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DEEPEN UNDERSTANDING AND MOVE FORWARD: ENERGY MARKET INTEGRTION IN EAST ASIA

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EXECUTIVE SUMMARY

It is widely believed that EMI in East Asia is beneficial for both developed and developing countries. However, such benefits are more often stated in qualitative ways than in quantitative ways. Since the benefits of EMI are not without questions, it is useful to do further quantitative studies to deepen our understanding on the impact of EMI. Moreover, even though EMI in the EAS region seems beneficial and promising, the way toward EMI will not be smooth and therefore the implementation of EMI should be carefully studied.

To address these needs, ERIA continued an EMI study project for the second year. Part of this year's studies will further deepen our understanding about the impacts of EMI; while the other part explore ways to move the EMI forward, which echoes the instructions from the leaders and the energy ministers. Considering the debates of shifting away from nuclear energy as a consequent of the triple disasters in Japan, two studies are dedicated to estimate the impact of reducing nuclear energy in national energy mix with Japan as a case study.

1. Key findings

In Chapter 2, Andrews-Speed finds that many services needed in order to develop and sustain a regional integrated energy market have the characteristics of a regional public good, though some may also be trans-regional or global in nature as well.

In Chapter 3, Yu's estimation shows that countries like Japan and New Zealand have the highest extents to EMI. By contrast, China has the lowest score of EMI, followed by Malaysia, India and Indonesia.

Step further, in Chapter 4, Sheng and Shi find that an integrated energy market may significantly help poor countries to catch up with rich countries in economic growth.

Moreover, the EAS region is more likely to achieve economic convergence than the rest of the world.

In Chapter 5, Zhang and Zha find that trade facilitation, including energy investment and infrastructure improvement, has played critical roles in boosting energy trade.

In Chapter 6, Doshi and D'Souza reveals that for the three years from 2007–2009 there is no secular Asian premium. On the contrary, in 2007 and 2009, Asia received a *discount* in its crude oil bill relative to the Atlantic markets.

Chapter 7 by Kojima and Bhattacharya finds that even if a partial removal of energy subsidies can ripe the benefits of market efficiency improvement and energy subsidy reduction also helps to push down the demand for subsidised commodities. Chapter 7 also shows that introduction of FDI increases not only the national GDP of the investing countries but also the regional GDP as the whole EAS region by 0.04%.

Wu in Chapter 8 shows that gas market integration has undergone through a common trajectory that consists of several steps including the creation of intra-country regional markets, formation of a national regulated market, deregulation, and international integration. In addition, LNG market will certainly play an important role in the regional gas market integration.

Chang and Li in Chapter 9 show that by adopting an integrated and competitive natural gas market in the region, overall welfare of countries involved in natural gas trade in the region improves by 5.5%. As a result of introducing new infrastructure, welfare of countries involved in natural gas trade in the region further increases by 0.3%.

In Chapter 10, Khalid, Zakariah, and Zarina find that resilient economies, especially developed EA countries, have consistent performance in terms of value added creation and imported inputs during the period of energy price surge.

Using a top-down CGE model, Itakura in Chapter 11 shows that nuclear energy is still the most favourable energy source in terms of costs and emissions in the current scenario. He finds that as Japan reduces the power generation by nuclear, the real GDP in Japan would be negatively affected and the deeper the cut, the larger the negative impact. He finds that even with the substituting role of fossil fuels being placed, it is not effective enough to mitigate the negative impacts.

From the energy system perspective, Bhattacharya and Kojima in Chapter 12 demonstrate feasibility of meeting future energy demand with certain emission reductions without nuclear in Japan, China and India. They analyse two alternative energy scenarios of nuclear phase-out, one is renewable energy dependent path and the other is fossil fuel dependent path. They show that electricity price is expected to increase under both the scenarios compared with the nuclear energy scenario, but renewable energy dependent path will have lesser increase than fossil fuel dependent path. Compared to the renewable energy dependent path, fossil fuel dependent path appears costly in the long term scenario for Japan, China and India given the same level of CO2 emissions reduction. Benefits of renewable energy are multifarious and observed in terms of total system cost, electricity generation cost and also in terms of reduced import.

2. Policy Implications

A significant amount of policy implications is proposed by these studies. It shows that EMI should be promoted actively, but in a gradual and incremental manner; interregional governance is necessary, and a regional coordinating agency is desirable; Cross-border cooperation in energy projects should be promoted and financed with proper funds; and gas market can lead the EMI. The following is detailed discussion.

One clear message from this report is that EMI is beneficial theoretically and empirically and thus should be promoted in a continuous and confident manner. Developed countries can play an important role by helping LDCs overcome the difficulty through capacity building programs. Even though LDCs may need more time to make preparation, a workable roadmap toward EMI is valuable.

Governments or public bodies should take the responsibility for managing or stimulating EMI based on the findings that EMI has public goods characteristics. A single high level organisation or an energy policy cooperation framework, similar to IEA, should be established. Different legal and institutional systems among the countries should be harmonized, and transparency of laws and regulations must be improved so as to support the expansion of energy trade in the region.

Cross-border cooperation in energy projects should be promoted and financed with proper funds. In addressing the shortage of investment, it is recommended to explore and establish multilateral and applicable financing approaches urgently. It is also recommended to remove fossil fuels subsides.

East Asia should develop a formal program to boost cross-border connectivity and trading for gas within the area and eventually achieve regional gas market integration. Steps should be taken to construct emergency gas stocks to support the effective operation of the growing transboundary gas networks. Gradual harmonisation of regulatory and technical standards in the gas sector should be started.

Completely shifting away from nuclear energy in the short run is not advisable. It is therefore desirable to design an appropriate mix of electric generation types based on the existing facilities and the feasibly planned future investment. However, more aggressive renewable energy policy is required.

3. Recommendations

EMI in East Asia should be pursued in a gradual and incremental manner. East Asian countries may consider to institutionalize an energy policy cooperation framework, or establishing a single high level regional organisation, similar to IEA.

Different technical, legal, and institutional systems among the member countries should be harmonized, and transparency of laws and regulations must be improved. The quality and timeliness of energy data and statistics need to be improved to enable transparency in the energy market.

Establish multilateral and applicable financing approaches, such as regional infrastructure fund and regional development banks.

Promote and nurture the development of gas markets in member states and phased sectoral reforms in relatively mature markets through multilateral agreements.

Act prudently to reduce fossil fuel subsidies.

Carefully review nuclear energy policy considering the revealed additional risks and uncertainties, as well as the costs and benefits. Individual and cooperative actions on improving safety operation and dealing with accidents should be considered. Meanwhile, East Asia needs to focus more towards its indigenous energy resources like renewable energy rather than looking for something which is not of its own like nuclear energy and or fossil fuel based technologies.

CHAPTER 1

Deepen Understanding and Move Forward: Energy Market Integration in East Asia

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1. Introduction

Energy Market Integration (EMI) in East Asia has been implemented in the past decade with the emergence of cooperation between ASEAN and its dialogue partners. ASEAN is working towards a single market by 2015, under the guideline of AEC (Bali Concord II, 2003). Considerable progress in the EMI was made as a result of cooperation achieved through the ASEAN plus Three (APT) process and, later through the East Asian Summit (EAS) 1 process (Shi and Kimura, 2010).

The main incentives to promote EMI are improving energy security, reducing carbon dioxide emissions, and facilitating regional integration. EMI is also expected to foster

[1] The EAS, which was established in 2005, comprises of the 10 member countries of the Association of Southeast Asian Nations (ASEAN), i.e. Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Vietnam, and their 6 dialogue partner countries, i.e. Australia, China, India, Japan, Republic of Korea and New Zealand. The US and Russia will join the EAS in 2011. For the current paper, we are still focusing on the 16 countries.

economic growth through facilitating trade in energy within the region, optimizing resource allocation across countries, improving the productivity of energy consumption in each country, and protecting the environment. It is therefore widely believed that EMI in East Asia is beneficial for both developed and developing countries. This is partly because rapid economic growth of a country in this region always requires steady energy resource supply and EMI can provide a guarantee for the energy resource supply from an institutional perspective and partly because many East Asian countries are less developed but resource abundant and thus EMI can facilitate their development. However, such benefits are more often stated in qualitative ways than in quantitative ways. Since the benefits of EMI are not without questions, it is useful to do further quantitative studies to deepen our understanding on the impact of EMI.

Moreover, even though EMI in the EAS region seems beneficial and promising, the way toward EMI will not be smooth and therefore the implementation of EMI should be carefully studied. East Asia has been pursuing economic integration — an effective instrument proved by the European and North American experience to maintain sustainable regional economic development and poverty reduction across countries, for quite a while. However, the progress on EMI so far is limited. This is not exceptional as EMI is often closely related to national sovereignty, energy security, and other sensitive issues such as subsidy removal. It is therefore necessary to find ways to move EMI forward.

To address these needs, ERIA continued an EMI study project for the second year. A detailed introduction about the background of this project can be found at the report for the previous study (Shi and Kimura, 2010). For the current study, ERIA recalls the EAS Energy Ministers' request in their fourth meeting of "how to reap the benefits from EMI and to assess the collaborative measures to improve the market regulatory framework and to establish a conducive environment for the flourishing of the energy industry" and the Chairman's Statement of the fifth East Asia Summit (EAS) on "emphasising the need for greater regional cooperation on energy, we welcomed the efforts to address market barriers and promote more transparent energy trade and investments, and enhance dialogue and communication between energy producers and consumers……".

In line with these instructions from policy makers and past studies, ERIA sets the topic of the current study as "Energy Market Integration in the East Asia Summit Region—— Deepen Understanding and Move Forward". Part of the studies will further deepen our understanding about the impacts of EMI; while the other part explore ways to move the EMI forward, which echoes the instructions from the leaders and the energy ministers. Considering the debates of shifting away from nuclear energy as a consequent of the triple disasters in Japan, two studies are dedicated to estimate the impact of reducing nuclear energy in national energy mix with Japan as a case study. All these studies attempt to inform member countries and raise their interests to participate in EMI.

The original proposals have been reported to the East Asia Summit Energy Cooperation Taskforce (ECTF) EMI work stream chair, co-chair, and other stakeholders at the early stage. The final research plan, including the study on nuclear energy issues, was reported to the 15^{th} EAS ECTF meeting held on 7 April 2011. A workshop was held to present the results of this study to the ECTF members on 25 August 2011 in Vientiane, Lao PDR. The major policy implications and recommendations were reported to the first EAS Energy Ministers' Meeting (EMM5) held in Brunei on 20 September 2011 and were highly appreciated by the ministers (ASEAN website, 2011).

A variety of qualitative and quantitative methodologies have been employed in these studies. For qualitative methods, public goods theory and comparative study method are two outstanding examples. The quantitative methods includes economic growth theory, principle component approach, input-output table, and econometrics. Both top-down approach such as Computable General Equilibrium (CGE), and bottom-up approach such as TIMES, are applied. Both empirical and simulation approaches are also taken.

The studies are organized as the follows: Chapter 2 to Chapter 7 are dedicated to deepening our understanding about the impact of EMI on the East Asian Region. Chapter 8 to Chapter 12 address some prominent issues during the process of moving the EMI forward. In particular, Chapter 11 and 12 examine policy issues related to the nuclear energy emerging from the March 2011 Japan earth quake and the Fukushima nuclear accident.

This overview report provides an overview of the 11 papers initiated under the current project. The report is organized as follows. Following the introduction, section 2 provides a brief overview of background, and the major findings. Section 3 reports policy implications and Section 4 summarize some policy recommendations.

2. Background and summary of key findings

Considering some of these studies are policy oriented while others are pure academic attempts, the differentiated interests of the ECTF and policy makers on the various issues, the fact that two projects are dedicated to study particularly for nuclear energy policy, we group the findings into three according to the characteristics of the findings where there are generated, that is, findings from policy oriented studies, those from nuclear energy policy studies, and those from academic studies. Due to technical and data limitations, the results from the academic studies, although are interesting and innovative, do not necessary reflect the reality in East Asia.

2.1 Background and findings from policy related studies

Chapter 2 provides an analytical framework addressing the public goods characteristics of EMI. In Chapter 2, Andrews-Speed applies a regional public goods approach to the study of EMI in East Asia, with a view to clarifying the outlook for such integration and the likely obstacles to be encountered. His study focuses on more specific services or actions that need to be delivered in order to achieve the following regional goals: security of energy supply, economic development, poverty alleviation, economic and technical efficiency, and environmental protection.

He adopts the idea of "aggregation technology" to facilitate the analysis. Seven types of "aggregation technology" were identified for regional public goods. The most basic one is 'summation', by which the total supply of the good is the sum of the contributions regardless of how much each party contributes. The supply of a good with 'weakest link' aggregation technology, such as pipeline, depends on the supply of the smallest contributor, just like the weakest link in a chain. The other extreme is 'best shot' technology, through which the total supply of the public good is determined by the success or actions of just one country, such as establishment of a new best practice in energy efficiency.

The purpose of the aggregation technology is to provide appropriate incentives for collective action to ensure sufficient supply of the public good. For example, the most efficient way to generate the "best shot" technology is to pool funds together and let one member do all the work. On the other hand, the most efficient way to manage the "weakest link" technology is to coordinate among various countries to make sure to provide capacity on the chain evenly.

The aggregation technology, together with the nature of the good, decides incentives for, the obstacles to, and the institutions needed for the delivery of a regional public good. The challenge for policy-makers is to design the institutions and instruments so as to address the weaknesses of the aggregation technology or to manipulate the technology in order to provide public goods in an efficient way (Barrett, 2006; Sandler, 2004, 2006, 2007; UNIDO, 2008).

In addition to proposing theoretical ideas relating to regional public goods, Chapter 2 also discusses the experience of the European Union in its attempts to develop a single energy market.

It finds that many services needed in order to develop and sustain a regional integrated energy market have the characteristics of a regional public good, though some may also be trans-regional or global in nature as well. Among them, the best management practice in energy efficiency is an example of pure public goods with the "best short" characteristic. Once the knowledge in improving energy efficiency has been generated, other countries do not need to generate their own. Any country can adopt it without competing with others, and it also cannot prevent other countries to adopt it as well. Another example of pure public good is emergency stocks, such as the US oil stock. Once it is used in case of high prices, everybody will be able to benefit because oil price will go down.

Both Chapter 3 and Chapter 4 apply the principal component analysis (PCA) approach to quantify the progress of EMI, but Chapter 4 further examines the impact of EMI on growth convergence. In Chapter 4, Sheng and Shi innovatively construct two indexes, the energy trade index and the energy market competition index, to measure EMI at the country level by applying the PCA approach[2] and use these measurements to examine the impact of EMI on growth convergence by estimating both the σ-convergence and β-convergence. This study addresses the role of EMI in narrowing development gaps (NDG), which is important in facilitating economic integration in East Asia.

Sheng and Shi find that an integrated energy market may significantly help poor countries to catch up with rich countries in economic growth, thus reduce income disparity across countries, and accelerate the step of the catch-up. When EMI has been implemented and the investment and technology progress are well controlled, the poor countries can save at least 10 years when catching up with rich countries that have double income per capita.

Moreover, a comparison among three regions, i.e., EU, NAFTA and EAS, shows that energy market in the EAS region has integrated more quickly than that in the EU or the NAFTA regions in recent years and EAS countries are more likely to achieve economic convergence than the rest of the world. Yet, the impact of the EMI process on economic convergence in the EAS region is relatively smaller than that in EU. The study also finds that investment and capacity building may help to facilitate the catch-up and promote economic convergence across countries.

Considering the fact that intra-regional energy trade has rapidly increased in East Asia in the recent ten years while applicable tariffs have been zero even before FTAs were established, Zhang and Zha examine the reasons behind the booming of trade in Chapter 5. They find that trade facilitation, including energy investment and infrastructure

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[2] The PCA is a powerful tool for analyzing data to form a comparable index across countries when no explicit weight is available; the PCA approach allows us to find an appropriate weight for each component.

improvement, while not tariff declining or elimination, has played critical roles in boosting energy trade. Furthermore, they find that for the energy trade, huge energy investment and infrastructure improvement have played critical roles. In addition, the trade facilitation among ASEAN countries, which is initiated to meet with new trade situation, such as ASEAN Trade Repository, have positive impacts on energy trade in the region. In terms of ASEAN gas and electricity cooperation, they find that China has been increasingly involved; and India will also play a more important role in gas cooperation.

They argued that with the growing energy trade among the EAS Region, the improvement of the trade facilitation is one of the key issues towards EMI, and will benefit for both the resource-rich countries and energy-deficit countries in the region.

In Chapter 6, Doshi and D'Souza investigate the "Asia premium", which has caused policymakers in Asia much concern especially in light of the high energy prices in the latter half of the recent decade. They use a new, high-frequency dataset to ascertain whether the Asia premium exists; then evaluate the arguments that fault the current formula-based pricing system with the existence of the premium; and finally address the issue whether EMI would be effective to mitigate the Asia oil premium if it exists.

They find a historical price differential of US$1-1.5 between the Asian and Atlantic markets. However, their analysis reveals that for the three years from 2007–2009 there is no secular Asian premium. On the contrary, in 2007 and 2009, Asia received a *discount* in its crude oil bill relative to the Atlantic markets.

In a summary, Doshi and D 'Souza conclude that the existence of the price differential between markets is a function of the reference price levels. Given that the price differential fluctuates between being a discount and a premium, there is an option value in maintaining the status quo. They thus argue that taking any action to mitigate the so-called premium will rather be premature or inefficient.

Chapter 7 by Kojima and Bhattacharya studies issues with energy pricing reform and investment liberalization in a Computer General Equilibrium (CGE) approach. The common practice of subsidies in East Asia makes the reform of energy pricing a necessary but challenging task. They find that even if a partial removal of energy subsidies can ripe the benefits of market efficiency improvement. It is estimated that around 500 Million USD of subsidy reduction per annum in the region can improve the regional economic condition in terms of real GDP by around 0.05% and its welfare by around 0.14% compared to the base line scenario of 2020. Energy subsidy reduction also helps to push down the demand for subsidised commodities in the market and also subsequently cuts the sales of subsidised energy commodities in the domestic market.

Energy sector investment liberalisation is another important issue of EMI that has been associated with methodological difficulty in quantitative economic analysis. Chapter 7 also developed a new multi-regional CGE model for conducting a quantitative assessment of electricity sector investment scenario in which the investment demands in the EAS member countries projected by the International Energy Agency are met. The assessment results show that for meeting energy sector investment demands, FDI will play an important role not only to benefit investing and hosting countries but also to increase the regional GDP as the whole. The most interesting finding shows that introduction of FDI increases not only the national GDP of the investing countries but also the regional GDP as the whole EAS region by 0.04%.

Using a qualitative method, Wu in Chapter 8 reviews the trends in global gas market integration and draws policy implication for gas market development in the East Asia. Wu classifies the natural gas markets in the EAS area into three groups, namely, the mature markets (Australia, Japan, New Zealand, and Singapore), the developing markets (China, India, Indonesia, Malaysia, South Korea, and Thailand) and the fledgling markets (Brunei, Cambodia, Laos, Myanmar, the Philippines, and Vietnam), according to the stage of market and regulatory development.

Wu finds that the experience of the two leading groups in the promotion of market liberalization and integration, the United States (US) and European Union (EU), shows that gas market integration has undergone through a common trajectory that consists of several steps including the creation of intra-country regional markets, formation of a national regulated market, deregulation, and international integration. For the implementation of the last step, namely international integration, it involves the standardization of the gas sector, harmonization of members' regulatory systems, and removal of cross-border trade barriers. EAS members can learn from the experience and lessons in the US and EU and work out a plan for gas market integration in the coming decades.

He argues that in terms of gas market integration in the region, LNG market will play an important role. With expanded capacities in terms of both pipelines and LNG terminals, a gas-to-gas competing market may appear in the EAS region. Traditionally the price of natural gas is tied with the price of oil. This is still the case in Asia. However, the gas pricing mechanism has changed in other parts of the world. In the US, due to gas-to-gas competition, the gas price is determined by the domestic gas market price, and imported gas is also linked to the domestic gas price (Fukushima, 2009). Similar market-oriented pricing mechanism also emerges in Europe.

2.2. Background and Findings from Studies of Nuclear Energy Policy in Japan

One emerging issue in the energy industry is about future policy on nuclear energy. Following Japan's nuclear accident at the Fukushima power plant after the Great East Japan Earthquake followed by an unprecedented tsunami, not only Japan but Asia as a whole is expected to learn a lesson on the risks and costs involved in the civilian nuclear energy program. The current Japanese nuclear crisis has revealed plethora of uncertainties over the future direction of Japanese energy policy as well as Asian energy policy which are integrated indeed, via the technological, financial, and nuclear energy knowledge sharing activities within the region.

As an aftermath of the devastating nuclear fallouts in Japan, many discussions and actions have been taken against nuclear energy. The shift of electric power sources will have economic impacts as well as environmental impact. Two studies were initiated to study this real policy issues.

Itakura in Chapter 11 uses a global CGE model to estimate economic impacts on production, consumption, and international trade. He shows what would be the economic impact of shifting the electric power generation away from nuclear by two simulations:

a) Reducing the electric power generation by nuclear in Japan and b) replacing nuclear power generation by fossil fuels.

The simulations show as Japan reduces the power generation by nuclear, the real GDP in Japan would be negatively affected and the deeper the cut, the larger the negative impact. If the use of nuclear in Japan was reduced by 20 per cent without any replacement, then the real GDP is decreased by about 40 billion US dollars, and this amount is almost equivalent to one per cent of GDP evaluated in 2004. He finds that even with the substituting role of fossil fuels being placed, it is not effective enough to mitigate the negative impacts.

From the energy system perspective, Bhattacharya and Kojima in Chapter 12 use a bottom-up method, the TIMES Integrated Assessment Model (TIAM-WORLD)[3] model to demonstrate feasibility of f meeting future energy demand with certain emission reductions without nuclear in Japan, China and India. They first establish the reference energy scenario (REF) that represents the business-as-usual situations of energy supply and demand before the Great Tohoku Earthquake and the Fukushima nuclear accident in March 2011. Based on this scenario, they assess the impacts of two alternative energy scenarios with gradual nuclear phase-out in Japan, China and India in terms of energy system costs, technology choice, and CO_2 emission. Both scenarios assume that nuclear power supply gradually goes off from the supply mix by 2050 with a three-step reduction target. Based on this assumption, the Fossil Fuel-Long Run (SFF-LR) scenario assumes that fossil fuels mainly substitute reduced nuclear energy supply while the Renewable Energy Scenario (REN) scenario assumes much higher dependence on renewable energy which is reflected through imposing minimum renewable energy share of 40% (15% from wind and 25% from solar) by 2050 with gradual escalation from the current share of less than 1%. To

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[3] The TIAM-WORLD model integrates the entire energy/emission system of the World, divided in 16 regions, including the extraction, transformation, trade, and consumption of a large number of energy forms. India, along with Japan and China are represented as individual regions in this model. The model contains explicit descriptions of more than 1500 technologies and several hundreds of commodities in each region. TIMES' economic paradigm is the computation of a inter-temporal partial equilibrium on energy and emission markets based on the maximization of total surplus, defined as the sum of suppliers and consumers surpluses.

compare these two alternative scenarios with equal footing in terms of emission reduction, the CO_2 emissions from the REN scenario are imposed on the SFF-LR scenarios as the upper limits of CO_2 emissions.

The study shows that electricity price is expected to increase under both the scenarios, but renewable energy dependent path will have lesser increase than fossil fuel dependent path. Compared to the renewable energy dependent path, fossil fuel dependent path appears costly in the long term scenario for all the three countries given the same level of CO2 emissions reduction. Benefits of renewable energy are multifarious and observed in terms of total system cost, electricity generation cost and also in terms of reduced import.

2.3. Background and Findings from Academic Studies

The studies reported at this section are academically significant but may not be able to generate robust results due to limitation of data and methodology. Therefore, findings and policy implications from this subsection should be carefully interpreted.

In Chapter 3, Yu measures EMI with the PCA approach from those aspects that have been identified in the previous year's EMI study (Shi and Kimura, 2010), namely, (1) energy trade and investment liberalization; (2) trans-boundary energy infrastructure development; (3) domestic energy market liberalization; and (4) energy pricing liberalization. Yu's estimation shows that countries like Japan and New Zealand have the highest extents to EMI. By contrast, China has the lowest score of EMI (-2.67), followed by Malaysia, India and Indonesia. The rest of the countries, which basically are the CLMV group, is located in between.

Chang and Li in Chapter 9 use a competitive equilibrium model to analyse the implications of an integrated and competitive natural gas market in the region. Apart from thwarting the monopolistic pricing behavior, they also seek the possibility to decouple prices of natural gas from that crude oil and thus add to the price advantage of natural gas. They raise two issues in their study: first, what would be the trade pattern of natural gas in the region when an integrated and competitive market of natural gas is introduced in the region? And second, what would be the impacts of additional infrastructure including pipelines and LNG terminals in the region?

Chang and Li show that by adopting an integrated and competitive natural gas market in the region, overall welfare of countries involved in natural gas trade in the region improves by 5.5%. In general, their study shows that the supply of natural gas from the region, which has cheaper transportation costs, increases its portion in the total supply of natural gas. By introducing new natural gas infrastructure in the region, Chang and Li observe that welfare of countries involved in natural gas trade in the region further increases by 0.3%.

Since many ASEAN countries are agricultural exporters, they may be vulnerable to an increase in energy price particularly to crude oil price hike because energy costs may play an important part in the food industry. Therefore, in Chapter 10, Khalid, Zakariah, and Zarina apply three different approaches, which are primarily based on the input-output (I-O) table methodology, to selected East Asian countries to evaluate whether there exist any potential benefits of the food industry from EMI. This study uses secondary data that are sourced but not exhaustive from the OECD and various selected EA countries' statistical agencies, particularly the DOS in Malaysia, Singapore etc.

Khalid, Zakariah, and Zarina find that resilient economies, especially developed EA countries, have consistent performance in terms of value added creation and imported inputs during the period of energy price surge. In addition, the price spread model implies that a doubling of crude oil price will cause CPI for food to rise by approximately 22%.

3. Policy Implications

A significant amount of policy implications is proposed by these studies. It shows that EMI should be promoted actively, but in a gradual incremental manner; interregional governance is necessary and a regional coordinating agency is desirable; Cross-border cooperation in energy projects should be promoted and financed with proper funds; and gas market can lead the EMI. The following is detailed discussion.

3.1 Determinated but Gradual Promotion of EMI

One clear message from this report is that EMI is beneficial theoretically and empirically and thus it should be promoted in a continuous and confident manner. Chapter 7 concludes that an integrated energy market can expedite both the process of pricing reform where the benefits and costs can be shared among the countries and the private sector investments in the forms of FDI to energy sector.

Chapter 3, 4 and 5 suggest that EMI should be promoted more confidently and positively not only among developed countries but also involving developing countries. The demonstrated benefits of EMI in facilitating NDG in Chapter 4 calls for deeper EMI within the East Asia and more active participation of less developed countries (LDCs). They also suggest that developed countries can play an important role by helping LDCs to overcome the difficulty through capacity building programs. Even though LDCs may need more time to make preparation, a workable roadmap toward EMI is valuable (Chapter 4).

Chapter 5 argues that Asian oil market mechanisms by trade and investment facilitation should be developed and enhancing dialogue between Asian oil consumers and producers is also very important.

Chapter 3 suggests that countries that have lagged behind the progress of EMI should work harder to catch up. Chapter 5 suggests that all countries should promote EMI by trade facilitation and take the advantage of existing RTA platforms to promote EMI.

In terms of implementation strategy, EMI in East Asia should be pursued in an incremental manner. Chapter 2 suggests EMI starts mainly at a sub-regional scale and the specific steps taken towards EMI should be chosen on the basis of their likely positive economic impacts and their likely ease of delivery. In this respect, proposals for sub-regional energy networks in Northeast Asia are to be encouraged and actively pursued. CJK could cooperate with other countries in the region and develop cross-border new energy projects aiming to renewable EMI, low carbon, and green economy (Chapter 5). Other initiatives that should be pursued at a sub-regional scale include: sea-lane security, emergency response teams, and pollution clean-up capacity.

Recognizing the importance of gradual approach, Chapter 10 recommends that the governments must step-up efforts to reduce market distortion with improvement in energy efficiency by means of scaling up chains of interconnectedness and integration to a point where efficiency could be enhanced.

3.2. Interregional Governance and Regulatory Framework

Chapter 2 suggests that governments or public bodies should take responsibility for managing or stimulating EMI based on the findings that EMI has public goods characteristics. Because of the special nature of energy, the development of an integrated energy market requires relatively sophisticated systems of energy governance, some of which will need to be legally-binding and will require states to yield a certain degree of authority to a supra-national institution (Chapter 2).

Chapter 2 and Chapter 5 propose that a single high level organisation or an energy policy cooperation framework, similar to IEA, should be established. Chapter 2 thinks the organization could be tasked of coordinating (1) the delivery of certain services and activities which are delivered across the whole region and (2) the various sub-regional initiatives. Sub-regional organisations can be established to oversee the delivery of services at this level.

Different legal and institutional systems among the countries should be harmonized, and transparency of laws and regulations must be improved so as to support the expansion of energy trade in the region. All countries need to improve the quality and timeliness of energy data and statistics, aiming at improving transparency in the energy market (Chapter 5).

3.3. Infrastructure, Investment and Subsidy

Cross-border cooperation in energy projects should be promoted and financed with proper funds (Chapter 5). Chapter 9 shows that new infrastructure clearly increases the general social welfare and brings new trade opportunities to specific countries in the region.

Relevant countries thus find supports for their investment in the expansion of the supply network for natural gas in the region, including both pipeline and LNG.

Chapter 5 suggests that infrastructure such as pipelines and LNG facilities should be built based on sound fund-raising structure that allows cooperation among governments and the private sector. Chapter 2 recommends that infrastructure projects could be developed jointly by neighbouring states, for example LNG terminals. Both Chapter 2 and Chapter 8 highlight a strategy to develop TAGP and APG as an immediate step toward the EMI.

Chapter 7 suggests energy sector investment liberalisation is needed to boost FDI flows and its potential benefit not only in economic terms but also for environmental considerations, which can be attained if some policy for encouraging FDI to target cleaner energy is implemented.

In addressing the shortage of investment, it is recommended to explore and establish multilateral and applicable financing approaches urgently. The first approach could be a regional infrastructure fund, such as ASEAN infrastructure fund from ADB and ASEAN-China Investment Cooperation Fund. The second approach could be regional development banks as proposed in Chapter 5, such as Northeast Asia Bank of Cooperation and Development and Southeast Asia Bank of Cooperation and Development.

As for domestic investment, Chapter 10 recommends regional governments to adopt sectoral energy investment plans in their respective countries to bolster their economic growth and consumption of more efficient and cleaner fuels.

Removal of energy subsidies is demonstrated to have multiple benefits and thus should be implemented even if it is a sensitive issue (Chapter 7). Chapter 7 also demonstrates that the common perception of subsidy removal that will affect the welfare and national GDP due to inflationary effect of energy price increase, may not be correct for this region.

Chapter 9's finding also suggests the need for removing subsidies. An integrated and competitive market will remove excess demand through removal of distortions such as subsidies, and increase the social welfare.

3.4. Gas Market Integration

Chapter 8 and Chapter 9 suggest that East Asia should develop a formal program to boost cross-border connectivity and trading for gas within the area and eventually achieve regional gas market integration. This goal could be achieved through the evolution of the current schemes such as TAGP and GMS or new initiatives such as the establishment of regional gas storage or gas exchanges. Chapter 2 also recommends that steps should be taken to construct emergency gas stocks to support the effective operation of the growing trans-boundary gas networks.

Chapter 8 suggests that several institutions in the EAS areas should coordinate better to promote their “gas” sector. One example is that the “gas” sections of these institutions could be merged to form an EAS Gas Agency (EGA).

Chapter 8 also suggests that the EAS states to set targets to gradually harmonise regulatory and technical standards in the gas sector through multilateral agreements. A set of mutually agreed and harmonised standards, or the EAS Best Practice (EBP) standards, can be implemented initially in the relatively more developed markets and then extended to other markets over time.

3.5. Nuclear Energy Policy

The two studies addresses nuclear energy issues from different perspectives. From macroeconomic perspective based on top-down methodology, shifting away from nuclear energy will incur significant damage on national economy (Chapter 11). From energy system perspective, nuclear phase-out is feasible and if nuclear is mainly replaced by renewable energy the total energy cost could reduce, even though electricity retail price is expected to increase whenever nuclear energy is replaced by fossil fuel or renewable energy (Chapter 12).

Both studies show that completely shifting away from nuclear energy in the short run is not advisable. It is therefore desirable to design appropriate mix of electric generation types based on the existing facilities and the feasibly planned future investment.

More aggressive renewable energy policy is required. The renewable energy dependent scenario is expected to have much lesser financial impact than the fossil fuel dependent scenario when nuclear energy will be phased out with reduced CO2 emission (Chapter 12).

4. Recommendations

ERIA has recommended to following policy to the EAS policy makers:

EMI in East Asia should be pursued in an incremental manner since an regional wide overall structure cannot be established at this moment. It can start at a sub-regional scale and from any small steps. Some concrete cooperation activities can be proceeded now, such as emergency gas stocks, sea-lane security, emergency response teams, and pollution clean-up capacity.

East Asian countries may consider to institutionalize an energy policy cooperation framework, or establishing a single high level regional organisation, similar to IEA, to coordinating activities in the energy sector and the delivery of certain services across the whole region. ASEAN can form the basis of such organisations in Southeast Asia, but steps need to be taken to establish a coordinating organisation for Northeast Asia and the whole East Asia .

Different technical, legal, and institutional systems among the member countries should be harmonized, and transparency of laws and regulations must be improved so as to support the EMI. The quality and timeliness of energy data and statistics need to be improved to enable transparency in the energy market.

It is recommended to explore and establish multilateral and applicable financing approaches, such as regional infrastructure fund and regional development banks.

Promote and nurture the development of gas markets in member states and phased sectoral reforms in relatively mature markets through multilateral agreements.

Although having a systematic and well planned subsidy reduction policy is a big challenge for the countries in this region, the time has come to act prudently to reduce such slow poising destructive policies to make the countries prosperous in the future.

Countries with interests on nuclear energy need to carefully review nuclear energy policy considering the revealed additional risks and uncertainties, as well as the costs and benefits that have been identified in these studies. Individual and cooperative actions on improving safety operation and dealing with accidents should be considered. Meanwhile, East Asia needs to focus more towards its indigenous energy resources like renewable energy rather than looking for something which is not of its own like nuclear energy and or fossil fuel based technologies.

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CHAPTER 2

Energy Market Integration in East Asia: A Regional Public Goods Approach

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This study applies a regional public goods approach to the study of energy market integration (EMI) in East Asia, with a view to clarifying the outlook for such integration and the likely obstacles to be encountered. In addition to drawing on theoretical ideas relating to regional public goods, the paper will also draw on the experience of the European Union in its attempts to develop a single energy market. The study shows that many services are needed in order to develop and sustain a regional integrated energy market that some of these services have characteristics of regional public goods, though some may also be trans-regional or global in nature as well. The study recommends that :EMI in East Asia should be pursued in an incremental manner and mainly at a sub-regional scale; and the specific steps taken towards EMI should be chosen on the basis of their likely positive economic impacts and their likely ease of delivery.

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1. Introduction

The integration of energy markets across the region is one of three major priorities for regional energy collaboration identified by the EAS Energy Ministers. The successful development of an integrated energy market across East Asia should yield significant economic benefits (ERIA, 2010). More specifically it would allow national governments to more easily address the four main energy policy challenges which face any country, namely:

- Security of energy supply and/or demand;
- Economic efficiency of the energy sector;
- Social equity, particularly access to affordable modern energy;
- Reduced emissions of pollutants from energy production and use.

Improvements in all these four aspects of energy management across the region through energy market integration (EMI) would yield both direct economic benefits in terms of economic growth as well as producing a number of positive externalities. These benefits have the character of public goods in that they are unlikely to be provided by private actors and, in the absence of government action, are liable to under-provision or over-use. Given that the intended market integration extends across a very wide region, the benefits of such market integration can be considered as regional public goods or even as trans-regional public goods.

The aim of this paper is to apply a regional public goods approach to the study of EMI in East Asia, with a view to clarifying the outlook for such integration and the likely obstacles to be encountered. This will provide a framework for prioritising the component tasks of EMI. In addition to drawing on theoretical ideas relating to regional public goods, the paper will also draw on the experience of the European Union in its attempts to develop a single energy market.

The report starts with a brief account of the energy challenges facing East Asia and the potential for an integrated energy market to address these challenges. This is followed by a short explanation of the distinctiveness of energy and energy policy, with reference to the public good elements of energy. The paper then provides an account of ideas relating to the provision of regional public goods and of their relevance to energy, which forms the framework for the subsequent analysis. The experience of the European Union is then examined briefly before the framework of regional public goods is applied to EMI in East Asia.

2. Key Energy Challenges Facing East Asia

The EAS region accounts for about 25% of world GDP in nominal terms, but the population is some 45% of the total. The EAS also forms a significant part of the world's energy system. It accounts for more than one-third of global commercial energy consumption and about 40% of carbon dioxide emissions (Table 1). The production and consumption of coal and of natural gas are roughly in balance, but the region is a major net importer of oil. As remaining reserves of oil and natural gas become progressively concentrated in areas outside the EAS region (e.g. the Middle East and C.I.S.), a growing share of energy demand is likely to require imported energy. Thus long-term security of energy supply is a priority for most countries in this region, regardless of their level of development. The richest countries seek to maintain their level of wealth, the rapidly developing economies seek to sustain their rate of growth, whilst the poorest states need energy to support the first steps of modernisation and to supply their people with basic amenities.

Although security of supply and social equity are probably the main national and regional energy policy concerns, economic and technical efficiency are also important because inefficiency can undermine measures taken to address the former two objectives. Environmental objectives are also becoming increasingly important across the region. The high level of coal reserves and the consequent reliance on coal, especially in China and India, exacerbates the challenges these countries will face in constraining emissions of carbon dioxide, nitrogen oxides and sulphur oxides, as well as land and water pollution. The increasing exploitation of offshore oil and gas and the growing volume of energy transported across the seas of the region all enhance the risk of accidents and marine pollution. Though increased energy efficiency and the growing use of renewable energy can both act to address many of these challenges, they require the appropriate technology to be available and appropriate economic incentives.

Table 1. EAS Share of World Commercial Energy Reserves, Production and Consumption, 2009

	Reserves	Production	Consumption
Oil	3%	10%	31%
Natural Gas	8%	12%	13%
Coal	31%	65%	65%
Energy consumption			36%
Electricity generation			36%
CO2 emissions		41%	

Source: BP Statistical Review of World Energy, 2010.
Note: Numbers are rounded.

In many respects, there is a very large degree of disparity between countries across the region, for example:

- The political and economic systems and ideologies, and in the legal systems;
- The state of development of the economy;
- The structure and rate of growth of the economy;
- The scale and mix of the primary energy resource;
- The scale, mix and rate of growth of energy supply and demand;
- The relative importance of net imports and net exports of energy;
- The structure and ownership of the energy industry, and the nature of energy markets, especially with respect to energy pricing;
- The state of the energy infrastructure and the proportion of the population with access to modern energy;
- The energy intensity and scale of carbon dioxide emissions.

For the purposes of this analysis, four groups of countries may be recognised on the basis of their stage of economic development, economic structure, energy consumption and carbon emissions (Table 2). The first group comprises OECD countries with advanced economies plus Brunei, with relatively high per capita energy consumption and carbon emissions, and with the capacity to invent, develop and deploy new technologies. Australia and Brunei are distinguished by their status as net energy exporters. The second group comprises the two large emerging economies in the region, China and India, which have in common their large populations, high degree of dependence on coal and high energy intensity. Both countries have the capacity to develop and deploy new technologies.

The third group spans a variety of ASEAN countries which are at various stages of economic development between the richest and the least developed in the region. All members of the group are net importers of energy, with the exception of Malaysia. Energy intensities are relatively high, and per capita energy consumption is relatively low. Capacity to develop and deploy new technologies varies between these countries.

The final group comprises the three least developed members of ASEAN which are distinguished by their low level of industrialisation, of per capita energy consumption and of per capita carbon emissions.

This diversity is the source of many of the regional energy challenges and yet at the same time provides some of the opportunities. The over-arching objective of EMI in the EAS region is to bring net economic benefits to the region through increasing energy cost competitiveness, energy security and developing cleaner energy. At the heart of this vision lies the concept of economic efficiency, which has three aspects in this context (Bannister *et al.*, 2008):

- Productive efficiency, which relates to the cost of producing a certain amount of energy;
- Allocative efficiency which reflects the overall benefit to society from the supply of energy, and is determined by the pricing system that provides signals to energy users;
- Dynamic efficiency is achieved by an appropriate balance between short-term and long-term concerns, and this particularly relies on encouraging investment in the extraction of energy resources, in the construction of new energy infrastructure and in the installation of new energy-using appliances.

Table 2. Selected Features of Population, Economy and the Energy Sector

	Population	GDP	GDP/ Capita	Share of Industry in GDP	Energy Consumption	Energy Consumption Per capita	Share of Coal	Energy Intensity	CO2 Emissions	CO2 Emissions Per capita
	Millions	Billion 2000 US$	US$	%	Mtoe	toe	%	toe/million 2000 US$	Mt-C	
	2007	2007	2007	2007	2007	2007	2005	2005	2005	
Australia	21	503	23,936	27	122	5.8	44.5	260	103.4	4.9
Brunei	0.4	7	17,944	71	2.4	6.3	0	366	1.4	3.5
Japan	128	5,206	40,745	30	526	4.1	21.1	106	342	2.7
Korea	48	734	15,158	37	218	4.5	23.8	342	136	2.8
New Zealand	4	64	15,178	25	17	4.1	11.6	277	8.7	2.2
Singapore	4.5	134	29,185	30	31	6.7	0	272	18.7	4.1
China	1,318	2,387	1,811	48	1,497	1.1	72.6	791	1,386	1.05
India	1,124	771	686	29	380	0.3	54.8	578	329	0.29
Indonesia	225	233	1,033	27	135	0.6	18.8	650	90.6	0.40
Malaysia	26	133	5,009	48	59	2.2	10.5	576	42.4	1.63
Philippines	89	107	1,202	32	37	0.4	15.3	392	20.4	0.23
Thailand	67	174	2,594	45	90	1.3	11.8	573	52.1	0.78
Vietnam	85	53	617	42	27	0.3	29.8	609	22.9	0.27
Cambodia	14.4	7	495	27	1.3	0.09	18.2	225	1.0	0.07
Lao	6	2.7	450	31	0.6	0.09	5.8	219	0.3	0.05
Myanmar	49	17	347	16	4	0.1	7.8	343	2.9	0.06

Source: Kimura, 2009.
Note: Statistics have been rounded for simplification, and are for illustrative purposes only.

Efficiency may be the concept which underpins the drive for EMI, but investment and trade are the key activities within the energy market which should lead to the realisation of the desired benefits. Investment is needed to exploit energy resources, to build infrastructure, and to develop and deploy new technologies. Trade which takes energy from exporters to importers enhances the energy security of the importers and can underpin economic development of both importing and exporting states. In certain circumstances, energy trade can reduce the environmental impact of energy production and use, and can lower the cost of energy supply (World Bank, 2008).

A recent study has shown that the liberalization of regional trade and investment and of national energy markets should yield substantial positive gains for the EAS region as a whole, in terms of GDP growth and carbon dioxide emission reduction (ERIA, 2010). This analysis showed that all the EAS countries should see positive GDP benefits, though many countries experience an overall growth of carbon dioxide emissions resulting from the economic growth. The study also argued that an integrated energy market requires not only trade and investment liberalisation, but also linkage of energy infrastructure, reform of domestic pricing systems for energy and liberalisation of national energy markets. However, such is the highly politicised nature of energy that these steps towards EMI, and their component tasks, are likely to prove very challenging to implement.

3. The Distinctiveness of Energy and Energy Policy

The energy industry is distinct from any other sector of the economy. It is a key input to all economic activity, especially in a modern economy, and is a key determinant of the standard of living in all societies. Its distinctiveness as a commercial activity arises from the large capital costs, the long-lead times, the economies of scale, the technical sophistication and the relatively high degree of risk involved. The energy sector may play a very important role in the economy of a nation with respect to the gross domestic product, to the balance of trade, to the availability of foreign exchange, and to the alleviation of poverty.

As a consequence of the distinctiveness and importance of the energy sector, a responsible government cannot avoid becoming involved in the governance of the energy sector, regardless of the nature of the economy and of the system of national governance. Markets alone cannot satisfactorily address a number of key challenges, for example:

- The difficulties of promoting competition on account of the natural monopoly characteristics of energy networks, the role of potential monopolists and cartels, and the high barriers to entry.
- The potential for the production and use of energy to cause harm to wider society and to the environment ('negative externalities').
- The need to manage finite, national natural resources, and to gather and provide market information.

The need to manage those elements of energy which have aspects of a 'public good', such as security of supply, access to basic energy services, and energy efficiency.

Though the effective governance of energy at a national level continues to be of crucial importance, it is no longer sufficient; for the energy industry, the energy markets and the impacts of energy production and use have become transnational, regional and even global in scale. Energy companies are internationalising, oil markets are global, gas markets are regional and growing in scale, energy supply networks span great distances, and environmental damage affects whole regions and even the entire globe. Therefore the governance of energy must also take place at levels above the nation, at regional, trans-regional and global scales.

For East Asia to develop an integrated energy market across the region, new systems of governance must be established which span the region. This then raises a number of questions concerning which aspects of energy should be governed at regional level and concerning the nature of the governing institutions and instruments. Of particular relevance is the number of aspects of energy which have the character of a public good, at least in part. These include (Hunt and Peralta, 2004; United Nations, 2005; Asian Development Bank, 2007; Wright, 2008; Cantore, 2009; Economic Commission for Latin America and the Caribbean, 2009; Goldthau, 2010):

- Security of energy supply;
- Emergency response;
- The prevention of environmental damage;
- The supply of energy to the poor;
- The effective management of primary resources;
- The efficient supply and use of energy services;
- The governance of the energy sector;
- Research and development;
- Capacity building;
- The provision of information.

Although most of these energy policy priorities are normally considered as *national* public goods, they also play an important role in any regional energy market. It is for these reasons that this paper explores the relevance of a regional public goods approach to EMI in East Asia.

4. Regional Public Goods: The Principles

The aim of this section is to provide insight into the main attributes of regional public goods, under five headings:

- Fundamental features of regional public goods
- Aggregation technologies
- Incentives for supply
- Regional organisations
- Supports and constraints for regional collaboration

4.1. Fundamental Features of Regional Public Goods

A public good is a service or a resource which provides benefits which are non-excludable and non-rival. Non-excludability arises from the impossibility or impracticability of excluding users. This results in over-use, especially by 'free-riders who have not contributed to the production of the public good. Non-rivalry arises from the marginal cost of supplying another user being zero. Additional users do not reduce the quantity of the good available to other users, and thus it is not worth spending the money excluding these users. The combination of non-excludability and non-rivalry generally results in over-use and under-supply of a public good. In contrast a private good is fully excludable and fully rival, and supply will, in theory, be efficient.

A range of goods exist which are intermediate between purely public and purely private (Table 3). Common goods are rival and non-excludable, and these are greatly prone to over-use. Impure public goods may be partially rival or partially excludable. They can take different forms and, like pure public goods, are liable to suffer from under-supply and over-use. Club goods are fully excludable, with a membership fee, and are often supplied efficiently. Though they are usually intended to be non-rival, they can easily become partially rival if the fee is not set sufficiently high or if too many parties are allowed to participate. A joint product is an activity which produces more than one benefit, of which at least one is a public good (Sandler, 2006).

Table 3. Classification of Public Goods, with Examples

	Rival	Partially rival	Non-rival
Excludable	**Pure private goods** Food Cars Fuel	**Club goods** Intelsat Canals International space station	Weather stations
Partially excludable	**Impure public goods** Information dissemination Extension services		
Non-excludable	**Common goods** Free access pasture Open pathways Hunting grounds Air corridors	**Impure public goods** Ocean fisheries Pest control	**Pure public goods** Pollution control Disease eradication Strategic weapons Sound financial practices Basic research

Source: UNIDO (2008).

The concept of a public good was originally formulated in the context of an individual nation, in order to show which services and resources should be provided by national governments. Transnational public goods also exist and can be delivered above the regional level, at trans-regional and global levels. The key distinctive feature of all transnational public goods is that, unlike for national public goods, no single body with the authority of a state exists to ensure the supply of the good. This therefore raises the challenge of collective action, through public or private parties, or both (Barrett, 2006; UNIDO, 2008).

A regional public good is one which can be provided by and shared by the countries of a region, and which provides benefits to individual countries and to the region as a whole (Ferroni, 2002; Hettne and Soderbaum, 2006). In principle, collective action by governments in the region should create positive spill-over effects across the region which are greater than those which could be generated by individual governments acting alone (Ferroni, 2002; Sandler, 2007). Certain of these public goods may be quite limited in their geographic extent, and may be better referred to as 'cross-border' public goods (UNIDO, 2008). Trans-regional public goods, as the term implies, benefit two or more contiguous regions, and global public goods, such as the reduction of carbon emissions, benefit the whole world (Sandler, 2007).

One of the key difficulties in the field of transnational public goods is deciding which level of governance or what size of region is most suited to providing the good. This is the issue of 'subsidiarity'. From the economic perspective, the scope of the regional institutions established to deliver the good should match the region benefitting from the spill-over, and the number of countries should be as small as possible in order to reduce transaction costs. This ideal may not be achievable or even desirable in many cases, for two main reasons: first, economies of scale may be better achieved by using an institution which already exists and which has a larger geographic scope than the specific public good under consideration; and, second, economies of scope may be enhanced by having one institution deliver a range of public goods (Hettne and Soderbaum, 2006; Sandler, 2007; UNIDO, 2008).

Most regional public goods fall under one or more of these six headings, though a degree of overlap exists between them:

1. Knowledge: for example, the provision of information, the publication of analyses of that information, scientific research and development, education and training, and dialogue.
2. Infrastructure: for example, the construction and operation of cross-border infrastructure to deliver services, and joint investment in infrastructure to gain

economies of scale. Infrastructure is not in itself a public good, but rather it provides services which have elements of a public good (Rufin, 2004).

3. Environment: for example, measures to prevent pollution, to reduce levels of pollution and to clean-up pollution.
4. Health: for example, preventing or eradicating disease, and stopping the spread of epidemics.
5. Peace and security: for example, shared responsibility for providing security in areas of common security concern.
6. Governance: for example, establishing and implementing shared standards, best practises and policy regimes, setting up regimes to address cross-border problems, and creating networks of regulatory agencies. Governance is an intermediate public good which is essential in order to generate the desired final public goods.

4.2. Aggregation Technologies

For any public good, the key to designing effective delivery of the good is to understand the 'aggregation technology'. The aggregation technology encapsulates the general nature of the institutions and instruments which must be created in order to deliver the public good, and the nature of the aggregator depends on the nature of the good to be delivered. The purpose of the aggregation technology is to provide the incentives for collective action to ensure sufficient supply of the public good. The challenge for policy-makers is to design the institutions and instruments so as to address the weaknesses of the aggregation technology or to manipulate the technology (Barrett, 2006; Sandler, 2004, 2006, 2007; UNIDO, 2008).

Seven types of aggregation technology may be identified for regional public goods (Table 4). The most basic one is 'summation', by which the total supply of the good is the sum of the contributions regardless of how much each party contributes. All contributions are perfectly substitutable. 'Weighted summation' resembles summation, except that in this case the relative importance or weight of the different contributions is variable. For such types of public good, it is very difficult to ensure that all parties contribute. The likelihood of under-provision is high, not least because marginal costs tend to rise as the amount provided by a particular party grows.

Table 4. Typology of Regional Public Goods, with Prognosis for Supply

Aggregation Technology	Pure Public Good	Impure Public Good	Club Good	Joint Products
Summation	*Undersupplied* Cleansing an ecosystem	*Partly undersupplied* Treating diseased patients. Deterring terrorism	*Efficient supply* Regional park. Regional waterway	Preserving rainforests
Weighted sum	*Partly undersupplied* Curbing spread of disease	*Overuse/undersupply* Reducing acid rain	*Efficient supply* Power network. Intelsat	Eliminating insurgency
Weakest link	*Supply may be efficient* Maintaining network integrity. Containing disease	*Overuse/undersupply* Monitoring disease outbreak	*Undersupply* Air traffic control	Security intelligence
Weaker link	*Efficient supply expected/possible* Maintaining financial stability	*Overuse/undersupply* Preventing spread of pest	*Undersupply* Transportation infrastructure	Internet connectivity
Best shot	*Undersupply or efficient supply* Developing a vaccine	*Undersupply or efficient supply* Gathering intelligence on terrorists. Disseminating research findings on climate change	*Efficient supply* Rapid reaction force. Satellite launch facility	Remote sensing of hurricanes
Better shot	*Undersupply or efficient supply* Quality control of food exports	*Overuse/some undersupply* Database Cleaning up oil spill	*Efficient supply* Biohazard facility	Bioprospecting
Threshold	*Limited undersupply* Regional flood control	*Limited undersupply* Forest fire suppression	*Efficient supply* Crisis management team	Regional peacekeeping

Sources: Sandler (2006, 2007), UNIDO (2008).

The supply of a good with 'weakest link' aggregation technology depends on the supply of the smallest contributor, just like the weakest link in a chain. Every contribution is important, but the failure by just one country to supply an adequate quantity of the good undermines the collective effort and renders the efforts of others wasted. 'Weaker link' technology is similar but implies that there is a gradation of 'weakness' among contributors. The risk exists that every country contributes only as much as the weakest country or countries, and that greater effort is expended on addressing the anticipated failure to provide the public good than on providing the good. This outcome can be avoided if the parties share common interests and goals, and if the wealthier or more competent countries help the weaker states through the provision of money, skills or other resources.

At the other extreme is ‘best shot’ technology, through which the total supply of the public good is determined by the success or actions of just one country. ‘Better shot’ technology is similar to best shot, except that the impact of each contribution is proportional to the size of that contribution. In principle, such aggregators avoid many of the challenges facing other technologies, but require coordination among the countries in the region to ensure that resources are not wasted by those countries which are unlikely to make the best shot contribution. Problems may arise if no country is willing or able to deliver the good, if a country fails to deliver on a promise to deliver to good, or if two or more countries are vying to be the provider.

The final type of aggregation technology is ‘threshold’ which requires a certain level of contribution to be made from the parties collectively before any benefit is realised. If the total contribution falls below this threshold, no benefit accrues to any party, only costs. Free-riding can only occur once the threshold has been reached. Examples include many forms of emergency response teams and facilities.

4.3. Incentives for Supply

The provision of regional public goods requires incentives. Collaboration which requires substantial and sustained commitments is likely to require a formal treaty with rewards and sanctions (Devlin and Mulder, 2006). This is especially the case for most summation technologies which require formal institutions in order to share costs or allocate (tradable) property rights, and to provide for credible and substantial penalties in the case of failure to adhere to the terms of the agreement (UNIDO, 2008).

Clearly one of the easiest types of regional good to supply is the club good, the provision of which will require a toll with possibly both a capacity charge and a variable charge. Cross-subsidies may be needed for goods with weakest link aggregators. For impure and pure public goods, most aggregation technologies present challenges, with the possible exception of best shot goods which can be effective as long as the single actor is able and willing to supply, and provided coordination is adequate. Avoiding under-supply or over-use with other types of technology requires measures which vary according to the aggregation technology. Even if a formal treaty and organisation is not necessary, a degree of coordination and cooperation will be required in order to deliver any type of regional public good efficiently (Barrett, 2006).

4.4. Regional Organisations

No regional organisation will have the authority of a national government because sovereignty lies with individual nations (Matthews, 2003). A supra-national approach to regional governance in which the regional body has real authority over member states is only possible if the individual states are willing to cede a significant amount of sovereignty to this body, as is the case with the European Union. This is rarely acceptable in other parts of the world. Rather, most regional cooperation is inter-governmental, with each state retaining veto power and with a secretariat which coordinates but has no authority.

