & \cdots & e_{m1} \\ e_{12} & e_{22} & \cdots & e_{m2} \\ \vdots & \vdots & \ddots & \vdots \\ e_{1m} & e_{2m} & \cdots & e_{mm} \end{bmatrix} \begin{bmatrix} \lambda_1 & & & 0 \\ & \lambda_2 & & \\ & & \ddots & \\ 0 & & & \lambda_m \end{bmatrix} = ED,$$

where D denotes the eigen-value matrix. Hence, we obtain: $C_X = EDE^{-1}$.

Based on the above derivation, the next step is to find some orthonormal matrix P where Q=PX such that its covariance is diagonalized in the sense that its off-diagonal terms are zero. It is easy to show that this orthonormal matrix P indeed is the eigenvector matrix E. To see this more formally, consider $Q = [q_1, q_2, \ldots q_n]$, we have: $Q = E^T X$ with its covariance matrix:

$$C_Q = \frac{QQ^T}{n-1} = \frac{E^T XX^T E}{n-1} == E^T\left(\frac{XX^T}{n-1}\right) E = E^T C_X E = E^T EDE^{-1} E = D$$
,

where the second last equality comes from the relationship $C_X = EDE^{-1}$, as shown above, whereas the last equality holds due to the fact that the inverse of an orthogonal matrix is its transpose. That is, the covariance of the matrix C_Q indeed is a diagonal matrix.

Finally, it is to pick the eigenvector e_k from the eigenvectors matrix E which is associated with the largest eigenvalue λ_k. The new vector $q_k = e_k^T X$, which has $1 \times n$ dimension, is the so-called principal component of the original vector X. In this way, the original $m \times n$ dimensional matrix is reduced to a $1 \times n$ dimensional matrix, which can be directly used for measuring the EMI progress in each country.

In this study, the EMI index for domestic energy market competition was constructed by aggregating a set of indices including: energy productivity; the share of electricity consumption in total energy consumption; and the energy use for road sector per tonne of CO2 emission. Each index reflects a different aspect of domestic energy market competition (for EMI) across countries. These three indices were generated from International Financial Statistics (IFS), World Development Indicators (WDI) and other sources using principal components analysis, to determine the status of EMI in each country in the East Asia Summit region. The PCA method has been used to aggregate the three indices into a unique measurement (See Tables A1 and A2 for the corresponding eigen value and weights), say the EMI scores, and the EMI index scores for each country were standardized between zero and five. A higher overall ranking implies a higher capacity to adapt to change and hence greater resilience in the face of external pressures. Similarly, regions with low overall scores are potentially more vulnerable to change.

Table A1. Eigen Value and Explanation Power of Components

Component	Eigen-Value	Difference	Proportion	Cumulative
Comp1	1.76	0.86	0.59	0.59
Comp2	0.89	0.55	0.30	0.88
Comp3	0.35	.	0.12	1.00

Source: Authors' own estimation.

Table A2. Weights Used for the EMI Index

Variable	Comp1	Comp2	Comp3
Energy consumption productivity	0.67	-0.20	-0.72
share of electricity in total energy consumption	0.35	0.93	0.07
Road sector energy use efficiency	0.65	-0.30	0.69

Source: Authors' own estimation.

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