The approach taken in building regional collaboration also depends on the extent of integration envisaged. At one end of the spectrum lies full market integration which will require a sophisticated system of rules and incentives in order to break down trade barriers and to ensure the free flow of goods and services. At the other extreme, states can agree to cooperate in certain sectors to deliver specific regional public goods. In between these two extreme lies policy coordination, or even policy harmonisation, which may accompany either market integration or sectoral cooperation (Matthews, 2003).

Global cooperation organisations tend to fall into one of three categories: standard setters, operational managers, and service providers. Regional cooperation organisations tend to embody all three characteristics. They may be formal organisations or networks, and they may be uni-dimensional or multi-dimensional. Thus regional organisation structures can be grouped into one of four categories (Hettne and Soderbaum, 2006):

- Uni-dimensional organisations which may focus on regional economic integration or regional finance (the regional development banks) or which may be limited to a single sector such as health, security, education or communications.
- Multi-dimensional organisations which may drive regional cooperation (such as ASEAN), those which enhance collaboration in a river basin, and certain UN organisations such as UNESCAP.

- Uni-dimensional networks promote cooperation and coordination in such activities as research and development, and may draw on civil society and private commercial parties as well as on public bodies. A regional electrical power pool, such as the Nordpool, is a more technically sophisticated example. A particular type of organisation which can be of great value in establishing a regional market is the regulatory network (Matthews, 2003; Berg and Horrall, 2008).
- Multi-dimensional networks are less common, and include growth triangles, development corridors and other micro-regional economic organisations.

The final organisation of relevance is the research institute, for research underpins the improved provision of many types of transnational public good (Hettne and Soderbaum, 2006).

Whatever combination of organisations are developed to promote the supply of public goods across a region, a number of general principles should be held in mind. First, policy research and operational management should not be considered as separate activities, but should be integrated in the same organisations. Second, the long-term aim of the regional organisations and institutions should be to encourage the emergence of new behavioural norms that support the delivery of regional public goods, not just to enforce them through rules. Finally, all regional organisations should be linked effectively both horizontally to other regional organisations in the same geographical area, and vertically to global and national organisations providing public goods. It may also be desirable to build links to regional organisations in adjacent regions in order to deliver trans-regional public goods (Hettne and Soderbaum, 2006; Sandler, 2007; UNIDO, 2008).

4.5. Supports for and Constraints to Regional Collaboration

As mentioned above, the main constraint to the effectiveness of international law and to the provision of transnational public goods is sovereignty (Barrett, 2006). Unwillingness to cede any degree of sovereignty to a supranational, regional organisation was widespread throughout much of the twentieth century. Though attempts were made by states to collaborate and even to integrate their economies across a region, the level of success was modest. Most of these efforts were defensive in nature, seeking to promote economic development through state-centred, protectionist approaches with formal rules and exclusive membership. With the exception of the European Union, most of these efforts failed in attaining their objectives for a range of economic and political reasons. The cost of integration was too high, the economic diversity among the participating states was too great, and governments lacked both political commitment and a willingness to yield sovereignty (Matthews, 2003; Hettne and Soderbaum, 2006).

This ‘old regionalism’ contrasts with the ‘new regionalism’ which takes a more open, informal and flexible approach to cooperation. Membership tends to be open to new parties, structures and systems are more heterogeneous and both formal rules and binding commitments with penalties for failure are rare. The typical new regionalism seeks to promote market reforms within the region in order to promote trade and integration, at the same time as seeking integration with global economic systems. From one perspective, the ‘new regionalism’ is to be welcomed as it engenders a higher degree of willingness to collaborate (Matthews, 2003; Hettne and Soderbaum, 2006; Devlin and Mulder, 2006; Sandler, 2007). On the other hand, such informal and flexible arrangements may be less able to deliver outcomes which require a high degree of commitment and contribution from all the parties.

In addition to these general forces which appear to be providing support for the provision of regional public goods, a number of other specific supporting factors can be identified which will tend to promote collaboration with a region, for example (Barrett, 2006; Devlin and Mulder, 2006; Sandler, 2007):

- A common history or cultural heritage;
- A common world view, especially with respect to economic and political issues;
- A perceived common threat;
- Leadership by one or more nations;
- A high degree of political will from all or most of the participating states;
- The participation of private actors, both commercial and civil society.

Conversely, regional collaboration can be inhibited or delayed by a wide range of factors, for example (Ferroni, 2002; Barrett, 2006; Devlin and Mulder, 2006; Sandler, 2007; UNIDO, 2008):

- The length of time needed to achieve noticeable benefits;

- The need for individual governments to amend national laws, structures and systems in order to adhere to the requirements of the collaborative initiatives;
- The need to compensate those states which either lose from the proposed arrangements or which need assistance to meet the required standards;
- Long-standing rivalries between nations within the region which may undermine the emergence of a regional leadership;
- Unwillingness by one or more nations to cede any degree of sovereignty;
- A lack of capacity in the regional organisations to support the delivery of the public goods;
- A lack of finance or of a regional body which can provide or transfer finance;
- A lack of confidence in the willingness of others to deliver on the commitments;
- The presence of economies with a high degree of state control and ownership.

The challenge for governments seeking to work together to deliver regional public goods is to recognise these constraints and to address them through a combination of (1) taking measures to tackle them directly, (2) directing efforts at delivering those goods which bring obvious benefits to the greatest number of states, and (3) designing the incentives in such a way as to overcome these constraints.

5. Regional Public Goods: Application to the Energy Sector

Section 3 of this report listed a number of elements of the energy system which have been identified by others as having characteristics of a public good, namely:

- Security of energy supply;
- Emergency response;
- The prevention of environmental damage;
- The supply of energy to the poor;
- The effective management of primary resources;
- The efficient supply and use of energy services;
- The governance of the energy sector;
- Research and development;

- Capacity building;
- The provision of information.

The aim of this section is to apply the ideas explored in Section 4 to the energy sector in order to more explicitly identify which features of the energy sector may be considered as regional public goods and how they may be classified and understood in this context.

The first step in this process involves recognising that although many 'high level' regional policy goals may have features which resemble a public good, they themselves comprise a large number of elements which require individual examination. Such 'high level' regional policy goals include:

- Security of energy supply;
- Economic development;
- Poverty alleviation;
- Economic and technical efficiency;
- Environmental protection.

The public good character of these policy priorities is taken for granted in this study, and, indeed, they are the over-arching policy objectives for EAS in the energy sector. Instead, this study focuses on the more specific services or actions which need to be delivered in order to achieve these broader goals. These will be considered under the five heading listed in Section 4.1, namely knowledge, infrastructure, environment, health, and security. Governance, as an intermediate public good, will be examined separately.

5.1. Identifying Regional Public Goods in the Energy Sector

A preliminary identification and classification of potential services which have features of a regional public good and which are required to be delivered in order to build an integrated energy market is shown in Tables 5 and 6. The aim of these tables is to be illustrative rather than exhaustive, and to show how the concept of regional public goods may be applied.

5.1.1. Knowledge

Knowledge in the broadest sense may be the most important public good required to support the development of a regional integrated energy market, because a market cannot operate without knowledge. A large number of types of knowledge have been listed in Tables 5 and 6 with the aim of illustrating the range of knowledge that is required and the variation in the characteristics of different types of knowledge which in turn are likely to affect the provision of the good.

Table 5. Selected Services which have Features of Regional Public Goods for A Regional Integrated Energy Market, Grouped by Field of Activity

Category	Service	Type of Good	Aggregator
Knowledge	Dissemination of research results	Pure PG	Weighted sum
	Joint public pronouncements	Pure PG	Weaker link
	Best practice laws, procedures and rules	Pure PG	Better shot
	Early warning systems	Pure PG	Best shot
	Market and reserves data	Impure PG	Weaker link
	Analysis of data	Impure PG	Better shot
	Technological research and development	Impure PG	Better shot
	Benchmarking data	Impure PG	Threshold
	Capacity building and training	Club G	Better shot
	Events and meetings	Club G	Weighted sum
Infrastructure	Network construction	Club good	Weighted sum
	Construction of shared infrastructure	Club good	Weighted sum
	Maintaining network integrity, security and access	Pure PG	Weakest link
Environment, natural resources, and health	Providing clean energy to cities and households	Pure PG	Weighted sum
	Effective husbanding of natural resources	Pure PG	Weaker link
	Reducing acid rain	Impure PG	Weighted sum
	Cleaning up after polluting event	Impure PG	Better shot
Peace and security	Construction of emergency stocks	Pure PG	Better shot
	Emergency stock sharing system	Club G	Weighted sum
	Sea-lane security	Pure PG	Better shot
	Network security	Pure PG	Weakest link
	Emergency response team	Club G	Threshold

Pure public goods include the public dissemination of research results, joint public pronouncements, the development and dissemination of best practices, and certain types of regional early warning systems. Most of the other types of knowledge are impure public gods, mainly on account of the potential for partial excludability. Capacity building, training, events and meetings are generally club goods.

With respect to the aggregation technology, the key distinction is between those goods which are best or better shot and those which are weakest or weaker link. Best or better shot goods include technological research and development, data analysis, capacity building and training, the development of best practices, and regional early warning systems. In a region which has one or more countries with the wealth, skills and technology, the likelihood of provision of these goods is relatively high, provided the leading nations wish to provide them. In contrast, those goods which are weakest or weaker link are more susceptible to the performance of the weaker or more reluctant members in the region. Examples include joint public pronouncements, and the provision of data on national energy markets and energy reserves. The second of these, data, is crucial for the effective operation of a regional energy market.

Two other groups of knowledge-related public good can be recognised. Dissemination of research results and events and meetings involve weighted sum aggregation, and the provision of benchmarking data requires threshold aggregation.

Table 6. Selected Regional Public Goods for a Regional Integrated Energy Market, Grouped by Type of Service and Aggregator

Aggregation Technology	Pure Public Good	Impure Public Good	Club Good
Summation			
Weighted sum	Dissemination of research results. Providing clean energy to cities.	Reducing acid rain	Network construction. Events and meetings. Emergency stock sharing system.
Weakest link	Maintaining network integrity, security and access.		
Weaker link	Joint public pronouncements. Husbanding of natural resources.	Market and reserves data.	
Threshold		Benchmarking data.	Emergency response team
Best shot	Early warning systems		
Better shot	Technology R & D . Best practice laws, procedures and rules. Emergency stock construction. Sea-lane security.	Cleaning up after pollution event. Analysis of data	Capacity building & training.

With respect to the aggregation technology, the key distinction is between those goods which are best or better shot and those which are weakest or weaker link. Best or better shot goods include technological research and development, data analysis, capacity building and training, the development of best practices, and regional early warning systems. In a region which has one or more countries with the wealth, skills and technology, the likelihood of provision of these goods is relatively high, provided the leading nations wish to provide them. In contrast, those goods which are weakest or weaker link are more susceptible to the performance of the weaker or more reluctant members in the region. Examples include joint public pronouncements, and the provision of data on national energy markets and energy reserves. The second of these, data, is crucial for the effective operation of a regional energy market.

Two other groups of knowledge-related public good can be recognised. Dissemination of research results and events and meetings involve weighted sum aggregation, and the provision of benchmarking data requires threshold aggregation.

5.1.2. Infrastructure

The construction and operation of infrastructure to transport energy across a region is one of the most fundamental requirements for an integrated energy market. Such infrastructure is required to transport oil, gas, coal and electricity. Although pipelines and electricity grids form the heart of a modern energy transport system, roads, canals, and railways also play an important role.

Trans-boundary infrastructure other than networks may also play an important role in the development of a regional energy market. Single infrastructure projects may be developed by two (or possibly three) neighbouring states along their shared borders. Examples include power plants, dams, oil refineries, LNG terminals, ports, or production facilities for an oil or gas field. Such shared projects are especially relevant in cases where resources straddle national boundaries or where individual states lack the resources or the requirement to develop the project on their own.

The construction of trans-boundary infrastructure and regional energy networks is usually a club good, from which actors can be excluded, and has features of a weighted sum aggregator, as different parties usually make different scales of contribution to the project. In contrast, maintaining the integrity of the network is a pure public good on account of the wide benefits this brings to society across the region in terms of economic development and poverty alleviation. However infrastructure integrity is often vulnerable to the actions or inactions of the least competent party and therefore has a weakest link aggregator. As a consequence, maintaining the integrity of a regional energy network will be much more challenging than constructing it in the first instance.

5.1.3. Environment, Natural Resources and Health

For the purposes of an analysis of the public good aspects of energy, it is appropriate to combine the environmental and health dimensions of energy, for the health impacts of energy production and use mainly arise from pollution of different types.

Two examples of energy services which yield pure public goods include the provision of clean energy in cities and households, and the effective husbanding or management of primary energy resources. The first involves removing local sources of atmospheric pollution produces by vehicles, power stations and industry, and providing gas or electricity to households instead of coal or biomass. This may require the provision of clean energy by other countries depending on their ability to supply clean energy. This involves weighted sum aggregation. The effective management of primary energy resources can be considered as a regional or even as a global public good, because once they have been wasted then they can usually never be recovered. Rather like maintaining the integrity of a network, the management of regional primary energy resources has features of a weaker link public good.

The reduction of greenhouse gas emissions is not addressed here, as that self-evidently a global public good, though regional approaches may be developed to address this challenge. In contrast, the reduction of acid rain through controlling sulphur dioxide emissions from power stations and other industries is certainly a regional public good, though impure in nature. The weighted sum aggregator arises from the dependence on the amount of emissions produced by different countries and the direction of prevailing winds with respect to the source of pollution and to potential areas of damage. In contrast, cleaning up after a polluting event, such as an oil or chemical spill, requires a best shot or better shot aggregator.

5.1.4. Security

For reasons discussed above, wider issues relating to security of energy supply are not examined here. Rather the focus is on a number of specific services which have a security dimension and which have elements of a regional public good.

The first two items relate to the ability to manage short-term disruptions in the international energy markets. They involve the construction and filling of emergency stocks of an energy commodity such as oil, gas or coal, and systems for sharing these stocks in the event of a market disruption. The construction and filling of emergency stocks is a pure public good, as the existence of such stocks acts to stabilise the market, and just a few countries in the region are needed to undertake this task, making it a better shot aggregator. Indeed, given the global nature of the oil market, the construction of oil stocks may better be considered as a global public good. In contrast, any system for sharing the stocks in the case of an emergency is a club good, and is subject to a weighted sum aggregator as different players will have different capacities and willingness to share.

The provision of physical security to energy transport routes is an important pure regional public good that all parties benefit from. Sea-lane security can be provided by one or more powerful states, making the aggregator best or better shot, whilst the security of onshore networks more closely resembles a weaker link good as a network is only as secure as its most vulnerable point.

The final example is the emergency response team created, trained and resourced to provide the initial response to an accident or natural disaster which affects an energy system, for example an explosion in a production or transportation facility. Unlike the clean-up operation which is an impure public good, the emergency response team is most likely a club good to which only certain countries contribute and from which only these countries benefit. The ability of the response team to react to emergencies in countries outside the ‘club’ may be constrained not only by the rules of the ‘club’ but also by the physical distance to other countries. The aggregator is of the threshold type, as an inadequate emergency response capability is usually unable to effect any meaningful action.

5.2. Governance for the Provision Regional Public Goods in the Energy Sector

As was noted above, the collective action required to deliver public goods at regional or trans-regional scales requires governance. The word ‘governance’ can be interpreted and applied in different ways. For international economic organisations, governance involves the management of economic and social affairs by government; for example through the allocation of public resources and the resolution of conflicts between actors, through the exercise of political authority, through the establishment and operation of institutions, and through the formulation and implementation of policies (World Bank, 1992). Measures of governance quality include accountability, participation, predictability, transparency, efficiency and effectiveness (Asian Development Bank, 1995).

In contrast, transaction cost economics and new institutional economics express the concept of governance in much more general terms. In the words of Oliver Williamson “Governance is an effort to craft order, mitigate conflict and realise mutual gains” (Williamson, 2000). This approach focuses on the governance of economic transactions where a transaction is defined as the transfer of a physical good, a commodity, a legal right or a natural resource between actors (Williamson, 2000; Hagedoorn 2009). In this context a governance structure may be “thought of as an institutional framework in which the integrity of a transaction, or related set of transactions, is decided” (Williamson, 1996, p.11).

Both definitions are relevant to this study, because effective governance is required at supra-national and national levels and at the level of the individual economic transaction. In order to determine the most appropriate form of governance for the provision of energy public goods across a region, a number of questions need to be addressed, as already indicated in the previous section:

- What are the overall objectives of the programme for energy cooperation?
- What incentives are needed to deliver the required public goods?
- What are the main supporting and constraining factors?
- Over what region or regions should this cooperation take place?
- What organisations of governance may be suited to these circumstances?

The first question to be addressed by the parties relates to the degree to which they seek to integrate their national energy markets. At one extreme, they might wish to embark on an ambitious programme to create a seamless regional energy market across which capital, commodities and services would flow freely, in the manner of the European Union's intended "single energy market". At the other extreme, the parties might prefer to restrict their cooperation to a few of the most needed energy services. In between these two extreme lie a range of options involving policy coordination and harmonisation, collaboration in the provision of selected public goods, and partial market integration between certain groups of countries in the region. Which approach is preferable or even feasible will to a great extent be determined by the other factors being examined in this section.

The nature of the incentives which will be required to provide the public goods will depend on the nature of the service and of the aggregator. Coordination and cooperation between nation states is a prerequisite for the provision of all regional public goods. What will vary is the extent to which rights, obligations and sanctions must be embodied in a formal treaty. Certain goods with summation or weighted sum aggregators are likely to require treaties, for example the construction of networks, a sharing system for emergency stocks, and the reduction of acid rain. In the case of club goods, those parties who do not wish to participate can easily be excluded and the agreement can be concluded without excessive difficulty. The provision of best shot or better shot goods such as early warning systems, research and development, pollution clean-up and the construction of emergency stocks only needs key parties to be willing to provide the service and to cooperate in its provision.

Weakest and weaker link goods are constrained by the inability or unwillingness of parties to collaborate in supply the good. Inability can be addressed through financial or technical support, for example in maintaining network integrity. But unwillingness to provide may be rooted in the political culture or in national attitudes towards sovereignty. The provision of data on national energy markets and energy reserves, and the management of primary energy resources are likely to be liable to such a constraint. Of more fundamental importance will be the inability or unwillingness of certain governments to open their energy sectors to foreign investment, to reform their systems for energy pricing, to remove the monopoly rights of the national energy champions, and to provide third-party access to energy infrastructure. These constraints to EMI are illustrated in the case of the European Union, as will be shown in the next section.

The supports for and constraints to regional collaboration elaborated in Section 4.5 are all applicable to the energy sector. Of particular relevance is the need for leadership from one or more nations and for a common world view relating to economics and politics. This arises from the profound relationship between energy, on the one hand, and national sovereignty and national security, on the other. The full integration of energy markets requires governments to cede ownership over their state-owned energy enterprises, to promote inward investment in the exploitation of primary energy resources, and to relax their control over domestic energy markets. Even less ambitious collaboration will require changes to national laws, structures and systems relating to energy. Rivalry between those nations which should be providing regional leadership and the need for cross-subsidies between nations may also prove important barriers to progress.

The geographic extent of collaboration in the provision of energy public goods will depend on (1) the geographic extent of the spill-over benefits from this collaboration and (2) economies of scale and of scope. The extent of the spill-over from the provision of energy public goods is highly variable. Some goods may have spill-overs which are very wide and may even extend beyond the region. Examples include the construction and filling of emergency stocks, research and development, and sea-lane security. Others, such as the construction and operation of an energy network, yield benefits mainly to those connected to the grid. Emergency response teams and pollution clean-up capacity will also have geographic limitations.

For a large region in which the countries seek to collaborate in a number of energy activities, the geographic extent of the spill-over from each activity is likely to be highly variable depending on such factors as the physical geography, the nature and location of energy resources, the location of centres of energy demand, and the degree of economic development. As a consequence it may be necessary to group activities into two or more levels of geographic spill-over, creating a hierarchy in which activities which cover the entire region are managed at the highest level; whereas those activities which most appropriately involve a sub-set of the parties are managed at lower levels, with the higher level of governance providing coordination. In other words, the larger 'region' could be divided into smaller ‘sub-regions’ for the provision of certain goods with a more limited spill-over. In this respect, the coordination between the ‘sub-regions’ would resemble the provision of trans-regional public goods mentioned in Section 4.

The type of organisation or organisations which are required will depend on three main factors:

- The overall goal of the regional energy cooperation;
- The nature of the regionalism;
- The nature of the specific activities to be coordinated.

As noted in Section 4.4, full regional integration which is intended to lead to a single regional energy market with free movement of commodities, capital and services will require a sophisticated system of rules and incentives. This may, in turn, require a formal supra-national organisation with powers of enforcement as is exemplified by the European Union, or at least formal and wide-ranging treaty such as the Energy Charter Treaty. Whether this is necessary, desirable or even feasible will depend on the nature of the emerging regionalism. Whilst formal supranational governance structures may be desirable in principle, such an approach is characteristic of the ‘old regionalism’. In contrast, ‘new regionalism’ prefers arrangements which are less formal and which lack binding commitments and enforceable sanctions. In these circumstances, it might prove difficult to move ahead with certain initiatives which involve substantial commitments from a large numbers of countries in the region.

Instead, effort may be best directed at making progress incrementally by focusing on a limited number of activities involving countries which are clearly able and willing to participate. Different organisations could then be created to manage defined sets of activities over certain ‘sub-regions’, under the overall coordination of the high-level regional organisation. The sub-ordinate entities could be structured in a manner so as to take advantage of potential economies of scale and scope, and to prevent a proliferation of entities. Some of these entities will be formal organisations with specific responsibilities for overseeing the implementation of certain activities such as cross-border energy transport or environmental protection, others may take the form of informal networks addressing research, development, information and even regulation.

6. Lessons from the European Experience

Whilst the European Union (EU) may seem remote from East Asia in physical, cultural, political and economic respects, its experience in attempting to develop an integrated energy market has relevance to the EAS, if only on account of the length of time this process of EMI has been running in the EU. The aim of this section is to briefly identify some lessons from the European experience which may be relevant to East Asia.

Formal collaboration between European countries in the field of energy began in the early 1950s with the establishment of the European Coal and Steel Community and the European Atomic Energy community. The first of these was created with the express ambition of building a common market for coal, then the most important source of energy. The next significant step taken was progressive development from 1968 onwards of emergency response mechanisms to react to disruptions to oil supplies, including the construction of oil stocks (Matlary, 1997).

A key feature of the EU is that the member states cede partial sovereignty to the institutions of the EU: to the Council of Europe which comprises the heads of government of each member state, to the European Commission which is a large and powerful civil service, and to the European Parliament which has members directly elected from the member states. Of these three bodies, it has been the Commission which has been the most active in promoting the single European energy market.

It was in 1986 that the Council of Europe first agreed on the need for greater integration of national energy markets and in 1988 it was resolved to introduce single internal energy market. A decade of proposals, drafting and negotiating then took place. The most significant measure to emerge was the Directive on Hydrocarbons Licensing which was issued in 1994 (Cross *et al.*, 2001). Though not obliging member states to open their territories for hydrocarbon exploration and production, the Directive did lay down procedures to be followed once such a decision had been made in order to minimise discrimination against companies from other member states. Legally-binding Directives relating to price transparency and to electricity and gas transit were issued, and Common Rules covering the removal of monopoly rights, the unbundling of vertically-integrated utilities and third-party access to transmission infrastructure were drafted (Lyons, 1996; Cameron, 2002).

Despite all these formal measures, little was achieved towards building a single energy market until 1996 and 1998 when the Electricity and Gas Directives respectively were adopted. This breakthrough was assisted by the progressive emergence of competitive energy markets at national level, for example in the United Kingdom, Germany, the Nordic countries, the Netherlands and Spain (Egenhofer, 1997). Despite this positive influence, the level of opposition to the Commission's core ideas remained high. As a consequence these Directives reflected compromise solutions to many key issues including third-party access to energy infrastructure and unbundling of utilities. Further, these Directives focused on the liberalisation of national markets and they failed to address key obstacles to the promotion of cross-border energy trade. One significant step towards addressing this deficiency was the establishment in 1998 and 1999 of Forums for the national electricity and gas regulators respectively (Cameron, 2002). These soon merged to form the Council of European Energy Regulators, an independent body which seeks to promote the development of the single energy market through providing coordination between national regulators and between these regulators and the European Commission.

Further Directives concerning the development of Europe-wide electricity and gas markets were adopted in 2003, but little progress was being made towards the creation of a single energy market. In 2007, the Council of Europe issued an "Energy Policy for Europe" which showed renewed political commitment at the highest level to the single European energy market, with three objectives: security of energy supply, a competitive energy market, and the environment, particularly climate change (de Jong, 2008). New measures were required to push forward EMI, and specifically to address continuing obstacles, for example (Nowak, 2010):

- The dominant position in markets of certain national energy companies and the high degree of vertical integration of many of these companies, features which provide high barriers to entry for competitors and prevent access to transmission grids;
- The distortion of competition through inappropriate price regulation;

- The insufficient independence of national energy regulators;
- A shortage of cross-border transmission capacity and high prices for access to such capacity.

A so-called 'Third Energy Package' of proposed measures was published in 2009 and took effect from March 2011. The main components are (Stanic, 2011):

- Unbundling of transmission from production and supply activities;
- Stronger powers and independence of national regulators;
- New rules to harmonise market and network operations across Europe,
- Higher standards of public service obligations and consumer protection;
- New institutions to promote cooperation between regulators and between transmission system operators.

The centrepiece of this new legislation was to have been the mandatory ownership unbundling of vertically-integrated energy utilities. The aim was to radically reduce the ability of energy companies to act in an anti-competitive fashion, in particular by restricting third-party access to transmission networks and by constraining investment in new network capacity. This proposal was over-ruled by two powerful member states, Germany and France (Nowak, 2010). As a result, countries may choose one of three forms of unbundling:

- Ownership unbundling;
- The creation of a independent system operator which leases the network from the utility;
- The creation of an independent transmission system operator which remains within the utility.

It is too early to say how well these new measures will succeed. But this brief history shows that much remains to be achieved twenty three years after the first formal declaration of the need to develop a single energy market in 1988. National interests relating to the support of national champions and the management of domestic energy markets still act to constrain progress on key issues. A small number of powerful interests have colluded to block progress for many years, and great determination and persistence has been required on the part of the Commission to sustain forward movement. In the field of energy, national interests appear to over-ride the collective interest (Eikeland, 2004), despite the relatively high degree of commonality in customs, norms and values across the member states with respect to culture, politics and economics.

This pessimistic evaluation of European energy policy has to be set alongside real progress in many respects. Of particular relevance to the theme of the single European energy market has been the gradual development of smaller regional energy markets *within* the EU which has been supported by the Commission and by the regulators since 2004. These markets take advantage of proximity between nations and of existing network links. These sub-regional networks have allowed local economic benefit to be realised by the participating states and can provide the building blocks for later integration to form a Europe-wide market once the necessary infrastructure has been built (de Jong, 2008). This suggests that EMI requires bottom-up initiatives as well as top down persuasion and enforcement.

7. Application to Energy Market Integration East Asia

The development of a fully integrated energy market across the East Asian region will prove to be an ambitious undertaking and could take several decades to accomplish. Achieving even the more modest objective of gradual and partial market integration will require sustained effort, determination and leadership. A very wide range of tasks need to be undertaken, some of which will be straightforward and others of which will be much more difficult. The application of regional public goods theory to EMI allows us to identify features in the region which may support and which may constrain EMI. It also provides a framework for assessing the type and geographic scope of governance required. The experience of the EU further illustrates the difficulties involved and highlights certain key obstacles to progress.

EMI requires a number of regional actions to be taken and services to be provided which have features of a regional public good. Some of these are illustrated in Tables 5 and 6. Governance has not been included in these tables for it is considered as an intermediate public good – that is to say, appropriate governance is the service which has to be provided in order that these other public goods can be delivered. Given the special nature of energy, its importance to national economic development, to national security and to national sovereignty, governance is the most critical public good required to deliver a regional energy market.

East Asia has a number of factors which tend to support steps to EMI. These include:

- Geographic contiguity, albeit over a vast distance;
- Certain commonalities of outlook and a general willingness to cooperate on economic issues (Dent, 2008);
- Complementarity across the region in terms of energy supply and demand, and energy mix;
- A number of countries with advanced economies and technological expertise which can act as best shot or better shot suppliers of public goods (for example, the first group in Table 2);
- A number of countries which can, in principle, act as political leaders in the integration process (a number of countries from the first and second groups in Table 2);

Set against these supporting factors are a number of potential constraints which include:

- The large geographic size of the East Asian region, along with the significant physical barriers across the region such as oceans and mountain ranges;
- A high degree of divergence with respect to history, culture, economics, and politics;
- Long-standing rivalries between key nations which potentially could provide leadership, as well as major unresolved security challenges and a strong emphasis on national sovereignty (Gurtov, 2002; Lincoln, 2004; Rozman, 2004);
- A number of very poor countries in a key location in the region which could prove to be weaker link actors in the management of regional infrastructure (for example, the fourth group in Table 2);
- A high degree of variability between the national energy sectors with respect to degree of development, ownership, market structure, and policy priorities.

These constraining factors will affect not only the provision of specific services, such as those listed in Tables 5 and 6, but will also restrict the rate at which effective governance systems which span the region can be developed. Of particular significance are issues relating to perceptions of national security, national sovereignty and state control of the energy industry. These concerns are likely to impede the reduction of market barriers, especially those relating to third-party access to energy infrastructure and to the monopoly power of national energy companies.

The experience of the EU shows that decades may be needed to make significant progress on some of these governance issues. The EU has many advantages over the East Asian region in terms of geographical size and contiguity, political and economic outlook, and the success in integrating markets for other goods and services. The key lesson from the EU experience is that full EMI can only proceed as rapidly as the slowest nation, or at least as the slowest nation with a key role to play in the market. The progress in developing the single European energy market has, in simple terms, followed the degree of acceptance of the *idea* of energy market liberalisation. During those periods in which the European public have increased their acceptance of the idea, there has been subsequent progress in integration. When the idea of energy market liberalisation is called into question, so is the ambition of EMI.

Despite the slow progress of EMI in Europe, a number of regional public goods in the energy sector are being delivered at a Europe-wide scale, and sub-regional market integration is moving ahead. The implications for the East Asian region are two-fold. Firstly, EMI should be pursued initially at sub-regional level. Secondly, the delivery of specific services at sub-regional level will support the eventual development of an integrated energy market. The specific energy services which could be delivered are best considered according to their degree of 'publicness' and to their aggregation technology.

The construction of trans-boundary infrastructure is in many respects a club good (though the operation of it has wider public goods benefits) and can therefore be delivered with a discrete number of willing and competent states. Given that oil and, to a lesser extent, coal are fungible commodities traded across global markets, the development of an integrated energy market mainly involves electricity and gas which in turn requires the construction and operation of transmission infrastructure. These are best constructed and operated at sub-regional level, in south-east and north-east Asia, but such markets will still face the operational challenges common to weaker and weakest link goods.

Trans-boundary infrastructure can also include projects that occupy a single location straddling an international boundary. These include power plants, dams, oil refineries, LNG terminals, ports, or production facilities for an oil or gas field. Given their weighted sum character, the delivery these infrastructure projects, as well as other club goods such as acid rain reduction and emergency stock sharing systems, will require very close collaboration between the participating states and, probably, formal legally-binding commitments from the parties.

A number of services or facilities which resemble best shot or better shot goods can be, or are already being delivered through the efforts of a small number of leading nations, for example:

- Early warning systems;
- Technological research and development;
- Best practice laws, regulations procedures and rules;
- Emergency stock construction
- Sea-lane security;
- Cleaning up after a pollution event;
- Analysis of data;
- Capacity building and training.

Except in the case of best shot goods which are delivered by a single nation, the effective delivery of these goods requires not only that the leading nations be prepared to deliver the good but also that they work together in a coordinated manner. This in turn raises the question of the geographical extent over which such coordination and delivery should take place. Many of the goods on this list could indeed be delivered across the East Asian region, but sea-lane security and cleaning up after a pollution event may better be provided at sub-regional level.

Services with weakest and weaker link features arguably provide the greatest challenge. Not only is delivery dependent on the ability and willingness of 'weak' states to participate effectively, but certain of these services are critical to the effective functioning of a regional energy market, for example:

- The availability of market and reserves data;
- The maintenance of network integrity and security;
- The effective husbanding of natural resources.

Each of these services is closely dependent on the nature of national systems of energy governance and on perceptions of national security. If nations which are vital in terms of energy supply or demand or in terms of location along network infrastructure are unable or unwilling to provide these goods, then the regional energy market is seriously undermined. In the case of East Asia, a number of countries which currently would be unable or unwilling to provide these public goods may be identified. As a consequence, progress towards an integrated energy market will have to be selective in terms of geographical area and in terms of the component goods to be delivered.

The design of the institutions of governance will depend on the nature of the governance required and on the geographic extent of the spill-over, taking into account economies of scale and scope, as discussed in Sections 4 and 5. Given the current state of development of the energy market in the East Asian region and the range of goods to be provided, these considerations suggest that a hierarchy of institutions be created, building on those which already exist.

At the highest level, an organisation could be established to provide *coordination* across the East Asian region:

- coordination of certain goods which are being delivered across the whole region, for example best shot and better shot goods, and any summation or weighted sum goods being delivered at regional level;
- coordination between sub-regional initiatives of different types.

At sub-regional level, a number of institutions may evolve depending on the region across which different goods are being developed and the nature of the governance required, for example coordination, treaty or governing body. In the case of the East Asian region, the challenge will be to design such institutions in a way which achieves economies of scale and scope. Whilst ASEAN and the countries of north-east Asia form natural geographic groupings, the effective inclusion of other states in sub-regional governing institutions may prove more problematic.

8. Policy Implications for the East Asian Summit

EMI has the potential to yield widespread economic benefits across East Asia, and some of these benefits have features of a public good. Whilst full EMI to form a single energy market is a task requiring decades of work, certain steps can be taken to move towards integration.

EMI in East Asia faces a number of obstacles, geographic, political and economic. The most intractable of these relate to issues relating to national security, national sovereignty and state control of the energy sector. The implications are two-fold:

1. EMI should proceed initially at sub-regional level, rather than across the entire East Asian region;
2. The specific steps taken towards EMI should be chosen on the basis of their likely positive economic impacts and their likely ease of delivery.

In this respect, initiatives such as the Trans-ASEAN Gas Pipeline and the ASEAN Power Grid, and proposals for sub-regional energy networks in Northeast Asia are to be encouraged and actively pursued. Given the geographic size of East Asia, these networks are likely to be restricted in scale to sub-regions rather than spanning the entire region, though the progressive development of national networks and trans-boundary interconnections may eventually allow some of these networks to span a large part of the region. The construction of such infrastructure projects can be undertaken by 'coalitions of the willing', and those states which do not wish to or are unable to participate can be excluded. If necessary, certain participating states can bear a disproportionate share of the costs, though raising finance from private sources may be difficult if key issues relating to the operation of these projects are not satisfactorily addressed.

Legally binding agreements will almost certainly be required for most of major, trans-boundary infrastructure projects to proceed, on account of the costs and risks involved. In the early years of EMI, it is likely that most legally binding agreements will be concluded at sub-regional, bi-lateral or tri-lateral levels, rather than across the entire region.

Whilst the costs and risks relating to the construction of transnational infrastructure projects are relatively easily managed, the real challenges emerge once they are commissioned, even if formal agreements are in place. On the one hand, they are open to deficient behaviour on the part of weakest link actors with respect to the operational integrity and security of the network. On the other hand, they are vulnerable to unilateral actions by one or more parties seeking to protect corporate or national interests, for example by denying access to the network. These difficulties can only be alleviated by the progressive convergence over time between the participating nations in respect of their improved competence in national governance and the openness of their national energy markets.

Indeed, openness and governance at *national level* (as well as at supra-national level) are key pre-requisites for EMI to proceed and to deliver significant regional benefits. States need to be open in their provision of information on energy resources and energy markets, and they need to be open in their provision of investment opportunities in their energy sectors. Effective and appropriate governance is needed in two respects. First, the domestic energy resources and industries should be regulated so as to use the available resources in as efficient and clean a manner as possible. Second, the structure and nature of the national energy industries and energy markets should be amenable to effective and efficient EMI. In many of the nations of East Asia, these attributes will require substantial domestic reforms (see also ERIA, 2010). Without such reforms, the progress of EMI will be severely constrained.

For these reasons, further analysis is necessary on the governance of the trans-boundary energy infrastructure and on the need for improved governance and openness in national energy sectors in the EAS region.

Other initiatives which should be pursued at a sub-regional scale, provided appropriate nations emerge to take the lead, include: sea-lane security, emergency response teams and pollution clean-up capacity.

A number of less tangible actions are already being taken in the East Asia region and these will provide long-term support to the progressive EMI. They include:

- technological research and development;
- the establishment and harmonisation of technical standards, such as the EAS-ERIA biodiesel fuel standards;
- the development and dissemination of best practices, for example in energy efficiency or in nuclear energy safety;
- data analysis and dissemination, for example on issues such oil stocks, and biofuels;
- capacity building and training in a range of fields including technology, management, policy and governance fields.

The relative degree of success of such programmes arises from the fact that much of the cost can be borne by a limited number of nations, whereas the benefits are widespread. Efforts should be made to enhance these programmes, and to ensure that their scope and impact is regional not just sub-regional.

The construction of gas stocks should be promoted. The issue of emergency stocks has a number of dimensions. In the case of oil, it could be argued that the IEA member states in the EAS region already hold sufficient stocks and that non-member states should just free-ride, unless a non-member state chooses to build its own stocks in order to use the stock in a different manner from the IEA member states. The case of natural gas is different. Gas markets which depend on trans-boundary pipelines are, by their nature, regional. It is therefore incumbent on the parties involved in that regional market to construct suitable stocks, to agree how such stocks should be used, and to abide by this agreement. Whilst the construction of these stocks can be carried out by a small number of more competent states, the effective use of these stocks is a potential a source of tension as a consequence of different national priorities. This issue is of immediate relevance to the Trans-ASEAN Gas Pipeline.

Because of the special nature of energy, the development of an integrated energy market requires relatively sophisticated systems of energy governance, some of which will need to be legally-binding and will require states to yield a certain degree of authority to a supra-national institution. Given the geographic extent and heterogeneity of the East Asian region, this study proposes that a single high level organisation spanning the entire region is formed with the task of coordinating (1) the delivery of certain services and activities which are delivered across the whole region and (2) the various sub-regional initiatives.

If not already in existence, organisations can be established at sub-regional level to oversee the delivery of services at this level. Given the well-established nature of ASEAN, it should form the basis of those organisations overseeing or regulating activities in Southeast Asia. This would achieve economies of scale and scope. Other types of organisation are likely to prove useful at local levels, for example the Mekong River Basin Commission.

Steps should be taken to develop a formal organisation for multi-lateral energy cooperation in Northeast Asia. In contrast to Southeast Asia, Northeast Asia lacks an established multi-lateral organisation which can provide support for sub-regional energy integration. The Tumen River Area Development Programme which involved China, South Korea, Mongolia and Russia is long defunct, the Shanghai Cooperation Organisation is built around Central Asia not East Asia, and the Six-Party Talks (which includes all the key players in Northeast Asia) is directed purely at security threats on the Korean Peninsula.

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CHAPTER 3

Measure the Energy Market Integration in East Asia: A Principal Component Analysis Approach[1]

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ABSTRACT

This paper measures the current energy market integration (EMI) in the 16 East Asia countries, comprising the ASEAN 10 countries, China, Japan, Korea, India, Australia, and New Zealand, by using the principal component analysis (PCA) approach. This comprehensive EMI index has four important components: (1) energy trade liberalization; (2) energy infrastructure development; (3) energy market liberalization; and (4) energy pricing liberalization. This index is constructed in two steps. I first construct the four indicators using PCA. After the predicted observation for the four indicators are obtained, I once again adopt the PCA method to calculate the EMI index. The scores show that countries like Japan and New Zealand have the highest extent of energy market integration. In contrast, countries like China and Malaysia, and India have lowest scores of EMI. Poorer countries are located in between. Such results are robust to different measures or data adopted.

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1. Introduction

In East Asia Summit region, ASEAN has long been pursuing the energy market integration (EMI) to support their sustainable economic growth. The first energy agreement, concluded between Thailand and Lao PDR, was signed in 1966, one year before the first ASEAN Declaration in August 1967. After the establishment of the ASEAN Council on Petroleum (ASCOPE) in 1975, cooperation widened to include all other fuels. In 1981 the Heads of ASEAN Power Utility Authorities (HAPUA) was established for work on electricity interconnection, and in 1986 the ASEAN Energy Cooperation Agreement outlined a wide range of areas for cooperation.

The great efforts that member countries have made in the past four decades has lead to significant progress in the direction of forming a regional unified energy market. To further promote integration, more information on the status of each country's extent of integration should be measured to inform the corresponding government for their future policymaking.

ASEAN 10 countries, China, and India, the so-called ACI countries, are still net importers of energy products such as oil, coal, natural gas, liquid national gas (LNG), and electricity from the rest of the world. Although the energy in Asia as a whole is almost self-sufficient, the energy supply is imbalanced between different regions. Due to the fast economic growth in the ACI bloc, such countries are experiencing a strong energy demand today. Studies like *World Energy Outlook* (2009) predict that the ACI countries will remain as trailblazers with respect to projected growth in primary energy demand. In particular, the annual energy demand of India will grow at 3.4 percent, followed by China at 2.9 percent, and ASEAN countries by 2.5 percent during 2010-2030. Given this growing demand of energy in East Asia area, there is an urgent need for such countries to join together to work for a regional energy integrated market.

According to recent work by Shi and Kimura (2010), the next steps for further EMI in the region lie in three areas: (1) regional agreements on energy trade and investment; (2) energy infrastructure development and national energy market liberalization; and (3) energy pricing reform and fossil fuel subsidies. Due to disparities in the level of economic development across countries, each country will have different abilities to participate in each dimension.

To assist policy making, this study aims to build up an index system by using the principal component analysis approach. The analysis measures the status of each country in EMI process of East Asia Summit region without imposing weights for each dimension. Contributing to previous literature, the study not only provides the aggregate level measure of EMI, but also information on each dimension that is comparable across countries, so that priorities for next-step in EMI can be identified.

The rest of the paper is organized as follows. Section 2 introduces some stylized facts on current situation of energy market integration in the ASEAN+6 countries, followed by an introduction of the principal component analysis in Section 3. Section 4 examines the predicted score of all sub-indicators for energy integration in this area, and accordingly, the final score for each country. In Section 5, the indexes are tested for robustness. Section 6 concludes.

2. Energy Market Integration in East Asia

As recognized by Feenstra (1998), trade integration and production disintegration are the two important features of international trade today. Like other manufacturing industries, this is true for energy trade as well. In this section, I investigate energy supply in East Asia area. To better understand regional trade, I also explore current energy demand in East Asia. My finding is that East Asia is an energy-thirsty region, despite its relatively abundant energy resources. Accordingly, regional energy trade plays an important role for sustainable growth in East Asia area. Energy market integration in East Asia remains needed and urgent.

2.1. Energy Supply in East Asia

East Asia is a relatively resource-rich area in terms of both energy reserves and current available supply. Located in southeast of Asia, most ASEAN+6 countries have substantial energy resources. As shown in Table1, eight of the sixteen countries have proven oil and gas reserves, and seven countries have substantial coal reserves. Moreover, China and the Northern part of the ASEAN region are rich in enormously powerful stream power which can be harnessed to generate electricity (Nicolas, 2009).

Oil production in East Asia is sizable. In particular, China is the 5th largest oil-producing countries in the world, according to the newest *BP statistical review of World Energy (2010).* India, Malaysia and Indonesia also produce large amounts of oil. Turning to the reserves and production in the gas market, one sees a similar story. ASEAN+6 countries hold more than 7% of global proven natural gas reserves, with the most significant reserves in Indonesia, China and Malaysia. East Asia accounts for around 12% of world natural gas production.[3]

In addition, this region holds considerable amounts of coal, especially in China and India. Since most of ASEAN+6 are developing countries, coal still plays a vital role. Today it is already widely recognized that East Asia has been the most important "world factory" and enjoyed the fast economic growth. Yet, without the abundant resources of coal, it is difficult to imagine countries in the area to achieve such economic growth.

Table 1. Energy Resources in East Asia (Reserves and Production) in 2009

Types	Oil		Natural Gas		Coal	
	Reserves (thousand million tons)	Production (million tons)	Reserves (trillion cubic meters)	Production (billion cubic meters)	Reserves (million tons）	Production （MTOE）
Brunei	0.1	8.2	0.35	11.4	—	—
China	2.0	189.0	2.46	85.2	114500	1552.9
India	0.8	35.4	1.12	39.3	58600	211.5
Indonesia	0.6	49.0	3.18	71.9	4328	155.3
Malaysia	0.7	33.2	2.38	62.7	—	—
Myanmar	—	—	0.57	11.5	—	—
Thailand	0.1	13.6	0.36	30.9	1354	5.3
Vietnam	0.6	16.8	0.68	8.0	150	25.2
Japan	—	—	—	—	355	0.7
South Korea	—	—	—	—	133	1.1
World Total	181.7	3820.5	187.49	2987.0	826001	3408.6

Source: BP Statistical review of World Energy 2010.

Although the overall energy resource availability is not a major challenge in East Asia, resource allocation is uneven in this region. Some countries are energy resource

[3] This is comparable to all America's reserves (BP Statistical review of World Energy 2010)

abundant whereas some others are resource scarce. As shown in Table 1, some of the northern East Asian countries like Japan and South Korea have close to no energy resources, despite being the most developed countries in East Asia. In sharp contrast, China and India, as the two emerging giants, are relatively abundant in energy reserve and production. Another notable exception is Singapore, which is deprived of any energy natural resources and accordingly heavily depends on its immediate neighbors (i.e., Indonesia and Malaysia) for its energy supply (Nicolas, 2009).

The third characteristic of energy situation in East Asian countries is the strong growing demand. In particular, according to the prediction of *World Energy Outlook* (2009), ASEAN primary energy demand expands by 76% between 2007 and 2030, an average annual rate of growth of 2.5%. This is much faster than the average rate in the rest of the world. Annual energy demand of India is expected to grow at 3.4 percent, followed by China at 2.9 percent. Whilst still in safe greenhouse gas (GHG) emission levels, the annual demand growth of ASEAN (2.1%) is still much higher than global average (1.5%). Take China for example, it will overtake the United States to become the world's biggest importer of oil and gas within a decade. China, along with India, also has the highest expected growth rate of gas consumption in the first three decades of the new century. All of these statistics clearly suggest that East Asia is a substantial energy market in the world today.

In summary, although East Asia as a whole is a relatively resource-abundant region, its energy market is imbalanced. Energy supply cannot meet the the rapid increase in primary energy demand. Such an excess demand for the whole area calls for further efforts in regional cooperation and intra-regional energy trade. The issue of energy market integration in East Asia is still ongoing, as discussed in the following subsection.

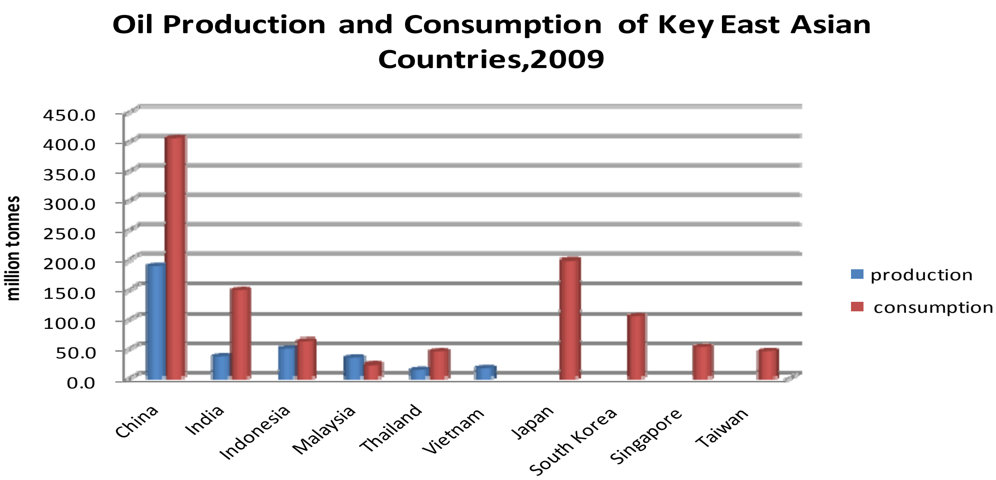
2.2. Energy Trade within East Asia

As mentioned above, Asia as a whole is nearly energy self-sufficient. East Asia holds vast oil, coal, and natural gas resources. However, the area is still a net importer of oil due in large part to its uneven resource allocation and high growth in energy demand. This uneven allocation presents an urgent need for regional energy trade. In this subsection I will investigate the current situation of energy trade in the area by each energy type: oil, natural gas, coal, and electricity.

2.2.1. Oil Trade

We first investigate the oil trade. As shown in Figure 1, there is a large gap between oil production and consumption of East Asian countries in 2009. Among these countries, China, India, Japan, and South Korea are the largest importers. The total oil imports of China, India, and Japan reached 612 million tons in 2008. Such a number is close to the oil imports of either US or Europe, amounting respectively to 637 and 681 million tons. By exporting its imported oil, Singapore indeed becomes the largest exporter and largest entrepôt in this region. Other oil exporters in East Asia include countries like Australia, China, India and Japan, but their export volumes are small.

Figure 1. Oil Production and Consumption for Key East Asian Countries

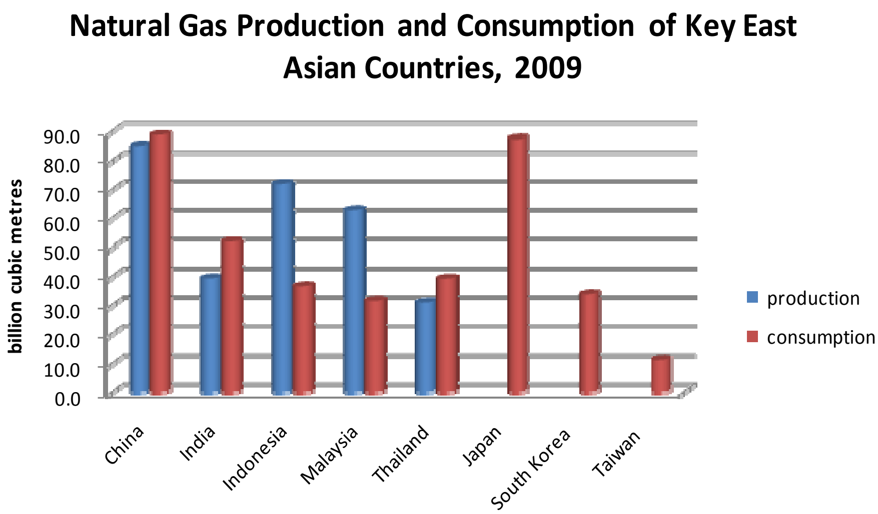


Source: BP Statistical review of World Energy 2010.

2.2.2. Natural Gas Trade

Natural gas is traded by pipeline or shipped as liquefied natural gas (LNG). As shown in Figure 2, China, Thailand and India have a small excess demand. Other countries like Japan, South Korea, and Taiwan have much greater excess demand. Indonesia and Malaysia have extra large supplies available for export.

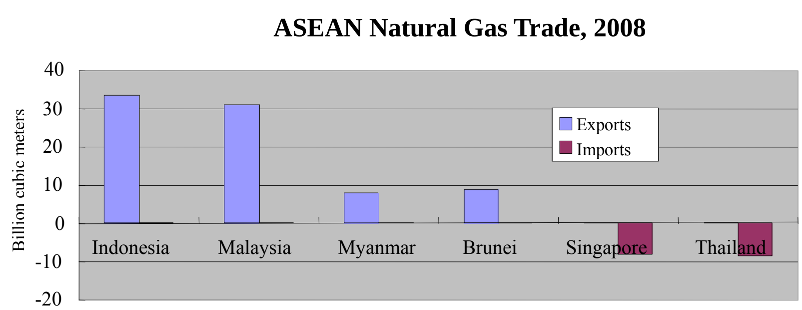
Figure 2. Natural Gas Production and Consumption in the Key East Asian Countries



Source: BP Statistical review of World Energy 2010.

Figure 3 hence shows the natural gas trade pattern by pipeline of ASEAN countries. Without a surprise, countries like Indonesia, Malaysia, Myanmar, and Brunei are net exporters of natural gas whereas Singapore and Thailand are net importers. In particular, Indonesia, both Malaysia, and Myanmar export natural gas to a single importer only. Precisely, Myanmar exports only to Thailand; and Indonesia and Malaysia export only to Singapore.

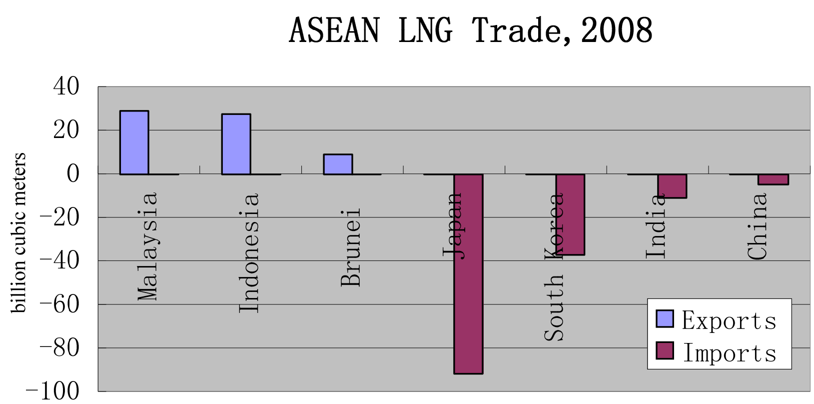
Figure 3. Natural Gas Traded by Pipeline in ASEAN Countries



Source: BP Statistical review of World Energy 2009.

Natural gas is also shipped as LNG in East Asia. Once again, the main LNG exporters are Malaysia, Indonesia and Brunei. Turning to the importer's side, Japan's LNG imports alone represented more than 40% of the world's total. In addition, countries like South Korea, India, and China, are other large LNG importers in Asia, as presented in Figure 4.

Figure 4. Natural Gas Traded as LNG in ASEAN Countries

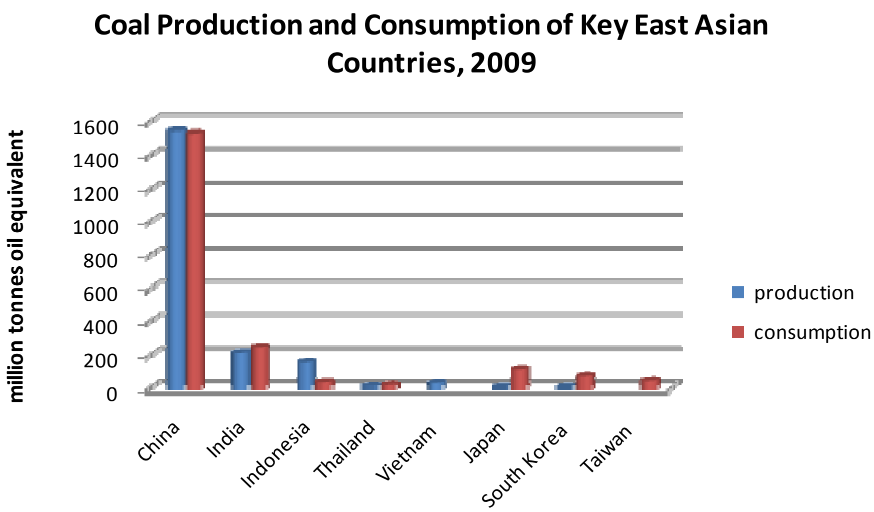


Source: BP Statistical review of World Energy 2008.

2.2.3. Coal Trade

It is well known that China is a large supplier of coal, producing 1552.9 million tons oil equivalent in 2009. China is also a huge coal consumer due to its fast economic growth. In 2009 its consumption on coal reached 1537.4 million tons. Both these two statistics dwarf their counterparts for other countries in East Asia, as shown in Figure 5. Coal exports from China, however, was declining at the rate of more than 12% per year in 2004-2007, even though coal production was growing at more than 8% during the same period. This was due in large part, to a growing domestic demand in China. Turning to other countries in the region, India ranks No. 2 in terms of both production and consumption of coal, though the magnitudes are only around 1/8 of China's production and consumption. The largest exporters in this market are Australia and Indonesia. Their total exports are around 491 million tons of coal exports in 2007, which represented 46% of the global exports. China, India, Japan and South Korea are the coal importers in the region.

Figure 5. Coal Production and Consumption of Key East Asian Countries



Source: BP Statistical review of World Energy 2010 .

2.2.4. Electricity Trade

China is the largest exporter of electricity in East Asia area and exported 14 TWh of electricity to Hong Kong and Macau in 2007, representing 19% of electricity exports in the whole Asia. Simultaneously, China imported 4.77 TWh, which represented 8% of electricity imports in the whole Asia. Besides of these, there are three completed electricity interconnections that facilitate electricity trade in the Southeast Asia sub-region. Namely, the Thailand- Malaysia market, Malaysia-Singapore market, and Thailand-Lao PDR market. In particular, India and Thailand are the two important importers of electricity in the region, respectively importing 4.96 TWh and 4.488 TWh in 2007.

2.3. Energy Market Integration in East Asia Today

Countries in East Asia have long made efforts to make integrate their energy markets integration. Perhaps the first effort is the energy agreement signed by Thailand and the Lao PDR in 1966, one year before the first ASEAN Declaration. After that, cooperation in all fuels of various forms has been gradually planned and achieved. Shi and Kimura (2010) provide a nice summary on past and current efforts made to foster energy market cooperation. EMI in East Asia was conducted by the following three components: (a) a series of ASEAN Plans of Action for Energy Cooperation (APAEC, 1999, 2004, 2009) which aims to highlight the importance to construct a reliable, transparent, and cooperative energy market; (b) the ASEAN Economic Community (AEC) blueprint emphasizes the establishment of interconnecting arrangements through regional cooperation in Trans-ASEAN Energy Networks comprising the Trans-ASEAN Gas Pipeline (TAGP) and the ASEAN Power Grid (APG) (APAEC, 1999); and (c) financial support for energy market cooperation. ASEAN receives large amount of funds for programs on coal and clean coal technology, energy efficiency and conservation (EE&C), renewable energy and regional energy policy and planning from dialogue partners, namely, the European Union, Japan, Australia, China, Korea, and India.

The regular meetings of ministers in East Asian countries and particularly ASEAN countries play a vital role in fostering regional EMI. Beyond ASEAN, many institutional cooperation frameworks have emerged in East Asia under the principle of ASEAN centrality in the past decades, such as ASEAN Plus One, ASEAN Plus Three (ASEAN plus China, Japan, and Korea) and EAS. There are also regular energy Ministers' meetings under these frameworks. Many work plans and programs have been adopted in the meetings, on fields such as energy security, oil markets, renewable energy and energy efficiency and conservation.

Table 2 presents the most important features of the energy market integration in Shi and Kimura (2010).

Table 2. Overview of EMI current status in Shi and Kimura's study (2010)

Areas	Current Status
Regional agreements on energy trade and investment	**Trade and investment has been broadly covered in the existing** **Bilateral/multilateral free trade agreement.** Beyond its own area, ASEAN has conducted negotiations for free trade (FTAs) and comprehensive economic partnership agreements (CEPAs) with many dialogue partners, including the "plus six" countries Bilateral FTAs between individual ASEAN member country and ASEAN dialogue countries have been moved forward while bilateral FTAs among the ASEAN dialogue partners are largely under negotiation.
Energy infrastructure development	**Currently proposed energy infrastructure projects have been limited to the ASEAN +China region only, though India has the potential to link.** Two flagship projects are APG and TAGP. Political trust is a huge barrier to trade in pipeline gas and electricity, and thus the demand for energy infrastructure.
National Energy Market Liberalization	**Market liberalization has been attempted in some countries, but lot more remains to be done.** In the EAS region, energy market liberalization has been conducted in Australia, Japan, New Zealand, the Philippines, and Singapore, while in others, energy markets are more or less restricted in some of the following ways: markets are dominated by some vertically integrated suppliers, prices are regulated, trade qualification is limited, electricity networks/gas pipelines are not open to access, and so on.
Energy pricing reform and fossil fuel subsidies	**Price restrictions and subsidies for energy commodities are often used in many EAS countries.** Energy prices have been liberalized in Australia, Japan, ROK, New Zealand, and the Philippines. Prices of electricity are more often regulated than coal, oil and natural gas.

Source: Shi and Kimura (2010).

The current consensus is that the further energy market integration is not only a requirement for the regional economics, but also good for the increasing the wealth of people in East Asia. Voluntary integration of energy markets will need to respect the different contexts facing each nation, and it is imperative to establish the current extent of the EMI. Without such information, there is no direction for policy makers. This analysis provides a reliable quantitative index to establish each nations' current degree of EMI, by using principal component analysis. I now provide an overview into the methods used in principal components analysis to construct an index.

3. The Method of Principal Component Analysis

Principal component analysis (PCA) is a way of identifying patterns in data, and expressing data in such a way as to highlight their similarities and differences. Since patterns in data can be hard to find in data of high dimension, since the luxury of graphical representation is not available, PCA is a powerful tool for analyzing data so as to form a comparable index across countries under the condition that there is no explicit weight available for the various components.

The PCA approach is an ideal instrument to explore the energy market integration in East Asia for two reasons. First, it is ideal to use a comprehensive indicator to measure energy market integration since any particular indicator can only interpret one perspective of the energy market integration in this emerging economy, which would lead to a possible measurement bias. Second, given that multiple indicators to measure the EMI is a must, any arbitrary weight among such indicators would create another serious estimation bias. By contrast, an adoption of the PCA approach can deal with such two empirical challenges well. Appendix A provides a careful scrutiny of the detailed technique of the PCA approach adopted in the present paper.

4. Measuring Energy Market Integration

The main aim of this section is to measure and calculate the scores of energy market integration for the ASEAN+6 countries. The final score comes from the main components of the following four indicators: (1) regional energy trade liberalization; (2)

energy infrastructure development; (3) national energy market liberalization; and (4) energy pricing liberalization, as suggested by Shi and Kimura (2010).

Two steps are required to calculate the final integration score. First, I determine the sub-components for each main component. Once the sub-components are chosen, I can adopt the PCA method to calculate its predicted principal component as an index. Second, with these four predicted indicators at hand, I are able to calculate the predicted principal component (i.e., the final score) of the market integration by country.

The rest of this section is organized as follows. I first examine each sub-component for each main indicator to obtain its predicted score, followed by the calculation of the final aggregated score of energy market integration by country.

4.1. Energy Trade Liberalization

As documented in Nicolas (2009), the ASEAN Free Trade Agreements were launched in 1992. The full free trade is set for 6 original ASEAN countries in 2010, and free trade expands before 2015 for the CMLV (Cambodia, Myanmar, Laos, and Vietnam) groups. The current objective for ASEAN countries is to form a larger FTA, including other Asia-Pacific countries. There are three different schedules are widely discussed. The first possibility is that the ASEAN countries join with China to have a new ASEAN+1 free trade area. The second possibility is to an ASEAN+3 FTA to include both ASEAN 10 countries and three other countries: China, Japan, and Korea. The last possibility is to extend the ASEAN+3 FTA to ASEAN+6 by including Australia, India, and New Zealand. The present paper takes a broader view, following the last suggestion to examine energy market integration in the 16 Asia-Pacific countries.

The coverage of the current AFTA not only includes the regular tariff reduction on commodities but also the phasing-out of various non-tariff barriers. In particular, the AFTA has a focus on the free-trade oriented energy sector. Currently the ASEAN 10 countries have already created a FTA with some other countries in the Asia-Pacific area. Therefore, to measure the trade liberalization in the energy sector for each country, we use the number of countries that have a FTA relationship with the country in the Asia-Pacific area. For example, each ASEAN country has already signed or completed the FTA agreements with Australia, China, India, Japan, Korea, and New Zealand, but it is not true in other cases. China only signed the FTA with ASEAN 10 countries and

New Zealand, and is negotiating with Australia for a possible FTA. In this way, each ASEAN country has a score with 16 to count number of countries with FTA agreement. In contrast, China is only assigned with 12 given that it currently has no view to sign a FTA with the other four countries.

Table 3. Status of FTA/EPAs in the EAS Region

	Australia	China	India	Japan	New Zealand	South Korea	ASEAN
Australia		□		□	●	□	●
China	□				●		●
India				□		□	●
Japan	□		□			□	●
New Zealand	●	●				□	●
South Korea	□		□	□	□		●
ASEAN	●	●	●	●	●	●	

NOTE: ●: FTA signed/concluded; □: under negotiation
Source: Shi and Kimura (2010).

However, this is far from the whole story of energy trade liberalization. There still exist some other economic indicators to help us understand energy trade liberalization in the East Asia region. Here I consider the following five indicators: (1) the ratio of energy net imports over consumption. A large number of this index indicates that the country strongly depends on international energy markets, since most of its domestic energy consumption is imported. (2) Energy production (thousand tons of oil equivalents) and total energy consumption. These two indicators measure the economic size of the energy market in a country. (3) Per-capita energy consumption (kg of oil equivalent per capita) which captures both the economic size and population of a country. (4) GDP per unit of energy use (constant 2005 PPP $ per kg of oil equivalent), which access the efficiency level of energy use. The larger the number, the more efficient the country is. Table 4A describes the basic summary statistics for the indicators above.

Table 4A. Summary Statistics for Indicators of Energy Trade Liberalization

Variable	Mean	Std. Dev.	Min	Max
Number of FTA Agreements Signed	9.625	0.957	9	12
Ratio of Energy Net Imports over Consumption	-35.13	170.3	-630	100
Energy Production (kt of oil equivalent)	221997	445529	0	1.80E+06
Total Energy Consumption (kt of oil equivalent)	262702	485155	2767	2.00E+06
Per-capita Energy Consumption (kg of oil equivalent)	2694	2285	319	7190
GDP per unit of energy use	5.876	1.455	4	9

Based on the above information, I am able to calculate the predicted score for the aggregated energy trade liberalization. For the sake of completeness, table 4B reports and sorts the Eigenvalues of six eigenvectors associated with data on energy trade liberalization.

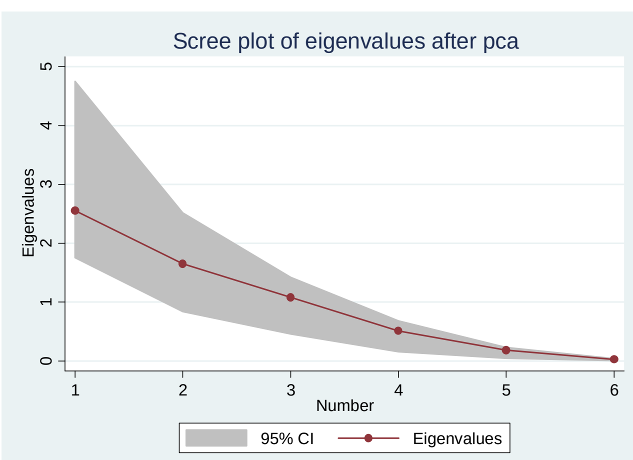
Table 4B. The Eigenvalue for the PCA for the Energy Trade Liberalization

Component	Eigenvalue	Difference	Proportion	Cumulative
C1	2.5529	0.9009	0.4255	0.4255
C2	1.6520	0.5710	0.2753	0.7008
C3	1.081	0.5741	0.1802	0.881
C4	0.5069	0.3253	0.0845	0.9655
C5	0.1816	0.1560	0.0303	0.9957
C6	0.0256	.	0.0043	1

Source: Author's own calculation.

Figure 2 sorts the six eigenvalues from top to down and report its 95% interval confidence. Here I also compute heteroskedastic bootstrap confidence intervals at the 95% level. Clearly, the highest eigenvalue is 2.552 whereas the lowest one is .02.

Figure 2. Plots of the Eigenvalues for the Index of Energy Trade Liberalization



I then report the correlation between the principal-component (PC) scores and the original data. As shown in Table 3C, the variable of number of FTA agreements signed or completed load heavily on C2 and C3. Similarly, Ratio of Energy Net Imports over Consumption draws heavily on C3 and C1. Energy Production significantly relies on C1 and C4. Total Energy Consumption is on C1 and C4. Per-capita Energy Consumption loads dramatically on C5 and C2. Finally, GDP per unit of energy use has significant weights on C4 and C3.

Table 4C. Correlation between Raw Data and Calculated Eigenvectors for Energy Trade Liberalization

Variable	C1	C2	C3	C4	C5	C6
Number of FTA Agreements Signed	0.252	0.534	0.318	-0.698	-0.251	-0.026
Ratio of Energy Net Imports over Consumption	0.194	-0.249	0.840	0.108	0.423	0.063
Energy Production (kt of oil equivalent)	0.575	0.215	-0.164	0.266	0.013	0.724
Total Energy Consumption (kt of oil equ.)	0.562	0.241	-0.041	0.407	-0.038	-0.676
Per-capita Energy Consumption (kg of oil equ.)	-0.302	0.633	-0.104	0.076	0.700	-0.013
GDP per unit of energy use	-0.401	0.384	0.392	0.509	-0.515	0.115

Source: Author's own calculation.

With these six eigenvalues at hand, I now pick the largest weight (i.e., 2.552) and use it to calculate the measured score for energy trade liberalization by country. Table 2D reports the score by country. Clearly, China, India, and Indonesia have higher extent of energy trade liberalization. This is due in large part to the large economic size of these countries. Economic size is captured implicitly by the indexes of total energy consumption and total energy production. This observation can be double-confirmed by observing that small countries like Brunei and Singapore have low scores of energy trade liberalization.

Table 4D. Score of Energy Trade Liberalization, by using PCA Approach

Country	Score	Country	Score	Country	Score
China	5.1034	Lao PDR	-0.1645	Japan	-0.4068
India	1.3743	Australia	-0.2799	Myanmar	-0.4884
Indonesia	0.6093	Malaysia	-0.3075	Philippines	-0.6024
Vietnam	0.1934	South Korea	-0.3319	Singapore	-1.8452
Thailand	-0.0770	New Zealand	-0.3474	Brunei	-2.3081
Cambodia	-0.1213				

Source: Author's own calculation.

4.2. Energy Infrastructure Development

As suggested in Shi and Kimura (2010), the extent of energy infrastructure is another important component of energy market integration in East Asia. To measure the energy infrastructure development in the region, the following indicators are chosen: (1) electric power consumption (kWh per capita); (2) road sector energy consumption (% of total energy consumption); and (3) road sector gasoline fuel consumption per capita (kt of oil equivalent). Electric power consumption is positively associated with energy infrastructure, though not a direct measure. In contrast, road sector energy consumption and road sector gasoline fuel consumption per capita are more tightly linked with the extent of energy infrastructure development, from both aggregate size and per-capita perspective. A potential indicator to measure energy infrastructure development is the length of gas pipelines in the ASEAN countries. Currently I leave this out from the calculation, but include it later as a robustness check. Table 5A summarizes the basic statistical information for the indicator mentioned above.

Table 5. Summary Statistics for Indicators of Energy Infrastructure Development

Variable	Mean	Std. Dev.	Min	Max
Electric power consumption (kWh per capita)	361.8	154.5	24	933
Road sector energy consumption	13.37	5.88	4	27
Road sector gasoline fuel consumption per capita	0.2	0.40	0	1

Source: Author's own calculation.

Similarly, I now calculate the predicted score for the eigenvalues for the three variables above by using the principal component analysis. In particular, I first calculate their covariance matrix of the three variables, and then obtain their eigenvectors and the associated eigenvalues. By sorting the eigenvalues from top to the bottom, table 5B demonstrates the eigenvalues of three eigenvectors associated with data on energy infrastructure development.

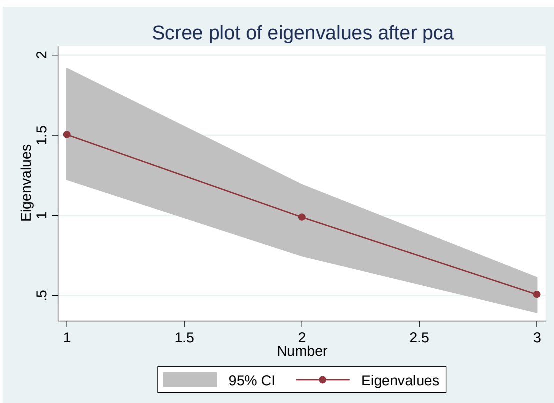
Table 5B. The Eigenvalue for the PCA for Energy Infrastructure Development

Component	Eigenvalue	Difference	Proportion	Cumulative
C1	1.5047	0.5154	0.5016	0.5016
C2	0.9893	0.4834	0.3298	0.8314
C3	0.5059	.	0.1686	1

Source: Author's own calculation.

From Figure 3, one can observe that the highest eigenvalue (1.504) is around 3 times larger than the lowest eigenvalue (.505). Once again, I compute and report the heteroskedastic bootstrap confidence intervals for each eigenvalue.

Figure 3. Plots of the Eigenvalues for Energy Infrastructure Development



Turning to the correlation between the principal-component (PC) scores and the original data, Table 5C shows that the variable of electric power consumption loads heavily on C2. By contrast, the variable of road sector energy consumption loans heavily on C1 and C3. Finally, road sector gasoline fuel consumption per capita significantly relies on both C1 and C3.

Table 5C. Correlation between Data and Calculated Eigenvectors for Energy Infrastructure Development

Variable	C1	C2	C3	Unexplained
Electric power consumption (kWh per capita)	0.264	0.937	0.228	0
Road sector energy consumption	0.703	-0.025	-0.711	0
Road sector gasoline fuel consumption per capita	0.660	-0.348	0.667	0

Source: Author's own calculation.

The last step is to calculate the score of the energy infrastructure development for each country, by adopting the eigenvector associated with the highest eigenvalue to multiply with the transposed standardized data. Table 5D reports the score by country. It seems that well-endowed resource countries such as New Zealand, Australia, and Brunei have a higher extent of energy infrastructure development. However, there is no predicted score for Lao PDR. In this sense, the comparison for this index is incomplete. I will address such a problem by using Wilberg's method shortly.

Table 5D. Score of Energy Infrastructure Development, by using PCA Approach

Country	Score	Country	Score	Country	Score
New Zealand	2.9688	Thailand	0.1086	India	-0.9024
Australia	1.9972	Indonesia	-0.1451	China	-1.3488
Brunei	1.3899	Japan	-0.2557	Myanmar	-1.4274
Philippines	0.8442	South Korea	-0.3772	Cambodia	-1.4274
Vietnam	0.2506	Singapore	-0.8630	Lao PDR	.
Malaysia	0.2301				

Source: Author's own calculation.

4.3. National Energy Market Liberalization

Shi-Kimura (2010) mention the positive and negative aspects of the policy landscape in each country. We now quantify each factor mentioned in their study. In particular, if the qualitative measure in Shi-Kumara (2010) is positive, I will assign a positive 1 point. Instead, if the qualitative measure is negative, a number of -1 is assigned to the factor. In addition, I adopt some other appropriate indicators which abstract from Shi-Kimura (2010). For example, I include index of nuclear energy (% of total energy use) and combustible renewable and wastes (% of total energy) inside. Based on this quantitative measure, I obtain the following data for the energy market integration in East Asia area as shown in Table 6A.

Table 6A. Data on Energy Market Integration Generated by Qualitative Index of Shi-Kimura (2010)

Country	Oil	Coal	Gas	Electricity	Nuclear Energy	Renewables
Australia	2	1	-1	4	1.3	4.3
Brunei	0	__	-3	-5	0.0	0.0
Cambodia	1	__	0	0	0.1	70.5
China	-3	1	-2	-1	3.2	9.9
India	1	-3	1	-2	2.7	27.2
Indonesia	-1	3	3	-3	3.7	27.5
Japan	3	3	2	1	15.3	1.4
Lao PDR	__	1	__	-2	—	—
Malaysia	-2	1	-2	-4	0.8	4.0
Myanmar	1	1	1	0	1.9	66.3
New Zeland	2	0	2	3	25.9	6.6
Philippines	2	__	-1	4	23.8	19.2
Singapore	3	__	2	2	0.0	0.0
South Korea	2	2	1	-3	16.9	1.2
Thailand	2	-1	3	-1	0.7	17.8
Vietnam	1	0	-2	3	4.6	44.0

Source: Author's own collection.

I then obtain the summary statistics in the following Table 6B. For the first five indexes, the maximum number for an economy is 4, which implies that the country has four positive aspects of achievements in energy market liberalization. In contrast, some countries have a score of -3, which implies that the country has three negative aspects in energy market liberalization.

Table 6B. Summary Statistics for Indicators of Energy Market Liberalization

Variable	Mean	Std. Dev.	Min	Max
Oil	0.9351	1.6918	-3	3
Coal	0.7324	1.4477	-3	3
Gas	0.2658	1.9137	-3	3
Electricity	-0.25	2.8636	-5	4
Nuclear energy	6.7624	8.7077	0	25.9
Renewables	19.690	22.641	0	70.5

Source: Author's own calculation.

Similar to before, I then calculate the eigenvectors and their associated eigenvalues of the six components by calculating their covariance matrix of the six variables, as shown in Table 6C.

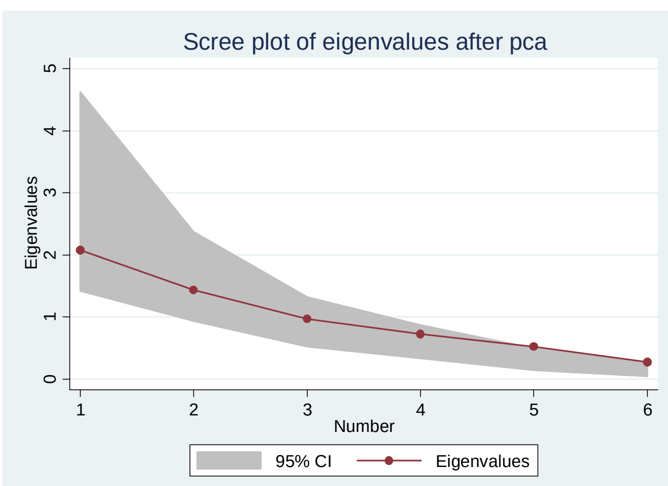
Table 6C. The Eigen value for the PCA for Energy Market Liberalization

Component	Eigen value	Difference	Proportion	Cumulative
C1	2.0785	0.6480	0.3464	0.3464
C2	1.4305	0.4624	0.2384	0.5848
C3	0.9682	0.2418	0.1614	0.7462
C4	0.7264	0.2030	0.1211	0.8673
C5	0.5233	0.2503	0.0872	0.9545
C6	0.2731	.	0.0455	1

Source: Author's own calculation.

We then plot the six Eigen values from top to down in Figure 4. A 95% interval-confidence shaped area with heteroskedastic bootstrap is also drawn there. Here I also compute confidence intervals. Clearly, the highest Eigen value is 2.55 whereas the lowest one is .02.

Figure 4. Plots of the Eigen values for the Energy Market Liberalization



The next step is to calculate the correlation between the principal-component (PC) scores and the original data, Table 6D shows that the variable of oil market liberalization loads heavily on C1. Data on coal market liberalization load significant on C4 whereas that of gas market liberalization is on C3 and that of electricity on C6. By contrast, the variable of nuclear energy consumption loans heavily on C5 whereas that of renewable resource loans heavily on C2 and C4.

Table 6D. Correlation between Data and Calculated Eigenvectors for Energy Market Liberalization

Variable	C1	C2	C3	C4	C5	C6	Unexplained
Oil	0.5953	0.155	0.1093	-0.1661	-0.3921	0.6545	0
Coal	0.0585	-0.6304	0.1642	0.7055	-0.2561	0.0944	0
Gas	0.3868	0.0754	0.7995	-0.0416	0.1429	-0.4281	0
Electricity	0.4921	0.2498	-0.4854	0.2561	-0.3096	-0.5462	0
Nuclear energy	0.4898	-0.2865	-0.274	0.0269	0.7646	0.1329	0
Renewable	-0.1027	0.6545	0.1055	0.6377	0.2826	0.2519	0

Source: Author's own calculation.

Finally, I calculate the score of the energy market liberalization for each country, by adopting the eigenvector associated with the highest Eigen value to multiply with the transposed standardized data. As shown in Table 4E, New Zealand has the highest level of energy market liberalization whereas Malaysia has the lowest level of energy market liberalization.

Table 6E. Score of Energy Market Liberalization, by using PCA Approach

Country	Liberalized Score	Country	Liberalized Score
New Zealand	2.3899	Lao PDR	-0.2326
Japan	1.9467	Myanmar	-0.2598
Philippines	1.8116	India	-0.5429
Singapore	1.1869	Cambodia	-0.6321
South Korea	0.7558	Indonesia	-0.7168
Australia	0.6226	Brunei	-2.0821
Thailand	0.3960	China	-2.1167
Vietnam	-0.1381	Malaysia	-2.3887

Source: Author's own calculation.

4.4. Energy Pricing & Fossil Fuel Subsidies

Similar to before, to measure energy pricing, I follow the qualitative indicators mentioned in Shi and Kimura (2010). In particular, I assign a score of one point to the affirmative perspective on energy pricing in the market of oil, coal, and gas, respectively. In contrast, a negative one point is assigned if a country has bad performance. Moreover, I also consider the following three components in the analysis: (1) pump price for diesel fuel (US$ per liter); (2) pump price for gasoline (US$ per liter); (3) fossil fuel energy consumption (% of total). Based on these criteria, I generate the following data in Table 7A to measure the behaviour of energy pricing and subsidies.

Table 7A. Data on Energy Pricing and Subsidies

Country	Oil	Coal	Gas	Electricity	Diesel price	Gas price	Fossil fuel consumption (%)
Australia	1	1	1	0	0.94	0.74	94.4
Brunei	-1	-	-1	-2	0.21	0.38	100.0
Cambodia	-1	-	-1		0.89	0.94	29.1
China	-2	0	-1	0	1.01	0.99	86.9
India	-1	0	0	-2	0.70	1.09	70.0
Indonesia	-1	1	-1	-2	0.46	0.60	68.8
Japan	1	1	1	0	1.54	1.74	83.2
Lao PDR	-1		-1	-1	0.76	0.92	
Malaysia	-1		-1	-1	0.53	0.53	95.5
Myanmar	-1		-1	-1	0.52	0.43	31.7
New Zeland	1	1	1	1	0.85	1.09	67.4
Philippines	2	1	1	1	0.81	0.91	57.0
Singapore	1	-	1	1	0.90	1.07	100.0
South Korea	2	1	1	1			81.9
Thailand	-1	1	-1	-1	0.64	0.87	81.2
Vietnam	0	1	-1	-1	0.77	0.80	51.4

Source: Author's own calculation

Table 7B reports the main summary statistics for indicators of energy pricing liberalization.

Table 7B. Summary Statistics for Indicators of Energy Pricing Liberalization

Variable	Mean	Std. Dev.	Min	Max
Oil	-0.125	1.2583	-2	2
Coal	0.8062	0.3409	0	1.0279
Gas	-0.1875	0.9811	-1	1
Electricity	-0.4841	1.0895	-2	1
Diesel price	0.7689	0.2910	0.21	1.54
Gas price	0.8739	0.3226	0.38	1.74
Fossil fuel consumption (%)	73.006	22.047	29.1	100

Source: Author's own calculation.

Once again, I follow the "cook book" to examine the eigenvectors and their associated eigenvalues of the six components by calculating their covariance matrix of the six variables, as shown in Table 7C.

Table 7C. The Eigen value for the PCA for Energy Pricing Liberalization

Component	Eigen value	Difference	Proportion	Cumulative
C1	3.5639	2.0922	0.5091	0.5091
C2	1.4717	0.3357	0.2102	0.7194
C3	1.1360	0.6957	0.1623	0.8817
C4	0.4403	0.1644	0.0629	0.9446
C5	0.2760	0.2027	0.0394	0.9840
C6	0.0733	0.0346	0.0105	0.9945
C7	0.0387	.	0.0055	1

Source: Author's own calculation.

Similarly, Figure 5 then plots the Eigen value for each eigenvector following an declining trend of those Eigenvalues. The highest Eigen value reaches 6.1 whereas the lowest one only has a number of 0.2.

Figure 5. Plots of the Eigenvalues for Energy Pricing Liberalization

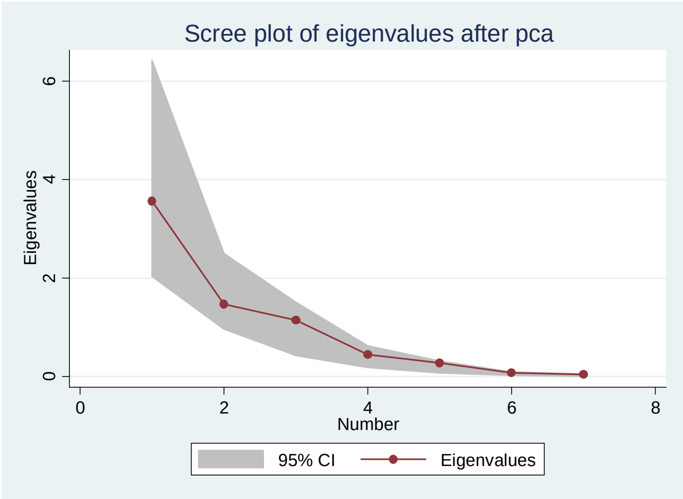


Table 7D reports the correlation between observed count data and the calculated eigenvectors for energy pricing liberalization. The most important component for oil pricing liberalization is C1 whereas the one for coal pricing liberalization is C2. Similarly, the most important component for gas pricing liberalization is C1 and that for electricity pricing liberalization is C5. Turning to diesel pricing continuum data, the most important component is C1. The one for gas pricing is C6. Finally, that for fuel consumption is C6 again.

Table 7D: Correlation between Data and Calculated Eigenvectors for Energy Pricing Liberalization

Variable	C1	C2	C3	C4	C5	C6	Unexplained
Oil	0.456	0.297	0.257	-0.074	-0.336	-0.002	-0.7206
Coal	0.138	0.712	-0.066	0.625	0.161	0.073	0.2182
Gas	0.485	0.015	0.245	-0.173	-0.463	-0.239	0.6349
Electricity	0.455	0.099	0.127	-0.442	0.704	0.260	0.0908
Diesel price	0.413	-0.261	-0.442	0.222	0.251	-0.659	-0.1424
Gas price	0.390	-0.352	-0.426	0.241	-0.222	0.660	0.0266
Fossil fuel consumption (%)	0.091	-0.451	0.690	0.520	0.199	0.030	-0.0277

Source: Author's own calculation.

Based on this, I then calculate the score of energy pricing liberalization by using the PCA approach (Table 7E). I find that Japan has the highest score on energy pricing liberalization, following South Korea, the Philippines, and New Zealand. In contrast, countries like Brunei and Indonesia have the lowest scores on energy pricing liberalization.

Table 7E. Score of Energy Pricing Liberalization, by using PCA Approach

Country	Liberalized Score	Country	Liberalized Score
Japan	3.4566	Vietnam	-0.6707
South Korea	2.1080	Lao PDR	-0.8987
Singapore	2.0943	Thailand	-1.0101
Philippines	2.0921	India	-1.0326
New Zealand	2.0466	Malaysia	-1.6417
Australia	1.4448	Myanmar	-1.9095
China	-0.6655	Indonesia	-2.0603
Cambodia	-0.6683	Brunei	-2.6850

Source: Author's own calculation.

4.5. The Second-Step PCA Results

Thus far, I have calculated the predicted scores for the four categories to measure the energy market integration: (1) energy trade liberalization; (2) energy infrastructure development; (3) energy market liberalization; and (4) energy pricing liberalization. Table 8A describes the summary statistics for such variables:

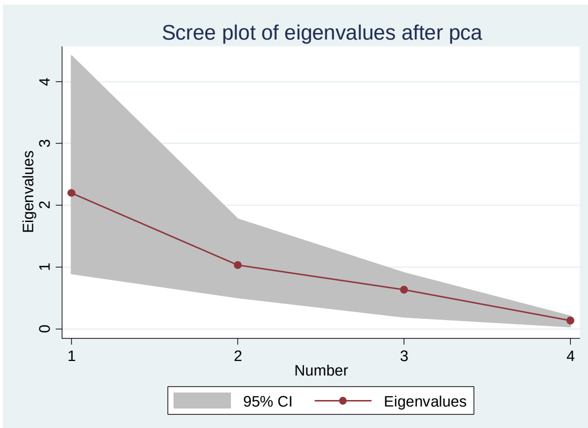
Table 8A: Summary Statistics for the Four Variables

Variable	Mean	Std. Dev.	Min	Max
Country Code	8.5	4.760	1	16
Energy Trade Liberalization	1.82E-08	1.597	-2.3081	5.1034
Energy Infrastructure Development	0.0695	1.286	-1.4274	2.9688
Energy Market Liberalization	1.02E-07	1.441	-2.3886	2.3899
Energy Pricing Liberalization	4.10E-08	1.8878	-2.6845	3.4566

Source: Author's own calculation

I now plot the four Eigenvalues in descending order, along with the heteroskedasticity robust confidence interval in Figure 6.

Figure 6. Plots of the Eigenvalues for EMI Index



The correlation of the four eigenvectors and the four predicted variables are summarized as follows:

Table 8B. Correlation between Data and Calculated Eigenvectors for EMI Index

Variable	C1	C2	C3	C4	Unexplained
Energy Trade Liberalization	-0.369	0.644	0.653	0.151	0
Energy Infrastructure Development	0.408	-0.519	0.750	-0.037	0
Energy Market Liberalization	0.617	0.286	-0.101	0.726	0
Energy Pricing Liberalization	0.563	0.484	-0.004	-0.670	0

Source: Author's own calculation.

Based on these information, I are now able to calculate the index of the energy market integration by country in Table 8C.

Table 8C. Score of Energy Market Integration, by using PCA Approach

Rank	Country	EMI Score	Rank	Country	EMI Score
1	New Zealand	2.5580	9	Brunei	-0.7296
2	Japan	1.7761	10	Cambodia	-0.9241
3	Philippines	1.7159	11	Myanmar	-1.0486

Table 8C. *(Continued)*

Rank	Country	EMI Score	Rank	Country	EMI Score
4	Australia	1.3289	12	Indonesia	-1.1205
5	Singapore	1.1947	13	India	-1.1606
6	South Korea	0.8364	14	Malaysia	-1.3673
7	Thailand	-0.1213	15	China	-2.6790
8	Vietnam	-0.2592			

Source: Author's own calculation

Clearly, New Zealand has the highest score of energy market integration (2.55), following by Japan, Philippines, Australia, Singapore, and South Korea. By contrast, China has the lowest score of energy market integration (-2.67), followed by Malaysia, India and Indonesia. The rest of the countries, which basically are the CLMV group, is located in between.

Although I have ranked almost all countries in East Asia area, the analysis omits Laos PDR. To include Laos PDR, I omit the index of energy infrastructure from the calculation, and re-perform the PCA analysis. Table 8D reports the modified ranking. Once again, Japan and New Zealand are the two countries with highest scores on EMI whereas China and Malaysia are the two countries with lowest scores. The CLMV group once again is caught in between.

Table 8D: Score of Energy Market Integration, by using PCA Approach with Missing Data

Rank	Country	EMI Score	Rank	Country	EMI Score
1	Japan	2.1941	9	Lao PDR	-0.3838
2	New Zealand	1.9079	10	Cambodia	-0.5031
3	Philippines	1.7034	11	Myanmar	-0.6749
4	Singapore	1.6706	12	India	-0.9018
5	South Korea	1.1514	13	Indonesia	-1.1751
6	Australia	0.8497	14	Brunei	-1.4201
7	Thailand	-0.1426	15	Malaysia	-1.6301
8	Vietnam	-0.3364	16	China	-2.3094

Source: Author's own calculation.

5. Concluding Remarks

Although East Asia is a relatively energy-abundant area in terms of its reserve and production, it still faces a challenge of insufficient energy supply problem due to the uneven energy allocation and high excess demand for energy. Therefore, intra-regional energy trade and further integration of energy markets is in urgent need. This in turn calls for a rigorous way to measure the current context of energy market integration in each country.

This paper provides such information by ranking of the extent of energy market integration for 16 East Asian countries, including the ASEAN 10 countries, China, Japan, Korea, India, Australia, and New Zealand. The extent of energy market integration (EMI) is measured by using a reliable statistical method -- the principal component analysis (PCA) approach. In particular, the score measuring the extent of EMI in each country is rooted by four important components: (1) energy trade liberalization; (2) energy infrastructure development; (3) energy market liberalization; and (4) energy pricing liberalization. Since each component also includes many sub-indicators, the final score of EMI in each country is conducted in two steps. I first calculate the measured score for each component. I then apply the PCA approach again to calculate the final scores of the extent of EMI.

My estimations show that countries like Japan and New Zealand have the highest extent of energy market integration. In contrast, countries like China and Malaysia, and India have lowest scores of EMI. The relatively poor ASEAN countries (i.e., the CLMV countries) are located in between. Such results are robust to different measures or different data adopted [I didn't find any different data in this analysis].

The policy implication for this finding is straightforward. Given that a further integrated energy market is good for each country, countries in East Asia area should try their every effort to foster their energy market integration. With the estimated score of EMI at hand, countries that have already lag behind the progress of energy market integration should work harder to catch up.

Several extensions and possible generalizations merit special consideration. One of them is to adopt the dynamic PCA method on panel data, to construct various indexes as such data becomes available. Another possible extension is to have more indexes to enrich the measure of energy pricing and fossil fuel subsidies. These are some possible research topics to pursue in the future.

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Appendix:

The Principal Component Analysis method is a popular approach to such analysis. Jolliffe (1986) is one of the first studies to systematically employ the PCA method. Rather than assigning an ad-hoc weight on each factor, the PCA method is able to find an appropriate weight for each component. In particular, the principal components sequentially capture the maximum variability among original data. It can guarantee minimal information loss, and hence is a good application to the real-world economic analysis. For example, Song and Sheng (2007) provide an interesting application to explain the economic growth after economic reform in 1979 in China.

The PCA 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. Let data X be a n*p matrix, by demeaning the data, I obtain the eigen-arrays U which are the principal components (PCs) of unit length. Similarly, I can obtain the eigen-genes V are the corresponding loadings of the principal components. The first q (q <p) PCs are chosen to represent the data. However, it is possible that I have missing data on some variables. In this case, I also have revised PCA approach, in particular, I use Wiberg's method.

We now go further to formally introduce the PCA approach.[4] In particular, consider a m*n matrix Y=[y1, y2,…yn] and the mean of each vector is $\overline{Y} = [\overline{y}_1, \overline{y}_2, \ldots \overline{y}_n]$, I first perform the demean process by defining $X = [y_1 - \overline{y}_1, y_2 - \overline{y}_2, \ldots, y_n - \overline{y}_n]$. The covariance of this matrix X is as follows: $C_X = \dfrac{XX^T}{n-1}$ which is a squared symmetric □× □ matrix. The next step is to make the eigen-decomposition for the covariance matrix C_X. In particular, I need to calculate m dimensional eigen-vector $E = [e_1, e_2, \ldots e_m]$ and their associated eigen-values $\lambda = [\lambda_1, \lambda_2, \ldots \lambda_m]$. Note 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. Now I can transform the

[4] Readers who are not interested in technical details can directly jump to the end of the section.

matrix as follow:

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

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

The next task is to find some orthonormal matrix P where Q=PX. I can show that this orthonormal matrix P indeed is the eigenvector matrix E. To see this more formally, consider $Q = [q_1, q_2, \dots q_n]$, I 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 and 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.

The last step 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.

Now I can summarize the cook-book steps to obtain the principal components in a reader-friendly fashion. I first demean the raw data in a matrix form, followed by calculating its covariance. I then find the eigenvectors and associated eigenvalues for such a covariance matrix. Finally, I rank all the eigenvalues and pick the largest one. The last step obtains the principal component of the matrix, which is just the matrix constructed by multiplying the eigenvector with the highest eigenvalue and the original demeaned matrix.

CHAPTER 4

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

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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.

1. Introduction

East Asia has pursued a policy of economic integration, starting with formation of the Association of Southeast Asian Nations (ASEAN) in the 1960s. As a further extension of the integration policy, the Association of Southeast Asian Nations (ASEAN) has recently initiated a dialogue with its partners including Japan, South Korea, China, India, Australia and New Zealand[1] (Shi and Kimura, 2010), for energy market integration (EMI). Although significant progress along EMI has been made, little has been know about its pattern in the region and associated economic impacts.

It is in no doubt from a theoretical perspective that EMI may promote regional economic development, but there are only a few empirical studies providing supportive evidence. Bhattacharya and Kojima (2008, 2010) find the benefits from EMI have generally outweighed costs. More generally, Park (2000), followed by Lee et al. (2009) and Lee and Plummer (2010) showed that free trade agreement (including energy products) may bring positive economic impact to member countries within the region. Three limitations have restricted the wide spread of the above literature. First, most of these studies used computable general equilibrium (CGE) models, neglecting how EMI can generate positive economic effects in the region. Second, EMI has always been defined as tariff cutting in these studies, which underestimates EMI's benefits through non-tariff barrier elimination, improvements in market accessibility and market deregulation. Third, all these studies focus on the net welfare of EMI but ignore its re-distribution effects across countries. In particular, they cannot inform policy makers on whether EMI may narrow development gaps (NDG) across countries and thus facilitate economic integration within a region. Thus, further empirical studies are required to address all three limitations.

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[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.

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.

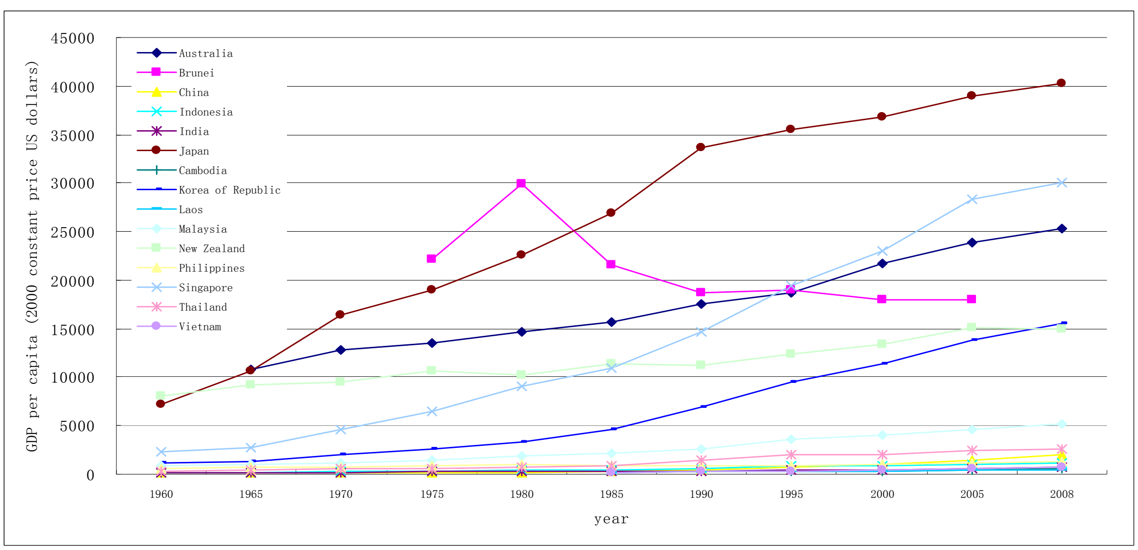
The remainder of the paper is arranged as follows. Section II briefly discusses the progress that EMI has made in the East Asian region and its impact on regional economic development. The channels through which EMI may impose its impact on regional disparity in economic growth are highlighted. Section 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, 2011).

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).

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).

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, 2011). 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.

First, 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.

Further exploring the role of EMI in NDG also has important policy implications for boosting economic integration and encouraging member countries' participation in EMI, 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.

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.

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

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

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

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'.

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.

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

(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 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

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

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

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 $\gamma 3$ is positive and significant and $\beta' > \beta$, we have evidence that EMI contributes to economic converge across countries. Second, if $\gamma 3$ is negative and significant and $\beta' < \beta$, 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

[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.

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).

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.

[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.

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 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. We use the first component (around 50 per cent of information) as an index in the regression (See Sheng and Shi (2011) for more detailed discussion on the PCA method).

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

where $Energy\_\text{int}_{it}$ 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 CO_2 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: We only report the EAS countries and major regions between 1960 and 2008 for simplicity.
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: We only report the EAS countries and major regions between 1960 and 2008 for simplicity. 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

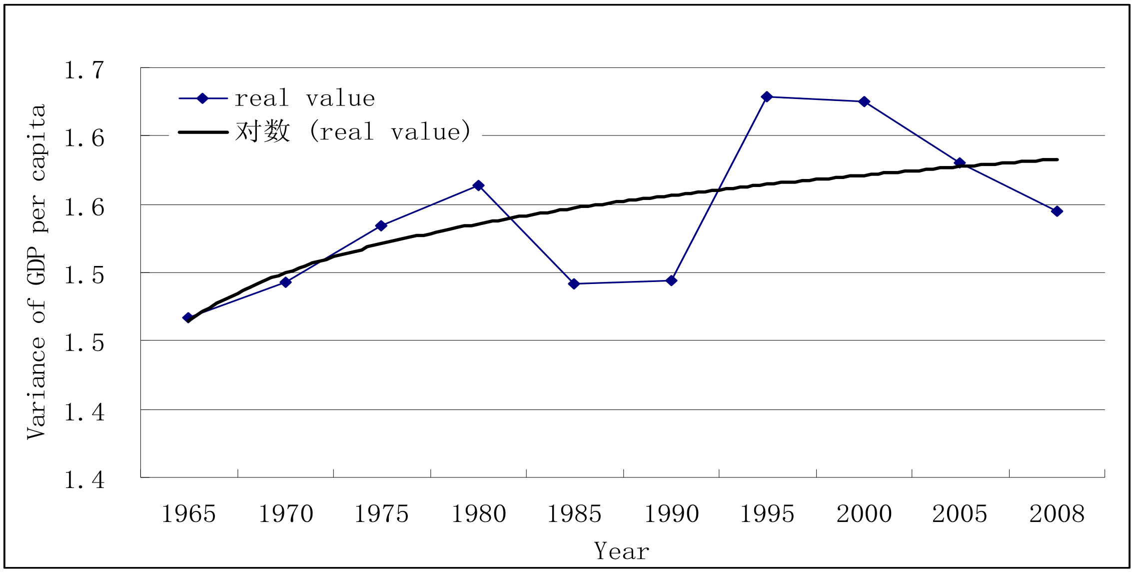
To better understand cross-country disparity in economic development and its changing trend over time, we first use σ-convergence analysis to examine the variance of real income per capita across countries. Figure 2 shows the logarithm of the standard deviation of GDP per capita of all countries in our 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.

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 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.

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

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.



Source: Authors' own calculation.

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.

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)	-0.008*	-0.022***	-0.096***	-0.074**

(lncgdp2000)				
	(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.

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 two findings that we wish to highlight.

First, 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.

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.

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.

Second, 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.

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.

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.

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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CHAPTER 5

Promoting Energy Market Integration in the EAS Region through Trade Facilitation: a Chinese Perspective

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Intro-regional energy trade is increasing rapidly in EAS Region in recent years. There are a lot of factors contributing for intro-regional energy trade booming, such as market demand, trade liberalization and trade facilitation. However, there are still several problems in the energy market of EAS region, such as insufficient level of energy supply, concerted effort, and the necessary infrastructure construction. An integration energy market is urgently required for resolving the problems. With the growing energy trade among the EAS Region, the improvement of the trade facilitation is one of key tools towards market integration, and will benefit both the resource-rich countries and energy-deficit countries in the region.

1. A Sketch of Intra-Regional Energy Trade

Intra-regional trade in energy is a way of life for member economies participating in the East Asian Summit (EAS) forum. Among the key points of rationale underpinning the establishment and progression of the EAS is pursuit of stronger ties in trade and investment among its member states. Amid continuation of uncertainties in world energy supply, in both physical and financial terms, given changes in energy economies outside the region, it is in the interest of all EAS states to make promotion of energy trade ties among themselves a goal for future discussion and action.

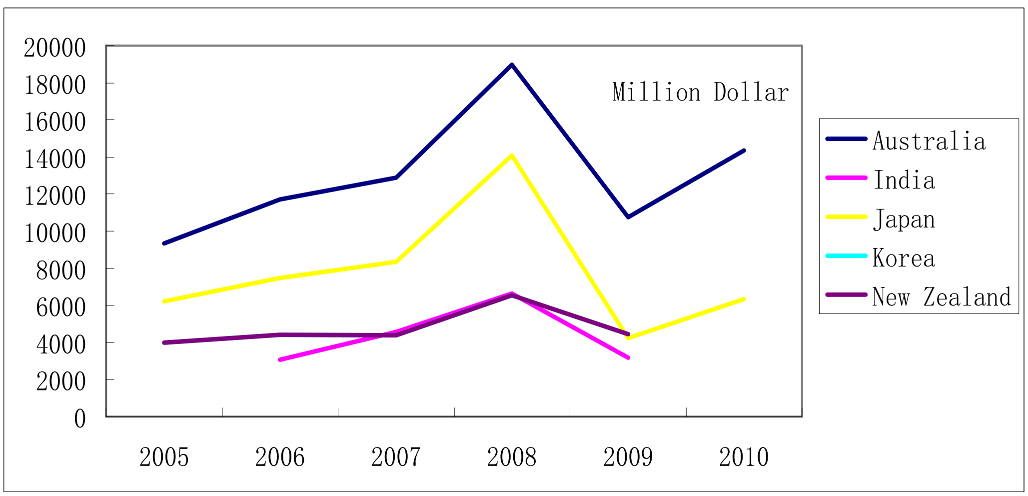
This study begins with a overview of intra-regional trade in energy. Our observation proceeds by observing flows in primary energy (oil, liquefied natural gas or LNG, coal, and electricity). In the second part of the study, we examine a number of policy mechanisms in place for facilitating overall trade flows. This examination is coupled with identification of challenges that still remain. On this basis, in the third and final section, we offer a few thoughts for making energy market integration in the EAS region an agenda item for action under the EAS framework for consultation and possible action.

A note of coverage of EAS in our study is in order. EAS membership has evolved to formally include Russia and the United States in the 2011 meeting. However, this study leaves inclusion of these two economies to future studies. The primary basis for our choice is the record of policy activism among those EAS members that seek to deepen energy trade ties among them. Indeed, promotion of primary energy trade has yet to become a major agenda item for U.S. policy choice with economies in the Asian side of the Pacific. Interconnectivity of energy flows between Russia and the EAS economies under the study warrants a separate study of its own. For a similar reason, the study touches on India only when available statistics is available. Most fundamentally, our approach reflects a matter-of-fact belief in that the EAS framework can become more effectual in dealing with sector-specific challenges among its members through solidifying its own existent trade policy programs. We emphasize that our approach by no means imply prejudicing future routes and choices of interactions within the forum.

1.1. Trade in Oil

The Association of Southeast Asian Nations (ASEAN) countries have abundant oil reserves. Traditionally, ASEAN oil exports flow to Northeast Asian markets of China, Japan, and South Korea. As indicated in Figure 1 below, in the more recent years, Australia emerged as the largest destination of ASEAN's exported oil. Japan, Korea and New Zealand continue to be significant for ASEAN oil export, while India has also entered ASEAN's oil trade scene. Obviously, the upward movement in Australian and Japanese imports of ASEAN oil is an indication of demand in those economies in the wake of the recent round of world economic fluctuations.

Figure 1. Major ASEAN Oil Export Destinations except China, 2005-2010



Data sources: UNComtrade

China is both an oil importer from and exporter to other EAS economies. In terms of import (see Table 1), Australia has emerged as a significant source of supply to China.

Papua New Guinea, New Zealand, and Myanmar became exports of oil to China in 2010 as well. Traditional suppliers such as Malaysia, Indonesia, Brunei and Thailand maintained their activism in supplying the China market.

Table 1. Selected EAS Sources of China's Crude Oil Import, 2005-2010, in 10,000 tons

Import Source	2005	2006	2007	2008	2009	2010
Australia	23	40	46	90	157	287
Malaysia	35	11	50	89	223	208
Indonesia	409	212	228	139	323	139
Brunei	50	42	40	8	53	102
Vietnam	320	87	50	84	103	68
Thailand	119	115	110	77	61	23
Papua New Guinea	0	0	0	0	0	7
Myanmar	0	0	0	0	4	0

Data source: Tian Chunrong.

Table 2 offers a summary of China's crude oil export to selected EAS countries. As shown, China's crude oil export destinations diversified to include India for the first time in 2010.

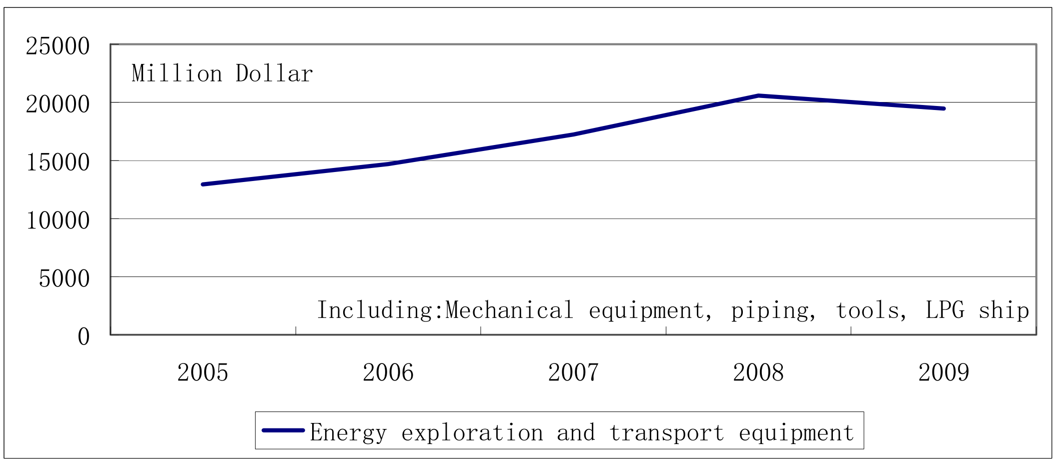
Table 2. Selected EAS Destinations of China's Crude oil Export, 2005-1020, in 10,000 tons

Export Destination	2005	2006	2007	2008	2009	2010
South Korea	206	175	107	65	163	61
Japan	95	86	46	117	74	61
United States	121	118	62	58	72	52
Thailand	6	1	14	5	24	24
Malaysia	59	15	0	16	4	12
Indonesia	162	104	35	26	9	8
Singapore	71	54	53	35	78	8
Australia	35	27	8	0	33	6
India	0	0	0	0	0	10

Source: Tian Chunrong.

Observation about the interconnected between China and ASEAN economies in energy should include attention to the role China plays in energy infrastructure investment and project development within ASEAN countries. In recent years, along with the implementation of "going abroad" program, Chinese enterprises have accelerated trade and investments in developing infrastructure development in energy projects within ASEAN economies. As can be seen in Figure 2, China's export to ASEAN of oil drilling equipments, oil and gas pipelines and liquefied gas vessels has been on the rise. It goes without saying that such trade is conducive to maintaining and enhancing energy production capacity of ASEAN economies.

Figure 2. China's Energy Exploration and Transport Equipment Exports to ASEAN



Source: UNComtrade

1.2. Trade in LNG

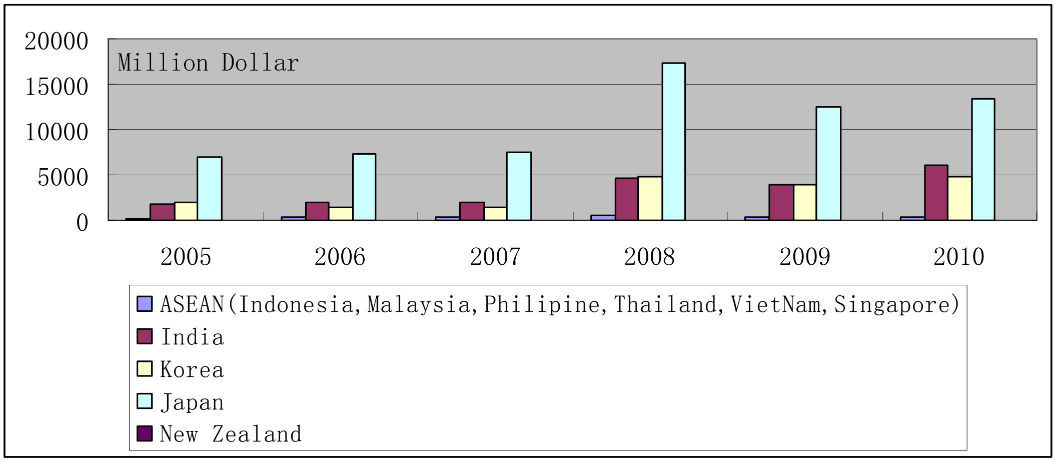
Before 2007, natural gas imported from Australia accounted for nearly 80% of the total import in the whole East Asia. In 2009, the amount of gas imported from Australia was about 774 million, still accounting for 62% of total gas import from East Asia.

Due to the lack of gas transport infrastructure between China and ASEAN, China and ASEAN gas trade has a long way to go in reaching its potential. At present, ASEAN is second behind Australia in exporting natural gas to China. Cross-border gas pipelines under construction or plan is expected to increase the share of ASEAN gas to the China market.

1.3. Trade in Coal

Australia is the one of the largest coal exporters in the world. The country is the main coal supplier of East Asia (except ASEAN). Japan is the largest coal importer of Australia in East Asia whose coal import from Australia was more than 15 billion dollars in 2008. India and Korea import about 5 billion dollars in recent years (Figure 4). Since 2009, China has become the net coal importer. Australia, Vietnam and Indonesia are the major coal exporters to China. There is a sharply increase of coal import from Australia in 2009,when the trade reached 4.89 billion in dollar terms, nearly 8 times as the trade in 2008. In 2010, China's coal import from Australia reached 5.44 billion dollars. New Zealand and ASEAN could satisfy the coal demand by domestic supply. The pattern of Australia being a key supplier of coal to the rest of Asian EAS countries is likely to continue.

Figure 4. Australia Coal Export to East Asia



Source: UNComtrade

1.4. Trade in Electricity

Cross-border trade in electricity is one feature, though often not prominently featured in general surveys, of China's pursuit of energy supply. For instance, Chinese import of electricity from Myanmar increased sharply in 2009. The import value was 239.9 thousand dollars in 2008. That value increased to 38.8 million dollars in 2009, an increase by 161.7%. This resulted largely from the entrance into full operation of the Ruili River hydropower station in the end of 2009. As background information, in 2006, China began investing in the Ruili River hydropower station in the border regions of the Myanmar. The project is the largest Chinese investment in Myanmar's Hydropower construction under a BOT (build - operate - transfer) mode.

Development of hydropower in the Greater Mekong Sub-region has a long history. As envisioned by such regional development promoting organizations as the Asian Development Bank, the countries of Cambodia, Laos, Myanmar, Thailand, Vietnam and China (its Yunnan Province and Guangxi Zhuang Autonomous Region), regional grid network interconnection is one effective way for addressing energy poverty that continues to hamper development potentials of the countries therein (Yu, 2003).

2. Is Trade Facilitation Promoting Energy Trade in EAS?

Several factors contribute to the intro-regional energy trade that is showing signs of a boom in the EAS region. Such factors include market demand, trade liberalization and trade facilitation policies. In the process of economic growth it's normal that energy demand is also increasing. The challenge is there must be sufficient infrastructure and facility in order to make potential demand becomes real demand. The energy consumption data and trade dada above show that energy supply both from domestic and international market has been provided in EAS. Therefore, the authors think that it's necessary to analyze whether the energy trade increasing is promoted by the factor of trade facilitation including infrastructure improvement or not.

Among the Asian EAS member states, Regional Trade Arrangements (RTAs) have been proliferated in the wake of the Asian Financial Crisis in 1997-98. In addition to ASEAN–China, ASEAN-Japan and ASEAN-Korea FTA, there are other bilateral FTAs such as China-New Zealand, ASEAN-Australia-New Zealand, ASEAN-India, Korea-India, and so on. Every FTA is a stage of the market integration. FTAs are benefiting for promoting energy and relative product trade by reducing and simplifying the custom procedures, improving infrastructure and transparency, and promote the economic cooperation about energy exploration and extraction cooperation projects. More and more dialogues within the FTA implement progress also help the related countries improving energy trade efficiency. All these have laid the solid basis for the preliminary integration of regional energy market.

As expected by related countries in EAS, the establishment and implement of 3 ASEAN+1 FTAs are promoting the trade among the area. In spite of the global economic downturn, trade in energy among ASEAN and the three Northeast Asian countries has remained robust. According to the BP Statistics Review of World Energy June 2010. Trade within these countries reached USD 413.8 billion in 2009, declining by only 15.5 per cent compared to USD 489.5 billion reported in 2008, registering a 27% share of total ASEAN trade last year. The 2009 value of total trade between ASEAN and its Plus Three Dialogue Partners was still higher than its pre-crisis level of USD 405.4 billion in 2007. Total flows of FDI from the three Northeast Asian countries into ASEAN were still strong with a slight decline of 1.3% from USD 8.4 billion in 2008 to USD 8.2 billion in 2009. Especially, ASEAN becomes the third biggest trade partner of China, surpassed Japan in 2009. Energy trade booming has made great contribution on trade booming between China and ASEAN. China's import ratio of energy and energy related products from ASEAN in the total import from ASEAN climbed to 3.3% in 2010 from 2.5% in 2009.

2.1. Effect of Tariff Reduction for Energy Trade

Tariff reduction is one of the most important contents in FTA. Taking China-ASEAN FTA as an example: Trade facilitation arrangements between China and ASEAN include two parts phases of tariff reduction: early harvest tax reduction and comprehensive tariff reduction, which is follow upon implementation of the first phase. When we kook at the tariff reduction tables for main energy products, we can see that the applicable tariffs were 0 before the FTA established, such as crude oil, anthracite and other coal, LNG and electricity etc. Just for fuel oil from ASEAN to China, the tariff has declined to 5% from 20%; for aviation turbine fuel from ASEAN to China the tariff has declined to 5% from 14%. However, considered the formal implementation of China-ASEAN FTA started on January1 2010, the conclusion is that tariff reduction has made no sense for intro-regional energy trade booming. That means in practice trade facilitation countermeasures play a very important role for energy trade in the EAS region. It is reasonable to believe that as the tariff levels fell over in recent years, governments have turned their focus on to non-tariff barriers (NTB) and other “non-traditional” sources of trade costs. Measures to facilitate trade and reduce such costs have therefore become a key priority for policymakers and international development institutions (World Bank IEG, 2006). The question is if the process of development ASEAN RTA facilitates the integration of regional energy market?

2.2. How Does Trade Facilitation Promote Energy Trade In EAS?

WTO, UNCTAD, UN/ECE and APEC have their different definitions on trade facilitation. The definitions from WTO and UNCTAD are mainly focusing on the process of international trade. APEC have more broad understanding such as "Adopting a more effective way to standardize the trade course and to improve the variables that have impact on the transaction process, such as customs procedures, transport formalities, insurance and the standardization of services, thus to achieve the purpose of reducing the trade costs. "This paper adopt the definition of APEC and refers infrastructure improvement as the part of trade facilitation.

That means trade facilitation is a very broad and complicated concept that includes all the efforts that during the cross-border movement of goods. For example how to reduce unnecessary procedures and controls? This is an important question because under the premise that the realization of legitimate management objectives is ensured, to reduce the associated costs and maximize the efficiency? The detailed contents of trade facilitation are covering many parts: transparency of laws and regulations, infrastructure improvement, the customs procedures; standards and harmonization; business mobility and e-commerce etc. For energy trade, huge energy investment and infrastructure improvement are playing critical roles.

UNCTAD estimates that the average customs transaction involves 20-30 different parties, 40 documents, 200 data elements (30 of which are repeated at least 30 times) and the re-keying of 60-70% of all data at least once.

2.2.1. Policy Dialogue and Coordinating

APT (ASEAN Plus Three) cooperation in energy has witnessed good progress. At the 13th APT Summit in October 2010 in Hanoi, Vietnam,oi the Leaders supported the on-going efforts to develop the “3rd ASEAN Energy Demand Outlook” and welcomed APT initiatives in specific fields such as energy security and oil stockpiling; natural gas and oil market; new and renewable energy; and energy efficiency and conservation, including the APT Oil Stockpiling Roadmap and APT Joint Workshop on Effective Energy Efficiency and Conservation Policy Guidelines, which was held in June 2010.

2.2.2. Energy Infrastructure Investment and Cooperation Promoting Energy Trade

Actually， ASEAN countries have already initiated a comprehensive set of cooperation with China, Japan and Korea on energy exploration and production. The China-ASEAN FTA provides a strong foundation for the continued expansion of regional economic, trade and investment activity. In recent years, with the deepening cooperation of China and ASEAN, the energy investment from China to ASEAN increased rapidly. A lot of projects have produced oil, gas, coal, electricity etc which have been exported to China or other EAS countries. This is a very important reason for energy trade and energy related products trade booming. Some bi-lateral co-operations are as following:

In Indonesia, Chinese energy investment reached US$9.47 billion in 2002. In 2006 China Huadian Corp. and PT PLN pumped US$2 billion into building an electricity generation plant on South Sumatra Island. CNOOC also paid for a 16.96 per cent share of the Tangguh Project which will produce 2.6 million LNG yearly for 25 years. Malaysia's PETRONAS and China's oil companies are jointly exploring a block in Indonesia. China's energy companies have invested a few projects in Malaysia. The China National Electric Equipment Corp. was contracted to build a coal electricity generation in Sabah and the Three Gorges General Corp. was authorized to construct a hydroelectricity plant in Sarawak.

China's energy companies in Philippine become active in recent years. In 2008, CNOOC was awarded a service contract by PNOC, and the Shenhua Group promised to offer 1.82 million tons of coal under a renewed contract with NAPOCOR. In 2009, China's State Grid invested US$3.9 billion to manage the Philippines National Power Transmission System for a period of 25 years (Li Tao and Liu Zhi, 2006). The booming Vietnamese energy market appears attractive to Chinese energy companies which have invested over US$6 billion in Vietnam since 2006. China's Harbin Electricity and Vietnam's Cam Pha Thermal Electricity are jointly financing US$348 million to build a thermal electricity generation plant in Quang Ninh province (Vietnam National Coal-Mineral Industries Holding Limited Company 2011, <http://vinacomin.net.vn/en.html>). CNOOC and Petrovietnam are cooperating 45 companies to explore oil and natural gas in the Beibu Gulf (CNOOC,2006, <http://www.cnooc.com.cn/>). China's Southern Grid and Vietnam Coal & Mining Group will build a US$1.1 billion thermal electricity plant in Vinh Tan, Binh Thuan province(Jin Yang,2010). US$4.5 billion will also be given by SINOPEC and Petrolimex to build the Nha Trang refinery(2008,<http://www.icis.com>).

In Myanmar China had invested in 28 projects, with the total investment to US$1.331 billion(Myanmar government, 2008). Energy cooperation between the two countries focuses on offshore energy resources and the China-Myanmar oil and gas pipelines. The total offshore E&P area for CNPC, SINOPEC and CNOOC is about 10 square kilometers. The route for the oil and gas pipeline runs from Kyaukryu Island to Mandalay, then to Ruili and Kunming. The pipeline will be 900 kilometers and pump 20 million barrels of crude oil to China, which amounts to a quarter of oil shipped via the Straits of Malacca. The pipeline which capacity is designed about 40 million barrels per day started to construct in 2010.

China and ASEAN have also developed widely cooperation on power grid interconnection and joint investment on power plants or hydropower station. China established the power forum and power grid interconnection & trade expert group, and signed the inter-government agreement on power interconnection and trade. Until the end of 2010, China have completed the 28 kw Plunglung station and 60 kw Ruili River station with the cooperation of the Myanmar, Sambor and stung Cheay Arenge station are ongoing under the cooperation of China and Cambodia. The Cheay Arenge station is planed 3.26 million kw accounting 63.3% of the total hydropower volume in Cambodia. China Southern Grid participated into investment in Vietnam's largest power project, Yongxing coal-fired thermal power plants.

Very naturally, all those huge energy investment projects have promoted the trade in energy including oil, gas, electricity etc, and related products including energy related products such as pipes, equipments and downstream products.

2.2.3. Improved Trade Facilities and Logistic Channel

2.2.3.1. The Trade Facilitation between China and ASEAN

Trade facilitation is an important part in China-ASEAN Cooperation. Both China and ASEAN have done amount of works to promote trade facilitation:

First, China and ASEAN countries have poured huge human and material resources in the infrastructure construction, such as of Kunming - Bangkok Road, and Kunming - Yangon Railway, improving the railway between China's Yunnan province and Vietnam to form the transport network from Kunming to Singapore. China and ASEAN also strengthen the development of the Mekong sub-region as well as encouraging the improvement of the Lancang-Mekong River navigation capabilities. Meanwhile, the Chinese Ministry of Communications also plans to sign with ASEAN, "China - ASEAN Framework Agreement on maritime transport cooperation" to strengthen bilateral maritime cooperation (Wu Chaoyang, 2011).

Second, in the field of customs inspection and quarantine cooperation, China and ASEAN started one-stop service test sites in some key border crossings, and strove to achieve "one declaration, one inspection, one release " management model. China and ASEAN countries Customs also proposed to establish an electronic verification system, using modern means to improve trade efficiency and facilitate customs clearance.

Third, in the labor-force and human resource exchanges, China and ASEAN have also simplified the visa application procedures. For example, the foreigners coming to China to discuss trade and investment, can apply for visas on arrival in many cities. China implements short-stay visa-free policy to foreigners coming from Singapore, Brunei and other members. In addition, APEC Business Travel Card holders can enter to China to conduct business without applying for a visa.

Fourth, China and ASEAN are committed to advance the standards with international standards. At present, the proportion of the China use of international standards has reached 46%. ASEAN countries have adopted international standards and the proportion is rising. China and ASEAN countries have actively participated in standards assessment activities in international and regional organizations to create conditions to facilitate bilateral trade.

Fifth, China and ASEAN countries customs adopted the "China - Nanning-ASEAN trade facilitation" mechanism. The initiative of “China-Nanning-ASEAN trade facilitation” mechanism is focusing on the process of WTO negotiations. Some countries proposed the establishment of national trade facilitation commission, and actively promote the process of national trade facilitation.

All of those measures have very positive impacts on energy trade between China and ASEAN. The trade process becomes smoother and efficiency improves higher and higher so that the energy trade volume is expending step by step. Meanwhile, complementary on energy between China and ASEAN is also embodying gradually.

2.2.3.2. The Trade Facilitation among ASEAN Countries

After signed a series of FTAs with other countries, ASEAN countries has to improve trade facilitation in order to meet with new trade situation. Especially, on the aspect of energy, ASEAN countries need to seek for multilateral cooperation and make energy as priority.

ASEAN Trade Repository

ASEAN is working towards the establishment of an ASEAN Trade Repository (ATR) by 2015 that would serve as a gateway of regulatory information at regional and national levels(2009,<http://www.cafta.org.cn>). The ATR, among others will carry information on tariff nomenclature; preferential tariffs offered under the ASEAN Trade in Goods Agreement (ATIGA); Rules of Origin; non-tariff measures; national trade and customs laws and rules; documentary requirements and list of authorized traders of Member States. Once established and fully functioning, the ATR and information will be accessible through the internet to business agencies like exporters, importers, traders, as well as government agencies and the interested public and researchers. Currently, ASEAN is developing the design and mechanism of the ATR.

ASEAN Single Window

With a view to achieve a more expeditious clearance and release of containerized shipments by Customs authorities, AMS are developing the ASEAN Single Window (ASW) which would provide an integrated platform of partnership among government agencies and end-users in the movement of goods across AMS. The AMS are also engaged in the process of continuously reforming and enhancing the ASEAN Rules of Origin (ROO) to respond to changes in global production processes, including making necessary adjustments.

The objective is to make the ROO more trade facilitative and, at least, as liberal as those contained in the ASEAN FTA arrangements. The revision of the ROO undertaken to this date has introduced other origin criteria as an alternative to the long-standing Regional Value Content (RVC) of 40%. This provides economic operators a wider option of co-equal methods of achieving ASEAN origin status for regionally traded products. AMS are also considering the establishment of the Self Certification scheme for the declaration of origin, which is a priority effort as envisaged in the ASEAN Economic Community (AEC) building process. The self certification scheme provides "certified economic operators" like exporters, Traders and manufacturers who have demonstrated their capacity to comply with the origin requirements to self certify the originating status of goods in replacement of presenting a Certificate of Origin issued by the issuing government authority.

2.2.4. Port Construction

Australia is important for China energy safety, as the main gas and coal resource supplier for China. The role of port in Australia becomes more and more important for energy trade between China and Australia. Australia has maintained its global leading coal exporter position. China and other Asian countries' surging demand, leading to unprecedented prosperity in NSW coal export industry Accompanied with coal exports booming, problems of transportation bottlenecks come up. In order to meet export demand from coalmining companies, the proposal of New South Wales (NSW) coal port expansion and renovation work has put on the schedule. According to relevant information, NSW PWCS Ports Corporation has two subsidiary ports, one of the world's largest coal export port of Newcastle, the other is Port Kembla. The current Newcastle port capacity is about 1.02 million tons / year, which has been upgraded to 113 million tons / year as the expansion project completed in the fourth quarter of 2009(2010,http://www.miningweekly.com). Australia Newcastle Coal Company and other major coalmining companies plan to build a new coal port on the second half of 2009. In the future, the trade facilitation between China and Australia can be the elementary concern by both sides. It can also be an important part of and contribute to the energy market integration (EMI) in the summit region.

3. Main Challenges

Although in the EAS region there is a substantial progress of trade facilitation which promoted energy trade and EMI, the related countries are still faced with challenges.

First, in many countries domestic oil and gas pipelines need to be constructed and improved. For example in Indonesia, Myanmar, Thailand, and Vietnam, the potential for pipeline construction remains very high. Currently, Vietnam’s growing demand for gas is met by LPG imports from Indonesia, Malaysia and Thailand. Indonesia’s success in developing a natural gas pipeline network will be dependent on the effective integration of field development activities in Sumatra and Kalimantan. The current situation poses a great challenge all countries in the region to achieve the goal of realizing an integrated energy market because of diversity among the nations.

Second, domestic EMI is a very essential basis for the integrated market in EAS.

It has distinct policies which are usually based on the sovereign law of the country. It's very difficult to imagine that the related countries will be interested and able to promote regional integrated market without domestic integrated market. At the same time, dynamic domestic market and regional market may impact each other. At least domestic EMI will impact on energy export to other countries. Energy markets in majority countries of the region are relatively immature, with strict import barriers and tight regulations. Cross subsidies in energy price and entangled energy tax systems can also deter creation of a competitive energy market and an influx of foreign investment capital.

Third, it's obvious that trade facilitation measures in all countries are still not enough for EMI. In resent years ASEAN becomes the opened and positive economic entity in Asia. At the same time, it's very obvious trade facilitation is still need to be improved in many aspects, such as transparency of laws and regulations, infrastructure improvement, capacity building, efficiency of custom and inspection procedure, business personnel movement etc.

Fourth, national energy policies can also impact on energy trading particularly, and obviously, those requiring self-sufficiency or diversity in energy supply. Big economic entities, such as China, Japan, South Korea, India and Indonesia, are seeking their energy security by multilateral approaches(Doh Hyun-jae ,2003). To some extent it seems that they are easier to become competitors in stead of cooperators. How to facilitate their negative behavior in the regional energy market also is a headache problem.

Fifth, lack of investment will be the main bottleneck both for trade facilitation and EMI. Improvement of trade facilitation and progress of EMI need a lot of investment both for soft projects and hard projects. While many energy cooperation schemes, such as oil and natural gas development projects and interconnection of electricity grids, involve enormous investment and the risks of investment are also high due to political tensions in the region as well as institutional impediments. It's relatively easier to construct domestic or bilateral energy projects but more difficult to construct multilateral cross border energy project because investment scale would be too big and negotiation would be too complex. Meanwhile, most of ASEAN members are developing countries and some of them are least developed and seriously lack of capital. That‘s why the multilateral regional financing approaches should be explored and established.

4. Case Study

At present integration of energy market in the EAS region is promoting and embodying by intro-regional energy trade on one hand, on the other hand the networks construction of crude oil and natural gas pipelines and power grids are the most significant contents which could be on behalf of a part of integration promoted by infrastructure improvement which is also belonging to the scope of trade facilitation.

4.1. Case study 1: ASEAN GAS GRID

On the basis of domestic gas pipelines the network construction within the countries in the summit region also started and has become the most typical case for EMI.

The first cross-border gas pipeline in ASEAN exports gas from Malaysia to Singapore and was commissioned in 1991. Then several regional gas pipelines have been completed and several more are in the process of design and construction or are envisaged. Myanmar-Thailand pipeline came into existence in late 1998. There are also pipelines such as Indonesia (West Natuna) to Singapore, Indonesia (South Sumatro) to Singapore etc. To date, Brunei Darussalam, Indonesia, Malaysia, Myanmar, Singapore and Vietnam have a total domestic gas pipeline network of around 9,200 km, including pipelines connecting gas fields and delivering gas from offshore fields to onshore receiving terminals. 11 bilateral connections have been established with a total of 3,020 kilometers of pipeline connections making possible the transmission of gas molecules to and from ASCOPE Member Countries. Over 2,400 km of pipelines are under construction, and over 4,200 km are being planned within the next few years. Full interconnection of these pipelines, which is envisaged by ASEAN to be done by 2020, would see the creation of an interconnected gas grid throughout ASEAN (Asia Pacific Energy Research Centre,2009)

A Trans-ASEAN Gas Pipeline (TAGP) Master-plan has been prepared and this serves as the blue print of action in undertaking the gas pipeline project in the region. ASCOPE has likewise started working on developing the necessary regulatory framework such as open access, gas transit principle and gas specification harmonization aimed at facilitating the implementation of the TAGP Project. The TAGP Project is already taking its shape with the completed gas pipeline interconnections. The TAGP project envisages the creation of a trans-national pipeline network linking ASEAN's major gas production and utilization centre. Once realized the TAGP will have the potential of linking almost 80% of the ASEAN region's total gas reserves and will embody a far-reaching expression of the region's energy interdependence and long-standing interest in the coordination of energy activities.

Next step, cooperating with China and India，Myanmar is becoming the most potential gas supplier and some of important gas pipeline will be constructed. India has been pushing for an early agreement on the Myanmar-Bangladesh-India gas pipeline proposal. Sino-Myanmar Oil & Gas Pipeline is important energy import channel of China which design capacity of oil is 22 million tons per year and the annual transport capacity of natural gas is 12 billion cubic meter per year. (Asia Pacific Energy Research Centre,2009) This project has been constructed since June 2010.

South Korea and India are cooperating in Myanmar is deepening EMI in the region. South Korea's Daewoo International operates and owns 60 per cent of Myanmar's gas-rich A-1 block, in which India's Oil and Natural Gas Corp. Ltd. holds 20 per cent stake, while GAIL India Ltd and Korea Gas Corp each hold 10 per cent. Daewoo's 100 per cent-owned A-3 block is close to A-1, which could hold 6.0 trillion cubic feet of recoverable gas.

4.2. Case study 2：ASEAN Power Grids (APG) and Electricity Trade with China

Currently, electricity is accessed by roughly 66% of the ASEAN member countries' population through grid power supply, stand-alone and distributed power generation systems. However, in each country the situation is quiet different. For example, in Cambodia electricity is not accessed by more than 85% rural area population. Electricity becomes a very important factor which could impact living standard, industries production, education for children, poverty reduction etc. That is why it becomes very urgent to make electricity interconnection and trade in the summit region. ASEAN Power Grids are not only providing electricity for the relevant countries but also becoming one of the most important platforms and parts for EMI.

4.2.1. ASEAN Power Grids (APG)

ASEAN countries have different power grids. While power grids of ASEAN 6 old members are more developed, ASEAN 4 new countries' grids technically are obsolete with unstable performance. There are many obstacles in integrating the power grid, especially technical issues. The unstable voltage, frequent power outages and unguaranteed power level at 220kV, etc. could seriously affect the overall performance of power grid. On the other hand, Regional electricity production grew at an average yearly rate of 8% from 1990 to 2005 and is projected to grow at 6.1% annually from 2005 to 2030. Enhancing electricity trade across borders, through integrating the national power grids of the ASEAN Member States, is expected to provide benefits of meeting the rising electricity demand and improving access to energy services.

The ASEAN Power Grid (APG) is a leading program towards ensuring regional energy security while promoting the efficient utilization and sharing of resources. To pursue the program, ASEAN adopts a strategy that encourages interconnections of 15 identified projects, first on cross-border bilateral terms, then gradually expand to sub-regional basis and, finally to a totally integrated Southeast Asian power grid system. Currently, the APG is in progress with four on-going interconnection projects and additional 11 projects are planned for interconnection in 2015(APAEC,2004). The investment requirement of the APG is estimated at USD 5.9 billion. A potential savings of about USD 662 million dollars in new investment and operating costs is estimated resulting from the proposed interconnection projects.

At present, there are three electricity interconnection routes lay through ASEAN: Thailand-Malaysia, Malaysia-Singapore, and Thailand-Lao. Several of proposed electricity interconnections those have substantial impact to ASEAN member countries of Thailand and Lao PDR under the ASEAN framework are designed for the capacity of 500 KV. Another major power transmission line proposed for the Greater Mekong is the one contained in the ASEAN plan between Myanmar and Thailand.

The APG also adds strength to the regional EMI and economic integration. Interconnected networks can provide countries with abundant natural resources but with relative low requirement for income generation from surplus electricity power. In contract, countries with huge power demand can tackle the problem of electricity shortage due to seasonal utility price fluctuation. Thus, the establishment of new electrical plants can be substituted by cross-border power transmission. At the same time, unnecessary and ineffective plants will be reduced and thus, make the Power Grid more efficient, cost saving and benefiting all countries in the region.

The grid interconnection between the countries in the region will bring huge economic efficiency to both investors and users, creating opportunities to expand power market, stimulate investment and trade, and greatly contribute to the each country’s energy security, as well as economic growth. In the near future, ASEAN will encourage small regions to cooperate to establish interconnect sub-regional power grid, after 2020, it will be expanded to all countries in the region.

Much of the rationale for enhanced interconnections in the Greater Mekong Sub-region are covering the exploration of hydro-power from Lao PDR and China's Yunnan province's exporting sectors to Vietnam and Thailand's logistic centers as well as the development of hydropower in Myanmar which is designed to export electricity to Thailand(Edvard Baardsen,2008). However, there are a lot of disputes on hydro-power construction which are mainly focusing on ecological and environmental impacts and immigrants issues

4.2.2. The Electricity Trade between China and ASEAN is Promoting APG+

In recent years China has jointed both power plants construction in those Southeast Asian countries that demand and welcomed some investments. Moreover, China has pursued cross-border electricity trade with those ASEAN countries where it is feasible to do so. That means China's has already been deeply involved in the process of regional electricity market integration on one hand. On the other hand China is also promoting the APG forward to APG + China and so on. China is playing a very important constructive role in the region. Regarding China's impact, it's very easy to see from the case of Vietnam and Laos.

Vietnam has joined ASEAN power grid for a long time, but mainly connected the grid with China, Laos, and Cambodia. Cambodia has potential in hydropower development, estimated at over 10,000 MW. Sub-regional energy integration and ASEAN regional grid help Vietnam to have better energy security. China's Yunnan Power Grid (YPG) is continuously strengthening cooperation with ASEAN countries. Electric power becomes a new growth point of Yunnan –ASEAN trade. YPG has built up 6 lines including two high voltage lines and four channels to transmit electricity to Vietnam. In the coming years, power transmitted from YPG to Vietnam would show rapid growth.

The electricity cooperation between Yunnan and Laos has also presented a rapid development in recent years. YPG and the northern Lao grid interconnected through a

115 kilovolt transmission line. As power interconnection projects has launched, YPG has undertaken the power transmission project in Laos. It is also the first offshore general contracting project for this corporation. As Yunnan's power producing capacity and market share continues to expand, it is becoming possible to supply power to other ASEAN countries so that the Yunnan-ASEAN cooperation will be deepened.

Being as major trade partner with China, ASEAN member countries draw massive Chinese investors' attention to electricity productions. China Guodian Corporation has cooperated with ASEAN and carried out a series of electricity projects with Vietnam, Laos, Myanmar, Thailand, and Cambodia. China Guodian has worked with Vietnam National Coal Corporation to jointly build a thermal power plant in Chongzuo, Guangxi. Chinese side has invested about 6.8 billion RMB in the project. The thermal power plant will enhance the industrial development in the northern part of Vietnam and play a significant supporting role. China Guodian has invested 5 billion RMB to build three power plants in Indonesia.

China Southern Power Grid (SPG) has also increased its investment in the ASEAN countries. Since 2004, SPG has constructed three 110-kv power lines to Vietnam. In 2006, the power grid connection between China and Vietnam was put into operation, whereby electricity from Yunnan was transferred to six provinces in Vietnam via a 220-kv power line. By the end of March 2010, China SPG had transferred 1.84 billion kilowatt hours of electricity to Vietnam via the four power lines which generated a sales volume of 80 million US dollars.

This case shows that the EMI between China and ASEAN at least could be reflected on three levels: electricity trade, power plants construction, and power plants and grids operation. In the process of project implementation, trade facilitation measures, especially infrastructure improvement is most needed and critical. Meanwhile, if the related countries are planning to go forward deepening integration of energy market, huge investment and applicable financial approaches would be priority which has to be emphasized.

5. Policy Implication

Integrating energy markets means opening-up and liberalizing the market for energy resources and are characterized by interconnections across states, free and open trade, secure and transparent investment frameworks, clear price signals, market transparency, and effective competition. In order to achieve goals above, the related foundational policies should be considered:

5.1. Consensus to Promote EMI in EAS Region by the Approach of Trade Facilitation is needed for all countries.

At present both trade facilitation and energy infrastructure are urgent to be improved in many countries. Governmental cooperation will rely on the consensus. There is still no a consensus for promoting EMI in EAS without which it would be difficult to go forward. It is no doubt the integrated market can enhance trade, boost infrastructure project, and compromise risk of energy market fluctuation. It's strongly recommend that all countries in the region should formulate the consensus to promote EMI by trade facilitation and to get benefit.

5.2. Institutionalizing a Regional Energy Cooperation Framework

In EAS, concerted energy strategies are absent due to the lack of energy cooperation mechanism in the region. Related countries have not garnered a position internationally that can match its amount of energy imports. Different legal and institutional system among the countries should be harmonized and transparency of laws and regulations should be improved so as to support the expansion of energy trade in the region. This is also important content of trade facilitation. The critical point is that Asian countries should institutionalize an energy policy cooperation framework. Such a framework should be modeled on the International Energy Agency (IEA), coordinate the energy policies of member countries and establish "coordinated emergency response measures". A regional energy cooperation institution needs not to take a physical form, but at least it should be realized functionally in the form of policy cooperation. The "Energy Partnership" declared by the ASEAN+3 energy ministers in 2004 is a first step and should be nurtured. Institutionalizing Regional Energy Cooperation would be the best way to enhance the inter-regional trade, making the energy supply multiple and stable.

5.3. To Explore and Establish Multilateral and Applicable Financing Approaches

There should be relevant financial institutions those being as major fund-raising institutions in East Asian Energy Market Integration Action. The first applicable approach could be the regional infrastructure fund. ADB has acted for ASEAN infrastructure construction fund which will provide a part of capital contributing to EMI. ASEAN-China Investment Cooperation Fund is another positive action which is amounted to 10 billion USD. The second applicable approach could be the regional development banks. The proposal of establishing Northeast Asia Bank of Cooperation and Development Bank (NEABCD) has been provided 20 years. Now it's time to act. Right now there are a lot of cross border projects of large scale in Northeast Asia and its financing requirements are very huge. It's predicted in next thirty years, the upgrading and renovation of current energy infrastructure in the Far East Area of Russia at least need 150 billion dollar investment[1]. ADB focuses on the operation of the impoverished area of Southeast and Central Asia, the investment on NEA region accounts for 4% of ADB total investment. NEABCD can become a complementation and cooperate with the current multilateral financial institutions. The Establishing the NEABCD could promote the EMI in the Region, meeting the large financial

[1] According to Cho and Katz, required net foreign capital inflow to Northeast Asia for infrastructure development is estimated to reach at 7.5 billion dollars a year for the next 15 or 20 years. This estimated amount is beyond the region's means, and existing tools like international financial institutions (notably, IBRD, ADB and EBRD), private direct investment in commercially viable infrastructure projects, and bilateral, government-to-government assistance cannot adequately cover those needs.

requirements in infrastructure and the requirement of sustainable development. The proposal of establishing Southeast Asia Bank of Cooperation and Development (SEABCD) also could be considered.

5.4. Taking the Advantage of Existing RTA Platforms to Promote EMI

At present ASEAN becomes the hub of regional economic integration. There are a number of RTAs which are containing the arrangement of trade facilitation. No matter how difficult to promote trade facilitation, at least a series of measures on trade facilitation has been listed in the agreement and needed for implementation. The more trade facilitation are implementing, the more progress of EMI. RTAs have provided institutional platforms for the energy trade and investment among the countries in EAS including the equipment trade on the infrastructure and facilitated the infrastructure investment including energy distribution channel, the power grid connection and power station construction. Taking the advantage of existing trade agreement requires more regulation transparency for both enterprises and government.

5.5. Improving the Quality of Energy Data, Statistics and Enhancing Information Exchange and Dialogue

Asian countries should strengthen their efforts to improve the quality and timeliness of energy data and statistics aiming at improving transparency in the energy market. Developed countries, such as Japan and Korea, should provide expertise to assist developing countries in capacity-building through proper channels. Enhancing dialogue between Asian energy consumers and producers is also very important. Major consuming countries should together to enhance dialogue with producing countries. Government dialogue should focus on removing of market bottlenecks such as investment and market substitution. In the dialogue, EAS countries, which are mostly energy importers, should take a common position as possible, based on consumers' interest vis-a-vis energy producers.

5.6. Improve Infrastructure and Creating Pre-conditions for EMI

Infrastructure such as pipelines and LNG facilities should be accelerated based on sound fundraising structure that allow cooperation between governments and the private sector. In particular, cross-border cooperation in energy projects should be promoted and financed. Such projects could include cross-border pipelines for oil or natural gas and joint development of oil and natural gas. Development and dissemination of technology on natural gas utilization, such as combined heat and electricity generation, and gas-to-liquid conversion, should be encouraged. Governments should provide sound public support for the commercial conducting of such projects, bearing in mind the necessity of practicality. Governments should show strong political leadership by acting as principles of promoting energy economics of scale, while guarding against impulses of economic nationalism.

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CHAPTER 6

The ‘Asia Premium’ in Crude Oil Markets and Energy Market Integration

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There is a widely-held perception that Asia has been paying a premium for its crude oil, the so-called “Asia premium.” This has led to calls for intervention among some observers of the Asian crude oil market in order to mitigate the so-called premium. More recently, it has been argued that the “premium” has been reversed because Asia has emerged as the dominant consuming region forcing the Middle East oil producers to reduce crude oil prices relative to the other oil consuming regions such as Europe and the US. We analyze the market structure and pricing mechanism of oil to understand whether the analysis supporting the argument for the existence of an “Asia premium” is tenable.

1. Introduction

It has been commonly believed that Asia pays higher prices for crude oil exported from the Middle East relative to their counterparts in Europe and the US. This price differential is referred to as the "Asia premium." There have been several papers by government-funded research institutions in the key Northeast Asian crude oil importing countries Japan, South Korea, and China (Ogawa, Y., *et al.*, 2000; Ogawa, 2002; Ogawa, 2003, Moon *et al.*, 2003; Lee, 2003a; Lee, 2003b; Koyama, 2003; Gong *et al.*, 2003) and by US academics (Soligo *et al.*, 2000) that have analyzed this issue and have estimated the magnitude and the variation of the so-called premium.

Ogawa (2002), a researcher at the Institute for Energy Economics Japan (IEEJ), estimated that the Asia crude oil premium to Europe averaged $0.94/bbl over the period January 1991 to June 2002. In another paper, Ogawa (2003) reported that "crude oil prices for Asia have remained higher than those of European and US markets by $1.00 - $1.50/bbl throughout the 1990s." More recently, Chiu *et al.* (2010) indicated in an article in the Wall Street Journal (WSJ) that the Asia premium was on average "about $1.20 a barrel since 1988."

Utilizing data from the Petroleum Intelligence Weekly (PIW), a leading industry trade publication, for the period 1990 – 97, Soligo *et al.* (2000) found that Saudi Free On Board (FOB) prices for crude oil destined for Asian markets have been on average $0.83 higher per barrel (bbl) than for Western Europe and $0.93 higher than for the United States. In another paper, Soligo *et al.* (2004) calculate the Asia-Europe differential for Saudi Arab Light FOB sales to average $0.90/bbl over 1988 – 2002, increasing to $1.48/bbl over 1997 – 2002. A careful study by Horsnell (1997), covering the period January 1992 – November 1996, came to the conclusion that the Asia-destined loadings for Saudi Arab Light (AL) realized prices were found to be on average $1.00 - $1.20/bbl higher than for European loadings. These quantitative estimates from the cited sources are broadly consistent, with the "Asian premium" estimated to average in the range of $1.00 - $1.50/bbl over the 1990s and the early part of the 2000s.

The IEEJ believes that refiners in Asia are already disadvantaged given poor Asian refining margins. Ogawa (2002) calculates that higher crude oil prices have caused refining margins to becoming negative at around minus $1/bbl since 1999; the Institute estimates that the Asia premium imposes an additional burden of $4-8 billion annually. Furthermore, it is claimed that higher crude oil prices also lead to higher prices for other energy commodities such as LNG and coal, which are linked to oil prices.[1] Similarly, the Korea Energy Economics Institute (KEEI) points out that the financial burden of extra costs adversely affects economic and industrial activity and leads to the deterioration of the competitiveness of Asian economies. Lee (2003) estimates the burden placed by the Asia premium on the Korean economy as being $0.8-0.9 billion a year.

Proposals offered to assuage the so-called premium include suggestions that the Middle East exporters consider adopting Brent crude as the reference price for Asian sales rather than the Oman/Dubai average which is the current reference; charge Asian customers an average of their US and European prices; and allow the spot trade of Arabian Light (AL) crude, thereby making AL effectively the marker crude for Middle East grades in Asia. To date, nothing has come out of the abovementioned proposals.

The world economy is witnessing a paradigm shift with the locus of economic clout shifting to Asia. This is driving a structural change in the oil markets. Chiu *et al.* (2010) assert that the "rising power of Asian oil consumers is increasingly helping them (to) buy oil more cheaply than their counterparts in the West, a reversal of the historical pattern." According to the PIW, Saudi Arabia sold Arab Light crude to Asia for about $6.40 less per barrel than it charged European buyers in March 2010. Tom Wallin, president of PIW, made another comment that "an Asian discount is looking more likely to be the new normal." More dramatically, the Global Oil Director at Platts, an industry price assessment agency, stated that "It's a game changer….the balance of power in pricing is drifting to Eastern markets."

Given this transition, we seek to revisit the question of the existence of the Asia premium. This study will make three contributions. Firstly, we will use a new, high-

[1] LNG and coal sold in Asia are typically indexed to crude oil prices, such as the Japan Customs-cleared Crude (JCC) price which is the average price of customs-cleared crude oil imports into Japan as reported in customs statistics. It is often referred to as the "Japanese Crude Cocktail" price.

frequency dataset to ascertain whether the Asia premium exists. Secondly, we will evaluate the arguments that fault the current formula-based pricing system with the existence of the premium. And thirdly, we will assess the most efficient energy market integration policies that should be adopted in order to mitigate the Asia oil premium if at all. We trace the evolution of the Saudi formula-based pricing mechanism in Section 2 to provide the background for oil pricing. In Section 3, we examine the structural characteristics of the oil markets and how these affect prices paid in different regions of the world. Section 4 analyses the arguments that Saudi Arabia discriminates against Asian buyers of its crude. In Section 5 we calculate difference in the oil price paid by Asia, Europe, and the United States. Section 6 discusses the most efficient policy prescriptions to mitigate the existing intra-regional oil price differentials for Asia. We conclude in Section 7.

2. The Saudi Formula-based Pricing Mechanism

In 1973/4 the Organization of the Petroleum Exporting Countries (OPEC) inherited from the Seven Sisters[2] a pricing regime that effectively administered the price of oil by fiat. The Seven Sisters in the pre-1974 period fixed a "posted price."[3] This was then used to compute royalties and the income tax paid to producing countries. When OPEC countries nationalized their upstream hydrocarbon assets, the administered price effectively was the price at which oil was sold and bought in arms-length transactions from the exporting countries.

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[2] The term refers to the seven oil companies, which formed the "Consortium for Iran" and dominated the global petroleum industry from the mid-1940s to the 1970s. The group comprised Standard Oil of New Jersey and Standard Oil Company of New York (now ExxonMobil); Standard Oil of California, Gulf Oil and Texaco (now Chevron); Royal Dutch Shell; and Anglo-Persian Oil Company (now BP). See Sampson, Anthony, "The Seven Sisters: The Great Oil Companies and the World They Shaped," New York: Viking Press (1975).

[3] A posted price is a price that a seller or a buyer makes public in some conventional way to give notice that she/he is prepared to accept or to offer a certain sum for a barrel of crude oil or a tonne of petroleum products. In the past US refiners used to post at the gate of their plant the price at which they were prepared to buy a barrel of crude oil on a given day (see Mabro, R. 2005). "The International Oil Price Regime Origins, Rationale and Assessment." *The Journal of Energy Literature,* Volume XI, No1, pp. 3-20

Mabro (2000) gives a detailed account of the changes in pricing regimes that the oil market witnessed. The administered (or fixed) price system collapsed in 1985. In the years leading to 1985, OPEC members were sharply divided over pricing policy and the fundamental long-term pricing strategy. This was particularly obvious in the 1980 conference in Algiers. OPEC official prices were falling out of line with competing freely-traded crudes in Atlantic Basin spot markets. The problem arose from the difficulty encountered by OPEC in defending a given price in the face of strong competition from emerging, and rapidly growing, non-OPEC sources. Increasing non-OPEC supplies, at a time of stagnant world demand, resulted in the emergence of considerable surplus capacity within the OPEC region. This induced intra-OPEC competition, which meant price discounting by several OPEC member countries to protect their export volumes. By adhering to the system of official prices, which most of OPEC was abandoning, Saudi Arabia was forced to reduce output and take on the role of a swing producer. Saudi Arabia suffered a continuous decline in the volume of their exports, from about 10 million barrels per day (mmbd) to under 3 mmbd between 1980 and 1986. In the end, the OPEC administered price system, which had been in operation since 1974, became unsustainable by the mid-1980s because it cost Saudi Arabia a huge loss in export revenues.

For a relatively short but dramatic period in 1986, "netback pricing" replaced administered prices. Under "netback" arrangements, the price of crude oil was referenced to the value of refined petroleum products derived from the given crude. In effect, netbacks guaranteed a refinery margin which, in periods of excess refining capacity that prevailed at the time, resulted in falling product prices. This, in turn, led to a collapse of crude oil prices. The effects were catastrophic for crude oil exporters. At one point oil prices, which were previously in the $24-26 per barrel (bbl) range, fell to $8-10/bbl.

The ensuing price recovery followed an OPEC meeting in November 1986. This meeting was significant as it changed the overall strategy from charging official administered prices to managing OPEC supply through the quota system in order to stabilize the price around a target level of $18/bbl. Given that neither the administered OPEC prices nor netback prices were acceptable any longer, a system of market-related formulae prices was gradually adopted. It involved setting "official" monthly discounts (or premiums) relative to the other marker or reference grades such as Brent or West Texas Intermediate (WTI).

We focus on the formula-based pricing mechanism used by Saudi Arabia's national oil company, Saudi Aramco, whose pricing system is loosely tracked by most exporters in the Middle East.[4] Saudi Aramco's sales to international buyers are made under long-term contracts, usually "evergreen" contracts renewable annually. The pricing formula generally has four components: point of sale, a market-related base price, an adjustment factor that is reflective of crude oil quality and the point of sale, and a timing mechanism that stipulates when the value of the formula is to be calculated (PIW, 2009).

The base price is calculated by taking the daily average of market prices of a particular widely-traded *reference* crude oil. The FOB price for European destinations is tied to Brent Weighted Average (Bwave)[5] data for Brent crude oil for the 10 days around the delivery of the cargo, about 40 days after loading at Ras Tanura.[6] For the USA, the FOB price is linked to West Texas Intermediate (WTI) crude oil for the 10 days around the delivery of the cargo about 50 days after loading at Ras Tanura port. For buyers in Asia, crude oil prices are linked to the average spot prices of Oman and Dubai crude oils during the month in which the crude is loaded at Ras Tanura for delivery to the Asian market. The base price is then adjusted by adding or subtracting an *offset* or *adjustment factor*. This adjustment factor takes into account the point of sale (to adjust for the freight costs) and the "quality differential" between the Saudi crude and the reference crude.

Crude oils differ from one another in chemical and physical properties which play an important part in their refining and subsequent value as refined petroleum products. The two most important characteristics of crude oils are specific gravity measured in degrees API (a scale devised by the American Petroleum Institute) and percentage of sulfur content by weight. Lighter crudes (those with higher API) produce a larger

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[4] Kuwait, Iran, Qatar and Abu Dhabi are among the other large oil producers using some form of formula prices for long-term contracts. Among the few Gulf crudes sold on the "spot" market (i.e. not based on term contracts with end-user and re-sale restrictions) are Oman and Dubai.

[5] It is a weighted index of Intercontinental Exchange (ICE) Brent crude oil futures contracts traded on any given day on the exchange.

[6] Ras Tanura is a city in the Eastern Province of Saudi Arabia located on the peninsula extending into the Persian Gulf.

number of lighter products, such as gasoline, which have higher market value. So other qualities being equal, lighter crude grades are expected to sell at a premium over heavier crude grades.

High sulfur content has an adverse effect on the value of crude oil, because it leads to higher operating costs for refineries due to special processing technologies (such as oxidative desulphurization technology) and maintenance requirements. In addition, new environmental legislation in many countries mandates lower sulfur content for gasoline and diesel. Therefore, high-sulfur (sour) crude is expected to sell at a discount relative to low-sulfur (sweet) crude of the same API. The "quality differential" is essentially the difference between the "gross product worth" (GPW) of the Saudi crude and the reference crude. GPW is calculated by multiplying the refined product yield of each barrel under a given refinery process configuration with the price of the resulting refined products in the spot market.

The Official Selling Price (OSP) for any particular Middle East export crude oil is simply the sum of the reference crude price and the announced monthly offset for given regional destinations, as explained above. For Atlantic markets, the reference crudes WTI[7] and B-Wave are traded in highly liquid markets with prices set competitively, both in physical barrel trades as well as in the organized futures markets of New York and London. In contrast, Asia has no well-established formal futures markets for crude oil.

In the absence of an established crude oil futures market, the Dubai Blend crude forward market successfully developed in the 1980s due to a number of conditions it fulfilled: its relatively large production volumes were not dominated by term contracts;

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[7] Saudi Aramco switched over to the Argus Sour Crude Index (ASCI) for its crude oil sales in the US in 2010. The Argus Sour Crude Index (ASCI) represents the daily value of US Gulf coast medium sour crude, based on physical spot market transactions. The ASCI price is the volume-weighted average of all deals done in three grades of sour crude traded in the US Gulf Coast, namely, Mars, Poseidon, and Southern Green Canyon. Saudi Aramco switched over from Platts WTI assessments to ASCI because WTI prices would often get "decoupled" from relative values in global crude oil markets (as measured by the WTI-Brent differential for example) whenever storage facilities at Cushing, Oklahoma become a binding constraint. See, for instance, a blog entitled "Cushing Cushion Oil Pricing Problem Reappears" by Peter Fusaro in the Energy Hedge Fund website in February 2009 where he states… "The long term WTI Cushing Cushion pricing problem has resurfaced. This occurs when US midcontinent crude oil markets detach from international oil markets… Rising crude oil stocks, which are stored in tanks at Cushing, are oversupplied depressing WTI prices in both the physical and paper markets." Accessed at http://energyhedgefunds.com/ehfc/modules/weblog/details.php?blog_id=67.

it was not marketed by a government monopoly but rather by a number of equity producers; and there were no re-sale restrictions. Price quotes for Dubai crude traded in the forward market[8] were based on assessments of deals done and bids and offers by energy pricing agencies such as Argus and Platts. However, as Dubai crude production went into decline in the early 1990s, there was a corresponding fall in liquidity in outright deals that provided absolute price signals. As a result, the Dubai market no longer served as an indicator of absolute prices, and instead became a relative price market where its price was set relative to Brent, and relative to the time structure of Dubai prices. The markets for Brent-Dubai spreads and Dubai inter-month spreads are well established, and Platts' assessed Oman-Dubai prices became the basis for pricing Middle East crude exports on term contracts to Asia.[9]

There has been extensive commentary in industry media regarding the imperfections of the Platts' Oman-Dubai price quotation. The fact remains, however, that the world's largest flow of crude oil – that is, the flow from the Middle East to Asia amounting to some 15 million b/d – is largely priced on the basis of this agency's assessments. The price assessment, based on the Platts "partials assessment methodology" and which allows delivery of Oman and Upper Zakum crude oils in lieu of Dubai, remains the reference quotation for Middle East term contracts.[10]

The Dubai Mercantile Exchange (DME) launched its Oman futures contract in June 2007, and since then has established itself as the key arena for physical Oman crude oil delivery. In the third quarter 2010, the exchange delivered 41.4 million barrels of Oman crude oil, an 82% increase on the same period last year.[11] However, its average daily volumes – which are typically below 3,000 lots (three million barrels) – pale in comparison with the150,000 lots (one hundred and fifty million barrels) normally traded in front month Brent contracts. The viability of Oman futures as an instrument for establishing a reference price for Middle East crude oil exports to Asia is uncertain. To

[8] The forward market refers to deals made for crude oil sales with delivery commitments in the future.
[9] The role of Dubai and Oman as reference crude oils for Saudi crude oil export pricing is discussed below in Section 4.
[10] The "partials" methodology is described in the Platt's website accessed at http://www.platts.com/IM.Platts.Content/MethodologyReferences/MethodologySpecs/crudeoilspecs.pdf
[11] See DME official website news items, accessed at http://www.dubaimerc.com/news/03nov10.aspx

date, the Saudi, Kuwaiti, Iranian and other Middle East OSPs for Asia-destined crude oil sales are based on Platts' assessments, and there is no indication that this will necessarily change anytime soon. No official announcements have been made by the region's national oil companies or their governing Ministries regarding any move towards adopting the Oman futures contract as their pricing basis.[12]

3. Structural Characteristics of the Market

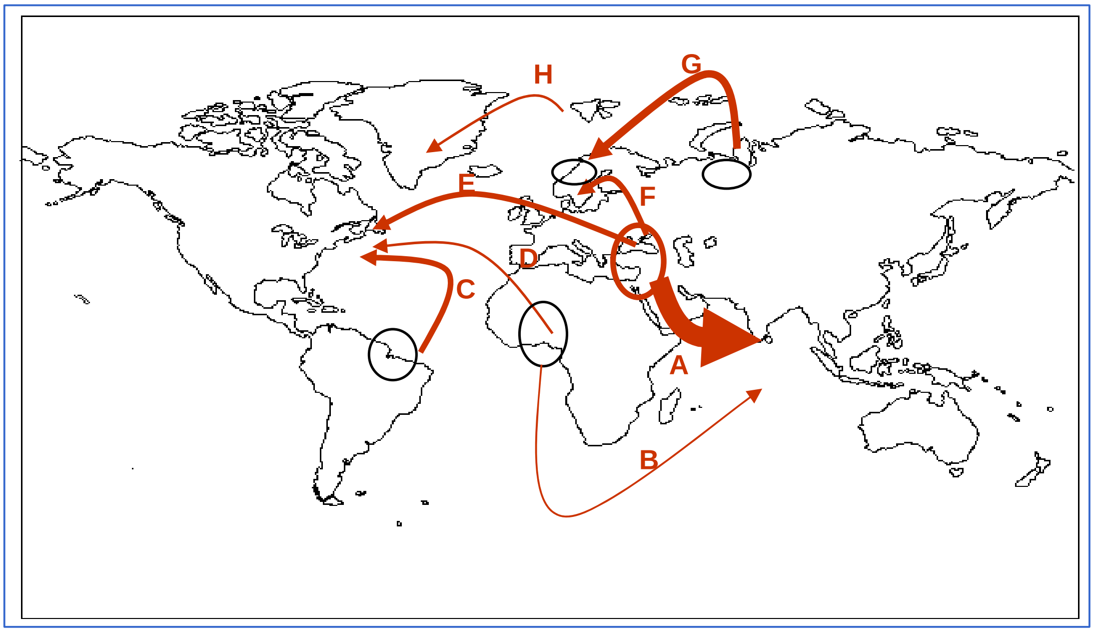
To help identify key patterns of the global oil trade, Figure 1 gives the estimated major inter-regional oil trade movements for 2009.[13] By far the largest single flow of crude oil trade is from the Middle East (Arab Gulf or AG) to the Far East (FE), of around 14.5 million barrels per day (MMBD); this reflects both the large base of demand in Asia (of around 25 MMBD) with limited intra-regional supplies from countries such as Australia, Indonesia, Malaysia, Brunei and Vietnam. The only other significant inter-regional flow of crude into the Far East is crude from West Africa (WAF), approximating some 0.9 MMBD. Part of the West African crude traded into the Far East is base-load, but the total quantum fluctuates depending on the Brent-Dubai differential (since West African crude is priced off Brent). More recent estimates suggest that West African imports into Asia increased by over 60% to some 1.75 million b/d in the first quarter of 2010 (Chiu *et al.*, 2010).

The North American (including the US and Canada) market not only produces significant proportions of its own crude requirements, but also has access to short haul and long haul crudes from Latin and Central America (LA, 3.8 MMBD), Europe (EUR, 0.8 MMBD), West Africa (WAF, 2.3 MMBD) as well as Arabian Gulf (AG, 1.9 MMBD). Europe is a large recipient of Former Soviet Union crude (FSU, 7.5 MMBD), apart from being a significant exporter of crude to other regions, but less so over time given the depletion of crude oil production in the North Sea. West African crude flows into the

[12] For a careful assessment of the DME Oman futures contract and its outlook, see Fattouh, B. "Prospects of the DME Oman crude oil futures contract", Oxford Energy Comment, March 2008.
[13] The figures include some refined product flows as well, but the broad magnitudes for crude flows are reasonably approximated by Figure 1.

Far East and its volumes increase as the arbitrage window allows. Urals and North Sea crudes occasionally flow into the Far East, also when the economics of inter-regional arbitrage allow. The base-load of crude supply for the Far East however remains the Middle East.

Figure 1. Major Crude Oil Flows 2009 (MMBD)



Note: A: AG => FE 14.5, B: WAF => FE 0.9, C: LA => US 3.8, D: WAF => US 2.3, E: AG => US 1.9, F: AG => EUR 2.3, G: FSU => EUR 7.5, H: EUR => US 0.8
Source: BP Statistical Review of World Energy (2010)

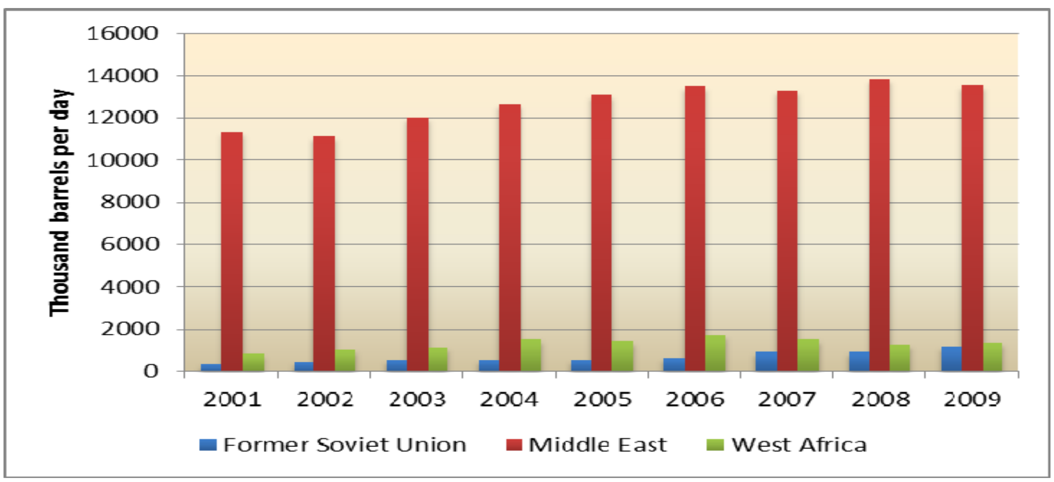
A substantial portion of the incremental non-OPEC supply is located in short-haul Europe/Mediterranean (North Sea/Russia/Caspian) and US Gulf Coast (Latin America/deepwater Gulf of Mexico) regions. However, most of the incremental global demand is located in the Far East. West Africa is a source of swing crude exports, flowing East or West (Atlantic markets) as arbitrage economics dictate.[14] Thus the pattern of global oil demand has a key asymmetric attribute: while the major portion of global incremental demand in the past two decades has come from the Far East, the

[14] West African producers are the closest potential suppliers to the Asia market in the sense that they are in the position to shift sales from other markets to Asia (Jaffe and Soligo, 2000). Essentially, when crude oil prices in the Far East are high enough relative to the European or North American regions, traders will re-direct West African crude oil flows into Asia.

majority of non-OPEC incremental crude supply has been Atlantic market focused as noted by Horsnell (1997).

To the extent that arbitrage makes it viable, North Sea, Russian, but particularly West African crudes flow into the Far East. The claim that lack of competition in Asia's crude oil market results in higher prices in Asia is thus an artifact of the pattern of global crude flows, which in turn is a function of geographic resource endowments, demand sources and transport costs. Thus, it seems apparent that higher crude oil prices in Asia, relative to the US and Europe, is in part reflective of a market that has access to few alternative sources of crude oil. As shown in Figure 2, crude oil supplies into Asia predominantly flow from the Middle East, with West African and FSU crudes constituting supplies at the margin. Roughly 82% of crude oil supplies into Asia originate in the Middle East.

Figure 2. Crude oil supplies into Asia from the Middle East, the Former Soviet Union, and West Africa



Source: BP Statistical Review of World Energy (2002-2010)

The different characteristics of oil markets between Atlantic (US and Europe) and Asia are summarized in the Table 1 below. The willingness to pay by buyers in Asia reflects their concerns with "security of supply". Term contracts constitute a predominant source of crude oil for Asian buyers, and regional crude markets have limited spot cargoes. This allows for far less supply and demand flexibility than can be observed in the Atlantic markets. In contrast, oil refiners in Europe and the US require crude oil supplies from the Middle East to be competitive with available short haul crude supplies in actively traded spot markets. Quite naturally, to remain competitive, Atlantic Basin refiners will be unwilling to pay higher prices for crude supplied under term contracts. In other words, Middle East crude exported to Atlantic markets under term contracts need to have spot market characteristics to remain competitive. Indeed, one may argue that it is not a premium that is charged to Asian customers as much as it is a discount that Middle East exporters need to bear in order to maintain market share in European and North American markets.[15]

Table 1. The structural differences between the Asian and Atlantic (US and European) markets

Atlantic Markets	Asian Markets
Spot crude competes actively with term crudes from the Arabian Gulf.	Far less spot traded crude competing with term contracts.
Buyers highly conscious of short term trading and business risks – risk management critical to refiner's loading program.	Buyers highly conscious of long-term supply security risk – term supply management dominate refiner's loading program.
Key refining regions (USGC, Rotterdam) can access multiplicity of short and long haul crudes in effective competition.	Total region massively net crude short, with heavy dependence on Middle East crude.
Supply and demand flexible and competitive among many alternative grades (demand is more "price elastic").	Less flexible supply and demand responses in crude markets, less alternative grades, fewer short haul sources (demand is less "price elastic").

While the liberalized markets of Europe and North America required refiners to actively manage risk in their crude oil loading schedules, the more regulated oil markets of Asia made supply security a dominant concern of Asian refiners in their purchasing and loading programs. In economic terminology, then, the markets in Atlantic and Pacific Basins differed in the price elasticities of demand, i.e. customers differed in their willingness to pay for crude oil between the two regions.

15 See for instance Horsnell (1997) who argues that growth of non-OPEC short haul crude supplies in the 1990s in Europe and the US were "forcing" discounts on Middle East oil exporters for them to remain competitive (pg 305).

4. Does Saudi Arabia Act as a Price Discriminator?

Among the various reasons given by researchers in the Northeast Asian institutes for the existence of the Asian premium, the following seem to be the most often cited:

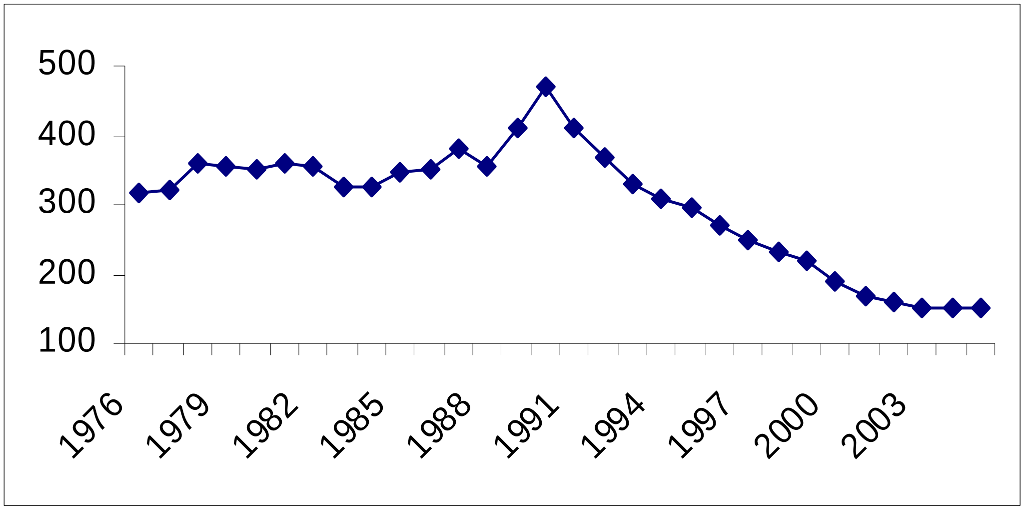
- **"Dubai illiquidity"**
  - "The price formation of Dubai is "in question due to its low liquidity and low transparency" (Ogawa, 2002)
  - "Since shipment of Oman crude is also limited to the Asian market, the problem of relatively higher crude oil prices for the Asian market is also seen when Oman is selected as the marker crude" (Ogawa, 2002)

The progressive reduction in Dubai crude oil exports, from its peak of over 400,000 b/d in early the 1990s, have long been noted (Ogawa, 2002). Figure 3 below shows the fall off in volumes by the mid-2000s, and industry estimates of current production range from 50,000 to 70,000 b/d. Limited and falling volumes of Dubai crude production has led to reports of "manipulation" and the need for an alternative marker since the 1990s (Ogawa, 2003). In response to media reports of "market squeezes", Platts introduced a new price assessment for Dubai crude in 2001 which allowed Oman deliverability in lieu of Dubai at sellers' choice on contract execution. This expanded the pool of cargoes significantly (from about 5 – 6 cargoes a month of Dubai to at least 30 – 35 cargoes of Dubai and Oman together). This made it difficult for any single player in the market to "squeeze" Dubai, i.e. corner the market for Dubai crude oil.

In 2006, Platts further revised its Far East benchmark assessment by allowing alternative deliveries of Upper Zakum into the Oman-Dubai pool, in order to counter the drop in Dubai production which exposed it to pricing plays (where market players take large position in the forward and paper markets which then allows them to control the physical supply of the crude stream) which proliferated in the 1990s and early 2000s. These changes to the Platts price assessment methodology seem to have resolved the problem at least for the present. Few observers now would argue that the "Asian premium" is driven by the paucity of Dubai cargoes.[16]

[16] See, for instance, "Platts copes with Shell buying spree", APS Review Oil Market Trends, October 8th, 2007.

Figure 3. Dubai Crude Oil Production



Source: Industry Sources

- **"Unresponsive adjustment factors"**

– "The largest factor for these premiums lies in the oil-producing countries' failure to have their adjustment factors respond adequately to market factors, when the Brent-Dubai differential narrows rapidly" (Ogawa, 2002)

In assessing the impact of Saudi's monthly offsets, and whether they are "responsive" in any precise use of the term, the first thing to note is the insignificant size of these offsets relative to the price of crude oil. Over the two years January 2007 – December 2009, when the Platts Oman/Dubai average quote was $74.65/bbl, the average value of the Arab Light (AL) offset was $0.70/bbl, or just about 0.93% of the Oman/Dubai price (See Appendix 1). When absolute prices of Oman/Dubai have been in the $20 - $26/bbl as they has been for much of the 1990s and 2000, average AL offsets would have been in a range closer to $0.15 - $0.25/bbl.

As explained in Section 2 on formula pricing, the offset needs to adjust AL (and other Arabian crude oil grades) values for two factors: refining value and freight cost, relative to the reference Oman/Dubai barrel. If freight values are held constant, then the AL offsets are primarily reactive, to changes in refining values of AL relative to Oman/Dubai.

Naturally, the monthly setting of Saudi Aramco OSPs (Official Selling Prices) is a widely watched variable among crude customers' pricing departments as well as the global industry media. Any competent analyst could set up models of refining values and track freight markets to investigate whether there is any systematic tendency for monthly movements of the Saudi offsets to overstate improvements in AL refining value relative to the Oman/Dubai barrel. It is therefore difficult for one to argue that Saudi Aramco marketing and planning departments would intentionally bias their in-house measures of refining values and freight market conditions in order to systematically "over-charge" its Asian customers. To date there is no empirical analysis that establishes this.[17] In Appendix 4, we present econometric test results which show that Saudi monthly offsets do not "cause" inter-regional crude oil price differentials.

While the Saudi monthly offset changes may sometimes have "overshot" in favor of the seller, it would be difficult to maintain that, on the whole, these offset changes support systematic, year-in and year-out overpricing by $1.00 - $2.00/bbl as claimed by the East Asian analysts. According to the empirical analysis conducted by Horsnell (1997), changes in AL offsets were "reactive to observed market conditions, with the results implying that $0.75 out of every $1 monthly change in refinery value differentials are reflected in the adjustment terms".

- **"Lack of competition" and "rigid supply rules"**

– "Due to the high dependence of Asia on Middle East crude oil, … the Middle East countries do not see any reason for price reduction on crude oil being sold to Asia…while they offer a price discount to the US and Europe" Soligo *et al.* (2000)

– "…oil producing countries intentionally widen the East-West price differential under the judgment that Asian oil-consuming countries have no option but to lift crude oil even if that crude oil prices is relatively high" Soligo *et al.* (2000)

– "Middle East crude oil suppliers restrict their sales to long term customers, and prohibit resale to third parties" Soligo *et al.* (2000)

Soligo *et al.* (2000) explain the existence of the premium via a static model of constrained price discrimination. They argue that Saudi Aramco's ability to restrict and

[17] The most careful study of Saudi pricing policy is Horsnell, op. cit. None of the econometric tests in his wide-ranging work support the "intentionality" argument.

monitor the destination of its oil sales and charge a price according to the destination are prerequisites for the existence of the premium. At the margin, the price differential between Asia and the US and European markets is limited by the difference between the freight costs of transporting West African crude oil cargoes to Asia and to the Atlantic markets. The static constrained optimization model presented by Jaffe *et al.* (2000, 2004) shows how region-specific prices can be set by the seller in order to allocate crude oil exports to maximize global revenues, so long as the regions cannot freely trade that commodity with one another. This is a straightforward exposition of the micro-economics model of price discrimination with segmented markets exhibiting different own-price elasticities of demand.[18]

These models however cannot explain why it is that these markets can *remain* segmented without resorting to a depiction of the Saudi role as a unilateralism practiced by a price discriminator. Here, we come to the essence of the argument asserting the existence of the "Asia premium" – which is that an imposition is made by the large oil producers in the Arabian Gulf to segment otherwise globally fungible markets. Jaffe and Soligo's positive analysis of Saudi pricing policy based on a price discrimination model might be read as implying that the Arabian Gulf exporters are not behaving as they "ought" to behave, as *non-discriminating* - read "responsible" – exporters.

The failure of the administered pricing system of the 1980s made it imperative that Gulf OPEC countries switch to selling crude oil to end-users in each of the major consuming regions through term contracts using reference crude oil prices. The switch occurred because the central imperative for Saudi crude oil pricing policy, in the aftermath of the 1985/86 price collapse was, and is, a "market responsiveness with a low profile"[19] in order to avoid being a price leader. Saudi crude exports, and by extension, Gulf OPEC crude exports, had to be price responsive to growing non-OPEC crude oil supplies in the 1980s and 1990s such that there did not emerge a two-tier pricing regime as it did under the Administered Price system.

Saudi crude prices had to be market determined, not market determining, and this could only be achieved by fixing a relationship with regional reference crude oils whose

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[18] See, for instance, Tisdell, C. (1972), "Microeconomics: the theory of economic allocation", Wiley & Sons, Sydney.

[19] We are in debt to Hosnell (1997) who uses this apt and concise phrase to describe Saudi oil policy (p. 295).

prices are discovered in large, liquid markets. As remarked by Ali Naimi, the Saudi Minister of Petroleum and Mineral Resources, "The fact is that within the existing complex market framework, with its wide diversity of players, no one can claim to have a Midas touch. We aim at a reference price, leaving markets to determine actual prices through their own dynamics."[20]

If Saudi policy were to allow re-sale of crudes by its customers, this would immediately lead to further transactions downstream, re-directing crude oil to higher priced markets from lower priced markets so long as inter-regional price differentials were higher than freight costs. This would in turn lead to an absolute price discovery, and once again, such independent price signals would lead to the creation of a global absolute spot price for Arabian crudes. In terms of physical flows, this situation would lead to Saudi Aramco crude exports "sloshing" from one region to another[21] depending on inter-regional price differentials relative to freight costs. For extended periods, Saudi exports would likely be fully concentrated in the closest and highest valued market, the East of Suez. Whilst oil-exporting countries could "globalize" their prices by ending end-user and re-sale restrictions on their crude oil exports, this would entail, in effect, a regression back to a situation approximating the pre-1985 administered pricing system, and discarding the current formula-based market-responsive pricing system.

Saudi Aramco's marketing strategy, as the world's largest crude oil exporter, is based on the objective of maintaining "significant" market share in key consuming regions around the world. The very size of Saudi Aramco's annual crude oil sales program necessitates a global presence. As for any global corporate actor with a significant export stake in the world market for any particular commodity or class of commodities, its legitimate concern would be to seek a share in all large markets, and not allow a total concentration of sales into one region. This makes sense to the extent that different markets do not have perfectly correlated refined oil product markets and business cycles. Given the scale of Saudi Arabia's role as crude oil producer and exporter, it would quite naturally be a strategic imperative for Saudi Aramco to be "a

[20] H. E. Ali Al-Naimi, "OPEC and the Changing World Energy Scene," OPEC Seminar Vienna, September 2001, pg. 5.

[21] Among economists, such extreme "sloshing" would be described as "corner solutions" where market share trade-offs would not be movements along a smooth market share curve but a non-contiguous movement from one end of the curve, crossing one axis, to the other end, crossing the other perpendicular axis.

large and preferred long term supplier of crude oil to the major consuming regions" of North America, Europe and the Far East. To achieve this risk-optimizing marketing strategy, a necessary corollary of Saudi oil policy would be to disable the customer's right to "onward-sell" its allotment of crude oil and thereby create independent selling price signals.[22]

In this context, it is a question not of an "Asian premium" but of European and US "discounts". These discounts were a burden on Arabian Gulf producers – Saudi Arabia in particular – had to bear, given the imperative to maintain market share in Pacific Basin markets in the face of competing non-OPEC short haul crudes. Put this way, it then becomes apparent that it is entirely possible that Saudi marketing strategy in fact *reduced* the potential net present value (NPV) of its hydrocarbon assets by having to discount its crude price into the Pacific Basin, in order to achieve some reduction in risk across a geographical portfolio of markets. This implied maintaining a higher share of Atlantic Basin markets than would otherwise be the case under unconstrained revenue maximization. One could argue that Saudi pricing policy reduced the NPV of its oil assets, in order to prudently reduce its market risk across regional markets. To achieve its role as a supplier of choice for crude oils around the world, Saudi policy endeavored to avoid putting all or most of its barrels in one region; it acted as would be required of any global risk-optimizing enterprise.

5. FOB Price Differentials 2007-2009: Reversal of the Asia Premium?

In a new twist to the "Asia premium" debate, Chiu *et al.* (2010) in the Wall Street Journal asserted that the "rising power of Asian oil consumers is increasingly helping them (to) buy oil more cheaply than their counterparts in the West, a reversal of the

[22] One way of putting this in more intuitive terms is the following thought experiment: a Japan-incorporated Toyota Corporation tells independent wholesale and resale car dealers around the world that they have been appointed to sell Toyota cars in their domestic markets (where such independent dealers are domiciled). Independent car dealers would therefore be forbidden from holding auctions to sell Toyota cars in non-domestic markets. This would be a requirement if the corporation wanted to set the effective price for Toyota car buyers around the world, and not have independent dealers setting absolute price signals for sales on a global basis.

historical pattern."[23] According to the *Petroleum Intelligence Weekly* (PIW), a leading industry journal, Saudi Arabia sold Arab Light (AL) crude to Asia for about $6.40 less per barrel than it charged European buyers in March 2010. The same Wall Street Journal article featured a comment by Tom Wallin, president of PIW, who opined that "an Asian discount is looking more likely to be the new normal." More dramatically, the Global Oil Director of Platts, an industry price assessment agency, stated that "It's a game changer….the balance of power in pricing is drifting to Eastern markets".

In our analysis, we focus on the biggest player in the Middle East, namely Saudi Arabia and its national oil company Saudi Aramco. We estimate the differentials in Arab Light (AL)[24] Official Selling Prices (OSPs) which are loaded on FOB terms at Ras Tanura port and destined for three major regions – United States (US), Western Europe (WE), and the Far East (FE) for the period over January 2007 to December 2009. For Asia, the monthly OSP is generated by adding the announced Asia offset for the month of loading to the reference crude price (the monthly average of Oman and Dubai price reported by Platts) for that same month of loading. For the US market, the buyer is charged the 10-days average of reference crude price (the front month WTI price settled at NYMEX) taken 50 days after the time of loading at Ras Tanura port, adjusted by the announced US offset for that same month of loading. Similar to US, the buyer in Western Europe market is charged the reference crude price (B-wave, a weighted average of Brent futures prices)[25] averaged over 10-days, adjusted by the announced Saudi Aramco offset for AL for European sales. This 10-day average price is taken 40 days after the time of loading at Ras Tanura. The offset will be negative if AL crude is at a discount to the reference crude and will be positive if AL is at a premium.

For all three regions, we used the daily price data for 2007, 2008, and 2009.[26] We

[23] See also an earlier article along the same lines by Demongeot, M., "The Asian oil premium? Almost gone, not coming back", Reuters, April 23, 2009.

[24] Arab Light is the largest stream of Saudi crude oil exports; the others are Arab Heavy, Arab Medium, Arab Extra Light, and Arab Super Light (this last stream exported only to the Far East).

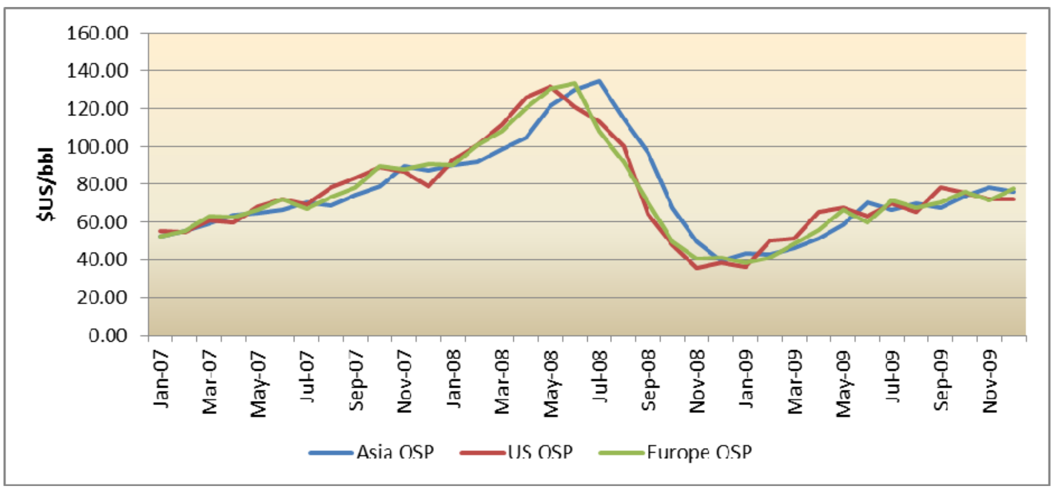
[25] This new 'B-wave' price linkage was first adopted by Saudi Arabia in July 2000, followed by Kuwait and, six months later, by Iran for oil pricing in its term contract sales to Europe. It replaced the traditional dated Brent benchmark after extensive reports of price manipulation and market "squeezes".

[26] In 2010, Saudi Aramco changed the methodology for the US and started using Argus Sour Crude Index (see footnote 24 above). For this reason, we excluded data from 2010 except when it was used to price crude loaded at the end of 2009 (note that Europe and USA-delivered crude oil cargoes arrive 40 and 50 days after date of loading at Ras Tanura respectively).

chose two different dates for the loading or bill of lading[27] (B/L) day. The loading day chosen first was middle of each month (15th). Then we assumed that the oil to be delivered to all three markets was loaded on this very same date, clearly to compare the prices of the same barrels for the three different regions on the same temporal basis. Once we worked out the time series and obtained results, we chose another, arbitrary date (5th day of each month of loading) and calculated another set of prices. This was done to test for sensitivity of our results to the choice of B/L date.

Before we start a discussion of the results, it is worth examining the general trends in the price of oil over the period under consideration. Figure 3 shows the movement of the OSPs.

Figure 3. AL OSPs For by Major Region



Source: Platts, Authors' calculations

Three distinctive trends are immediately noticeable: One uptrend from January 2007 to July 2008 prior to the financial crises, reaching almost $140/bbl on a monthly average basis; secondly, the collapse of the prices, from $140/bbl to below $40/bbl following the financial crises which began in the third quarter of 2008; thirdly, a recovery and uptrend from the end of 2008 and early 2009.

27 It is document issued by a carrier to a shipper, acknowledging that specified goods have been received on board as cargo for conveyance to a named place for delivery to the consignee who is usually identified.

Table 3 below summarizes our results for Asia/Europe differentials for two different assumed B/L dates and compares them with the *Petroleum Intelligence Weekly* (PIW) estimates presented in the Wall Street Journal article.

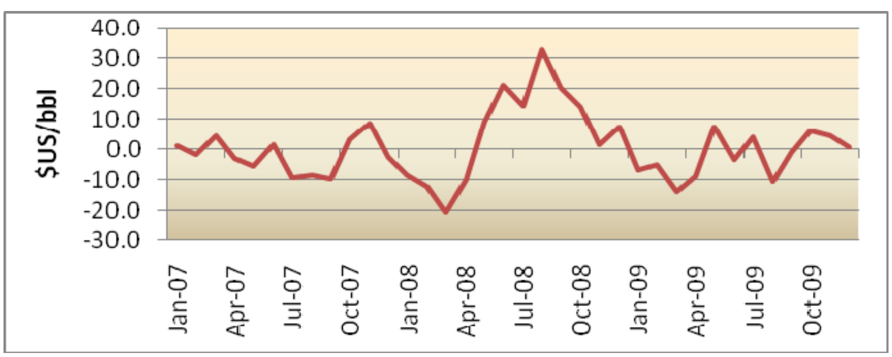
Table 3. Asia-Europe FOB Price Differentials for Arab Light

Year	B/L (5th)	B/L (15th)	PIW
2007	-2.24	-3.57	-2.00
2008	4.59	5.06	7.00
2009	-0.04	-0.91	-0.50

Source: Author's calculations; Chiu *et al.* (2010).

The price differentials between Asia and Europe, as can be seen, are large and highly volatile. In 2007, Asia experienced a large 'discount' relative to Europe ranging from \$2.00/bbl to \$3.57/bbl. Then, in 2008, Asia experienced a very large 'premium' to Europe, ranging from \$4.59/bbl to \$7.00/bbl. In 2009, the premium reverses again, and Arab Light sold to Asian buyers was at a discount to Europe ranging from \$0.04/bbl to \$0.50/bbl. Over the three years studied, Asia paid a small premium of \$0.19 relative to Europe.

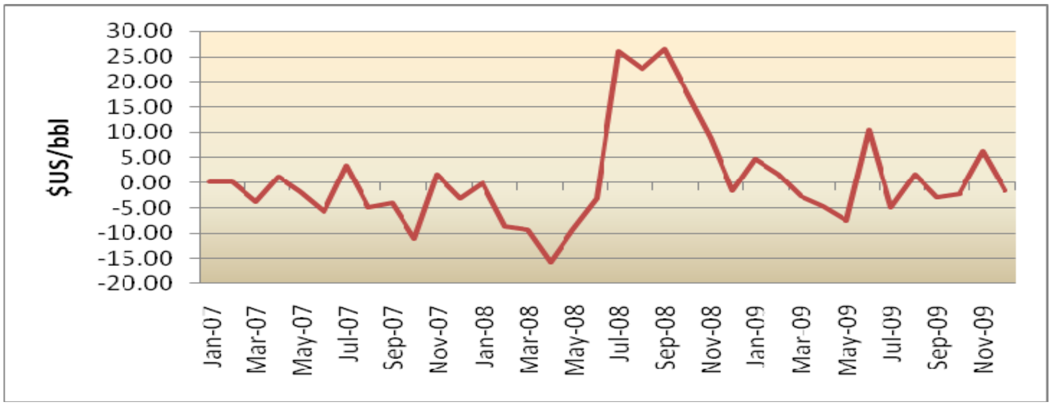
Figure 4. Asia-US AL FOB Price Differential



Source: Platts, Authors' calculations

Figure 4 shows that the OSP differential between Asia and US for Arab Light (AL) ranges from a negative \$20/bbl to over \$30/bbl over 2007-2009. In 2007, we estimate that Asia paid on average \$2.00/bbl less for its FOB purchases of AL crude, while it paid about $4.70/bbl more in 2008 (when the differential spikes starting in March 2008) and $1.90/bbl less in 2009.

Figure 5. Asia-Europe AL FOB Differential



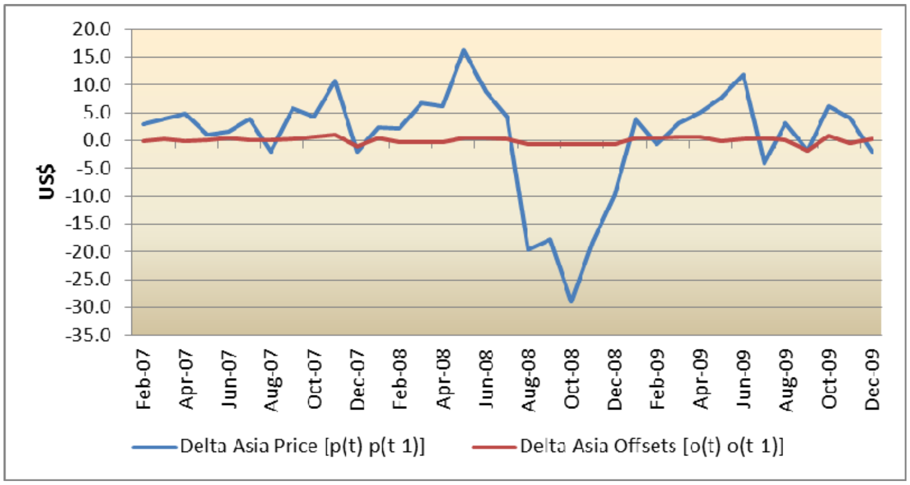
Source: Platts, Authors' calculations

Similarly, Figure 5 shows that the OSP differential for FOB AL between Asia and Europe also ranges from a negative ($15/bbl) to a positive ($25/bbl) number. On average, Asia paid $2.24/bbl less in 2007, $4.60/bbl more in 2008, and $0.04/bbl less in 2009. Therefore, akin to the Asia-US differentials, annual averages for OSP differentials between Asia and Europe are also volatile.

We measured the FOB differentials for AL sold in the three markets utilizing a different arbitrary loading date. The arbitrary loading date chosen for all three markets was the 5th of each month. This advanced the pricing for crude destined to both Europe and the US by 10 days (from 15th to the 5th of the consecutive month). Note that Asian pricing always remains the same with regards to the loading date, since for Asian sales the pricing period is the average of the month of loading irrespective of the actual B/L date in the month.

Figure 6 below shows a plot of the change in the Asia offsets along with a plot of the change in the Asia OSP. During 2007-2009 the change in Asia offsets is insignificant compared to change in the Asia Official Selling Prices (OSPs). We can see that the magnitude of the change in the Asia offsets is very small compared with the magnitude of the change in the Asia OSPs.

Figure 6. Change in the price of the Asia OSPs and the Asia offsets ($/bbl)



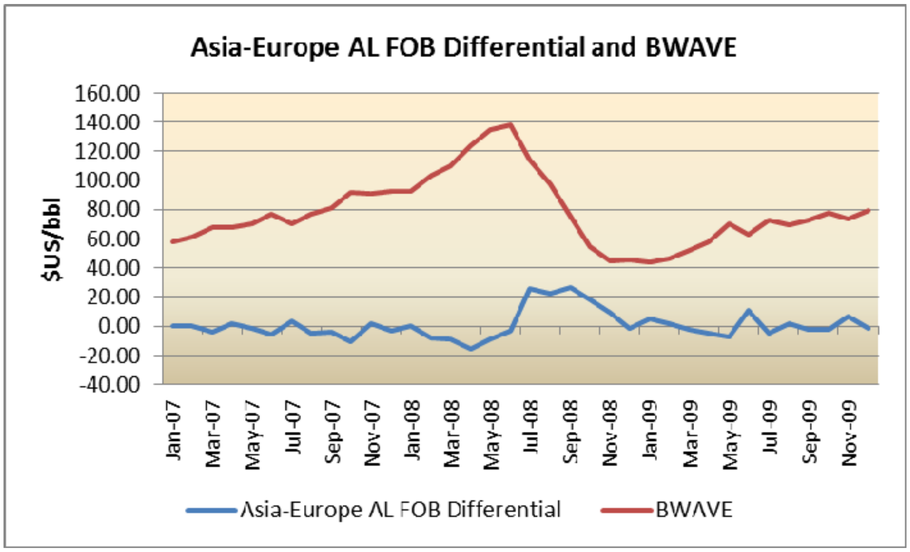
Source: Platts, Authors' calculations

As can be seen in Figure 7, the Asian AL OSPs increase to a discount of between $10 - $20/bbl to European AL OSPs in March – May 2008 as B-wave trends up sharply from $90/bbl to $140/bbl. When B-wave trends upward, pricing on a 10-day average 40 forward will be higher than pricing the Oman/Dubai average monthly price for the month of loading for Asian sales. That is, in a rising market for B-Wave reference crude, one expects crude oil arriving in Europe some 40 days after loading at Ras Tanura to be higher priced than that loaded for the Far East which is priced on the average of the month of loading at Ras Tanura. When B-Wave falls off steeply from the $140/bbl peak to around $40 beginning around June/July 2008, we see the Asian OSP quickly becoming a premium over the European OSP of up to $20/bbl (around July to September 2008). A similar relationship of Asian OSP to US OSP holds, as shown in Figure 8. In short, whether Asian customers were paying a premium or enjoying discounts over the past 3 years, relative to their counterparts in the Pacific Basin, seems to be determined by whether absolute reference crude prices in the US or European markets were on an uptrend or a downtrend.

While Saudi Aramco aspires to be a major and preferred long term supplier of crude oil to each of the major consuming regions of North America, Europe and Far East, nevertheless, Saudi Aramco crude exports to Asia have grown significantly over time as a proportion of total crude exports over 1995 – 2008, from less than 50% to over 60%

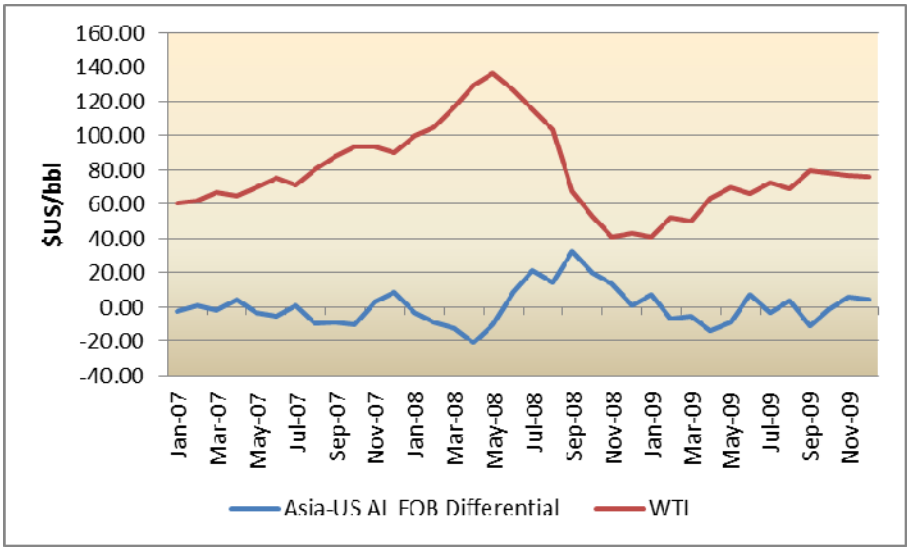
(see Figure 9). This is not unexpected, given that Asia constitutes a natural market for Middle East oil both geographically and logistically.

Figure 7. Asia-Europe AL FOB Differential and BWAVE



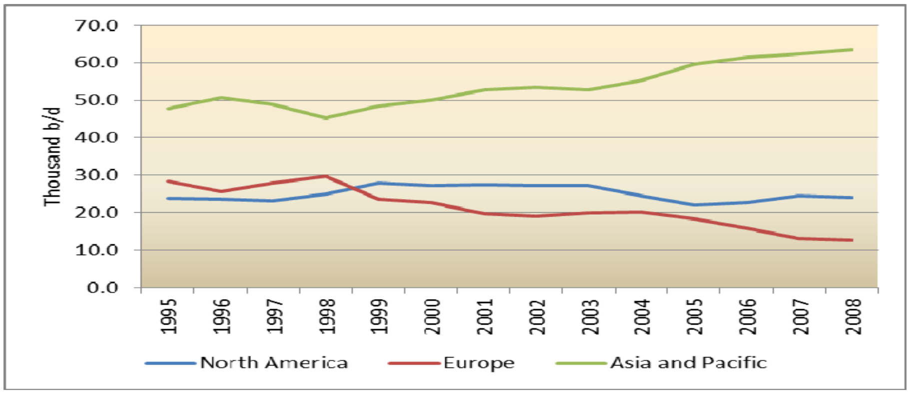
Source: Platts, Authors' calculations

Figure 8. Asia-US AL FOB Differential and WTI



Source: Platts, Authors' calculations

Figure 9. Saudi Arabia's Crude Oil Exports by Destination



Source: UN Comtrade Database

There have been important developments that have expanded the crude oil diet for many Asian customers, introducing newer crude oil grades from non-traditional sources. The Saudi crude oil share of the key China and India markets has reduced from 2009 to 2010, while those of West and Central Africa and Latin America have increased in both countries.[28] Arabian Gulf crudes accounted for nearly 45% of China's crude oil imports in the first 7 months of 2010, compared to the 52% in the year-ago period, while West African and Latin American market shares increased. In India, the crude oil purchasing decisions by Reliance in favor of Latin and African sources reduced the Middle East share of the country's crude oil imports in the first 7 months of 2010, relative to the previous year's comparable period.[29]

Another recent development is the completion of the East Siberia–Pacific Ocean (ESPO) pipeline, the first phase of which was completed in 2009. ESPO crude (32.6 API and about 1% sulfur) is not too dissimilar from Omani crude (33.3 API and 1.06% sulfur). ESPO is almost exclusively sold on tender basis by the main producers: Rosneft, Surgutneftegaz, TNK-BP and Gasprom. The sales are priced with reference to Platts Oman or Dubai average monthly quotations. According to reports, ESPO has quickly gained a foothold at the expense of Middle Eastern grades, buoyed by shorter

[28] See Hua, J. and Tan, F. "Mideast crude battles to recoup lost ground", Thomson Reuters Petroleum Review, November 2010 issue, pg. 6.

[29] See, Verma, N. "India's Mideast crude import slump may reverse", Thomson Reuters Petroleum Review, November 2010 issue, pg. 9.

transit times and lower freight rates to northeast Asia, and reduced restrictions on usage than Middle Eastern crudes.[30]

In the context of the analysis presented in this section, the claim in the Wall Street Journal article that "the rising power of Asian oil consumers is increasingly helping them (to) buy oil more cheaply than their counterparts in the West, a reversal of the historical pattern" (see endnote 36 above) seems rather inapt. Oil prices, i.e. Arabian Gulf OSPs, are not "bargained" between Arabian Gulf producers and Asian buyers, and have precious little to do with "the rising power of Asian consumers" as such. They are set by relatively mechanical formulas which add the reference crude prices to announced monthly regional offsets. To the extent that added supplies of ESPO, African and Latin crude oils put pressure on Arabian Gulf supplies into Asia at the margin, this would indeed support lower crude oil acquisition costs for Asian customers.

6. Policy Implications

In the literature on the so-called Asian premium that has emerged from Asian research institutes, several policy proposals have been put forth as possible measures Asian consuming countries can take to challenge this cost burden.

One proposal is to source oil from regions other than the Middle East, primarily Central Asia and Russia (Calder, 2005). Of course, it is self-evident that if Asian consuming countries could source their crudes from regions outside the Middle East at a cost less that the value of the perceived Asian premium, they (or their agents, the Asian state-owned and private oil companies) would already have done so. As discussed, whenever Brent-related prices were low relative to the Oman-Dubai prices, larger volumes of West African crudes would flow East.

Another policy proposal mentioned was the subsidization of freight costs of crude oil sourced from outside the Middle East. For example, Korea's Ministry of Commerce, Industry and Energy proposed subsidizing non-Middle Eastern crude imports by paying for the difference in freight costs between shipping crude from non-Middle Eastern

[30] See, for instance, Hall, S. "IEA: Russia's ESPO Crude May Become an Asian Benchmark", January 18, 2011, Dow Jones Newswires.

sources and shipping crude from the Middle East. In theory, if the cost of freight subsidies can measurably reduce the risk profile of any particular country, and if that improvement could be quantified in terms of potential benefits to societal welfare, one could make a theoretical justification for such a policy.

But it is difficult to argue that geographical diversification can reduce price volatility. Today's liquid global oil markets make various crude oils highly fungible and refining values rapidly get arbitraged to approximate their shadow price according to location and quality. Other suggestions to reverse this phenomenon have for the most part focused on getting the oil producers to deviate from their marketing strategy by seeking to form a consortium that raises the countervailing bargaining power of Asian consumers in demanding an alteration of the status quo. We have seen in Sections 2, 3, and 4 that this strategy has neither been successful in the past. Given the market structure and heterogeneous interest of the concerned agents, be they oil producers or consumers, continued implementation of this strategy is likely to continue to be unsuccessful. Most observers of crude oil markets would find it difficult to believe that several Asian countries would unite to take some sort of joint stand on price negotiations.

In any case, any such negotiations would only affect the level of *offsets* that Middle East producers actually determine to adjust the reference crudes. That is, the producers determine the offsets that they announce monthly for their official selling prices, they do not determine the price of the reference crude to which the offsets are applied. In Asia, the reference crude is Oman-Dubai (as reported by Platts), and Asian consumers would need to explain what Middle East producers can do about the reference crude prices at any specific time in order to alleviate inter-regional price differentials which burden the Asian consumer more relative to their European and US counterparts.

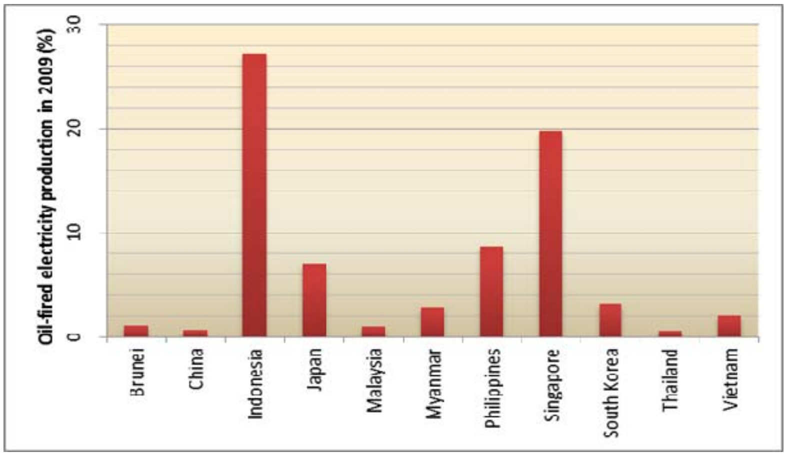
There are significant structural differences between the Asian markets and their Atlantic counterparts. Asia is massively net short of crude oil that creates a strong dependency on the Middle East for supplies. There have been few alternative sources to replace crude oil imports from the Middle East such as West African crudes. One recent new entrant into the Asian crude market is the ESPO crude from Russia, priced mostly off Dubai, and according to some recent reports, has already begun to make Asian markets more competitive. In general, Asian markets are still characterized by risk averse behavior given the tendency to lay a greater emphasis on security of supply where buyers are locked into term contracts which translates into a lower price elasticity of demand in Asia. The spot markets in the East of Suez region, though active and liquid, still constitute a small volume of crudes relative to term contract volumes.

Most importantly, contrary to previous studies that used data prior to 2002, our analysis reveals that for the three years from 2007–2009 there is no secular Asian premium. In fact in 2007 and 2009, Asia received a *discount* in its crude oil bill relative to the Atlantic markets. Given that the price differential between the Asian and Atlantic markets fluctuates between being a discount and a premium, there is an option value in maintaining the status quo. Taking any action to mitigate the so-called premium will be premature and inefficient. Furthermore, our analysis reveals that the prices of the reference crudes drive the discount or premium. As these prices are determined in world markets, energy market integration will do precious little to affect the price differential either way. In effect, there is no obvious link between the so-called Asia premium and energy market integration.

This is not to say that energy market integration will not prove beneficial. Energy market integration provides the impetus for the efficient utilization of resources, deepening of investments, and increasing trade flows between countries. Energy market integration would necessarily entail improving the competitiveness of the energy industry in Asia via liberalization, harmonization of rules, regulations, and standards across countries in the region. All these would enable countries in the region to achieve gains from trade in natural resources and to benefit from market-led investments and trade. It should be noted however that the heterogeneity of income levels and environmental standards across Asia militate against a region-wide conformity in energy services/products.

Countries in the region need to let the markets set the price for energy. Several countries in East Asia subsidize fossil fuel-based energy consumption. Subsidies cause distortions in the price signal resulting in the inefficient consumption of energy. Figure 10 reveals that approximately 26% of Indonesia's electricity is produced by fuel oil, a relatively expensive fuel, given the elevated levels of crude oil prices since the temporary slump in prices during the 2008 financial crises. Subsidies for electricity as well as petroleum products have resulted in inefficient fuel-fired power plants being used in electricity generation, let alone being unsustainable burdens on public finance, at the expense of crucial investments in infrastructure and public goods necessary for the rapidly growing Asian economies.

Figure 10. Oil-fired Electricity Production in 2009 (%)



Source: Enerdata, Global Energy and CO_2 Database

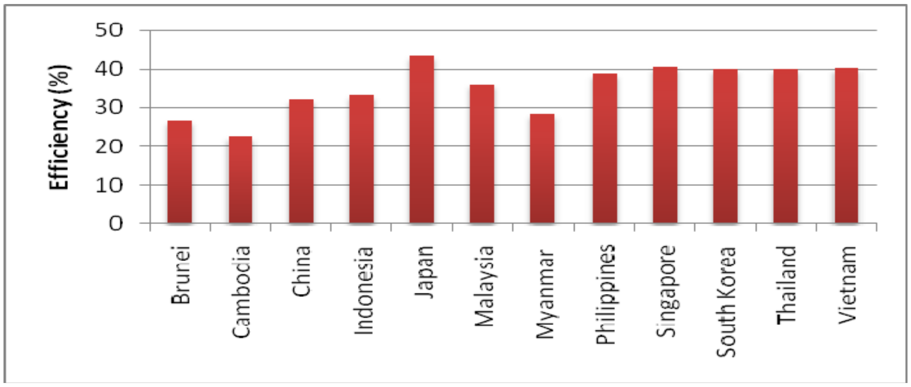
A more competitive energy sector would increase investment in a country's electricity sector and probably shift electricity generation away from fuel oil to natural gas reducing the demand for crude oil.[31] Furthermore, a switch to natural gas-fired power plants from fuel oil-fired plants would raise the efficiency of the electricity sector in the country. Figure 11 indicates that Indonesia's energy efficiency is lower than that of Japan, Malaysia, Indonesia, Thailand, Singapore, etc. Thus, promoting competitive markets and gradually phasing out energy subsidies would be lead to efficient use of energy resources.

Market integration also implies a sharing of information and processes. In the case of electricity generation, there exists an opportunity for countries in the region to build on the expertise of one another. This will happen if energy markets are opened up to competition, allowing more efficient entrants to operate. Figure 12 highlights the differences is the technical characteristics of energy systems in different countries

[31] A competitive levelized cost of electricity and the short time required to build a combined cycle gas turbine (CCGT) power plant have resulted in the rapid deployment of natural gas-fired plants for electricity generation. Cases in point are the UK and Singapore electricity markets after liberalization.

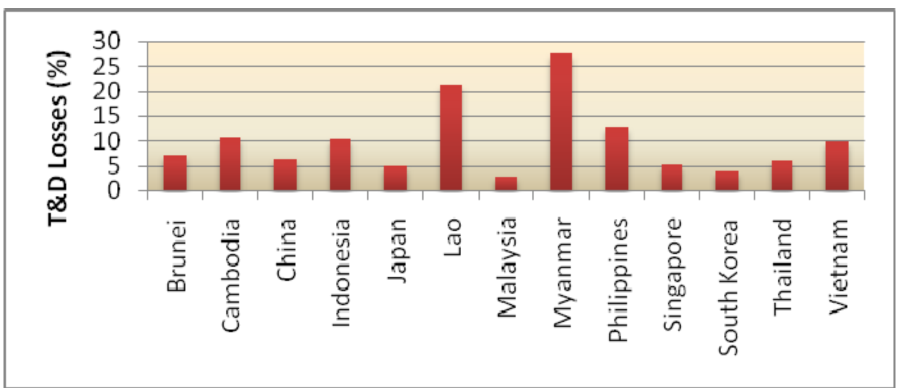
throughout East Asia. Transmission and distribution losses vary considerably amongst the countries with the worst performer being Myanmar with losses of approximately 27%. The best performer is Malaysia with losses of approximately 3%.

Figure 11. Efficiency of Thermal Power Plants in 2009 (%)



Source: Enerdata, Global Energy and CO_2 Database

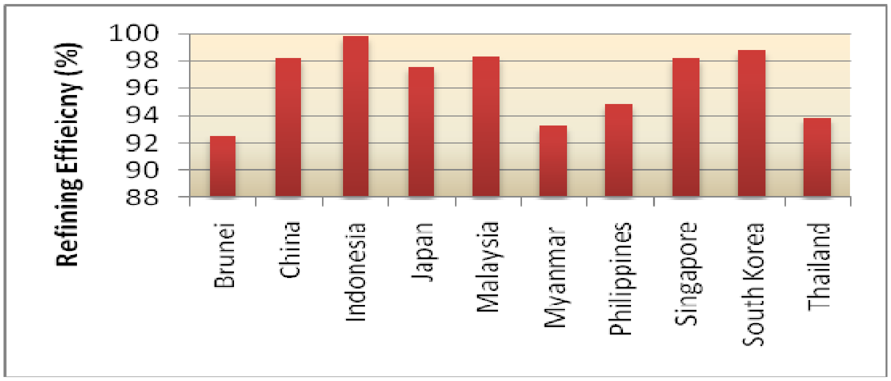
Figure 12. Transmission and Distribution Losses in 2009 (%)



Source: Enerdata, Global Energy and CO_2 Database

The strategy of sharing technical expertise in design and operation of could extend to the crude oil-intensive petrochemical sector. Figure 13 shows us the efficiencies of the refinery sector in 2009. The differences in efficiency are of course reflective of the vintage of capital stock; however, there might be the possibility of a gain from knowledge sharing. National oil companies in the petrochemical sector might improve their efficiency when exposed to competition. Hence market reform is crucial in the petrochemical industry as well.

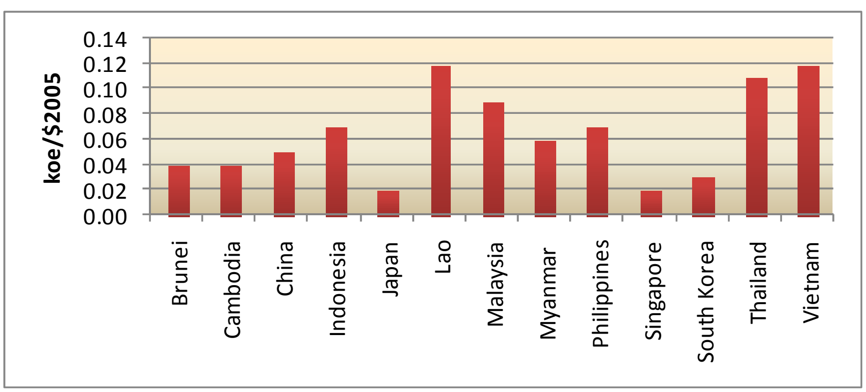
Figure 13. Refining Efficiency in 2009 (%)



Source: Enerdata, Global Energy and CO_2 Database

The substantial differences in energy intensity in the transport sector, as illustrated in Figure 14, point to the scope of energy demand reduction via pragmatic transport policies. This is again an area where the sharing of transportation policy experiences can bring about some positive outcomes in energy consumption reductions as some countries in the region, such as Singapore, have had considerable success in designing operational and efficient transport policies.

Figure 14. Energy Intensity of the Transport Sector in 2009



Source: Enerdata, Global Energy and CO_2 Database

7. Conclusions

Several studies suggest a historical price differential of US$1-1.5 between the Asian and Atlantic markets. However, analysts are divided over the interpretation of this differential. Some view it as a premium that Asia pays for its crude oil supplies from the Middle East. Others interpret it as a discount that the Atlantic markets receive given the imperative of Middle Eastern national oil companies, which have large export programs, to diversify exports by region to mitigate risk.

Since 1986, Saudi prices are set only in relation to reference or marker crude prices, never independently signaling absolute price levels. Saudi Aramco, and by extension, the other Arabian Gulf NOCs who essentially follow its lead, are more appropriately seen as a *price takers* in international markets for crude oil, in that Arabian Gulf crude oil prices are market-determined.[32] This conclusion fits well with what observers know about the overall Saudi exporting strategy.

[32] Note that this is quite different from the argument often made that OPEC as a group sets global crude oil prices by imposing production quotas on its members. This "OPEC as cartel" argument is not the subject of this paper.

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Appendix 1. Asia Offsets as a percentage of the Oman/Dubai Reference Prices

Month	Platts Oman/Dubai ($US/bbl)	Asia Offsets	Offsets as a % of the Oman/Dubai Price
Jan-07	52.25	0.15	**0.29**
Feb-07	55.23	0.05	**0.09**
Mar-07	58.83	0.25	**0.42**
Apr-07	63.70	0.15	**0.24**
May-07	64.69	0.15	**0.23**
Jun-07	65.94	0.55	**0.83**
Jul-07	69.78	0.55	**0.79**
Aug-07	67.83	0.55	**0.81**
Sep-07	73.46	0.75	**1.02**
Oct-07	77.19	1.35	**1.75**
Nov-07	86.97	2.35	**2.70**
Dec-07	86.01	1.35	**1.57**
Jan-08	87.96	1.75	**1.99**
Feb-08	90.35	1.55	**1.72**
Mar-08	97.31	1.25	**1.28**
Apr-08	103.75	1.05	**1.01**
May-08	119.65	1.45	**1.21**
Jun-08	128.07	1.85	**1.44**
Jul-08	132.04	2.05	**1.55**
Aug-08	113.09	1.35	**1.19**
Sep-08	96.02	0.70	**0.73**
Oct-08	67.69	0.00	**0.00**
Nov-08	49.94	-0.65	**-1.30**
Dec-08	40.76	-1.25	**-3.07**
Jan-09	44.29	-0.85	**-1.92**
Feb-09	43.31	-0.45	**-1.04**
Mar-09	45.71	0.25	**0.55**
Apr-09	50.13	0.90	**1.80**
May-09	57.84	0.80	**1.38**
Jun-09	69.44	1.00	**1.44**
Jul-09	64.95	1.40	**2.16**
Aug-09	68.05	1.50	**2.20**
Sep-09	67.90	-0.25	**-0.37**
Oct-09	73.24	0.60	**0.82**
Nov-09	77.80	0.15	**0.19**
Dec-09	75.45	0.50	**0.66**

Source: Platts; authors' calculations

Appendix 2. (B/L is the 15th of the month)

Month	Asia OSP	US OSP	Euro OSP	Asia Premium to the US	Asia Premium to Europe
Jan-07	52.4	54.491	54.596	-$2.10	-$2.20
Feb-07	55.28	56.3	59.153	-$1.03-	-$3.88
Mar-07	59.08	57.337	62.638	$1.74	-$3.56
Apr-07	63.85	60.953	64.592	$2.90	-$0.74
May-07	64.84	70.309	67.092	-$5.47	-$2.26
Jun-07	66.49	70.988	71.896	-$4.50	-$5.41
Jul-07	70.33	72.547	66.725	-$2.22	$3.60
Aug-07	68.38	77.839	75.138	-$9.46	-$6.75
Sep-07	74.21	88.673	83.273	-$14.46	-$9.06
Oct-07	78.54	83.786	90.686	-$5.25	-$12.15
Nov-07	89.32	89.008	89.841	$0.31	-$0.52
Dec-07	87.32	78.926	87.273	$8.40	$0.05
Jan-08	89.71	97.321	95.506	-$7.61	-$5.80
Feb-08	91.9	101.976	98.517	-$10.07	-$6.62
Mar-08	98.56	113.505	112.708	-$14.95	-$14.15
Apr-08	104.8	126.237	126.501	-$21.43	-$21.70
May-08	121.1	136.43	133.251	-$15.33	-$12.15
Jun-08	129.92	114.144	121.498	$15.78	$8.42
Jul-08	134.09	107.327	109.167	$26.76	$24.92
Aug-08	114.44	87.969	94.656	$26.47	$19.79
Sep-08	96.72	61.339	60.294	$35.38	$36.42
Oct-08	67.69	42.738	46.775	$24.95	$20.91
Nov-08	49.29	40.885	36.944	$8.41	$12.35
Dec-08	39.51	39.299	41.158	$0.21	-$1.65
Jan-09	43.44	41.297	36.975	$2.14	$6.46
Feb-09	42.86	50.872	45.837	-$8.02	-$2.98
Mar-09	45.96	57.272	46.601	-$11.32	-$0.65
Apr-09	51.03	72.196	59.164	-$21.17	-$8.13
May-09	58.64	63.841	65.396	-$5.20	-$6.76
Jun-09	70.44	68.126	65.627	$2.31	$4.81
Jul-09	66.35	67.76	70.839	-$1.41	-$4.49
Aug-09	69.55	66.471	66.32	$3.08	$3.23
Sep-09	67.65	78.402	75.268	-$10.75	-$7.62
Oct-09	73.84	72.903	75.999	$0.94	-$2.16
Nov-09	77.95	77.046	74.506	$0.90	$3.44
Dec-09	75.95	70.553	72.022	$5.40	$3.93

Source: Platts; authors' calculations

Appendix 3. (B/L is the 5th of the month)

Date	US OSP	Europe OSP	Asia Premium to the US	Asia Premium to Europe
Jan-07	54.99	52.17	-2.6	0.22
Feb-07	54.37	55.04	0.9	0.23
Mar-07	61	62.86	-1.92	-3.78
Apr-07	59.58	62.5	4.27	1.35
May-07	68.07	66.62	-3.23	-1.78
Jun-07	72.09	72.08	-5.6	-5.6
Jul-07	69.2	66.8	1.12	3.53
Aug-07	78.1	73.28	-9.72	-4.9
Sep-07	82.95	78.19	-8.74	-3.98
Oct-07	88.57	89.53	-10.03	-10.99
Nov-07	86.43	87.59	2.89	1.72
Dec-07	78.93	90.31	8.43	-2.95
Jan-08	92.76	89.79	-3.05	-0.08
Feb-08	100.55	100.44	-8.65	-8.54
Mar-08	111.2	107.7	-12.65	-9.14
Apr-08	125.63	120.37	-20.82	-15.57
May-08	131.62	130.26	-10.52	-9.16
Jun-08	121.03	133.05	8.89	-3.13
Jul-08	112.96	108.02	21.14	26.07
Aug-08	100.09	91.84	14.36	22.6
Sep-08	64.04	70.12	32.68	26.6
Oct-08	47.75	49.64	19.94	18.05
Nov-08	35.57	40.36	13.72	8.93
Dec-08	38.37	41.06	1.14	-1.55
Jan-09	36.15	38.57	7.29	4.87
Feb-09	49.87	41.02	-7.02	1.84
Mar-09	51.17	48.58	-5.21	-2.62
Apr-09	65.01	55.57	-13.98	-4.54
May-09	67.73	66.19	-9.09	-7.54
Jun-09	63.25	59.92	7.19	10.52
Jul-09	69.86	71.18	-3.51	-4.83
Aug-09	65.52	67.69	4.04	1.86
Sep-09	78.37	70.4	-10.72	-2.75
Oct-09	75.1	75.91	-1.25	-2.07
Nov-09	72.16	71.64	5.79	6.31
Dec-09	71.87	77.48	4.08	-1.53

Source: Platts; authors' calculations

Appendix 4. Econometric Tests for Causality

In this appendix we test whether the hypothesis that there exists a causal relationship between the adjustment factors and the price differential, i.e., the adjustment factors are the *cause* and the price differentials are the *effect*. We use a simple test of causality proposed by Sims.[1] The intuition behind the test is as follows: If the adjustment factors cause the price differential, it must mean that future values of the adjustment factor would not have any effect on the current price differential (as the cause should precede the effect). If this is not true, then we would be remiss in making the claim that the adjustment factors cause the price differential.

Accordingly, we ran the following regression:

$$Y_t=\alpha+\beta_{t-1}X_{t-1}+\beta_t X_t+\beta_{t+1}X_{t+1}+u_t$$

For our case, X represents the Saudi monthly adjustment factor for Asia bound crude and Y represents the price differential between Arab Light (AL) free on board (FOB) crude for delivery to Asia and the US or Europe. We then test the null hypothesis that $\beta_{t+1} = 0$. If X is to "Granger cause" Y,[1] then the coefficient of the lead term, β_{t+1}, must be statistically equal to zero. We find that when we regress the price differential on the adjustment factor, the null hypothesis is rejected (see tables A and B below). This means that causality does not run from the adjustment factor to the price differentials for FOB-priced AL crude at Ras Tanura. We also tested the hypothesis that the monthly change in the adjustment factors (from one month to the next) causes the change in the price differential (from one month to the next). We found that there was no causal relationship between them.

Our analysis reveals that for the three years from 2007–2009 there is no secular Asian premium. In fact in 2007 and 2009, Asia received a *discount* in its crude oil bill relative to the Atlantic markets. We find that the existence of the price differential between markets is a function of the reference price levels. Given that the price differential fluctuates between being a discount and a premium, there is an option value in maintaining the status quo. Taking any action to mitigate the so-called premium will be premature and inefficient.

Energy market integration provides the impetus for the efficient utilization of resources, deepening of investments, and increasing trade flows between countries. However, in the context of the so-called Asian oil premium with globally integrated oil markets, there is no necessary link with energy market integration. The crucial question that now needs answering is how efficient is the oil price discovery mechanism, which is currently performed by price assessment agencies such as Platts and Argus. This is our future research direction.

Table A. Regression of the Asia-Europe AL FOB price differential on the adjustment factor for Asia-bound crude

Dependent Variable: Price Differential Europe-Asia
Method: Least Squares

Sample(adjusted): 2 35
Included observations: 34 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.360739	2.068010	1.141551	0.2627
Adjustment Factor(-1)	3.910083	2.780538	1.406233	0.1699
Adjustment Factor	3.593386	3.606695	0.996310	0.3271
Adjustment Factor (1)	-9.447022	2.782326	-3.395368	0.0019
R-squared	0.327688	Mean dependent var		0.852353
Adjusted R-squared	0.260457	S.D. dependent var		10.01486
S.E. of regression	8.612451	Akaike info criterion		7.254426
Sum squared resid	2225.229	Schwarz criterion		7.433998
Log likelihood	-119.3252	F-statistic		4.874044
Durbin-Watson stat	1.094883	Prob(F-statistic)		0.007048

Table B. Regression of the Asia-US AL FOB price differential on the adjustment factor for Asia-bound crude

Dependent Variable: Price Differential US-Asia
Method: Least Squares

Sample(adjusted): 2 35
Included observations: 34 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.776658	2.315243	0.767374	0.4489
Adjustment Factor (-1)	4.507220	3.112955	1.447891	0.1580
Adjustment Factor	4.446161	4.037881	1.101113	0.2796
Adjustment Factor (1)	-10.91271	3.114957	-3.503325	0.0015
R-squared	0.340371	Mean dependent var		0.237647
Adjusted R-squared	0.274409	S.D. dependent var		11.31943
S.E. of regression	9.642080	Akaike info criterion		7.480282
Sum squared resid	2789.091	Schwarz criterion		7.659854
Log likelihood	-123.1648	F-statistic		5.160047
Durbin-Watson stat	1.156157	Prob(F-statistic)		0.005381

CHAPTER 7

Pricing Reform and Enhanced Investment in the Energy Sector: A Way towards East Asian Economic Development

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The combination of energy pricing reform and energy sector investment liberalisation is thus expected to enhance economic development in the region and also to encourage people to use more efficient and cleaner fuels. This study indicates that even if the partial removal of energy subsidies has occurred, further removal can yield further benefits of market efficiency. Energy sector investment liberalisation is another important issue of energy market integration that has been associated with methodological difficulty in quantitative economic analysis. This study developed a new multi-regional computable general equilibrium (CGE) model for conducting a quantitative assessment of electricity sector investment scenario in which the investment demands in the EAS member countries projected by the International Energy Agency are met. The most interesting finding shows that introduction of FDI increases not only the national GDP of the investing countries but also the regional GDP as the whole EAS region by 0.04%.

1. Introduction

The East Asian Summit region including ASEAN and six other major economies of Asia is expected to be the economic growth hot spot over the next few decades. Being the growth engine of economic development, this region needs the attainment of dual objectives of sustainable economic development and achieving emissions reductions targets to combat global warming and climate change. Therefore, it is imperative to have an efficient and integrated energy market in the region. On one hand, efficient market can bring an affordable, reliable and sustainable supply of energy and can also ensure its effective consumption. Integrated markets can additionally ensure the trade competitiveness of the countries in the region, which can protect the economic development of individual country. The EAS region comprises 16 members, who have varied economic, social and environmental conditions. The EAS region comprises five developed, two transitional and nine developing economies with a population of more than 3 billion people. The region needs between 5 and 6 trillion USD of investment in the energy sector by 2030 to meet the tremendous energy demand required to fuel its economic growth.

Taking the note of conclusions and recommendations made in the AAECP Energy Policy and Systems Analysis Projects – ASEAN Energy Market Integration published in August 2005, which provides the starting point of the current study, we have identified the following priority issues which are required to be addressed in this region to develop a harmonized and integrated energy market:

- Removal of energy trade barriers
- Improvement of physical linkages of energy infrastructure across the EAS region
- Liberalisation of investments in the energy sector in the region as a consequence of market integration
- Energy pricing reform
- Liberalisation of domestic energy market and deregulation

However, in this study we have mainly focused on two major issues: energy pricing reform and liberalization of energy sector investments in the domestic markets. This is part of a continued effort to assess the impacts of such changes in the regional economy and environment.

Energy market integration is expected to be followed by energy investment liberalisation in the region. Investment capital is expected to flow from developed to developing countries to explore, develop and trade energy commodities across the region. It is expected that due to eased border restrictions and an improved investment environment, foreign direct investments will increase in the developing economies' energy sector. However, it is also envisaged that China and India being the two major transitional economies in this region might also get involved in supporting energy resources and infrastructure development in other developing countries.

It is also envisaged that in the process of energy market integration, member countries will make some attempts to rationalise their respective energy markets through energy price reform and more specifically by removing energy subsidies. Energy subsidies are downplaying the development prospects of the region by inserting more market distortions and revenue losses to the Governments. High subsidies are also fuelling the excess use of energy which is often imported at high cost. Therefore, energy market harmonization and integration will require a uniform and undistorted pricing system across the region so that energy can be traded freely and without much economic downturn among the participating countries.

2. Research Objectives

East Asian energy market integration is viewed as a step towards overall regional economic development and narrowing the development gap. With varied energy resources, demand and availability, the East Asian region needs a coordinated approach to harness and utilize its huge potential of energy resources to fuel its economic growth. Among various actions required for energy market integration, the removal of energy price distortions and creation of an enabling environment for investment in this sector are the two key tasks for policy makers. Across the region energy commodities are variedly taxed and subsidized which engender huge market distortion and hinder harmonization of the energy market. It is also estimated that the region needs 6 to 10 trillion USD of investment over the next couple of decades in the energy sector to meet the future demand. Such huge investment is also expected to impact the domestic and regional economy.

Given this background, our research objectives are as follows:

- Economy wide impact analysis of reduction and removal of subsidies on energy commodities; and
- Economy wide impact analysis of increasing level of investment in the energy sector.

3. Energy Price Reform

In the context of market maturity, regulation on energy commodity pricing is considered very essential. The more matured the market is, the less regulated and controlled the energy prices are. Based on this basic principle we found that countries' overall economic growth is highly correlated to energy commodity pricing regulation and control. These price controls often happen through restricted price pass-through to the consumers, which are in essence price subsidies. Subsidies are provided with the objective of protecting the poorer sections of consumers being negatively affected by international oil price fluctuation. However, often these subsidies are perverse in nature and distort the market in a bigger way while producing negative incentive for misuse and overuse of cheaper energy sources. It has been further observed that in the East Asia region energy subsidies are deep rooted in their social and political structures starting from the ages of colonization by the Western forces when providing cheaper energy to the local people was a strategy for over extraction of natural resources without much protest. Nevertheless, the presence of energy subsidies is a stumbling block for East Asian economic development via the route of its energy market harmonization. In this study we therefore, would like to investigate the market and environmental impacts of energy price reform in the form of reduction and removal of subsidies for energy commodities, in particular coal, oil, and natural gas, electricity and gas.

3.1. Model

We employed the Regional Environmental Policy Assessment (REPA) model for assessing the potential impacts of energy pricing reform in the EAS region. The REPA model is a multi-regional computable general equilibrium (CGE) model developed based on the GTAP-E model (Burniaux and Truong 2002) for conducting integrated policy impact assessment encompassing environmental, economic and poverty impacts in East Asia (Kojima 2008). The version of the REPA model applied to this subsidy analysis employs 22-region 32-sector aggregation of the GTAP database Version 7 (see Annex-I and II), in which all the 16 EAS members are treated as a single region.[1] The sectoral aggregation maintains the most detailed energy sector (commodity) classification of the GTAP database where six energy sectors are classified.

3.1.1. Recursive Dynamic Setting

The REPA model incorporates dynamics towards 2020 by solving for a series of static equilibria connected by exogenous evolution of macroeconomic drivers. For each time step, the following macroeconomic drivers were exogenously shocked to update the data sets: Population, Capital stock, Skilled and unskilled labour and Economy-wide total factor productivity (TFP).

Except for economy-wide TFP, growth rates of exogenous drivers and GDP were estimated based on the unpublished macroeconomic projections of the Center for Global Trade Analysis at Purdue University. Then, growth rates of economy-wide TFP were obtained by calibration against the projected GDP growth and other macroeconomic drivers. It is worth noting that this methodology does not use an equation of motion of physical capital to update the stock of physical capital. The employed methodology assumes that the evolution of the economy during each time step is represented as the shift of steady-state equilibrium caused by exogenous shocks. This method is consistent with the steady-state equilibrium assumption underpinning static general equilibrium theory. The current study employed single time step for the entire simulation period (2004-2020).

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[1] GTAP Version 7 data set aggregates Brunei Darussalam and Timor-Leste as one region (labelled as other South-east Asia), but we assume that this region represents the economy of Brunei Darussalam as its GDP share based on 2008 World Bank GDP ranking reaches 95.8%.

3.12. CO_2 Emission Module

The current version of REPA model employs a different approach to calculate CO_2 emissions from the GTAP-E model. The REPA model calculates CO_2 emissions based on fossil fuel consumption by each industrial sector as well as final consumers (private households and the government) and deduces fossil fuel uses as feedstock. The GTAP-E model focuses on the supply of fossil fuels to the domestic market. The GTAP-E model deduces crude oil use by the petroleum and petroleum and coal products sector only, but applying this method to the energy volume data included in the GTAP version 7 data sets with coefficients provided by Lee (2008) resulted in a significant overestimation (by 11.8 % as the whole world) compared with the CO_2 emission data for the GTAP version 7 (Lee 2008). Therefore we added other potential feedstock usage of fossil fuels and we finally deduced the following fossil fuel uses as feedstock purposes:

- Coal (coa), crude oil (oil) and petroleum and coal products (p_c) used by the petroleum and petroleum and coal products sector (p_c)
- Natural gas (gas) used by the gas manufacture/distribution sector (gdt)
- Petroleum and coal products (p_c) used by the chemical, rubber, and plastic products sector (crp)

This method resulted in a slight underestimation (by - 0.9% as the whole world), which seems reasonable as some portion of the deduced usage may include combustion usages in reality.

3.2. Database Construction

Identification of actual subsidized energy commodity is a challenge due to very complex pricing mechanism. Starting from well head to retail pump there are several taxes and duties levied on the energy commodity in various stages. Moreover, across the region there are different types of price protections given by the national Governments which affect the final pricing of the commodities in the markets. The majority of them come in the form of reduced taxes and duties on occasions of higher international crude oil price. Energy price pass-through is an overall indicator of such price protectionism based on the price-gap concept, which is used to identify subsidized commodities in the retail market.

Using the price gap analysis followed by the price pass-through test, it has been identified that in the East Asia Summit region there are mainly three types of refined fuels in the markets whose retail market prices are less than the actual market determined prices: Domestic LPG, kerosene and transport diesel. All these fuels' market prices are not fully pass-through in the case of international crude oil price changes during 2004 and 2005. These are the subsidized fuels which are in general prevailing across the region in all the 16 member countries. Other fuel types more or less follow full market price pass-through except certain exception like gasoline in Indonesia and Malaysia.

In the GTAP database and model there are three types of prices: producers' price, market price and consumers' price. From the zero profit condition we obtain the producers' price. From supply and demand equilibrium, otherwise known as market clearing condition, we obtain market-determined prices. Finally from the household welfare maximization we obtain the consumers' price. Though the prices are determined separately and endogenously, they are linked to each other via government intervention as taxes or subsidies. The final prices of fuels in the market comprises both producers' tax/subsidy and consumers' tax/subsidy. If P_H, P_D and P_Y are the consumer price, market price and producers' prices of some domestic fuel, say kerosene, then they are linked as follows in the GTAP model:

$$P_H = P_Y (1+\alpha)(1+\beta)$$

$$P_D = P_Y (1+\alpha) \text{ and}$$

$$P_H = P_D (1+\beta)$$

Where, α is the producer' tax/ subsidy and β is the consumers' tax/subsidy (sign is positive when it is tax).

It has been observed that for the domestic subsidized fuels (kerosene, LPG and diesel) the subsidies are provided at the consumer price end rather than producers' price end.

In the GTAP 7 database, we have petroleum and coal products (p_c) as a combined sector which includes all the major refined petroleum products: gasoline, diesel, aircraft fuel, kerosene, LPG, lubricants, naphtha and other petroleum products like coke and bitumen. GTAP records all these items together as net taxed mainly due to heavy taxation on gasoline, aviation fuel, naphtha and fuel oils. Across the region all these petroleum refined products are taxed domestically at different stages of their production chain. In the context of energy subsidy removal for full-scale price pass-through in the region, it is necessary to differentiate the taxed and subsidized items from the common heading of petroleum and coal products in the GTAP database. Based on the above discussion, we have further created two different sectors after separating the petroleum and coal products combined sector as follows:

- **p_c_tax:** This includes all commercial fuels which are primarily taxed in all the countries in the EAS region. This sector includes gasoline, naphtha, fuel oil, heavy oil, lubricants, petroleum coke and bitumen and other refinery products.
- **p_c_sub**: This includes all domestically used fuels plus fuel that affects household disposable income, i.e. transport diesel. It is assumed that the transport diesel price is highly elastic to the consumer price index and cost-push inflation in the market. So in most countries the transport diesel prices are not fully passed through to the market. Remaining fuels are domestic LPG and kerosene which are often subsidized as a welfare measure of the Government.

Figures 1 and 2 show the major country-wise percentage distribution between commercial and domestic use fuels as per our given definitions above. This indicates that in the region, developing countries have more price supported fuels for domestic users than developed countries and, excluding gasoline, diesel fuel comprises the majority of petroleum refined products. Therefore, continued price support for such a major fuel will have significant economic impacts.

Figure 1. Country-wise Composition of Supply of Petroleum Products

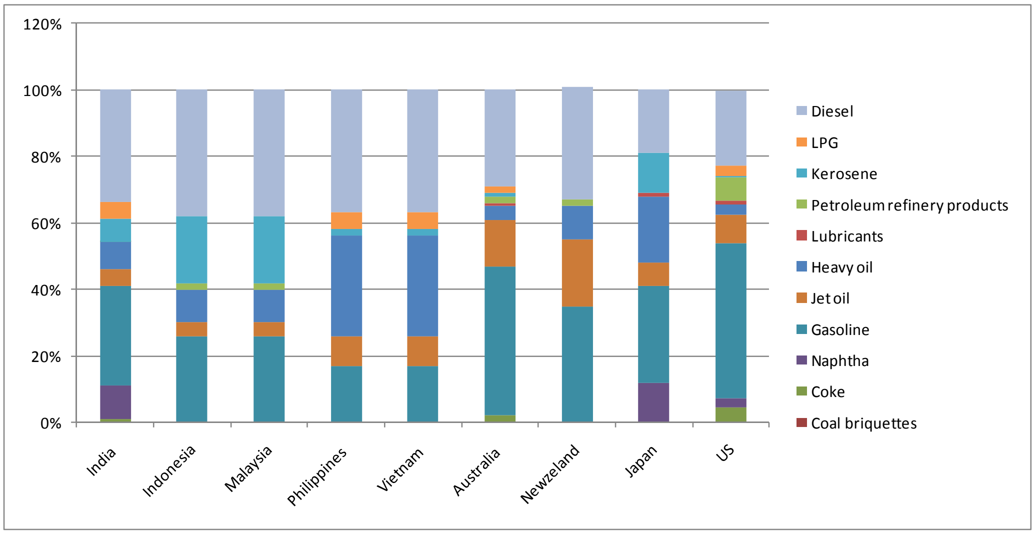
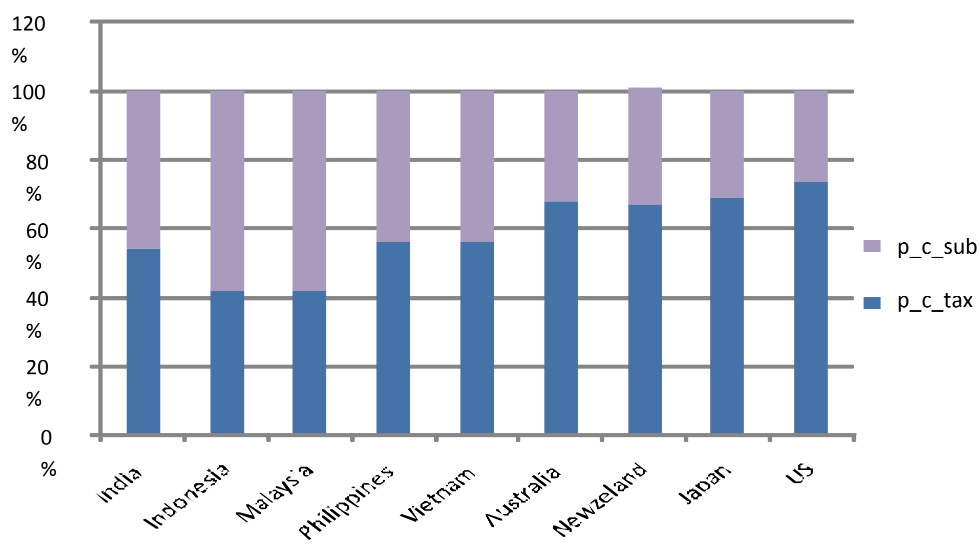


Figure 2. Country-wise Ratio of Taxed and Subsidized Fuels



In the process of conducting GTAP 7 database splitting, we need detailed information on production, consumption, export and import values of commercial and domestic fuels which are at present aggregated under the petroleum and coal products sector. Though data availability is very poor, especially for domestic fuels like kerosene and LPGs in the developing countries, we used the following assumptions to simplify the splitting process.

- For splitting production inputs such as capital, labour and intermediate inputs, we assume that the input shares for the domestic and commercial fuels are the same as those of crude oil intermediate input. Crude oil is the single largest intermediate input for all these fuel commodities.
- We obtained export and import data of domestic and commercial fuels and the ratios used to split the petroleum and coal products sector export and import values from the national statistics.
- We use the same ratio of consumption of domestic and commercial fuels in the market for splitting the value of household purchase of domestic and commercial fuels. These ratios are obtained from the refined fuels consumption data for each country. The same ratios have also been used to split household imports and intermediate purchase and imports.

We have used the Splitcom Software developed by Monash University in Australia to split the GTAP 7 database with our desired sectoral disaggregation of p_c_tax and p_c_sub. The software can use varieties of information on different parameters to split the variable into desired sub categories. In general, the standard splitting occurs under the assumption of equal ratio of 50-50 of all the factor inputs, intermediate purchase, imports and exports and also among household, government and intermediate firms' consumption. However, simple level splitting was not useful for this study as it dealt with the tax and subsidies related to the energy commodities. Splitcom also provides an option to disaggregate the sector using market prices and taxes (altogether the agent's price).

During the process of subsidy data collection it has been identified that the majority of the subsidies are going to the consumers rather than the energy producers. As a matter of fact, the GTAP recorded Producers' Tax (i.e. PTAX) were not subject to our modification. We only focused on consumer level taxes and subsidies (i.e. DPTAX) which are determined in GTAP as the difference between the VDPA (value of domestic purchase at agent's price) and VDPM (Value of domestic purchase at market price). In general if the difference is positive then consumers are paying tax for that commodity to buy and if it is negative then it is subsidy for the consumers. Therefore, in the Splitcom software we used the output, supply and price level splitting for the consumers which are denoted by the row weights in the split matrix. Colum weights represent the splitting weights of the producers of the commodities using different factor inputs and intermediate commodities including labour and capital. As PTAX is not the target of our analysis, we therefore, used the standard ratio of 50-50 split of the base price and taxes of all the inputs for the production. Table 1 shows the final splitting ratios that have been used for the consumption and production side splitting of the petroleum and coal products sector of the GTAP 7 database.

Table 1. Final Splitting Shares Used for Splitcom Splitting User Weights Preparation

	Petroleum and Coal Products Consumption Share		Petroleum and Coal Products Import Share		Petroleum and Coal Products Export Share		Petroleum and Coal Products Output Share	
	p_c_tax	p_c_sub	p_c_tax	p_c_sub	p_c_tax	p_c_sub	p_c_tax	p_c_sub
China	0.46	0.54	0.60	0.40	0.60	0.40	0.54	0.46
Japan	0.70	0.30	0.69	0.31	0.69	0.31	0.69	0.31
Korea	0.70	0.30	0.69	0.31	0.69	0.31	0.69	0.31
Cambodia	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Indonesia	0.11	0.89	0.10	0.90	0.16	0.84	0.16	0.84
Laos	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Myanmar	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Malaysia	0.11	0.89	0.10	0.90	0.16	0.84	0.16	0.84
Philippines	0.56	0.44	0.56	0.44	0.56	0.44	0.56	0.44
Singapore	0.70	0.30	0.74	0.26	0.74	0.26	0.74	0.26
Thailand	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Vietnam	0.56	0.44	0.56	0.44	0.56	0.44	0.56	0.44
Brunei	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
India	0.46	0.54	0.60	0.40	0.60	0.40	0.54	0.46
Australia	0.62	0.38	0.69	0.31	0.41	0.59	0.68	0.32
New Zealand	0.59	0.41	0.67	0.33	0.67	0.33	0.67	0.33
Brazil	0.46	0.54	0.60	0.40	0.60	0.40	0.54	0.46
EU	0.70	0.30	0.74	0.26	0.74	0.26	0.74	0.26
USA	0.70	0.30	0.74	0.26	0.74	0.26	0.74	0.26
Russia	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
MENA and Venezuela	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Rest of the world	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

The major problem that we faced in the database preparation was data inconsistency between the GTAP record and subsidy data recorded from other external sources. GTAP doesn't record subsidies separately in the database. So we had to collect from third party sources which were often very large compared to the total output values. As a result, it was impossible to use the collected information as subsidy amount for p_c_sub commodity as it was creating negative agents' price for the particular energy commodity. In other words, consumers are getting paid for buying the commodity. In reality this situation doesn't exist. We had to make the subsidy data consistent with the GTAP recorded data on VDPA and VDPM for each commodity. To do so, we made some data adjustments using the following assumptions:

- If the country's VDPM of petroleum and coal products sector is higher than the total subsidy amount recorded from the external sources, then we will take the whole amount (100%) as consumer subsidy for the petroleum and coal products sector for that particular country.
- If the VDPM of petroleum and coal products sector is lower that the total subsidy amount recorded from the external sources then for the East Asian developing countries we use the ratios between 30-40% as the consumer level subsidies depending upon the country's energy sector profile, total amount of subsidy paid and historical trends of subsidy etc. As a result, Indonesia and Malaysia falls under the highest level, i.e. 40% of total subsidy goes to the consumers and 30% is for the transitional economies like China and India. However, due to data inconsistencies, our adjustments are envisaged to undermine the total impacts of subsidy in the analysis. It is partial in nature and therefore, the impacts are also indicative and partial. Table 2 shows the adjustments in the total subsidy amount which are used for the analysis.

Table 2. Adjustment of Subsidy Amounts for GTAP Base Data Consistency

Region	Actual Subsidy Amount Recorded (M$)	GTAP Derived VDPM for p_c_sub (M$)	Subsidy Removal for the Simulation (M$)	Adjusted Subsidy as % of Total Recorded Subsidy
China	27,800	8,657.7	8,340	30%
Japan	465	4,366.3	465	100%
Korea	400	1,895.1	400	100%
Cambodia	300	13.8	0	0%
Indonesia	11,400	4,616.5	4,570	40%
Laos	N/A	7.4	0	0%
Myanmar	N/A	87.8	0	0%
Malaysia	3,500	1,803.1	1,400	40%
Philippines	200	275.7	200	100%

Table 2. *(Continued)*

Region	Actual Subsidy Amount Recorded (M$)	GTAP Derived VDPM for p_c_sub (M$)	Subsidy Removal for the Simulation (M$)	Adjusted Subsidy as % of Total Recorded Subsidy
Singapore	0	58.3	0	0%
Thailand	3,100	2,006.0	1,240	40%
Vietnam	1,400	74.0	0	0%
Brunei	2,000	33.9	0	0%
India	18,300	7,199.7	5,759	31%
Australia	8,000	1,230.9	615	8%
New Zealand	N/A	250.3	0	0%
Brazil	1,000	4,209.5	1,000	100%
EU	3,900	14,155.2	3,900	100%
USA	184	24,185.0	184	100%
Russia	38,700	3,726.8	1,863	5%
MENA and Venezuela	9,000	8,740.4	8,653	96%
Rest of the world	270,000	19,356.3	9,678	4%

With this subsidy data we further developed the splitting ratio of the subsidised energy commodity prices for their base value and the tax/subsidy amount. In addition, we used the ratios mentioned in the table 1 under the column heading of consumption, export and import for the output and supply ratio of the taxed and subsidized petroleum commodities. Finally, using all these ratios we created the final weights for splitting the petroleum and coal products sector in the consumer side in the database. For the producer side, where petroleum and coal products is used as production intermediates of other goods and services, we used the output ratios mentioned in the table 1, determined from the national refinery through-put. For intermediate supply we used the 50-50 ratio between domestic and import supply and for the base and tax, we also used a 50-50 share.

After aggregating all these ratios we finally derived the column weights for splitting the petroleum and coal products sector from the producers' point of view. Splitcom finally use the row and column weights all together to split the original GTAP 7 database petroleum and coal products sector into p_c_tax and p_c_sub sectors. Moreover, after splitting the database it is appeared that very few countries are actually net subsidized. In our estimation, Indonesia, Cambodia and Brunei are net subsidized. In the policy simulation we could only reduce subsidies from these countries in the East Asia Summit region.

3.3. Simulation Results

After adjusting the subsidies that can be reduced or removed without creating the negativity of the VDPA (which otherwise makes the energy commodity free of charge), we shocked the model with the 100% subsidy removal policy. This 100% subsidy removal is not the 100% actual amount of subsidy removal that exists in the market. The simulation results are analysed for three main indicators of the economy and environment: GDP as macro economic performance indicator, equivalent variation to measure social welfare and CO_2 as the environmental indicator. Table 3 shows the simulation results.

Table 3. Percentage Change to BAU 2020

Regions	Real GDP	CO_2	EV	Regions	Real GDP	CO_2	EV
China	-0.002	0.05	0.03	Brunei	-0.073	-0.85	-0.80
Japan	0.007	0.19	0.04	India	0.259	0.04	0.08
Korea	0.005	0.19	0.08	Australia	0.007	0.12	0.03
Cambodia	0.000	-0.06	0.01	New Zealand	0.004	0.14	0.05
Indonesia	0.812	-10.84	1.98	Brazil	-0.006	0.12	0.02
Laos	-0.157	0.02	0.01	EU	0.004	0.10	0.03
Myanmar	-0.048	0.09	0.04	USA	0.002	0.08	0.02
Malaysia	-0.017	0.06	-0.05	Russia	-0.039	0.16	-0.12
Philippines	-0.005	0.09	0.05	MENA and Venezuela	-0.034	0.12	-0.17
Singapore	-0.027	0.65	-0.07	Rest of the world	-0.003	0.07	0.00
Thailand	0.002	0.12	0.12	Total	0.010	-0.11	0.03
Vietnam	-0.023	0.03	-0.04	EAS Total	0.046	-0.50	0.14

The simulation results show that the removal of energy subsidies has all the positive impacts on the economy and the environment as desired. Subsidy removal works as a productivity efficiency improvement booster and agent for reduction of market distortions, which resulted in higher economic output. This has been reflected in the regional as well as domestic macroeconomic performance. As we mentioned earlier, due to subsidy data adjustment we only found Indonesia, Brunei and Cambodia as net subsidized countries. Due to subsidy removal they are the highest gainer of macroeconomic benefits and social welfare, including emissions reduction. Indonesia's economic gain is the highest among all other countries in all aspect. As a matter of fact, the whole region benefits even though only a few countries remove their energy subsidies.

3.4. Policy Implications

The major policy implication of this study is demonstration of the benefits of energy price reform on the economy, social welfare and environment as a whole. For example, a 475 Million USD equivalent subsidy removal[2] from the Indonesian domestic energy retail market (mainly the consumers' subsidy) resulted in a 10% decrease in the total amount of demand for domestic subsidised energy commodities i.e. kerosene, LPG and diesel compared to the baseline scenario. Policy makers in general perceive energy subsidies as a tool to provide social welfare to the poorer sections of their nations. Amidst increasingly volatile energy market, especially due to extreme uncertainties in the international prices, the East Asian Summit region seemingly face difficulties in continuing with the huge burden of subsidies. This study shows an indication that even a small removal or reform of the energy pricing could fetch desired results for policy makers. It is demonstrated that the common perception of subsidy removal that it will affect the welfare and national GDP due to inflationary effect of energy price increase, may not be correct for this region. There is ample evidence that energy price reform can bring larger benefits to the countries.

4. Energy Sector Investment

It is envisaged that the energy market integration will create an environment for satisfying anticipated energy sector investment demand by foreign direct investment (FDI) or domestic investment. According to the World Energy Investment Outlook

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[2] Due to data inconsistency between the GTAP 7 database and the externally collected energy subsidy data for Indonesia, it appears in the modified GTAP 7 database that Indonesia is having 457 Million USD net subsidies in the economy on 2004. In this study we simulated the scenario of removal of entire 457 Million USD as a policy measure to reduce energy subsidies in Indonesia. Work needs to be done to remove these discrepancies and match the subsidy amount with the reality. However, rather than precisely, this simulation indicates the impacts of energy subsidy removal on the economy and environment more on direction of changes. This can help policy makers to further think on how to deal with the energy subsidy issues in the market.

2003 (IEA 2003), the electricity sector obtains the majority of energy sector investment, around 60-70% of the total. In this section we first assess the potential impacts of satisfying projected electricity sector investment demand without FDI. Then, we illustrate how FDI inflow would change the results.

4.1. Model

In computable general equilibrium (CGE) models, investment is usually specified as domestic investment such that all the household savings are invested to nationwide capital stock. The sectoral capital input is determined endogenously based on profit maximisation, conditional on factor price and market equilibrium, which determines the equilibrium factor price. It is a rather difficult task to simulate sector specific investment using CGE models due to this endogenous sectoral capital allocation determination mechanism. We found that the standard CGE models such as the GTAP model have practical difficulty in giving exogenous shocks to sectoral factor inputs, and we instead employ a multi-sectoral Ramsey-Cass-Koopmans type growth model to conduct energy sector investment analysis. In this model the household saving rate is endogenously determined based on dynamic utility maximisation of the representative household. Instead of conventional perfect foresight assumption, we employ a simple expectation formation process for households in which households assume that exogenous variables will stay constant at their current levels (Kojima 2007).

Production technology is specified as a Leontief function for intermediate goods and CES (constant elasticity of substitution) function of factors of production. Production factors are capital, skilled labour, unskilled labour, land and natural resources. Capital and labours are mobile across sectors, while other factors are sector specific. Similar to the pricing reform simulation, the growth rates of labour endowment were estimated based on the unpublished macroeconomic projections of the Center for Global Trade Analysis at Purdue University.

Based on the GTAP version 7, we constructed a global social accounting matrix (SAM) with 11-sector and 22-region aggregation. The regional aggregation scheme is the same as pricing reform simulation, while the sectoral aggregation scheme is much simpler than the pricing reform simulation as shown in Table 4.

Table 4. Sector Aggregation Scheme

Code	Sector	Code	Sector
xag	Agriculture, forestry and fishery	p_c	Petroleum and petroleum and coal products
coa	Coal mining	ely	Electricity
oil	Crude oil	gdt	Gas distribution
gas	Natural gas	trp	Transportation
omn	Other mining	xsv	Other services
xmf	Other manufacturing		

Commodity trades are specified through the world market assumption. Given domestic and world prices, producers allocate their products to domestic and world markets according to the CET (constant elasticity of transformation) equation. Imported and domestically produced commodities form a CES composite (the Armington assumption). Note that accommodating endogenous determination of both export and import sides requires the world market clearance in which exported commodities from all sources are mixed and bilateral trade flows are not traceable. If policies affecting bilateral trade flows (such as import tariff reduction) are important, endogenous determination of either export or import must be abandoned and the world price is no more the market clearing price. For example, the GTAP model discards the export side optimisation and the bilateral trade flows are completely determined by import demands.

Another unique feature of our model is the introduction of FDI. In our model, household savings can be invested not only in domestic capital stock but also in the capital stock of other regions. The household receives a return from FDI while the capital goods corresponding to the invested amount are produced in the recipient region.

4.2. Policy Scenarios

First, we simulate the business-as-usual (BAU) scenario against macroeconomic projections of population and non-capital factor endowments. Then, the electricity sector investment scenario (INV) is simulated with exogenously given electricity sector capital input reflecting the projected electricity sector investment. The INV scenario assumes no FDI, while the FDI scenario introduces FDI in addition to the electricity sector investment scenario same as the INV scenario.

Annual electricity sector investment of the EAS member countries is estimated based on IEA's World Energy Outlook 2003 as shown in Table 5.

Table 5. Annual Electricity Sector Investment Demand in EAS

Unit: (Mil. USD/yr)

Regions	Annual Demand	Regions	Annual Demand
China	47,800	Philippines	1,200
Japan	14,442	Singapore	331
Korea	2,097	Thailand	2,296
Cambodia	69	Vietnam	611
Indonesia	3,617	Brunei	79
Laos	35	India	14,500
Myanmar	110	Australia	1,977
Malaysia	1,632	New Zealand	299

Source: Authors' estimation based on IEA (2003)

Then, the exogenously fixed electricity sector capital inputs are determined by the equation of motion of capital stock.

Under the FDI scenario, it is assumed that Japan, Korea, Singapore and Australia provide FDI to ASEAN members (excluding Singapore), China and India. The amount of FDI flown into each recipient country is equal to the 10% of the estimated electricity sector investment, and the FDI inflow is provided by the four countries with equal share (25%).

4.3. Simulation Results

Table 6 shows the impacts of two policy scenarios (INV and FDI) on real GDP. Please note that due to technical reasons the following simulation results were obtained based on 2004-2005 simulation period.

The assessment results show that meeting electricity sector investment demands without FDI can provide mixed economic and environmental impacts. As this simulation gives exogenous shock to electricity sector capital input, it results in negative impacts for the whole EAS region of 0.06%. This is understandable, because the employed model assumes that general equilibrium is already attained in the base year BAU, and the exogenous shock to electricity sector's capital input necessarily causes market distortion. In the real world, insufficient electricity supply due to insufficient accumulation of capital incurs social and economic loss, most notably energy poverty.

For example, a lack of electricity supply makes fresh food storage impossible in Indian rural areas and results in huge economic losses. Modelling such reality remains as a challenge.

Table 6. Impact on Real GDP

(% change from BAU)

Regions	INV	FDI	Regions	INV	FDI
China	-0.13	-0.46	Vietnam	0.00	-0.15
Japan	-0.03	0.10	Brunei	-2.14	-5.56
Korea	-0.06	0.29	India	0.04	-0.09
Cambodia	0.03	-0.08	Australia	-0.14	0.33
Indonesia	-0.16	-0.22	New Zealand	-0.03	-0.04
Laos	-0.01	-0.18	Brazil	0.06	0.05
Myanmar	-2.13	-2.24	EU	-0.01	-0.02
Malaysia	0.10	0.00	USA	0.00	-0.01
Philippines	0.08	-1.29	Russia	0.01	0.03
Singapore	-0.01	2.12	MENA and Venezuela	0.01	0.05
Thailand	-0.09	-0.18			
Rest of the world	0.00	-0.01	EAS Total	-0.06	-0.02

It is interesting that the introduction of FDI mitigates this negative economic impact by 0.04%. The results of FDI scenario show that four FDI investing countries gain from FDI. Table 7 shows the impacts of policy scenarios (INV and FDI) on CO_2 emissions.

Table 7. Impact on CO_2 Emissions

Regions	INV	FDI	Regions	INV	FDI
China	1.04	1.02	Vietnam	-0.03	-0.10
Japan	-0.34	0.70	Brunei	32.19	29.96
Korea	-0.27	-0.19	India	0.76	0.73
Cambodia	2.72	2.45	Australia	-1.02	-0.72
Indonesia	2.08	2.08	New Zealand	-0.18	-0.20
Laos	1.80	1.74	Brazil	-0.04	-0.07
Myanmar	-1.80	-1.78	EU	-0.02	-0.04
Malaysia	0.45	0.44	USA	-0.01	-0.03
Philippines	5.96	9.50	Russia	-0.01	-0.05
Singapore	-0.33	-0.03	MENA and Venezuela	-0.01	-0.06
Thailand	-0.62	-0.60			
Rest of the world	-0.02	-0.04	EAS Total	0.60	0.80

The introduction of FDI further increases the region wide CO_2 emissions. This result reveals the limitation of our analysis in which environmental benefits of energy sector investment such as replacement of inefficient energy technologies by cleaner technology are not reflected. This remains an important challenge for the future study.

Lastly, Table 8 shows the net present values of equivalent variations (EV), that represents social welfare. The net present value (NPV) of EV of electricity sector investment is mixed, and the introduction of FDI is basically favourable for investing countries (except for Australia).

Table 8. Net Present Value of EV

(USD per person)

Regions	INV	FDI	Regions	INV	FDI
China	0.079	0.064	Vietnam	0.001	-0.016
Japan	-0.021	0.137	Brunei	2.044	-0.728
Korea	-0.002	0.031	India	-0.014	-0.070
Cambodia	0.149	0.092	Australia	-0.124	-0.178
Indonesia	-0.002	-0.013	New Zealand	-0.000	-0.000
Laos	-0.005	-0.017	Brazil	0.034	0.034
Myanmar	0.428	0.428	EU	-0.000	-0.001
Malaysia	0.027	0.010	USA	-0.000	-0.000
Philippines	-0.617	-1.450	Russia	-0.002	-0.002
Singapore	0.002	0.114	MENA and Venezuela	-0.000	-0.001
Thailand	-0.162	-0.257	Rest of the world	0.000	-0.000

4.4. Policy Implications

Energy sector investment liberalisation is an important issue for energy market integration, and the development of quantitative assessment tools is an important research area. This section explained our CGE model designed for conducting such a quantitative assessment of electricity sector investment including foreign direct investment. The assessment results do not convincingly demonstrate the potential benefits of energy sector investment, but they provide useful insight to develop more empirically relevant policy assessment tools.

Given the above caveat in mind, the most important policy implication are the economic benefits of FDI compared with domestic investment. Our analysis shows that introduction of FDI increases not only the national GDP of the investing countries but also the regional GDP of the whole EAS region. Energy sector investment liberalisation is needed to boost FDI flows, and our analysis demonstrates its benefit. If some policy can encourage FDI to cleaner energy, both economic and environmental benefits can be achieved.

5. Conclusions and Recommendations

Energy price reform and increasing investment in the energy sector as measures of energy market integration do have significant impacts on both the regional economy and environment. Energy price reform removes market distortions and increases economic efficiency and productivity. In turn, this positively affects overall macroeconomic growth and the environmental through reducing GHG emissions. On the other hand, increasing sectoral capital flow emphasizes investments in cleaner and more efficient technologies, encouraging consumers to shift to cleaner fuels. This is especially beneficial for the developing economies where still majority of the consumers are using low cost, inefficient and dirtier energies.

The East Asia Summit region can consider its energy market to be integrated under the framework of gradual and systematic energy price reform. This will reduce the financial burdens of respective governments and will also help them to reduce the costs of market distortion with improvement in energy efficiency. Regional governments can also develop energy sector investment plans in their respective countries to bolster their economic growth and consumption of more efficient and cleaner fuels.

This study tries to demonstrate such potential benefits of energy pricing reform and an increasing level of energy sector investment in quantitative manner using computable general equilibrium models. The challenges associated with quantitative assessment of energy pricing reform are data issues in which further disaggregation of fossil fuel commodities are required to identify net subsidised commodities. On the other hand, quantitative assessment of energy sector investment requires a departure from the widely used CGE models like the GTAP model which are not well suited in giving exogenous shocks to sector specific factor inputs. Our original CGE model partially overcomes the challenge, and reveals the necessity of further improvements, such as the introduction of economic and social costs of insufficient energy supply, and further distinction between conventional technologies and cleaner technologies.

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CHAPTER 8

Gas Market Integration: Global Trends and Implications for the EAS Region#

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East Asia is already the main destination of the world's commercial liquefied natural gas (LNG). However, the gas markets in the EAS area are either underdeveloped or fragmented. The objectives of this study are twofold, namely, i) to present a review of the trends in global gas market integration and ii) to draw implications and make recommendations for gas market development in the EAS area. To achieve the goal of an integrated gas market in the EAS region, governments in member economies must work together to implement a plan. Specifically, four recommendations are made to the EAS states: adopt a formal program to promote and nurture the development of gas markets in member states and phased sectoral reforms in relatively mature markets; set targets to gradually harmonise regulatory and technical standards in the gas sector; coordinate better to promote their "gas" causes; and boost cross-border connectivity and trading within the area and eventually achieve regional gas market integration.

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1. Introduction

Natural gas as a source of cleaner fuels is important in many economies and will increasingly be so important globally. However, many gas markets in the world are either under-developed or fragmented. As trade in gas led by LNG trade increases, market integration as occurred in other sectors has been promoted in various regions of the world. The objective of this document is to review trends in the world's major gas markets, examine the status of market integration and draw policy implications for gas market integration in the East Asia Summit (EAS) area. The rest of the paper begins with a brief review of global gas markets, in particular gas consumption and trade in the EAS area. This is followed by an examination of gas market integration in the United States (US) and European Union (EU) which are the world's two largest gas consumers. Subsequently gas market development in individual EAS member economies is explored. Finally implications and recommendations for gas market integration in the EAS area are discussed.

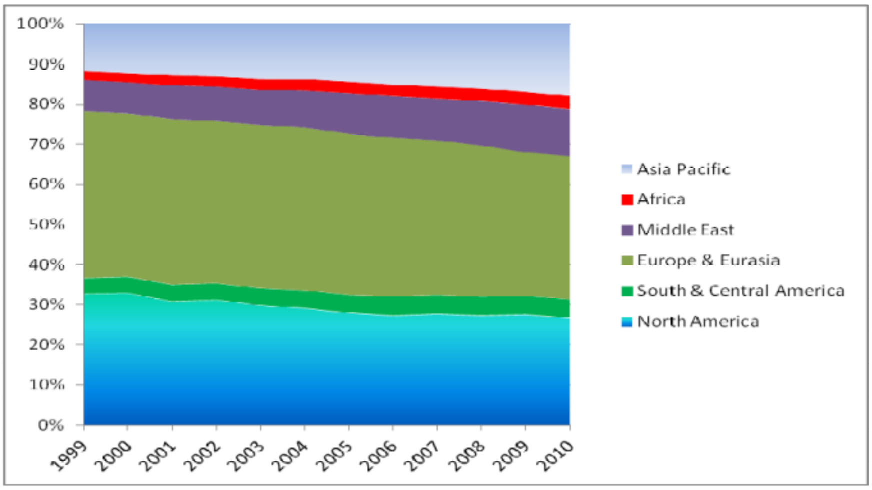
2. Global Gas Markets

The latest statistics show that in 2010 global gas production of 3193 billion cubic metres (bcm) and consumption of 3169 bcm were almost balanced with a small surplus. Europe and North America account for the lion's share of total consumption though the shares of the Asia Pacific and Middle East regions are increasing over time (Figure 1). Among the regions, Europe, North America and the Asia Pacific are the net importing regions. In 2010, about 30.8% (975 bcm) of the total volume of natural gas consumed were traded through either pipelines (21.4%) or LNG trade (9.4%).[1] As gas resource distribution is geographically unbalanced, the top five traders accounted for about a half of the market share. Specifically, the top five exporters (Russia, Norway, Qatar, Canada and Algeria) provided more than a half of the traded gas. The top importers were in

[1] LNG is often measured in terms of millions of tons (MTs). 1 MT of LNG is equivalent to 1.38 bcm of natural gas (EIA, 2003).

turn the US, Japan, Germany, Italy and the UK which also purchased about 50% of the gas traded internationally (Table 1).

Figure 1. World Gas Consumption by Region, 2010



Note: Data are drawn from BP (2011a).

Table 1. Major Gas Traders, 2010

World top importers		World top exporters	
Countries	Volume (bcm)	Countries	Volume (bcm)
US	105.5	Russia	199.9
Japan	93.5	Norway	100.6
Germany	92.8	Qatar	94.9
Italy	75.3	Canada	92.4
UK	53.6	Algeria	55.8
EAS importers		**EAS exporters**	
Countries	Volume (bcm)	Countries	Volume (bcm)
South Korea	44.4	Indonesia	41.2
China	16.4	Malaysia	32.0
India	12.2	Australia	25.4
Thailand	8.8	Brunei	8.8
Singapore	8.4	Myanmar	8.8

Note: Data are drawn from BP (2011a).

As both the US and Germany also exported natural gas, Japan was effectively the world's largest net gas importer in 2010.[2] Apart from Japan, other important gas importers in the EAS area include South Korea, China and India.[3] In 2010, the largest

[2] In 2010 gas exports from the US and Germany were 32 bcm and 15 bcm, respectively (BP, 2011a).

[3] It is noted that Taiwan's gas imports in 2010 amounted to 14.9 bcm and was hence effectively the fourth largest importers in East Asia (BP, 2011a).

gas exporters in the EAS area were Indonesia, Malaysia and Australia (Table 1). In absolute terms, EAS importers and exporters (with the exception of Japan) are not yet compatible with the top players in the world. But this situation may change in the coming decades. China's and India's gas imports will continue to grow and become key buyers in the global markets. Australia has the potential to become one of the world's largest gas exporters.

In the past decade (2001-2010), global demand for natural gas has increased steadily with an average rate of growth of 2.8% per annum (BP, 2011a). The share of natural gas in primary energy consumption was about 24% in 2010.[4] By 2030 world primary energy consumption is projected to increase by 39% with an annual rate of growth of 1.7% (BP, 2011b). More than half (57%) of the projected growth in energy consumption will originate from power generation. The shares of gas and non-fossil fuels are expected to gain at the expense of coal and oil. Among the fossil fuels, natural gas consumption is projected to grow fastest, with an annual rate of 2.1% (Table 2). This growth rate projection is slightly higher than the average annual rate of 1.8% during 2008-2035 forecasted by IEA (2011). Non-OECD economies would contribute 80% of the increase in gas consumption (BP, 2011b). By 2030 natural gas, oil and coal could converge to market shares of approximately 26% each in primary energy consumption, with the remaining 22% being equally divided among the major non-fossil fuels, namely, nuclear, hydro and renewables (BP, 2011b). Similar projections are also reported by IEA (2011) in which the predicted shares of coal, oil and natural gas in primary energy consumption are 22%, 27% and 25%, respectively. The driving forces for the growth in natural gas consumption are the increased use for electricity generation (with a growth rate of 2.6% per annum) and industrial activities (2.0% per annum) (Table 2). Part of this consumption growth would be met by increased LNG supply, which is projected to expand at the rate of 4.4% per annum during 2010-2030. If this growth target is reached, the LNG share in global gas supply would increase from 9% in 2010 to 15% in 2030 (BP, 2011b).

[4] This figure is estimated using information from BP (2011b).

Table 2. Projected Average Growth Rates (%)

Categories	BP 2010-2030	IEA 2008-2035
Primary energy consumption	1.7	1.2
Hydro	2.0	2.1
Renewables	8.2	2.6
Nuclear	2.9	1.9
Coal	1.2	0.4
Oil	0.9	0.4
Gas	2.1	1.8
OECD	1.0	0.9
Non-OECD	3.0	2.6
Non-OECD Asia	4.6	4.9
China	7.6	7.7
India	4.7	6.5
Power	2.6	1.9
Industrial use	2.0	
LNG	4.4	
OECD	5.2	
Non-OECD	8.2	

Note: Data are drawn from BP (2011b) and IEA (2011).

The largest increase in gas consumption would be from the EAS region. Demand is expected to grow at the annual rate of 4.6% during 2010-2030 in Asia excluding Japan (BP, 2011b). Growth in gas consumption would be particularly fast in the two emerging giants, namely China (7.6% per annum) and India (4.7% per annum). Natural gas consumption would amount to 9% of China's primary energy consumption in 2030. In 2010, 4% of Chinese energy consumption was natural gas. Growth would also be strong in ASEAN. This is confirmed by IEEJ (2009) which predicts that ASEAN as a group would enjoy a rate of annual growth of 4.5% during 2010-2020 and 5.5% during 2020-2030.

The growth in demand for LNG is projected to be around 8.2% per annum in Asia excluding Japan. More than 74% of the increased LNG demand would be from China and India (BP, 2011b). Australia is expected to overtake Qatar to become the world's largest LNG exporter around 2020. In the aftermath of the Fukushima nuclear power plant accident in Japan, many countries' policy makers will revisit their nuclear energy programs. This could lead to even more consumption of natural gas in electricity generation in the coming decades.

3. Market Integration Initiatives

For decades, gas markets or pipeline gas markets mainly exist locally or regionally. Trade in gas has been limited due to geographic distance. As the oil price increases and the world's environmental condition deteriorates, natural gas as a cleaner energy becomes more affordable and increasingly a tradable good. Market integration, both sub-regionally and globally, then emerges as a goal to be pursued in many parts of the world. The economic rationale for market integration is well documented in the literature (Williamson, 1996 and Majone, 1996). Specifically, there are several factors which are driving gas market integration in the world. The first factor is the increasing demand for gas consumption due to rising world energy prices and hence increasing affordability to consumers. As a result, numerous local or national gas markets have emerged in the world. In the midst of global economic integration, policy makers in the world economies are keen to promote the link and integration between various gas markets as it has occurred in other economic areas such as the manufacturing sectors and telecommunications. Second, the expansion of LNG trade has made it possible for the emergence of a global gas market where gas can be sold at spot prices or with long term contracts. In 2010, LNG accounted for 30.5% of total gas traded (BP, 2011a). Third, market integration is promoted as a measure to provide the security of gas supply and hence the stability of gas prices.

Various initiatives towards gas market integration have been proposed or implemented so far. In particular the two major gas-consuming regions, namely, the United States (US) and European Union (EU), are leading the world in the promotion of market liberalization and integration. In the United States, gas market regulation began in 1938 when the Natural Gas Act was enacted to guide interstate gas transmission and sales. However, it was in 1978 when the Natural Gas Policy Act was promulgated that gas market liberalization began. The implementation of the Natural Gas Policy Act helped create a single national natural gas market, equalize supply with demand and let market forces establish the wellhead price of natural gas. In 1985, the Federal Energy Regulatory Commission (FERC) issued Order No. 436 which changed how interstate pipelines were regulated and provided pipeline customers more flexibility in purchasing natural gas and making transportation arrangements. The era of open access began (and hence Order No. 436 is also called the Open Access Order). Later, under FERC Order No. 636 (1992), interstate pipeline services were further restructured. Under FERC Order No. 436, pipeline unbundling was voluntary. Order No. 636 made unbundling mandatory. That is, interstate pipelines are required to 'unbundle' their services; essentially separating the sales of natural gas from its transportation.

Due to production deregulation and open access to the interstate gas pipelines, active spot markets for wholesale natural gas throughout the pipeline network emerged rapidly. Through these markets, a large number of gas consumers buy gas directly from a large number of gas sellers on a short-term basis. The spot market share over total gas consumption in the US increased dramatically from 5% in 1983 to 70% in 1987 (Sutherland, 1993). Cuddington and Wang (2006) provide empirical evidence of market integration in the East and Central regions during the 1990s. These authors also argue that limited physical connectivity between the West and other regions made it impossible to create a single national market at that time. To deepen the reforms, the open access order was strengthened by the circulation of two more documents, Order No. 637 and Order No. 639 in 2000. After almost three decades of deregulation, gas market in the US is now the world's largest and most integrated single market. This is confirmed by empirical findings (Siliverstovs *et al.*, 2005 and Mohammadi, 2011).

The history of gas market liberalization and integration within the European Union (EU) is much shorter than that in the US. As part of the EU economic integration drives, gas market liberalization and integration programs were initiated in the late 1990s. The implementation process began with the introduction of the European Gas Directive in 1998, which was further strengthened by the release of the EU Acceleration Directive in 2003 (EC, 1998 and 2003). These initiatives have brought fundamental changes in the natural gas sector across many European countries. As such, the natural gas industries have transformed from vertically integrated monopolies to more competitive structures (Haase, 2008; Harmsen and Jepma, 2011). However, among EU members, the progress of liberalization is very different. For example, gas market liberalization in the UK started much earlier than in other EU members, and has become the best practice model in the EU. In 1986 the British government privatized the then publicly-owned, vertically integrated gas transporter and supplier in the UK, namely British Gas. At the same time the gas sector was deregulated to allow for competition in the wholesale and contract markets for large consumers while retailing and pipelines were still monopolized. Competition was eventually introduced into the retailing sector (residential and small consumers). Further deregulation led to the break-up of British Gas into several separated entities in the 1990s. Though limited, the initial reform was very successful. According to Juris (1998), during 1986-1995 residential and industrial gas prices fell by 24% and 47% in real terms, respectively, and gas consumption increased by 38% in the UK. Through several reviews and subsequent regulatory interventions and adjustments, deregulation in the UK gas sector has created one of the most liberalized markets in the world. There is now genuine competition at all levels of the gas supply chain in the UK although many more amendments to the Gas Code can be anticipated in the future (Heather, 2010). Natural gas has recently overtaken oil to become the largest source of primary energy in the UK with a share of 39.16% in 2009 in comparison with those of oil (37.41%) and coal (14.93%) according to Heather (2010).

However, gas market deregulation was initiated much later in continental Europe than in the UK. Only in the last decade has market liberalization and regional integration been accelerated in some economies.[5] The reform progress in others is slow, but is catching up quickly, for example in Germany, Luxemburg and Sweden. Haase (2008) introduced a scoring method to rank the EU states in terms of gas industry regulatory function and competencies. The former covers issues such as market opening, network access conditions and unbundling. The latter refers to competencies, capacities and degree of autonomy of the regulators. The combined score gives a measure of regulatory comprehensiveness in an economy. According to Haase (2008), the UK was ranked number one in 2005 followed in turn by Demark, Spain, the Netherlands and Italy with France, Sweden, Germany and Luxembourg in turn at the bottom of the ranking list. Since 2005, many countries have moved forward in gas market liberalization. For example, the German Energy Law (Energiewirtschaftsgesetz)

[5] These members include Denmark, Spain, the Netherlands, Italy, Belgium, Austria, Ireland and France (Haase, 2008).

was introduced in 2005 with the aim to speed up gas market reforms in Germany (Growitsch *et al.*, 2009).

The experience of the world's two largest gas consumers, US and EU, shows that gas market integration undergoes a common trajectory, which consists of several steps including the creation of intra-country regional markets, formation of a integrated national market, deregulation and international integration. The implementation of this last step involves the standardization of the gas sector, harmonization of members' regulatory systems and removal of cross-border trade barriers. EAS members can learn from the experience and lessons in the US and EU and develop a plan for gas market integration in coming decades.

4. Gas Markets in the EAS Region

According to the stage of market and regulatory development, we can broadly devide the natural gas markets in the EAS area into three groups: the mature markets, the developing markets and the fledgling markets (Table 3). Relatively more advanced gas markets or the "mature markets" exist in some EAS countries, namely, Australia, Japan, New Zealand and Singapore. A gas market is yet to be created (and hence the term "fledgling markets") in other countries including Brunei, Cambodia, Laos, Myanmar, the Philippines and Vietnam. Those which stand between the "mature" and "fledgling" market categories are classified as the "developing markets" and include China, India, Indonesia, Malaysia, South Korea and Thailand.

4.1. Mature Markets

The "mature markets" refer to economies with relatively well-developed gas infrastructure, a large share of natural gas over total energy consumption and a liberalised or partially deregulated domestic gas sector. Among the sixteen EAS members, Australia, Japan, New Zealand and Singapore fall in this category. These economies set the best practice standards within the EAS area and are also in the process of catching up with international best practice.

Table 3. Gas Consumption in EAS Economies

Market classification	Country	Consumption (billion cubic meters)	Shares of gas over primary energy consumption (%)
Mature markets	Australia	28.73	21
	Japan	94.10	17
	New Zealand	3.82	19
	Singapore	6.85	25
Developing Markets	China	84.39	4
	India	40.07	6
	Indonesia	42.99	25
	Malaysia	44.25	51
	South Korea	35.32	14
	Thailand	36.89	29
Fledgling markets	Brunei	3.41	79
	Cambodia	0.00	0
	Laos	0.00	0
	Myanmar	2.03	13
	Philippines	3.54	8
	Vietnam	7.11	18

Notes: Unless stated otherwise, the statistics are based on 2008 data reported in APEC (2011). The shares are gas consumption over primary energy consumption. Indian data are drawn from Corbeau (2010). Data for Myanmar are 2005 figures reported in IEEJ (2009).

In Australia, natural gas accounts for about 21% of primary energy consumption currently (Table 3). This figure is projected to increase to 33% by 2030 (Syed *et al.*, 2010). About 50% of Australian natural gas is exported in the form of LNG. Due to geographic constraints, the gas market in Australia now comprises of three separate regional markets, namely Western Australia, South-eastern Australia and the Northern Territories. Gas market reform for third party access is still ongoing, though substantial progress has been made since the enactment of the National Third Party Access Code for Natural Gas Pipeline Systems in 1997. The reform involved the breakup of government-owned vertically integrated gas utilities into separate transmission and distribution businesses. Some of them have since been privatized. This process of reform has been strengthened by the decree of the National Gas Law (NGL) in 2008 and its Amendment in 2009. The gas law and its amendment aim to ensure the functioning of a single gas market regulator and to send the right signals for efficient infrastructure investment in the country.

In Japan, natural gas amounts to 17% of primary energy consumption in 2008 (Table 3). Gas supply is almost sourced entirely through imported LNG from Indonesia, Australia, Qatar, UAE, Russia, Malaysia, Brunei and Oman (Takahashi, 2004). For this reason, Japan accounted for 31% of the world's traded LNG in 2010 (BP, 2011a). Traditionally Japanese imported LNG has been over-priced to ensure stable supply (APEC, 2011). To reduce costs and hence prices, regulatory reforms were initiated in 1995 through the enactment of the Gas Utility Industry Law and its Amendments in 1999, 2004 and 2007. The reform measures provide guidance for price-setting, new entries and open access. Now Japanese gas and electric utilities are under tremendous pressure to reduce costs and lower prices even though the reform has not covered all sections of the gas market.

New Zealand has so far been self-sufficient in natural gas supplies. Natural gas has a share of 19% in the country's primary energy consumption (Table 3). Gas sector reform began with the enactment of the Gas Act in 1992, which was subsequently amended in 1993, 1997 and 2000 (Coull and Bamford, 2010). Currently the gas sector is "co-regulated" by the government and the Gas Industry Company (GIC), an industry body established under the Gas Act 1992 (APEC, 2011). The government has never rejected a GIC recommendation on the basis of policy grounds (IEA, 2010b). It is argued that the "co-regulated" system can combine the benefits of industry self-governance with government oversight to ensure delivery of public policy objectives.

In Singapore, the 2001 Gas Act sets the legal basis for the separation of the contestable component of the gas industry (that is, gas retail and gas import) from the monopolistic component (that is, gas transportation). Since 2008, the Gas Network Code (GNC) has specified the GNC's rules which govern the activities of gas transportation, providing open and non-discriminatory access to Singapore's onshore gas pipeline network (APEC, 2011). In 2008, over 80% of Singapore's electricity was generated using natural gas, which was imported from Malaysia and Indonesia through four cross-border pipelines (Wong and Reinbott 2010). Currently, four companies hold gas import licences. There are also two domestic gas pipelines which are not interconnected yet. Singapore is also expected to receive LNG in 2013. For this purpose, new imports of pipeline gas are subjected to the approval by the Energy Market Authority of Singapore, a regulatory body responsible for the gas industry.

4.2. Developing Markets

In 2010 China's domestic production of natural gas amounted to 94.5 BCMs and imports of LNG exceeded 9 MTs.[6] For the first time, China also imported natural gas of 4.4 BCMs from central Asia via the cross-border gas pipelines. Thus the rate of China's dependency on gas imports was about 15% in 2010. China's reform in the late 1990s has sought to separate business from regulatory roles in state-owned enterprises (SOEs). While the major oil and gas companies are partially privatized, the state is still the majority share-holder of those companies.[7] On 30 August 2007, China released its National Gas Utilization Policy, which was intended to ease natural gas supply and demand, and optimise the structure of natural gas utilisation. China is still in the process of constructing a national gas grid. Over the next 10 years (2010-2020), more than 25 000 kilometres of pipeline are expected to be commissioned to form a gas trunk line network 'running through east–west and north–south and connecting overseas' (APEC, 2011). In the currently fragmented markets, gas has been under-priced and hence is heavily subsidized by governments. Reform in the gas sector has been discussed and experimented with at a very slow pace. The latest speculation is that China may raise domestic gas prices in August 2011 (Liang, 2011). Interconnectivity and unbundling are still at the stage of being debated. For example, it is reported that China Gas Association proposed a so-called "X+1+X" model which implies competitive suppliers and distributors with a monopolized grid system. The implementation of the reforms likely still has a long way to go, as a national pipeline network is expected to be completed in 2020.

India's natural gas market is still at the early stage of development. Both the regulatory framework and gas distribution infrastructure are underdeveloped. SOEs such as Oil and Natural Gas Corporations (ONGC), Oil India Ltd (OIL) and Gas Authority of India Ltd (GAIL) dominate the sector in particular the upstream

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[6] The information is drawn from China Petroleum Enterprise Association (2011).

[7] China's whole and retail gas market is dominated by three SOEs, namely, China's National Petroleum Corporation (CNPC), China's National Petroleum and Chemical Corporation (SINOPEC) and China's National Overseas and Offshore Corporation (CNOOC).

businesses. Gas pricing follows a two track-system, namely the administrative price mechanism (APM) and market mechanism (non-APM). Gas produced by the SOEs is charged at the APM price while private companies and joint ventures receive the non-APM price (Corbeau, 2010). The non-APM price can be two or three times as high as the APM price. Until 2006, gas produced by ONGC and OIL and distributed by GAIL has been sold at the APM prices. In 2007, APM gas has a domestic gas market share of 75% (Jain and Sen 2011). The heavy subsidies in the form of price gaps are absorbed by the SOEs and federal government. In 2006 the Petroleum and Natural Gas Regulatory Board (PNGRB) was created and subsequently the PNGRB Act was promulgated. In 2008, with the construction of the 1400 km "East-West" pipeline, the private company Reliance Gas Transportation Infrastructure Limited (RGTIL) entered the pipeline business. Thus the Indian gas sector has moved from pure state ownership to a mixed structure of state and private ownership. In the 2010/2011 financial year, a major pricing reform is to increase APM gas prices to the market level (set by the private company, Reliance Industries Limited). The government subsidizes the end-users directly. These initiatives lay the foundation for further reforms and hence the introduction of competition into the gas market.

Indonesia is a major gas exporter in the EAS region, with 55% of gas produced being exported in 2008. Of the exported gas, Japan has a share of 70%. Gas accounts for 25% of primary energy consumption in the country. The enactment of the Oil and Gas Law (Law No. 21/2001) requires that the state-owned oil company, Pertamina, relinquishes its governmental roles to the new regulatory bodies BP MIGAS and BPH MIGAS, and the termination of Pertamina's monopoly in upstream oil and gas activities (APEC, 2011).[8] Currently, the transport of natural gas in Indonesia is separated from supply, which lays the foundation for further reform of the gas sector.

In Malaysia, natural gas accounts for about 51% of Malaysia's primary energy consumption. The country is the world second largest LNG exporter. The gas sector is in general highly regulated and dominated by the state-owned company, Petronas and gas prices are set by the government. Companies need a Petronas licence to operate in

[8] BP MIGAS (Badan Pelaksanaan Minyak dan Gas) is responsible for granting licences and managing contracts. BPH MIGAS (Badan Pengatur Minyak dan Gas) has regulatory responsibilities for trading, distribution and retailing.

the upstream industry. In terms of deregulation, Malaysia is lagging behind its neighbouring countries Singapore and Indonesia.

South Korean natural gas amounted to 14% of primary energy consumption in 2008. Although reform was envisaged in the 1999 Basic Plan for Restructuring the Gas Industry and the 2001 Implementation Plan, little progress has been made so far. In the aftermath of the Asian financial crisis, Kogas was partially privatized (43%) in 1999. Kogas still monopolizes Korea's natural gas industry including the gas import, storage, transportation and wholesale businesses.

In Thailand, the Petroleum Authority of Thailand (PTT) is the single buyer, transporter and reseller of natural gas, which amounts to 29% primary energy consumption in the country in 2008 (Table 3). One-third of natural gas consumption relies on imports, mainly through pipeline gas from Myanmar (with LNG imports expected in 2011). As for the reform of the gas sector, though a Power Development Plan was launched in 2010, unbundling the PTT is still a long way off.

4.3. Fledgling Markets

Six EAS members fall into the "fledgling markets" category. These members are the relatively less developed ASEAN members. In Laos, biomass is still the main source of energy with other fuels having a small market share and being imported mainly from Thailand. Thus gas market and infrastructure is yet to be developed. The government is still struggling to increase the level of electrification of households, which is currently at about 70%. Cambodia also relies on biomass as the main source of energy. The first significant oil and gas discovery in Cambodia was announced by Chevron in 2005 (World Bank, 2007). However commercial production has not started yet. In Myanmar, although biomass accounts for over 60% of total energy consumption, a small gas market exists and provides about 13% of the country's total fuel demand (Table 3). The country also started exporting pipeline gas to Thailand in 1998. It is now the fifth largest gas exporter in the EAS region. Gas exploration and production is open to foreign companies. The state-owned company, Myanmar Oil and Gas Enterprise (MOGE), however dominates the domestic gas sector.

Brunei Darussalam (Brunei for short) is a net energy exporter. More than 90% of Brunei's LNG was exported to Japan in 2009. Domestically natural gas accounts for about 80% of primary energy consumption. However, the gas market in Brunei is mainly vertically integrated. That is, the government or its agencies are responsible for supply, transmission and distribution. Deregulation has so far not been on the agenda of government policies.

In the Philippines, 40% of the country's energy is imported. Gas has a share of 8% of primary energy consumption in 2008 (Table 3). In general, gas market and infrastructure development in the Philippines is still at the early stage. Currently gas production is enough to meet the country's domestic requirements. In the future the Philippines is expected to import pipeline gas via the proposed Trans-ASEAN Gas Pipeline (TAGT) network.

Gas accounts for 18% of primary energy consumption in Viet Nam (Table 3). The gas industry is dominated by the state-owned company, Viet Nam Oil and Gas Group (PVN), through its arm, The Gas Corporation, which was incorporated in August 2006. The government has an unbundling plan for electricity (2005-2022). But the gas sector is yet on the government's agenda for liberalization.

4.4. Gas Trade between EAS Members

Within the EAS area, members have been actively engaged in natural gas trade either via pipelines or in the form of LNG (Table 4). While some members (Indonesia, Malaysia, Australia, Brunei and Myanmar) are net gas exporters, others (Japan, South Korea, China, India, Thailand and Singapore) are net importers. As shown in Table 4, EAS exporters, mainly export within the region (89% of total exports) while major EAS importers, such as Japan, South Korea and China, also buy from non-EAS countries (45% of total imports). Thus EAS as a group is a net importer. In 2010, net imports of natural gas by EAS members amounted to over 72 BCMs (Table 4). In terms of pipeline gas trade, EAS only accounts for about 4% of the world total while LNG imports by EAS members amount to 55% of the world total in 2010 (BP, 2011a). Thus in terms of gas market integration in the region, LNG market will unavoidably play an important role.

In terms of cross-border connectivity, several sub-markets have been operating with many new pipeline connections being constructed or considered. One of the most important projects is the Trans-ASEAN Gas Pipeline (TAGP) project which was endorsed in the ASEAN Plan of Action on Energy Cooperation (APAEC) 1999-2004 and is expected to link the existing and proposed new gas pipeline networks in ASEAN states by 2020. TAGP is important not only for the connectivity between ASEAN members but also due to its role in integrating gas markets in continental Asia. Currently selected ASEAN states are interconnected through gas pipelines over 2600 km in length (Table 5). To complete the interconnection of ASEAN networks, new pipelines of several thousands of kilometres will have to be constructed (ASEAN, 2010). An additional possible connection is the Philippines-Brunei-Malaysia link.

Table 4. Intra-EAS Gas Trade Movement, 2010

Major Importers	Major Exporters						EAS Imports	World Imports	EAS Shares Over world
	Australia	Brunei	China	Indonesia	Malaysia	Myanmar			
Australia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0%
China	5.2	0.0	0.0	2.5	1.7	0.0	9.3	16.4	57%
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2	0%
Japan	17.7	7.8	0.0	17.0	18.6	0.0	61.0	93.5	65%
Malaysia	0.0	0.0	0.0	2.9	0.0	0.0	2.9	2.9	100%
Singapore	0.0	0.0	0.0	7.0	1.5	0.0	8.4	8.4	100%
South Korea	1.3	1.1	0.0	7.4	6.4	0.0	16.2	44.4	36%
Thailand	0.0	0.0	0.0	0.0	0.0	8.8	8.8	8.8	100%
EAS Exports	24.2	8.8	0.0	36.8	28.1	8.8	106.7	192.4	55%
World Exports	25.4	8.8	3.8	41.2	32.0	8.8	120.1	975.2	12%
EAS/World	95%	100%	0%	89%	88%	100%	89%	20%	

Note: Raw data were drawn from BP (2011a). Unless stated otherwise, the unit is billion cubic meters.

Table 5. Cross-border Gas Pipelines in East Asia

Pipeline Names	Length (km)	Completion Year
Malaysia-Singapore via Johore Straits	5	1991
Yadana, Myanmar-Ratchaburi, Thailand	470	1999
Yetagun, Myanmar-Ratchaburi, Thailand	340	2000
West Natuna, Indonesia-Singapore	660	2001
West Natuna, Indonesia-Duyong, Malaysia	100	2001
South Sumatra, Indonesia-Singapore	470	2003
Malaysia-Thailand JDA	270	2005
Malaysia-Singapore	4	2006
Malaysia-Vietnam via PM3-Ca Mau pipeline	325	2007

China-Myanmar	870	2013

Source: Author's own compilation using information from ASEAN (2010).

5. Policy Implications

The review in the preceding section demonstrates the existence of highly heterogeneous gas markets and regulatory regimes in the EAS region. In some member economies, a gas market is yet to be developed. Overall natural gas as a source of primary energy consumption still plays a relatively small role in the EAS area, particularly in large EAS members such as China and India (Table 3). There is no doubt that gas consumption will increase in many EAS member states in the near future. A critical question is whether supply can meet demand in the long run and hence, whether it is wise to invest in infrastructure. While the EAS group is a net importer of natural gas, the global gas resource base is vast. According to the International Energy Agency (IEA, 2011), recoverable conventional gas resource is equivalent to more than 120 years of current consumption level in the world while total gas resources could sustain today's production for over 250 years. Among EAS members, China and India have the potential to become important suppliers of unconventional gas in the future. Given the abundance of global gas supply, gas markets in the EAS area are expected to expand in the coming decades. Thus, development in natural gas infrastructure and regulations in the EAS region have long-term implications.

As the gas market expands, regional market integration will become important. To achieve the goal of an integrated gas market in the EAS region, governments in member economies must work together to implement a plan which will lead to the harmonisation of regulatory standards and hence integration of gas markets while different national characteristics are also taken into account. These characteristics include national gas market size, existing networks, import infrastructure and market structure. Specifically, the work plan should aim to achieve several objectives, namely, to 1) promote the development of gas markets in individual EAS member economies, 2) harmonize regulatory standards in natural gas sectors within the region, 3) strengthen the coordination between multiple institutions and eventually, 4) achieve the goal of cross-border integration within the EAS area. Each of the four objectives is in turn detailed as follows though this is not necessarily the order of implementation of these tasks in practice.

5.1. Development of Gas Markets in EAS Member Economies

As shown in the preceding section, natural gas markets across individual EAS member economies are very diverse in terms of their level of development. To achieve the goal of gas market integration within the EAS region, gas market development in member economies should be promoted first. While recognizing differences in the stage of economic development, members should be encouraged to develop internal gas markets following the best practice within the region and hence the process of catch-up can be shortened significantly. Issues involved include:

- The optimum gas market structure with regard to individual members' economic and environmental conditions;
- Specific policies in infrastructure development such as the construction of pipelines;
- Country-specific pricing policies;
- Internal market integration;
- Introduction of competition through deregulation; and
- Timetable for gas sector reforms.

5.2. Harmonization of Regulatory Standards

To prepare for regional market integration, the gas regulatory and technical standards within the EAS area should be harmonized through multilateral agreements. The harmonized standards will define best practice in the gas sector within the EAS area. Emerging and new markets can adopt those standards at an earlier stage so that the process of catch-up with best practice later can be significantly shortened. Specifically, the gas industry regulatory and technical standards cover

- Metering and quality standards;
- Legal and tax issues;
- Trading systems;
- Standard contract forms;
- Pricing mechanism; and
- Other general regulatory issues.

5.3. Coordination between Multiple Institutions

Within the EAS area, multiple institutions exist and share the same objective of promoting gas or energy market integration. Examples include the APEC Energy Working Group formed in 1990, ASEAN Plan of Action for Energy Cooperation established in 1997, EAS's Energy Cooperation Task Force (ECTF) initiated in 2007 and ASEAN plus three (APT) Natural Gas Forum, started in July 2010. The ASEAN Plan of Action for Energy Cooperation, overseen by the ASEAN Centre for Energy (ACE), has made some progress in constructing the ASEAN Power Grid (APG) and Trans-ASEAN Gas Pipeline (TAGP) (Table 5). In 2010, the Ministers of APT countries commended a regional dialogue on natural gas, namely APT Natural Gas Forum, acknowledging the Forum's contribution in facilitating a robust information exchange and closer cooperation in the areas of gas trade, market development, research and development, and technical cooperation across the region. The Ministers supported the initiatives proposed by the APT Natural Gas Forum 2010 (i) to develop a compendium of natural gas policies, development, projects and plans of the APT countries, and (ii) to initiate preparatory activities for conducting a study on natural gas market in the APT region. They further noted that APT countries will continue to chart the appropriate direction for the natural gas industry in the region.

The Energy Cooperation Task Force (ECTF) was set up by the EAS group in 2007. Energy market integration (EMI) in the EAS area is one of the three program streams undertaken by ECTF (Shi and Kimura, 2010). A series of workshops have been conducted under this scheme (Bannister *et al.*, 2008, ERIA 2010 and 2011). There are considerable overlaps in the missions of these institutions. Coordination between these institutions could lead to more efficient use of public resources and a unified voice for the promotion of gas market integration in the region.

5.4. Cross-border Integration within the EAS Area

The eventual goal of the coordinated efforts in the EAS gas sectors is to achieve market integration. This can be realized through several steps. The first step will be the interconnection of gas pipelines in subregions within the EAS area. These sub-regional markets include ASEAN, China-Myanmar, India-Myanmar and The Greater Mekong Sub-region (GMS involving two Chinese provinces, Thailand, Viet Nam, the Laos, Cambodia and Myanmar). In addition, there are also current or potential connections with non-EAS pipeline networks such as the China-Turkmenistan, China-Russia and India-Iran pipelines. These connections will essentially become part of an integrated EAS market. The next step is to integrate sub-regional markets. Interconnection may be possible for land-bound economies such as ASEAN, China, India and Korea.

In addition, the LNG market is an integral part of the gas market in the EAS area and can play a key role in the integration of gas markets. In 2010, LNG imports by and exports from EAS members accounted for about 60% and 32% of the world's total trade, respectively (BP, 2011a).[9] With more LNG terminals being constructed in China, India and Thailand, demand for LNG in the EAS area is set to increase significantly. This trend will not only supplement cross-border trade in pipeline gas, but also has implications for gas pricing in the region. Traditionally the price of natural gas is tied with the price of oil. This is still the case in Asia, however, the gas pricing mechanism has changed in other parts of the world. In the US, due to gas to gas competition, the gas price is determined by the domestic gas market price, and imported gas is also linked to the domestic gas price (Fukushima, 2009). A similar market-oriented pricing mechanism is also emerging in Europe. With expanded capacities in terms of both pipelines and LNG terminals, a gas to gas competing market may appear in the EAS area.

6. Conclusions and Recommendations

This study briefly reviewed the status and trend of global gas market integration. Global awareness of climate change, rising affordability and improved technology have made natural gas, both conventional and unconventional, the preferred fossil fuel in the coming decades. While the US and EU are leading the world in gas consumption, trade and market liberalization, the rest of the world, in particular the EAS area, is catching

[9] The import share of 60% in 2010 includes LNG imports of 14.9 bcm by Taiwan, officially a non-EAS member.

up rapidly. Among the sixteen EAS members, there is considerable heterogeneity in terms of gas usage, trade participation and sectoral reforms. With abundant supplies both in the region and globally, natural gas consumption is to grow rapidly in the EAS area. Thus gas market integration becomes attractive and indispensable in the coming decades. To make this possible, it is recommended that the EAS states should adopt a formal program to promote and eventually achieve gas market integration within the region. Specifically, four recommendations are made:

- *Recommendation One*: Through multilateral agreements, EAS states should adopt a formal program to promote and nurture the development of gas markets in member states and phased sectoral reforms in relatively mature markets. ERIA's EMI workshop series is the first step to achieve this goal.
- *Recommendation Two*: Through multilateral agreements, EAS states should set targets to gradually harmonise regulatory and technical standards in the gas sector. A set of mutually agreed and harmonised standards, or the EAS Best Practice (EBP) standards, can be implemented initially in the relatively more developed markets and then extended to other markets over time.
- *Recommendation Three*: Several institutions in the EAS areas should coordinate better to promote their "gas" causes. For example, the "gas" sections of these institutions could be merged to form an EAS Gas Agency (EGA) so that a unified voice could be heard in the EAS region.
- *Recommendation Four*: EAS states should develop a formal program to boost cross-border connectivity and trading within the area and eventually achieve regional gas market integration. This goal could be achieved through the evolution of the current schemes such as TAGP and GMS or new initiatives such as the establishment of regional gas storage or gas exchanges.

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CHAPTER 9

An Integrated Asian Natural Gas Market: Potentials and Policy Implications

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In this study, we ask two questions: First, what would be the trade pattern of natural gas in the East Asia Summit region when an integrated and competitive market of natural gas is introduced? Second, what would be the impacts of additional infrastructure, including pipelines and LNG terminals, in the region? Investigating these questions under a consistent computational framework, this study contributes to justifying and motivating the policies which promote regional integration of natural gas market and investment in new infrastructure. We find that with an integrated and competitive regional natural gas market, supply should come more from within the region, which has cheaper costs of transportation than from external suppliers with relatively cheap costs of production and transportation. The model thus implies clear and significant welfare gains in moving towards such an integrated market. Additionally, new infrastructure clearly increases general social welfare and brings new trade opportunities to specific countries in the region. Relevant countries thus find support for their investment in the expansion of the regional supply network for natural gas, including both pipeline and LNG.

1. Introduction

In coming decades, the global consumption of natural gas is predicted to increase 38% by 2035, and regionally in Asia to increase by as much as 94% by 2035 (IEA, 2010). This increase is driven both by the growing demand in energy and the decreasing relative price of natural gas against crude oil. According to BP Statistical Review of World Energy 2010, the price of liquefied natural gas (LNG) for Japan has become lower than that of crude oil since 2002. The growing environmental concern also pushes many Asian economies to switch to natural gas. Altogether natural gas trade in the region is predicted to boom.

While strong demand for natural gas is forecast in the region, the current natural gas market in the region is not well developed. First, the market in the region is dominated by long-term contracts, with prices of natural gas and LNG pegged to that of crude oil. Second, the natural gas market in the region is to a large extent, not connected by natural gas networks. Both hinder the formation of a competitive natural gas market in the region, and contribute to the "Asian Premium" imposed on imported natural gas, especially in the form of LNG.

As European and U.S. natural gas markets have shown, an integrated regional natural gas market generates enough "gas-to-gas" competition and hence eliminates any premium paid to imported natural gas. Apart from thwarting the monopolistic pricing behavior, an integrated natural gas market could drive the prices of natural gas to be independent of that of crude oil, adding to the price advantage of natural gas. (Davoust, 2008; Rogers, 2010).

It is therefore interesting to establish: First, what would be the trade pattern of natural gas in the region when an integrated and competitive market of natural gas is introduced in the region? This analysis provides a benchmark measure of efficiency gains of such market, as well as rationale to move towards it by integrating the region market. Second, what would be the impacts of additional infrastructure in the region, including pipelines and LNG terminals? Additionally and subsequently, what would these changes imply on prices of natural gas and welfare level to countries in the region? By investigating these questions using a consistent framework, this study will contribute to justify and motivate the policies which promote regional integration of natural gas market and new pipeline and LNG infrastructure.

2. Methodology

There are numerous studies and models of natural gas market either for the U.S. market or the European market. These models include the Canadian Natural Gas Allocation Model (CGAM), the Strategic Model of European Gas Supply (GASMOD), the Gas Market System for Trade Analysis in a Liberalizing Europe (GASTALE), the North American Gas Trade Model (GTM), the EIA Short-Term Integrated Forecasting model (STIFS), and so on (Rowse, 1986; Holz et al, 2005; Boots et al, 2003; Beltramo, 1985; Costello, 1999).

These alternative methods of treating gas markets yield differing conclusions, resulting in differing policy recommendations. In spite of the different findings, a common conclusion that stands firm is that regional gas markets have progressively become more integrated with increasing LNG utilization and pipeline extensions. The natural gas markets around the world are expected to become increasingly more liberalized and competitive as greater linkages enable natural gas consumers to have more options insofar as the choice of vendors is concerned. With greater supply alternatives in which competitive pricing would prevail, producers might not able to exercise market power for the fear of consumers reverting to other suppliers.

A model for the Asian natural gas market is to be built by following this body of literature. Specifically, this model considers the ASEAN connectivity master plan and the plans for diversification into the LNG market. By doing so, it fully appreciates the potential of the Asian natural gas market and examines the trend of regional liberalization in natural gas markets in a Non-Linear Programing (NLP) approach. Following and modifying Beltramo et al (1986), the model computes a competitive equilibrium among natural gas trading Asian countries.

The natural gas markets in the model are interconnected at a single point in time. It is assumed that economic growth and prices of alternative energy sources are exogenously determined and fixed. It provides a static competitive framework in which wellhead and consumer prices are analyzed, as well as the flows of natural gas between the regions in question. Prices adjust so as to equilibrate demand and supply among importing and exporting countries respectively. As fixed demand can be imposed on countries that are involved in 'take-or-pay' (TOP) contracts with suppliers, it would serve as a lower bound on the quantity demanded. Capacity constraints can also be imposed on gas producing countries so that they would incorporate reproducibility limits. Overall, market equilibria are derived by solving the maximization problem of the sum of consumers' benefits less the costs of production and transportation costs associated with trade flows, subject to constraints on quantities traded and prices such as upper and lower bounds.

In sum, this study builds up a competitive partial equilibrium model to analyze the Pan-Asian natural gas market. In the natural gas trade model (GTM), unlike Beltramo et al (1986), total transportation costs have been treated differently to reflect the possible and potential role of liquefied natural gas (LNG) in the Asian natural gas market. The model is solved by GAMS (General Algebraic Modeling System), a nonlinear programming software.

3. The Model

The model includes two groups of participants: a group of regional participants, who both produce and consume natural gas; and a group of external participants, who are considered external suppliers of natural gas to the region. Such modeling allows us to focus on the regional natural gas market.

For each participant in the region as a consumer of natural gas, it has the following inverse demand function:

$$g(z_j) = \alpha_j z_j^{\beta_j} \qquad (1)$$

where $z_j>0$ is the demand from country *j*, β_j and α_j are respectively the demand exponent and demand constant for country *j*.[1] $\beta_j < 0$ is the reciprocal of the price elasticity of demand η_j for natural gas in country *j*:

$$\beta_j = \frac{1}{\eta_j} \tag{2}$$

Given the price elasticity of demand for natural gas, the constant α_j can be determined by using a pair of reference values for price and quantity demanded in the region's demand function.

Each participant, both in and out of the region as a supplier of natural gas, has the following supply (marginal cost) function $f(y_i)$:

$$f(y_i) = \chi_i + \frac{\delta_i}{(c_i - y_i)} \tag{3}$$

where y_i is the quantity supplied from country *i*, c_i is the production limit for country *i*, and both χ_i and δ_i are supply constants for country *i*. The marginal cost function allows the elasticity of supply to be high at low production levels and approach zero as the country approaches its production limit c_i. When $\delta_i = o$, a unique supply case is obtained whereby the supply curve is a reverse L-shaped. In this case, the marginal cost of production remains constant up to any upper bound imposed on *y*.

The supply function describes the supply conditions of the natural gas market in a useful and reasonable way, because once a natural gas field is commissioned ('uncapped'), it is virtually impossible to 're-cap' the field. Therefore, with the constant emissions of natural gas, it is easier to increase natural gas supplies to meet rising demand when initial demand levels are lower than vis-à-vis a situation of high initial demand. This implies more elastic supply under low demand conditions. Conversely, if market demand is strong then natural gas supplies would be inelastic due to limits imposed by production capacity.

Natural gas can be delivered via either pipelines or LNG. Transportation costs from supply country *i* to demand country *j* can be expressed as:

$$\text{Transportation costs} = ptc_{ij} \cdot xp_{ij} + ltc_{ij} \cdot xl_{ij} \tag{4}$$

[1] α_j contains the influence of income, which is assumed exogenous in this simple model.

where xp_{ij} is the quantity of natural gas delivered from *i* to *j* by pipeline, and xl_{ij} is the quantity of natural gas delivered from *i* to *j* by LNG. ptc_{ij} is the unit transportation cost of delivering natural gas via pipeline from country *i* to *j*, and ltc_{ij} is the unit transportation cost of delivering natural gas via LNG from country *i* to *j*.

xp_{ij} and xl_{ij} are constrained by not only the capacity limits of transportation means, but also the total quantity y_i that a supplier is willing to supply at a certain price, and the total quantity z_j that a consumer is willing to take at a certain price. Therefore, it is subjected to the following constraints:

$$\sum_j (xp_{ij} + xl_{ij}) \leq y_i \quad \text{(Supply constraint, country } i\text{)} \tag{5}$$

$$\sum_i (xp_{ij} + xl_{ij}) \geq z_j \quad \text{(Demand constraint, country } j\text{)} \tag{6}$$

The model's objective function is a conventional 'social welfare' maximizing nonlinear programming problem (NLP). This type of NLP is widely used to calculate competitive equilibria in commodity markets (Takayama and Judge, 1971; Labys and Yang, 1991). Essentially, the model maximizes consumer benefits less producers' costs and transportation costs:

$$\sum_j \int_{w=W}^{z_j} g_j(w)dw - \sum_i \int_{w=0}^{y_i} f_i(w)dw - \left[\sum_{i,j} ptc_{ij} \cdot xp_{ij} + \sum_{i,j} ltc_{ij} \cdot xl_{ij} \right] \tag{7}$$

Mathematically, it is easy to show that this algorithm computes the results of a perfectly competitive market, in which consumers maximize their own utility and producers maximize their own profit (Mathiesen, 2010).

4. Data

To apply this model of optimization, the parameters of the inverse demand function and the supply function need to be estimated.

α_j of country *j* is estimated as

$$\alpha_j = \frac{p_j}{q_j^{\frac{1}{\eta_j}}}, \tag{8}$$

using historical demand prices and quantities of the consumer. p_j is a historical demand price of the consumer, and q_j is the corresponding historical demand quantity of the consumer.

Assume that we have two historical data points for each supplier *i* to estimate the coefficients of its cost function: a high historical price p_{1i}, with a corresponding historical supply level q_{1i}; a low historical price p_{2i}, with a corresponding historical supply level q_{2i}. c_i is a constant, representing the capacity of production of the country. Putting the data into Equation (3), we have two equations, and can easily solve for the two unknown variables δ_i and χ_i.

δ_i of country *i* is estimated as

$$\delta_i = \frac{(p_{1i} - p_{2i})}{\frac{1}{(c_i - q_{1i})} - \frac{1}{(c_i - q_{2i})}}. \tag{9}$$

And χ_i of country *i* is estimated as

$$\chi_i = p_{1i} - \left(\frac{\frac{(p_{1i} - p_{2i})}{\frac{1}{(c_i - q_{1i})} - \frac{1}{(c_i - q_{2i})}}}{(c_i - q_{1i})} \right). \tag{10}$$

The data of natural gas demand, supply, and transportation are collected from and estimated according to BP Statistical Review of World Energy 2010, BP Statistical Review of World Energy 2009, NGI 2010, UN Commodity Trade database, and various other sources of information including Asian Pacific Review Trans-Asian Pipe (2003), Global LNG (2011), and PetroMin (2004). The costs of transportation by pipeline and LNG are estimated according to Jensen (2002).

Data of the price elasticity of natural gas demand η_j are not directly available. Instead, the price elasticity of electricity demand is used as a proxy, since natural gas is mainly used for power generation in the region. The data are collected from and estimated according to Bose and Shukla (1999), Chang (2007), Francisco (1988), Hosoe and Akiyama (2009), and Ishiguro and Akiyama (1995), and von Hirschhausen and Andres (2000).

Table 1 presents data of natural gas supply from countries within the region as well as countries outside of the region. Table 2 presents data of natural gas demand from countries within the region. Table 3 presents data of capacity of transportation means of natural gas. Table 4 presents data of transportation costs. And Table 5 shows how new infrastructure to be added by 2010 would change the capacity of various transportation means among the countries involved.

For Table 5, we apply additional information on new natural gas infrastructure projects, including both pipeline and LNG, which are under construction or proposed to come online by 2020. Major changes in infrastructure include the Trans ASEAN Gas Pipeline (TAGP), the Donggi-Senoro Gas Block Development Project of Indonesia, the Sabah – Sarawak Gas Pipeline Project of Malaysia, the two onshore gas pipeline projects and the Fourth Gas Transmission Pipeline Project of Thailand, and the Block B – Omon Pipeline Project and the Second Nam Con Son Pipeline Project of Vietnam.

Table 1. Supply of Natural Gas to the Region

Country	High Price ($/Mbtu)	High Price Quantity (bcm)	Low Price ($/Mbtu)	Low Price Quantity (bcm)	Capacity Limit (bcm)
Algeria	14.48	85.80	9.96	81.40	85.90
Australia	8.99	38.30	6.21	42.30	42.40
Bangladesh	1.42	19.70	1.24	17.90	19.80
Brunei	11.06	12.20	8.64	11.40	12.30
China	3.79	85.20	3.74	80.30	85.30
Egypt	13.36	59.00	13.21	62.70	62.80
Guinea	10.91	6.67	1.54	5.90	6.77
India	4.93	30.50	2.60	39.30	39.40
Indonesia	9.52	69.70	5.30	71.90	72.00
Malaysia	10.86	64.90	7.61	62.70	65.00
Myanmar	10.47	12.40	5.04	11.50	12.50
Nigeria	13.79	35.00	8.93	24.90	35.10
Oman	9.81	24.10	5.01	24.80	24.90
Philippines	4.28	3.88	2.92	3.91	4.01
Qatar	10.79	77.00	8.37	89.30	89.40
Russia	10.00	601.70	6.77	527.50	601.80
Thailand	10.47	28.80	5.04	30.90	31.00
Tobago	13.205	39.30	8.90	40.60	40.70
UAE	8.72	50.20	6.27	48.80	50.30
USA	6.00	593.40	5.62	574.40	593.50
Vietnam	3.33	8.00	3.20	7.90	8.10
Yemen	11.45	10.73	7.80	0.54	10.83

Source: Authors' own estimation based on data sources mentioned in the context

Table 2. Demand of Natural Gas in the Region

Country	Demand Price ($/Mbtu)	Demand Quantity (bcm)	Price Elasticity of Demand
Bangladesh	2.02	19.70	-0.50
Brunei	9.49	2.60	-0.50
China	4.44	88.62	-0.60
India	5.03	51.20	-0.68
Indonesia	5.97	36.60	-0.50
Japan	9.42	85.90	-0.10
Korea	10.50	34.33	-0.39
Malaysia	8.21	31.50	-0.48
Myanmar	5.33	3.27	-0.50
Philippines	3.52	3.78	-0.50
Singapore	8.79	9.70	-0.20
Taiwan	12.38	11.79	-0.37
Thailand	5.89	39.20	-0.50
Vietnam	4.18	7.59	-0.50

Source: Authors' own estimation based on data sources mentioned in the context

Table 3. Capacity of Natural Gas Transportation Means (Unit: bcm)

From\To	Bangladesh	Brunei	China	India	Indonesia	Japan	Korea	Malaysia	Myanmar	Philippines	Singapore	Taiwan	Thailand	Vietnam
Algeria				2.25 $^{\Phi}$			2.17 $^{\Phi}$							
Australia			7.17 $^{\Phi}$	3.54 $^{\Phi}$		18.29 $^{\Phi}$	4.17 $^{\Phi}$					3.02 $^{\Phi}$		
Bangladesh	19.70 $^{\Omega}$													
Brunei		40.88 $^{\Omega}$				8.99 $^{\Phi}$	1.58 $^{\Phi}$							
China			73.10 $^{\Omega}$											
Egypt			1.36 $^{\Phi}$	1.61 $^{\Phi}$		1.52 $^{\Phi}$	1.59 $^{\Phi}$					1.36 $^{\Phi}$		
Guinea			0.55 $^{\Phi}$	0.72 $^{\Phi}$		2.17 $^{\Phi}$	1.99 $^{\Phi}$					1.14 $^{\Phi}$		
India				58.40 $^{\Omega}$										
Indonesia			3.32 $^{\Phi}$	2.68 $^{\Phi}$	36.60 $^{\Omega}$	19.85 $^{\Phi}$	6.70 $^{\Phi}$	10.22 $^{\Omega}$			10.22 $^{\Omega}$	6.37 $^{\Phi}$		
Malaysia			3.83 $^{\Phi}$	3.20 $^{\Phi}$		19.74 $^{\Phi}$	10.76 $^{\Phi}$	31.50 $^{\Omega}$			10.22 $^{\Omega}$	6.66 $^{\Phi}$		
Myanmar									10.22 $^{\Omega}$				10.22 $^{\Omega}$	
Nigeria			1.68 $^{\Phi}$	1.92 $^{\Phi}$		2.37 $^{\Phi}$	1.83 $^{\Phi}$					2.53 $^{\Phi}$		
Oman			1.24 $^{\Phi}$	1.50 $^{\Phi}$		4.59 $^{\Phi}$	7.20 $^{\Phi}$					1.31 $^{\Phi}$		
Philippines										10.22 $^{\Omega}$				
Qatar			5.49 $^{\Phi}$	13.19 $^{\Phi}$		15.23 $^{\Phi}$	14.22 $^{\Phi}$					6.50 $^{\Phi}$		
Russia			0.91 $^{\Phi}$	1.33 $^{\Phi}$		4.35 $^{\Phi}$	2.01 $^{\Phi}$					0.90 $^{\Phi}$		
Thailand													31.00 $^{\Omega}$	
Tobago			2.05 $^{\Phi}$	2.65 $^{\Phi}$		2.11 $^{\Phi}$	2.87 $^{\Phi}$					2.05 $^{\Phi}$		
UAE				0.87 $^{\Phi}$		7.45 $^{\Phi}$								
USA						0.95 $^{\Phi}$								
Vietnam														20.44 $^{\Omega}$
Yemen							0.29 $^{\Phi}$							

Table 4. Unit Transportation Costs (Unit: $/Mbtu)

From\To	Bangladesh	Brunei	China	India	Indonesia	Japan	Korea	Malaysia	Myanmar	Philippines	Singapore	Taiwan	Thailand	Vietnam
Algeria				2.52$^{\Phi}$			3.26$^{\Phi}$							
Australia			2.33$^{\Phi}$	2.55$^{\Phi}$		2.70$^{\Phi}$	2.73$^{\Phi}$					2.61$^{\Phi}$		
Bangladesh	0.60$^{\Omega}$													
Brunei		0.85$^{\Omega}$				2.10$^{\Phi}$	2.06$^{\Phi}$							
China			2.23$^{\Omega}$											
Egypt			2.79$^{\Phi}$	2.22$^{\Phi}$		3.00$^{\Phi}$	2.96$^{\Phi}$					2.82$^{\Phi}$		
Guinea			3.47$^{\Phi}$	3.08$^{\Phi}$		3.69$^{\Phi}$	3.63$^{\Phi}$					3.50$^{\Phi}$		
India				1.17$^{\Omega}$										
Indonesia			1.94$^{\Phi}$	2.06$^{\Phi}$	0.67$^{\Omega}$	2.13$^{\Phi}$	2.09$^{\Phi}$	0.85$^{\Omega}$			0.85$^{\Omega}$	1.95$^{\Phi}$		
Malaysia			1.92$^{\Phi}$	2.09$^{\Phi}$		2.12$^{\Phi}$	2.07$^{\Phi}$	0.60$^{\Omega}$			1.09$^{\Omega}$	1.94$^{\Phi}$		
Myanmar									0.60$^{\Omega}$				1.17$^{\Omega}$	
Nigeria			3.26$^{\Phi}$	2.93$^{\Phi}$		3.48$^{\Phi}$	3.44$^{\Phi}$					3.30$^{\Phi}$		
Oman			3.17$^{\Phi}$	2.00$^{\Phi}$		3.30$^{\Phi}$	3.23$^{\Phi}$					3.00$^{\Phi}$		
Philippines										0.60$^{\Omega}$				
Qatar			2.57$^{\Phi}$	2.07$^{\Phi}$		3.44$^{\Phi}$	3.38$^{\Phi}$					3.15$^{\Phi}$		
Russia			2.16$^{\Phi}$	3.15$^{\Phi}$		1.94$^{\Phi}$	2.04$^{\Phi}$					2.24$^{\Phi}$		
Thailand													1.01$^{\Omega}$	
Tobago			3.33$^{\Phi}$	3.38$^{\Phi}$		3.20$^{\Phi}$	3.27$^{\Phi}$					3.38$^{\Phi}$		
UAE				2.04$^{\Phi}$		3.41$^{\Phi}$								
USA						2.18$^{\Phi}$								
Vietnam														0.85$^{\Omega}$
Yemen							2.70$^{\Phi}$							

Ω: Pipeline transportation; Φ: LNG transportation. *Source: Authors' own estimation based on data sources mentioned in the context*

Table 5. Transportation Means with New Infrastructure (Unit: bcm)

From\To	Bangladesh	Brunei	China	India	Indonesia	Japan	Korea	Malaysia	Myanmar	Philippines	Singapore	Taiwan	Thailand	Vietnam
Algeria			1.65$^{\Phi}$	2.25$^{\Phi}$	0.15$^{\Phi}$	0.20$^{\Phi}$	2.17$^{\Phi}$			0.03$^{\Phi}$	0.15$^{\Phi}$		0.12$^{\Phi}$	
Australia			20.17$^{\Phi}$	3.54$^{\Phi}$	1.20$^{\Phi}$	19.97$^{\Phi}$	4.17$^{\Phi}$			0.26$^{\Phi}$	1.20$^{\Phi}$	3.02$^{\Phi}$	1.00$^{\Phi}$	
Bangladesh	19.70$^{\Omega}$													
Brunei		40.88$^{\Omega}$	3.95$^{\Phi}$		0.35$^{\Phi}$	9.48$^{\Phi}$	1.58$^{\Phi}$			0.08$^{\Phi}$	0.35$^{\Phi}$		0.29$^{\Phi}$	
China			73.10$^{\Omega}$											
Egypt			4.15$^{\Phi}$	1.61$^{\Phi}$	0.25$^{\Phi}$	1.87$^{\Phi}$	1.59$^{\Phi}$			0.05$^{\Phi}$	0.25$^{\Phi}$	1.36$^{\Phi}$	0.21$^{\Phi}$	
Guinea			3.01$^{\Phi}$	0.72$^{\Phi}$	0.22$^{\Phi}$	2.48$^{\Phi}$	1.99$^{\Phi}$			0.05$^{\Phi}$	0.22$^{\Phi}$	1.14$^{\Phi}$	0.18$^{\Phi}$	
India				58.40$^{\Omega}$										
Indonesia		10.22$^{\Omega}$	17.87$^{\Phi}$	2.68$^{\Phi}$	68.55$^{\Omega/\Phi}$	21.65$^{\Phi}$	6.70$^{\Phi}$	30.66$^{\Omega}$		0.28$^{\Phi}$	11.51$^{\Omega/\Phi}$	6.37$^{\Phi}$	11.30$^{\Omega/\Phi}$	10.22$^{\Omega}$
Malaysia			20.36$^{\Phi}$	3.20$^{\Phi}$	1.47$^{\Phi}$	21.78$^{\Phi}$	10.76$^{\Phi}$	31.50$^{\Omega}$		10.54$^{\Omega/\Phi}$	11.69$^{\Omega/\Phi}$	6.66$^{\Phi}$	11.44$^{\Omega/\Phi}$	10.22$^{\Omega}$
Myanmar			10.22$^{\Omega}$	10.22$^{\Omega}$					10.22$^{\Omega}$				10.22$^{\Omega}$	
Nigeria			5.54$^{\Phi}$	1.92$^{\Phi}$	0.34$^{\Phi}$	2.85$^{\Phi}$	1.83$^{\Phi}$			0.07$^{\Phi}$	0.34$^{\Phi}$	2.53$^{\Phi}$	0.29$^{\Phi}$	
Oman			7.17$^{\Phi}$	1.50$^{\Phi}$	0.53$^{\Phi}$	5.33$^{\Phi}$	7.20$^{\Phi}$			0.11$^{\Phi}$	0.53$^{\Phi}$	1.31$^{\Phi}$	0.44$^{\Phi}$	
Philippines										30.66$^{\Omega}$				
Qatar			25.92$^{\Phi}$	13.19$^{\Phi}$	1.82$^{\Phi}$	17.76$^{\Phi}$	14.22$^{\Phi}$			0.39$^{\Phi}$	1.82$^{\Phi}$	6.50$^{\Phi}$	1.51$^{\Phi}$	
Russia			4.46$^{\Phi}$	31.33$^{\Omega/\Phi}$	0.32$^{\Phi}$	4.79$^{\Phi}$	2.01$^{\Phi}$			0.07$^{\Phi}$	0.32$^{\Phi}$	0.90$^{\Phi}$	0.26$^{\Phi}$	
Thailand													31.00$^{\Omega}$	
Tobago			6.45$^{\Phi}$	2.65$^{\Phi}$	0.39$^{\Phi}$	2.66$^{\Phi}$	2.87$^{\Phi}$			0.08$^{\Phi}$	0.39$^{\Phi}$	2.05$^{\Phi}$	0.33$^{\Phi}$	
UAE			3.11$^{\Phi}$	0.87$^{\Phi}$	0.28$^{\Phi}$	7.84$^{\Phi}$				0.06$^{\Phi}$	0.28$^{\Phi}$		0.23$^{\Phi}$	
USA			0.35$^{\Phi}$		0.03$^{\Phi}$	0.99$^{\Phi}$				0.01$^{\Phi}$	0.03$^{\Phi}$		0.03$^{\Phi}$	
Vietnam														40.88$^{\Omega}$
Yemen			0.11$^{\Phi}$		0.01$^{\Phi}$	0.01$^{\Phi}$	0.29$^{\Phi}$				0.01$^{\Phi}$		0.01$^{\Phi}$	

Ω: Pipeline transportation; Φ: LNG transportation. *Source: Authors' own estimation based on data sources mentioned in the context*

5. Simulation Results

Based on the above data, two experiments are run. The first one tests the implications of an integrated and competitive natural gas market in the region; and the second one tests the implications of new infrastructure for natural gas transportation in the region.

Table 6 presents the current real natural gas trade pattern in the region. Table 7 presents the results of our first experiment, which estimates the trade flows under an integrated and competitive natural gas market in the region. Table 8 compares the current trade flows in Table 6 with the optimized trade flows in Table 7, and lists the changes in terms of both quantities and prices. Table 9 presents the results of our second experiment, which also estimates the trade flows under an integrated and competitive market, with new infrastructure considered. Table 10 compares these trade flows with those from Table 7, showing how additional infrastructure for natural gas transportation further contributes to natural gas trade in the region.

These tables draw our attention to the changes in the trade patterns in terms of trade routes, quantities, and prices. In addition and importantly, changes in the objective value of equation (7) are direct measures of how an integrated and competitive regional market and new infrastructure are justified. They could also be derived from the two experiments and will be reported separately in the next section.

It is also important to note that participants in an integrated and competitive market are driven by pure economic forces. Therefore, besides the costs of transportation as shown in Table 4, the structure of costs and demand embeds the results that follow. This information is presented in Appendices A and B. For example, the supply from Egypt, Qatar, and Tobago disappears in the optimized trade pattern as their costs are estimated to be among the highest. And China and India have relatively lower willingness-to-pay, and therefore have to cut certain amount of their consumption in the optimized trade pattern.

Table 6. The Current Trade Flows (Unit: bcm)

From\To	Bangladesh	Brunei	China	India	Indonesia	Japan	Korea	Malaysia	Myanmar	Philippines	Singapore	Taiwan	Thailand	Vietnam	Total Supply	Supply Price
Algeria				0.16 $^{\Phi}$			0.08 $^{\Phi}$								0.24	9.96
Australia			4.75 $^{\Phi}$	1.12 $^{\Phi}$		15.87 $^{\Phi}$	1.75 $^{\Phi}$					0.60 $^{\Phi}$			24.09	6.21
Bangladesh	19.70 $^{\Omega}$														19.70	1.42
Brunei		3.49 $^{\Omega}$				8.11 $^{\Phi}$	0.70 $^{\Phi}$								12.30	8.64
China			81.06 $^{\Omega}$												81.06	3.79
Egypt			0.08 $^{\Phi}$	0.33 $^{\Phi}$		0.24 $^{\Phi}$	0.31 $^{\Phi}$					0.08 $^{\Phi}$			1.04	13.21
Guinea			0.08 $^{\Phi}$	0.25 $^{\Phi}$		1.70 $^{\Phi}$	1.52 $^{\Phi}$					0.67 $^{\Phi}$			4.22	1.54
India				38.57 $^{\Omega}$											38.57	2.60
Indonesia			0.72 $^{\Phi}$	0.08 $^{\Phi}$	36.60 $^{\Omega}$	17.25 $^{\Phi}$	4.10 $^{\Phi}$	1.26 $^{\Omega}$			8.49 $^{\Omega}$	3.77 $^{\Phi}$			72.27	5.30
Malaysia			0.88 $^{\Phi}$	0.25 $^{\Phi}$		16.79 $^{\Phi}$	7.81 $^{\Phi}$	30.24 $^{\Omega}$			1.21 $^{\Omega}$	3.71 $^{\Phi}$			60.89	7.61
Myanmar									3.27 $^{\Omega}$				8.29 $^{\Omega}$		11.56	4.73
Nigeria			0.08 $^{\Phi}$	0.32 $^{\Phi}$		0.77 $^{\Phi}$	0.23 $^{\Phi}$					0.93 $^{\Phi}$			2.33	8.93
Oman			0.09 $^{\Phi}$	0.35 $^{\Phi}$		3.44 $^{\Phi}$	6.05 $^{\Phi}$					0.16 $^{\Phi}$			10.09	4.21
Philippines										3.78 $^{\Omega}$					3.78	2.92
Qatar			0.55 $^{\Phi}$	8.25 $^{\Phi}$		10.29 $^{\Phi}$	9.28 $^{\Phi}$					1.56 $^{\Phi}$			29.93	7.73
Russia			0.25 $^{\Phi}$	0.67 $^{\Phi}$		3.69 $^{\Phi}$	1.35 $^{\Phi}$					0.24 $^{\Phi}$			6.20	6.77
Thailand													30.91 $^{\Omega}$		30.91	5.89
Tobago			0.08 $^{\Phi}$	0.68 $^{\Phi}$		0.14 $^{\Phi}$	0.90 $^{\Phi}$					0.08 $^{\Phi}$			1.88	8.90
UAE				0.17 $^{\Phi}$		6.75 $^{\Phi}$									6.92	5.63
USA						0.86 $^{\Phi}$									0.86	6.00
Vietnam														7.59 $^{\Omega}$	7.59	3.33
Yemen							0.25 $^{\Phi}$								0.25	7.80
Total Demand	19.70	3.49	88.62	51.20	36.60	85.90	34.33	31.50	3.27	3.78	9.70	11.80	39.20	7.59		
Demand Price	2.02	9.49	4.44	5.03	5.97	9.42	10.5	8.21	5.33	3.52	8.79	12.38	5.89	4.18		

Ω: Pipeline transportation; Φ: LNG transportation. *Source: Authors' own estimation based on data sources mentioned in the context*

Table 7. Trade Flows in an Integrated and Competitive Natural Gas Market in the Region (Unit: bcm)

From\To	Bangladesh	Brunei	China	India	Indonesia	Japan	Korea	Malaysia	Myanmar	Philippines	Singapore	Taiwan	Thailand	Vietnam	Total Supply	Supply Price
Algeria							2.17 $^{\Phi}$								2.17	9.86
Australia						18.29 $^{\Phi}$	4.17 $^{\Phi}$								22.46	9.05
Bangladesh	19.60 $^{\Omega}$														19.60	1.44
Brunei		2.27 $^{\Omega}$				8.99 $^{\Phi}$	0.92 $^{\Phi}$								12.18	11.64
China			73.10 $^{\Omega}$												73.10	3.74
Egypt															0.00	10.77
Guinea			0.29 $^{\Phi}$	0.72 $^{\Phi}$		2.17 $^{\Phi}$	1.99 $^{\Phi}$					1.14 $^{\Phi}$			6.31	2.61
India				39.01 $^{\Omega}$											39.01	6.14
Indonesia					27.06 $^{\Omega}$	19.85 $^{\Phi}$	6.70 $^{\Phi}$				9.70 $^{\Omega}$	4.29 $^{\Phi}$			67.60	9.59
Malaysia						19.74 $^{\Phi}$	10.76 $^{\Phi}$	27.54 $^{\Omega}$				5.46 $^{\Phi}$			63.50	9.60
Myanmar									2.26 $^{\Omega}$				10.11 $^{\Omega}$		12.38	10.53
Nigeria						2.37 $^{\Phi}$	1.83 $^{\Phi}$								4.20	8.90
Oman						1.74 $^{\Phi}$	3.49 $^{\Phi}$								5.23	10.47
Philippines										3.97 $^{\Omega}$					3.97	2.59
Qatar															0.00	10.33
Russia						4.35 $^{\Phi}$	2.01 $^{\Phi}$					0.90 $^{\Phi}$			7.26	6.77
Thailand													17.71 $^{\Omega}$		17.71	10.69
Tobago															0.00	13.53
UAE						7.45 $^{\Phi}$									7.45	6.10
USA						0.95 $^{\Phi}$									0.95	5.62
Vietnam														7.76 $^{\Omega}$	7.76	3.15
Yemen							0.29 $^{\Phi}$								0.29	7.80
Total Demand	19.60	2.27	73.39	39.73	27.06	85.90	34.33	27.54	2.26	3.97	9.70	11.79	27.82	7.76		
Demand Price	2.04	12.49	6.08	7.31	10.26	13.77	13.70	10.20	11.13	3.19	10.44	11.54	11.70	4.00		

Ω: Pipeline transportation; Φ: LNG transportation.

Table 8. Changes between the Current Trade Flows and the Trade Flows in an Integrated and Competitive Natural Gas Market

From\To	Bangladesh	Brunei	China	India	Indonesia	Japan	Korea	Malaysia	Myanmar	Philippines	Singapore	Taiwan	Thailand	Vietnam	Total Supply	Supply Price
Algeria				-0.16$^{\Phi}$			+2.09$^{\Phi}$								+1.93	-0.10
Australia			-4.75$^{\Phi}$	-1.12$^{\Phi}$		+2.42$^{\Phi}$	+2.42$^{\Phi}$					-0.60$^{\Phi}$			-1.63	+2.84
Bangladesh	+0.10$^{\Omega}$														+0.10	+0.02
Brunei		-1.22$^{\Omega}$				+0.88$^{\Phi}$	+0.22$^{\Phi}$								-0.12	+3.00
China			-8.50$^{\Omega}$												-7.96	-0.05
Egypt			-0.08$^{\Phi}$	-0.33$^{\Phi}$		-0.24$^{\Phi}$	-0.31$^{\Phi}$					-0.08$^{\Phi}$			-1.04	-2.44
Guinea			+0.21$^{\Phi}$	+0.47$^{\Phi}$		+0.47$^{\Phi}$	+0.47$^{\Phi}$					+0.47$^{\Phi}$			-2.09	+1.07
India				0.44$^{\Omega}$											+0.44	+3.54
Indonesia			-0.72$^{\Phi}$	-0.08$^{\Phi}$	-9.54$^{\Omega}$	+2.60$^{\Phi}$	+2.60$^{\Phi}$	-1.26$^{\Omega}$			+1.21$^{\Omega}$	+0.52$^{\Phi}$			-4.67	+4.29
Malaysia			-0.88$^{\Phi}$	-0.25$^{\Phi}$		+2.95$^{\Phi}$	+2.95$^{\Phi}$	-2.70$^{\Omega}$			-1.21$^{\Omega}$	+1.75$^{\Phi}$			+2.61	+1.99
Myanmar									-1.01$^{\Omega}$				+1.82$^{\Omega}$		+0.82	+5.80
Nigeria			-0.08$^{\Phi}$	-0.32$^{\Phi}$		+1.60$^{\Phi}$	+1.60$^{\Phi}$					-0.93$^{\Phi}$			+1.87	-0.03
Oman			-0.09$^{\Phi}$	-0.35$^{\Phi}$		-1.70$^{\Phi}$	-2.56$^{\Phi}$					-0.16$^{\Phi}$			-4.86	+6.26
Philippines										+0.19$^{\Omega}$					+0.19	-0.33
Qatar			-0.55$^{\Phi}$	-8.25$^{\Phi}$		-10.29$^{\Phi}$	-9.28$^{\Phi}$					-1.56$^{\Phi}$			-29.93	+2.60
Russia			-0.25$^{\Phi}$	-0.67$^{\Phi}$		+0.66$^{\Phi}$	0.66$^{\Phi}$					+0.66$^{\Phi}$			+1.06	0.00
Thailand													-13.20$^{\Omega}$		-13.20	+4.80
Tobago			-0.08$^{\Phi}$	-0.68$^{\Phi}$		-0.14$^{\Phi}$	-0.90$^{\Phi}$					-0.08$^{\Phi}$			-1.88	+4.63
UAE				-0.17$^{\Phi}$		+0.70$^{\Phi}$									+0.53	+0.47
USA						+0.09$^{\Phi}$									+0.09	-0.38
Vietnam														+0.17$^{\Omega}$	+0.17	-0.18
Yemen							+0.04$^{\Phi}$								+0.04	0.00
Total Demand	-0.10	-1.22	-15.23	-11.47	-9.54	0.00	0.00	-3.96	-1.01	+0.19	0.00	0.00	-11.38	+0.17		
Demand Price	+0.02	+3.00	+1.64	+2.28	+4.29	+4.35	+3.20	+1.99	+5.80	-0.33	+1.65	-0.84	+5.81	-0.18		

Ω: Pipeline transportation; Φ: LNG transportation.

Table 9. Trade Flows with New Infrastructure for Natural Gas in the Region (Unit: bcm)

From\To	Bangladesh	Brunei	China	India	Indonesia	Japan	Korea	Malaysia	Myanmar	Philippines	Singapore	Taiwan	Thailand	Vietnam	Total Supply	Supply Price
Algeria							2.17 $^{\Phi}$								2.17	9.86
Australia						19.97 $^{\Phi}$	4.17 $^{\Phi}$					3.02 $^{\Phi}$	1.00 $^{\Phi}$		28.16	9.04
Bangladesh	19.60 $^{\Omega}$														19.60	1.44
Brunei		1.09 $^{\Omega}$				9.48 $^{\Phi}$	1.58 $^{\Phi}$								12.15	10.10
China			73.10 $^{\Omega}$												73.10	3.74
Egypt															0.00	10.74
Guinea				0.28 $^{\Phi}$	0.22 $^{\Phi}$	2.48 $^{\Phi}$	1.99 $^{\Phi}$				0.22 $^{\Phi}$	1.14 $^{\Phi}$	0.18 $^{\Phi}$		6.51	4.35
India				39.01 $^{\Omega}$											39.01	6.26
Indonesia		1.34 $^{\Omega}$			25.94 $^{\Omega}$	21.65 $^{\Phi}$	6.70 $^{\Phi}$				8.84 $^{\Omega}$	6.37 $^{\Phi}$	0.45 $^{\Phi}$		71.28	10.10
Malaysia						15.84 $^{\Phi}$	10.76 $^{\Phi}$	27.53 $^{\Omega}$				0.36 $^{\Phi}$	10.22 $^{\Omega}$		64.71	10.27
Myanmar									2.26 $^{\Omega}$				10.11 $^{\Omega}$		12.38	10.55
Nigeria						2.85 $^{\Phi}$	1.83 $^{\Phi}$								4.68	8.90
Oman							2.83 $^{\Phi}$								2.83	10.47
Philippines										3.97 $^{\Omega}$					3.97	2.59
Qatar															0.00	10.32
Russia					0.32 $^{\Phi}$	4.79 $^{\Phi}$	2.01 $^{\Phi}$				0.32 $^{\Phi}$	0.90 $^{\Phi}$	0.26 $^{\Phi}$		8.60	6.77
Thailand													5.30 $^{\Omega}$		5.30	10.71
Tobago															0.00	10.43
UAE					0.28 $^{\Phi}$	7.84 $^{\Phi}$					0.28 $^{\Phi}$		0.23 $^{\Phi}$		8.63	6.10
USA					0.03 $^{\Phi}$	0.99 $^{\Phi}$					0.03 $^{\Phi}$		0.03 $^{\Phi}$		1.08	5.62
Vietnam														7.76 $^{\Omega}$	7.76	3.15
Yemen					0.01 $^{\Phi}$	0.01 $^{\Phi}$	0.29 $^{\Phi}$				0.01 $^{\Phi}$		0.01 $^{\Phi}$		0.33	7.80
Total Demand	19.60	2.42	73.10	39.28	26.80	85.90	34.33	27.53	2.26	3.97	9.70	11.79	27.79	7.76		
Demand Price	2.04	10.95	6.12	7.43	11.14	12.39	13.70	10.87	11.15	3.19	10.95	12.20	11.72	4.00		

Ω: Pipeline transportation; Φ: LNG transportation.

Table 10. Changes between the Trade Flows in an Integrated and Competitive Natural Gas Market and the Trade Flows with New Infrastructure

From\To	Bangladesh	Brunei	China	India	Indonesia	Japan	Korea	Malaysia	Myanmar	Philippines	Singapore	Taiwan	Thailand	Vietnam	Total Supply	Supply Price
Algeria							0.00 $^{\Phi}$								0.00	0.00
Australia						+1.68 $^{\Phi}$	0.00 $^{\Phi}$					+3.02 $^{\Phi}$	+1.00 $^{\Phi}$		+5.70	0.00
Bangladesh	0.00 $^{\Omega}$														0.00	0.00
Brunei		-1.18 $^{\Omega}$				+0.49 $^{\Phi}$	+0.66 $^{\Phi}$								-0.03	-1.54
China			0.00 $^{\Omega}$												0.00	0.00
Egypt															0.00	-0.03
Guinea			-0.29 $^{\Phi}$	-0.44 $^{\Phi}$	+0.22 $^{\Phi}$	+0.31 $^{\Phi}$	0.00 $^{\Phi}$				+0.22 $^{\Phi}$	0.00 $^{\Phi}$	+0.18 $^{\Phi}$		+0.20	+1.74
India				0.00 $^{\Omega}$											0.00	+0.12
Indonesia		+1.34 $^{\Omega}$			-1.12 $^{\Omega}$	+1.80 $^{\Phi}$	0.00 $^{\Phi}$				-0.86 $^{\Omega}$	+2.08 $^{\Phi}$	+0.45 $^{\Phi}$		+3.68	+0.51
Malaysia						-3.90 $^{\Phi}$	0.00 $^{\Phi}$	-0.01 $^{\Omega}$				-5.10 $^{\Phi}$	+10.22 $^{\Omega}$		+1.21	+0.67
Myanmar									0.00 $^{\Omega}$				0.00 $^{\Omega}$		0.00	0.02
Nigeria						+0.48 $^{\Phi}$	0.00 $^{\Phi}$								+0.48	0.00
Oman						-1.74 $^{\Phi}$	-0.66 $^{\Phi}$								-2.40	0.00
Philippines										0.00 $^{\Omega}$					0.00	0.00
Qatar															0.00	0.00
Russia					+0.32 $^{\Phi}$	+0.44 $^{\Phi}$	0.00 $^{\Phi}$				+0.32 $^{\Phi}$	0.00 $^{\Phi}$	+0.26 $^{\Phi}$		+1.34	0.00
Thailand													-12.41 $^{\Omega}$		-12.41	+0.02
Tobago															0.00	-3.10
UAE					+0.28 $^{\Phi}$	+0.39 $^{\Phi}$					+0.28 $^{\Phi}$		+0.23 $^{\Phi}$		+1.18	0.00
USA					+0.03 $^{\Phi}$	+0.04 $^{\Phi}$					+0.03 $^{\Phi}$		+0.03 $^{\Phi}$		+0.13	0.00
Vietnam														0.00 $^{\Omega}$	0.00	0.00
Yemen					+0.01 $^{\Phi}$	+0.01 $^{\Phi}$	0.00 $^{\Phi}$				+0.01 $^{\Phi}$		+0.01 $^{\Phi}$		0.04	0.00
Total Demand	0.00	+0.15	-0.29	-0.45	-0.26	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-0.03	0.00		
Demand Price	0.00	-1.54	+0.04	+0.12	+0.88	-1.38	0.00	+0.67	+0.02	0.00	+0.51	+0.66	+0.02	0.00		

Ω: Pipeline transportation; Φ: LNG transportation.

6. Analysis of the Results

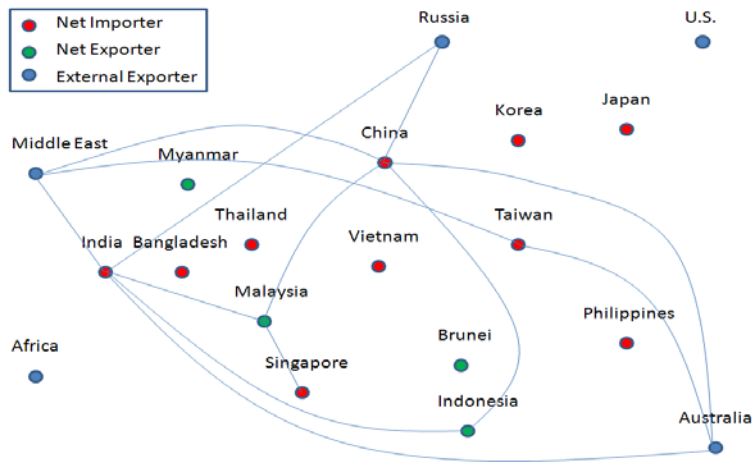
The comparison between Table 6 and Table 7 leads us to the following observations: First, in the integrated and competitive market, China and India will need to reduce their total consumption, and meanwhile cut off most of their LNG imports except that from Guinea. This is driven both by their willingness to pay for natural gas and their transportation costs of natural gas importation. In other words, it is not economic yet for the two countries to import LNG from various sources. Under current trade pattern, that China and India import certain amounts of LNG from various sources might be due to energy security concerns, as well as subsidies on natural gas in their domestic markets.

Second, Japan and Korea are to concentrate their imports from a smaller number of sources. They will cut off imports from Egypt, Qatar, and Tobago, decrease import from Oman, and increase imports from the rest of their original sources of imports. Third, optimally Singapore will obtain all of their imported natural gas from Indonesia via pipeline. Fourth, Taiwan will rely on Guinea, Indonesia, Malaysia, and Russia to satisfy its demand, and cease importing from other sources. Fifth, Thailand will increase import from Myanmar, while reducing its own production, and in total its consumption should be reduced. And sixth, Philippines and Vietnam, which are self-sufficient in natural gas, would slightly increase their production and consumption.

These changes are summarized by Table 8. Correspondingly, the following figure shows the trade routes that would be canceled under an optimized trade pattern.

Overall, prices that the importing participants are paying will increase significantly when an integrated and competitive market is in place. This is due to the model omitting the role of subsidies, which are prevalent in the region. Subsidies would lower the cost of local supply and therefore reduce the cost of imported gas. Nor does the model incorporate energy security objectives, which conventionally requires diversified sources of supply. Therefore, in this integrated and competitive model, we see supply of natural gas from the region, which has cheaper transportation costs, to increase its portion in the total supply of natural gas to the region by 5.5%. As a result of such an optimization to the current trade pattern, the objective value, which is the value of the benefit function, also increases by 5.5%.

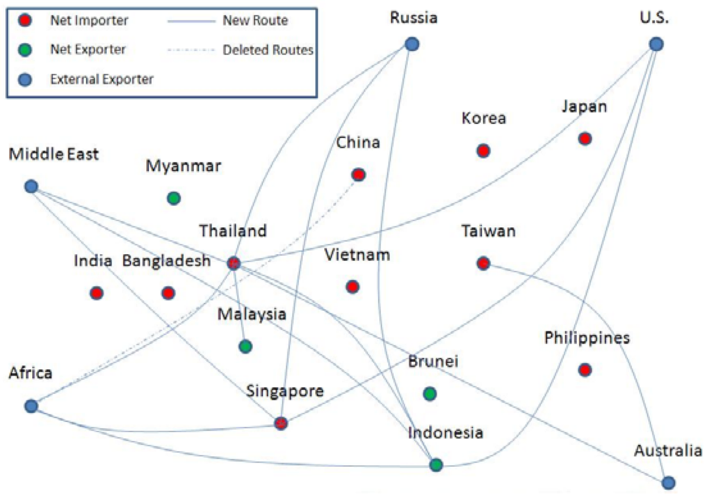
Figure 1. Inefficient Trade Routes removed from the Current Trade Pattern after optimization



The comparison between Table 7 and Table 9 leads us to the following observations: First, with the new pipeline and LNG terminals in place, Brunei and Indonesia will be able to import from cheaper sources, while increasing its exports at higher prices to other importers in the region. Brunei imports from Indonesia via pipeline, and Indonesia imports LNG from a few external countries. Second, Singapore and Thailand will start importing LNG from various external exporters, although the amounts are still relatively small compared to their imports via pipeline. Third, for its pipeline imports, Thailand will use the supply from Malaysia to substitute a significant part of its domestic supply. Fourth, production and exportation of Indonesia and Malaysia will be promoted by new infrastructure, as will the supply prices of the two countries. And fifth, Japan and Brunei will see a significant drop in the prices of natural gas.

These changes are summarized by Table 10. Correspondingly, the following figure shows the trade routes that would be created or canceled as results of the new infrastructure.

Figure 2. Changes of Trade Routes with New Infrastructure Added



Additionally, with the new pipeline and LNG terminals in place, the objective value, which is the value of the benefit function, will increase by 0.3%. This result should be read more as directional rather than a quantitative indicator of how the new infrastructure would improve welfare. This is because the definition of our welfare function is not a directly comparable measure against the measure of production costs and transportation costs. This renders the value of the objective value scalable under different assumptions about the coefficients of the welfare function. But the direction of changes in the objective value will remain under any assumption.

7. Conclusions and Policy Implications

This study uses a competitive equilibrium model to analyze the implications of an integrated and competitive natural gas market in the region. If one believes that a market as such is efficient and naturally brings the security of supply, the results show what the allocation of such a gas market looks like, with each participants acting on pure economic rationale. It is shown that more supply should come from within the region, which has cheaper costs of transportation, than from external suppliers with relatively cheap costs of production but high costs of transportation.

In addition, the implications of new infrastructure of natural gas to come online by 2020 are derived. The results show that general welfare of the region would be promoted by the new infrastructure, and also how specifically certain participants could benefit either as an importer or as an exporter.

To policy makers, our results convey the following messages:

- An integrated and competitive natural gas market in the region implies clear and significant welfare gains. Policy makers should heed on such economic gains.
- An integrated and competitive market also shows that excess demand will be removed as a result of removing distortions such as subsidies, increasing social welfare. This rationalizes why subsidies should be removed.
- New infrastructure clearly increases social welfare, and brings new trade opportunities to specific countries in the region. Relevant countries thus find support for their investment in the expansion of the supply network for natural gas in the region, including both pipeline and LNG.

This study required simplifications to visualize what an integrated natural gas market in the region looks like and in what possible ways participants could benefit from it. Although we recognize these strong assumptions such as full competition and no subsidy distortions deviate from the current reality of gas markets in the region, especially in the case of results about China and India. Despite this divergence, the model provides us with useful conclusions.

Future research on the fundamentals of the natural gas market in the region could focus on two issues. First, as already mentioned, an imperfect competition model, which allows subsidy distortions, would be a better approximation of reality. Second, it is better to use price elasticity of demand of natural gas instead of that of electricity in modeling the demand of natural gas.

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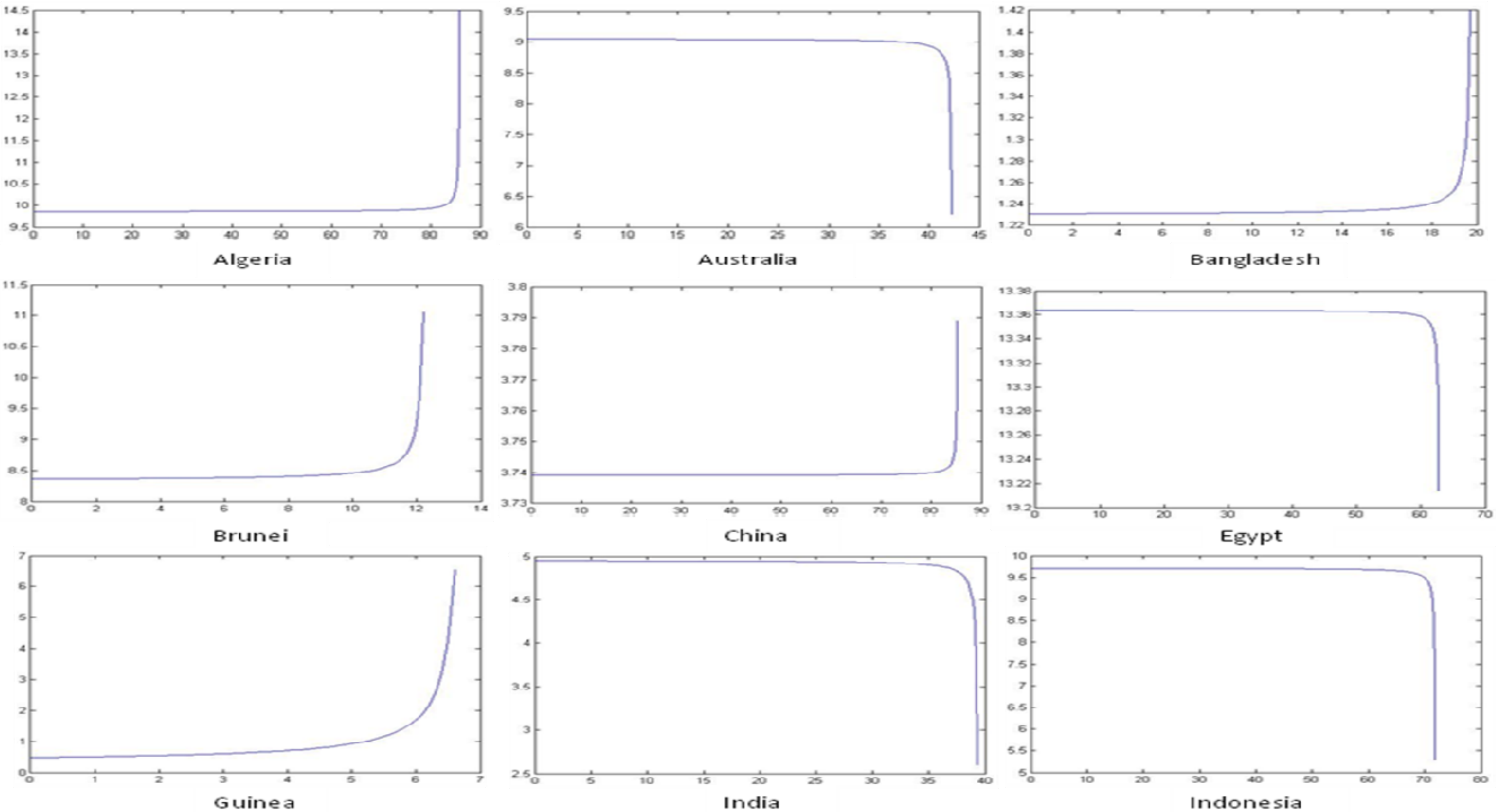
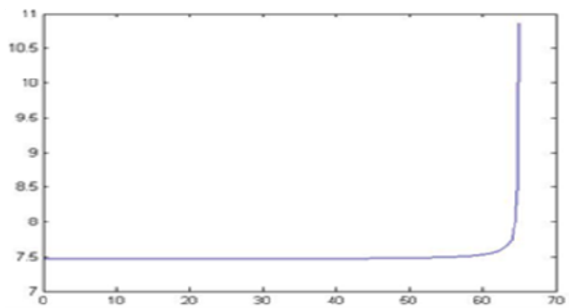
Appendix A.   Estimated Marginal Cost of Suppliers





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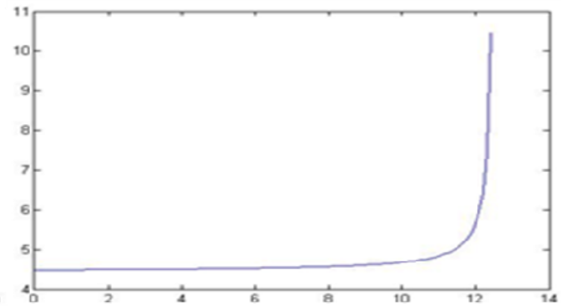

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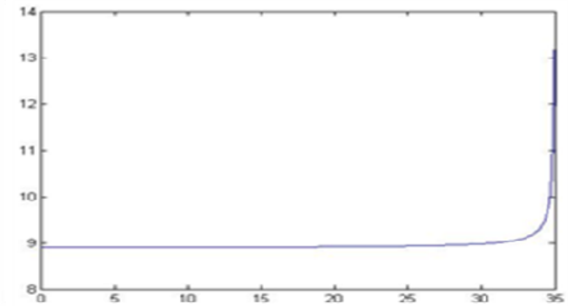

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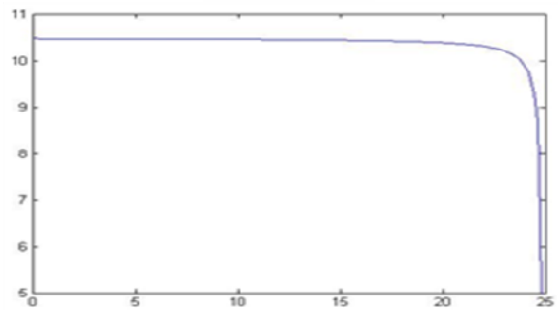

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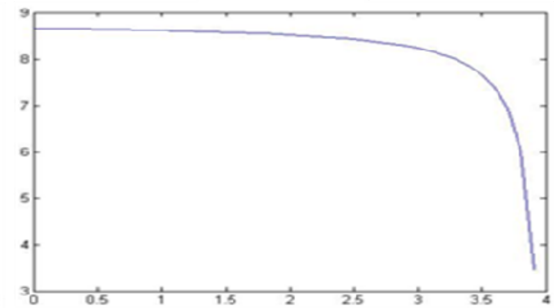

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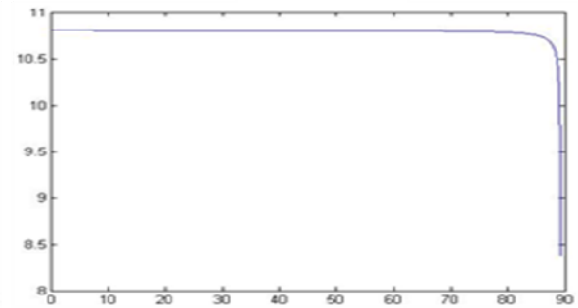

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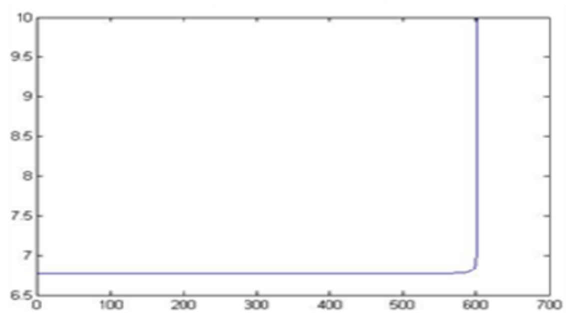

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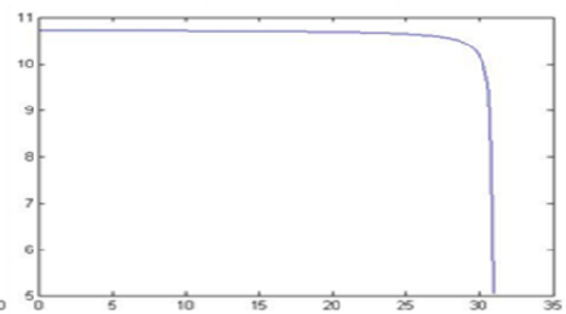

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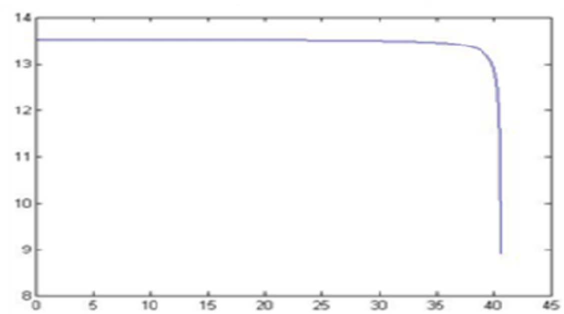
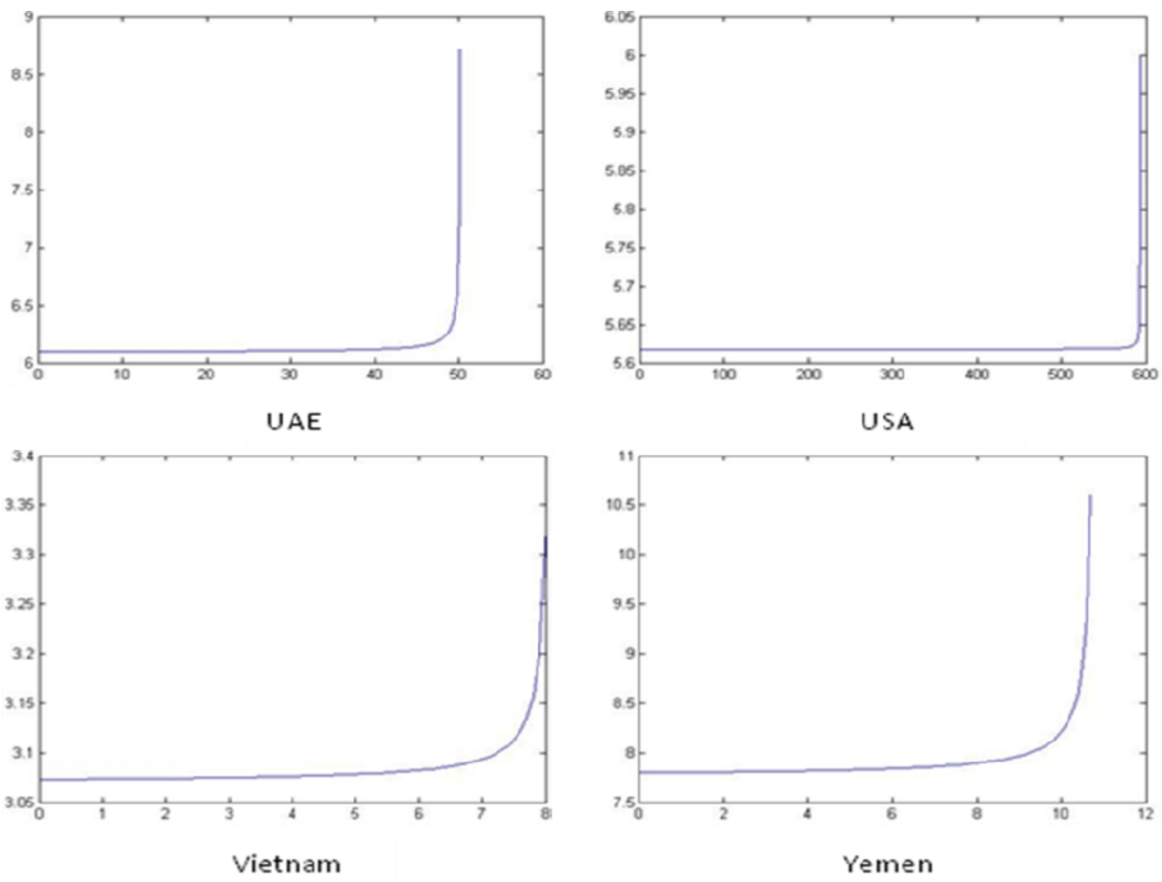
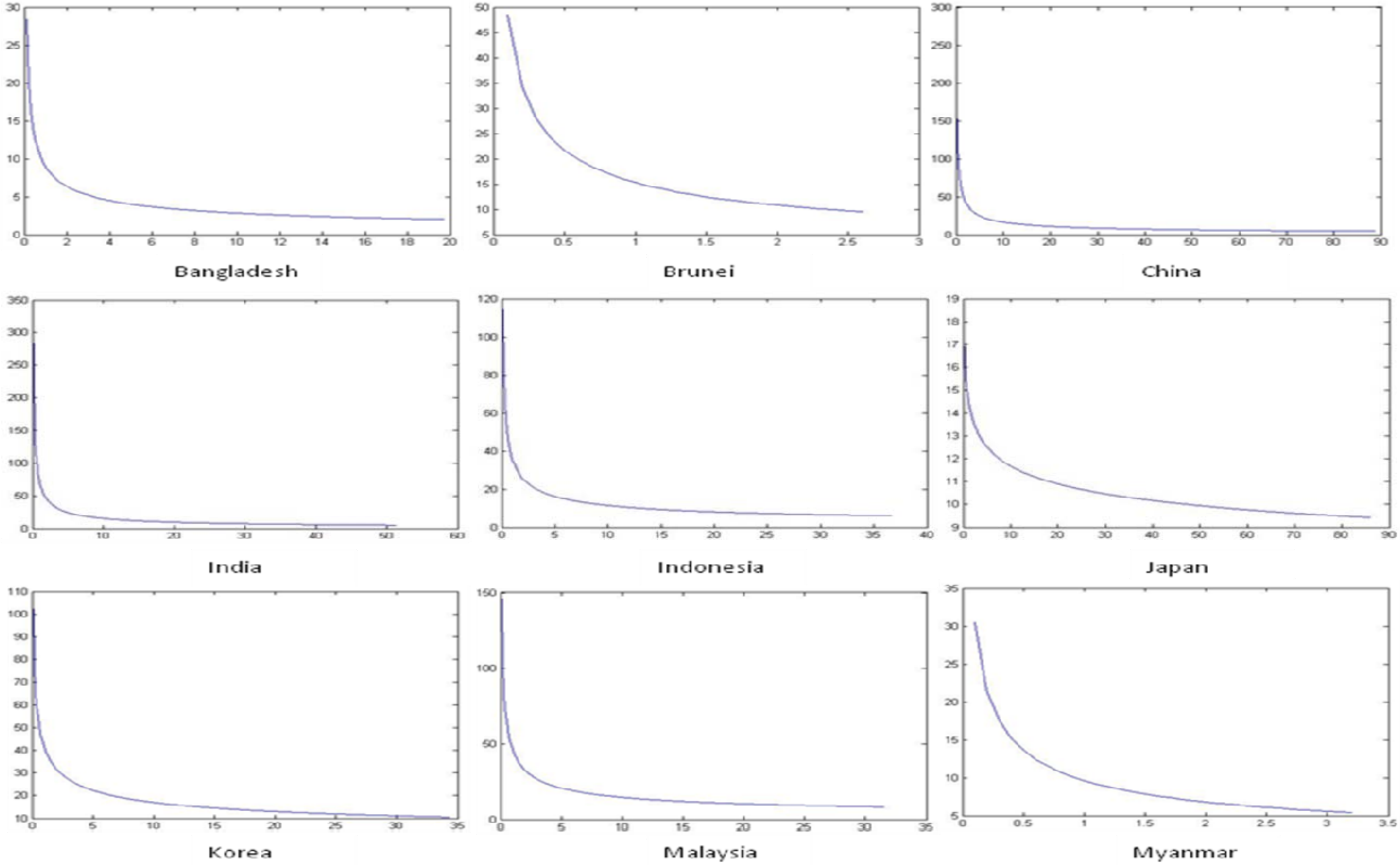
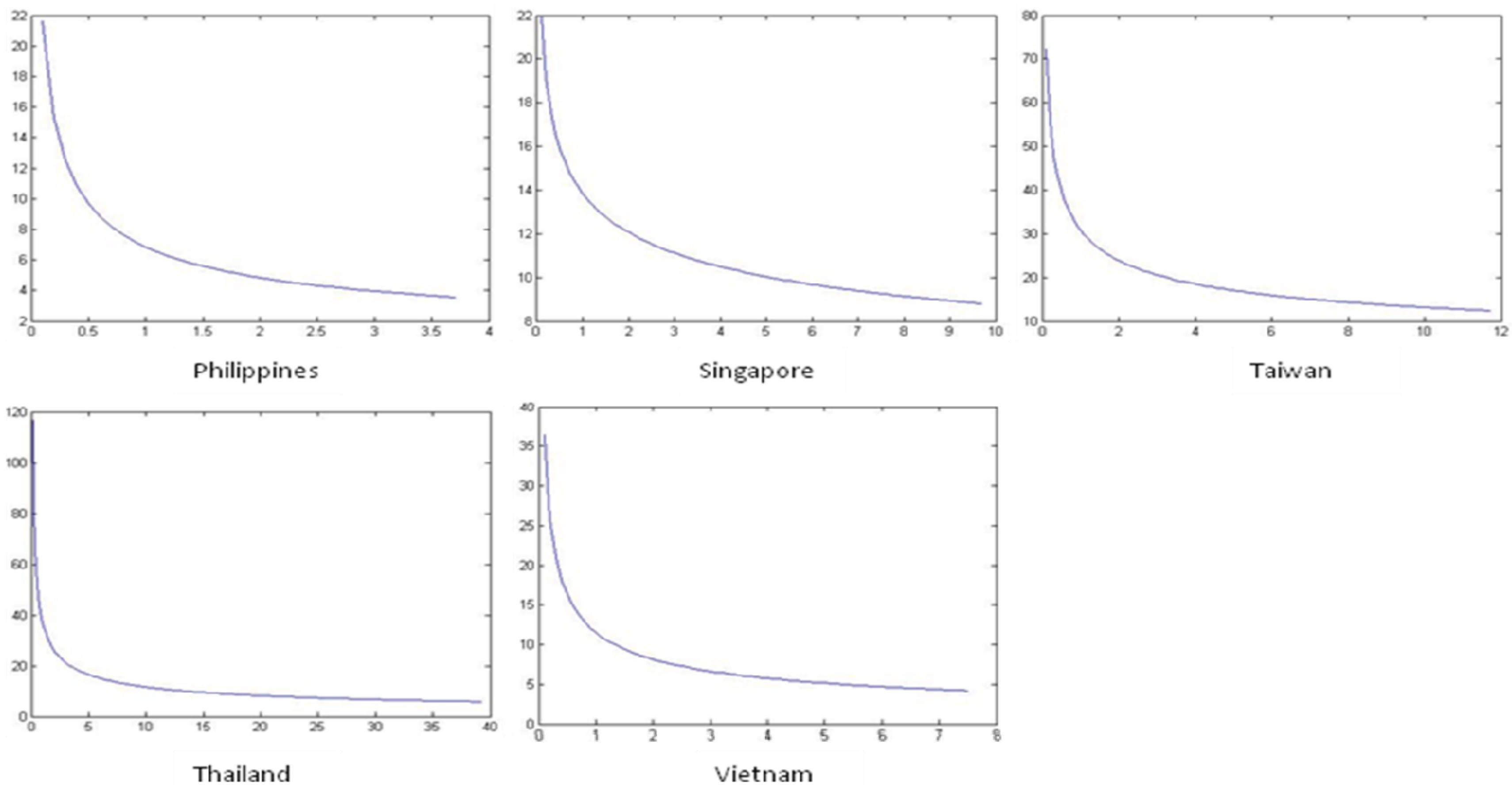


Tobago


UAE
USA
Vietnam
Yemen

Appendix B. Estimated Demand Function of Countries in the Region




Philippines
Singapore
Taiwan
Thailand
Vietnam

CHAPTER 10

Effect of Energy Price Increase on East Asian Region's Food Industries' Interconnectedness and Integration

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The most immediate effects of energy price increase ripples in many production systems is traceable from the intermediate demand sector of an economy. In particular, the production of agriculture, manufacturing, services and several other sectors portray significant energy utilization in their inter industry relationship. We focus our study on the effect of an energy price increase on interconnectedness and integration of the East Asia (EA) region's economy with emphasis on food industries. It draws together findings from selected EA countries in three different approaches. These approaches mainly employs an input-output (I-O)-based methodology with the latest extended version to examine the effect of rising energy prices onto food and non-food sectors' energy intensity, sectoral performance as well as retail price. We find that developed EA countries had demonstrated consistent performance having lower energy intensity, higher generating capacity and resilient to price changes in times of higher energy prices. Based on these findings, the East Asian Summit is hopeful to deliberate on closing their gaps by increasing interconnectedness and integration under the framework of gradual and systematic energy market reform. This will enhance activities in stimulating energy efficiency, output generating capacity and firmer energy market to price volatility especially in developing EA countries. Regional governments can also adopt sectoral energy investment plans to bolster economic growth and consumption of more efficient and cleaner fuels.

1. Introduction

Energy has been for a long time a strategic commodity that has garnered importance over time and whose importance is only next to the national security of a nation. In addition, a voluminous body of literature had recognized that neither a nation nor a region could fully insulate itself from the effect of an oil shock. The most immediate effect of energy price increase is felt throughout an economy, even in the most basic of activities i.e. in the production of food, agriculture etc. Like all regions, the East Asia (EA) region, with emerging markets and Newly Industrialized Countries (NIC), aspires to be a fast expanding and food producing hub with wide-ranging capacities, nonetheless is vulnerable to increases in energy price, particularly to crude oil price hikes.

There exist issues that need to be dealt with by the EAS, particularly concerning competitiveness and efficiency in energy utilization. At one hand there are concerns on glaring disparity in energy and trade integration amongst EA countries particularly between developed and developing countries. On the other, there are potential measures for EA countries with diversified characteristics to undertake further integration routes that could enhance both their energy and inter-trade advantages. However, the main discussion of this paper lies on exactly how these different countries cope or vulnerable to energy price increase given their emphasis on different inter industry structure and at diverse stage of development.

Recently there has been an unsuccessful attempt towards integration in the region. Even though there are efforts to reduce trade barriers as ways to enhance economic integration as basically five stage of economic integration suggested by Balassa (1961), energy market integration (EMI) too could be enhanced by reducing barriers to interconnectedness and integration. Similarly in terms of successfulness of a common market (CM), the establishment of free trade in goods and services allows for the free mobility of capital and labor between member countries. Taking the most advanced type of economic integration such as the European Union as an example; the EAS must consider the responsibility for fiscal policy to a supra-national authority and adopt a common currency among member countries. These types of economic integration are also referred to as regionalism. Burfisher et al. (2003) describe a major transition from shallow to deeper economic integration in some regional trade areas (RTA). The old version of regionalization is based on traditional trade theory that describes trade creation versus trade diversion, as adopted from the Viner-Meade (1950, 1955) theoretical framework. The new regionalism focuses more on broader issues such as linkages between trade and productivity, rent-seeking behavior, the role of FDI and productivity growth and the integration between developed and developing countries.

Interestingly, Hamaguchi (2008) defines integration as a regional economy that is linked through interconnected networks of firms' productive activities. From business' point of view, activities may include different stages, starting with establishment of business concept, through to research and development, production and commercialization. The production process, in turn, consists of various intermediate goods (parts and components) and the final assembly. We define the term "production integration" as the production process that is physically divided into different units, but is united through systematic logistic arrangement. Such division is also called fragmentation in the literature of international trade (Jones and Kierzkowski 2000). However, distinguishing between food and non-food categories, the production system is more dynamic with food at the firm level, which is highly dependent on energy as an input of production. Developed and developing EA countries currently have different productive capacities in generating output.

Hamaguchi (2008) also posits that dividing the production process may be counter-productive because it increases administrative and logistic costs. Production integration is meaningful if the production process is composed of fractions with quite different resource intensity, because productivity of a firm should increase by allocating each fraction in the location where its most intensively used resource is abundant. The productivity gains from fragmentation are large if resource endowments are sufficiently different between countries; hence a firm can locate labour-intensive production process in an unskilled, labor abundant country and knowledge intensive process is in a country abundant in highly educated people. Therefore, this concept of integration warrants some interest in investigating chains of value added and imports shares of food and non-food production.

1.1. Terms of Reference

Our main objective focuses on the scope of EMI and examines its consequences during increases in energy prices. The study conducts an examination of the current state of the EAS energy market under the influence of increase in energy price and identifies the direct and indirect effects of such an increase, which subsequently affect energy intensity, sectoral performances and consumer food product prices.

1.2. Study Conduct

The study is undertaken in several steps:

- Initial desk studies of the food industries and energy requirement situation in selected 16 EAS countries.
- Country data and information collection by team members to setting-up profiles of food industries from the perspective of key energy policy makers and food industry personnel. This will yield insights into their priorities and concern, beyond the data and information from I-O tables and findings from the analysis. We generally succeeded in gathering key information on a few ASEAN countries, particularly Singapore, Thailand and Indonesia, with some interviews and telephone conversations for some countries. In addition, we drew upon our regional and local knowledge particularly on ASEAN countries, in particular of Malaysia, Singapore and Indonesia.
- This report combined I-O based simulations in three different models or approaches to form this final report.

1.3. Outline of Report

The report begins with an introduction to the EA food industry and its relationship with energy prices and an increase in EMI. Section 2 reviews some relevant literature on integration. Section 3 covers the methodology and framework of the study, highlighting the capability of an I-O based method. Section 4 focuses on results and findings on intensity, sectoral price effects and consumer food product prices and section 5 finally concludes with recommendations and future course of study.

2. Background of Study

2.1. EA and World's Food Share

EA countries exported 36.7 percent, imported 31.5 percent and produced 48.5 percent of global food production (FAO 2008). EA economies, especially developing countries, still endeavor to be fast growing food producers. The food sectors in the EA region have grown and integrated into a modern food-processing hub at the global level, generating income and revenue to the EA economies.

Beyond these benefits, there are issues of competitiveness and efficiency of utilizing energy resources between food and non-food industries. These issues has been exacerbate by oil price increases and it becomes critical to establish how best energy and domestic inputs are integrated and interconnected in the quest to cope with higher energy price while maintaining overall efficiency. Furthermore, food industry contributes significantly to other sectors in terms of input materials for further chains of production.

2.1.1. Rising Energy and Food Prices in EA

There are many studies that have revealed the significant correlation between an economy's performance and energy. Bernstein (1990) envisaged a recession could be triggered in the United States if oil price increased by US$40 and stayed at that level for 6 months. McKibbin (2004) predicted that a permanent double increase in oil price from the base of US$25 would cause OECD's real GDP to fall 1.6 per cent. In the EA region, Gan (1985) posits that the 1973-74 oil crises had adversely affected Malaysia which is at that time highly dependent on exports of commodities. Fong (1986) found that the oil crisis in 1974 affected OECD countries with a low GDP, widespread of inflation, and CPI as high as 13% in many OECD countries. Zakariah and Shahwahid (1994) indicated that fluctuation of export commodities during the Gulf War adversely affect the Malaysian economy especially in the 1990s. In July 2008, the CPI registered an increase of 8.2 per cent, driven by an increased oil price of US$145 per a barrel. In the same month of the subsequent year, the oil price falls with the CPI fluctuate to 5.2 per cent. A study from the Malaysian economic structure in 2000 shows that a doubling effect of oil price increase would raise competitive food markets by as much as 1.28% on particularly; Food & Non-Alcoholic Beverages items (Khalid, 2010).

2.1.2. The ASEAN Economic Community (AEC)

The end-goal of this long-standing initiative in economic integration set out in ASEAN Vision 2020 is the establishment of a single market and production base, with a strategy for economic integration throughout ASEAN and its international economic competitiveness. Components of efforts include:

- The ASEAN Free Trade Area (AFTA), which is not yet agreed upon;
- The ASEAN Framework Agreement on Services (AFAS), which assists trade and cooperation in services;
- The ASEAN Investment Area (AIA);
- Regional integration in about a dozen nominated production areas (which does not include energy);
- A road map for financial and monetary integration, covering the development of key financial market mechanisms and liberalization;
- A trans-ASEAN transportation network including major interstate highway and rail networks, and a roadmap for integration of the air travel sector;
- The promotion of interconnectivity and interoperability in telecommunications, information and communications, and cooperation on tourism and food security; and
- The promotion of trans-ASEAN energy networks, consisting of the trans-ASEAN gas pipeline (TAGP).

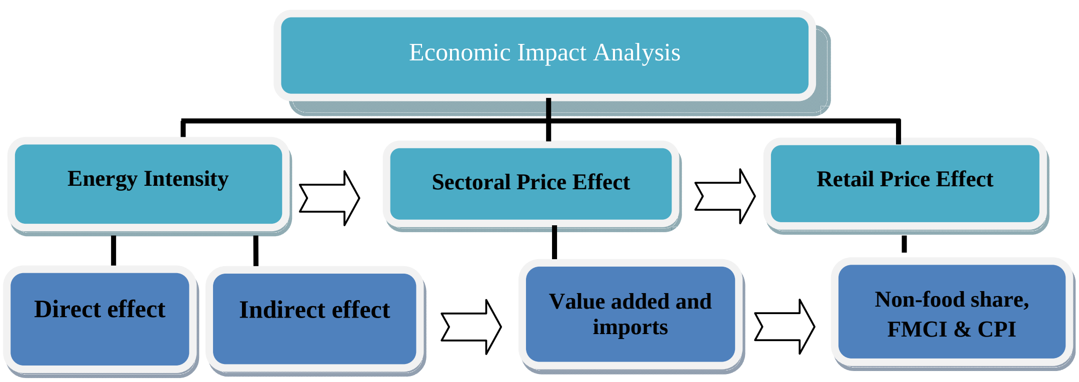
At the moment there has been little success in reaching these agreements and arrangements. An in-depth study of the above arrangements will assist efforts to enhance interconnectedness and integration and the achievement of vision 2020.

3. Methodology

3.1. Analytical Framework

The EMI has been defined in terms of developing more efficient and flexible markets to promote energy cost competitiveness, energy interconnectedness and cleaner energy. The EAS had proposed various efficiencies measures to enhance the process of integration such as *productive efficiency*[1], *allocative efficiency*[2] and *dynamic efficiency*[3]. However, our efficiency standpoint will be from the dimensions of energy intensity, sectoral inter industry capacity as well as price effects on consumer food products in times of increase in energy prices. To analyse this, we combine three different approaches represented by the following framework to present the said analysis illustrated as the following Figure 1.

Figure 1. Schematic Diagram of Analytical Framework



3.2. General Equilibrium and Market Efficiency in EA

The above three different dimensions in Figure 1 assume that there exist a general equilibrium environment in which households and firms maximize their objectives.

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[1] Productive efficiency occurs when a given level of output is achieved at the lowest optimum cost

[2] Allocative efficiency occurs when relative prices of different products (e.g. different fuels) are set equal to the cost of each extra unit of production, known as marginal cost. This means that firms or individual can opt for different fuel to achieve outcome for them (energy intensity). The rising oil price had effects on allocative efficiency in terms of energy intensity

[3] Dynamic efficiency is achieved when the appropriate expenditure achieves a balanced stream of increase overtime in line with increases in energy prices. Increase in energy generally has consequences for the disposable income of households

This will result in market equilibrium, where efficient utilization of resources will give the highest returns to both sides. In this light the I-O based model has been popularly used as a general equilibrium model and widely employed to exhibit inter industry relationship. Based on many I-O studies, a general framework such as illustrated in the above Figure 1 will able us to examine energy as inputs and its relationship between food and non-food sectors. For the purpose of this report, we firstly focus on how efficiently energy is used by employing energy intensity analysis and then on relative sectoral price changes for selected EA countries. Thirdly, we will examine the vulnerability of producers and consumers to changes in retail price of food, brought about by energy price increase.

There exist many global, regional and domestic energy markets operating in the EAS region. These multi-regional markets have varying generating capacities in its production system that includes competitiveness with a well-defined market structure and the interconnectedness of energy infrastructure between the EAS countries. An efficient market will operate uninterrupted by the oil price volatility, with the capability to diversify its resources and insulates its market against the effect of oil price increase. In contrast, a susceptible country to oil price volatility will have adverse effects that accrue not only to the economy itself, but will dampen enthusiasm for measures to increase competitiveness and integration. Thus, by examining this impact, mitigation measures may be formulated by the EAS to protect the most vulnerable.

3.3. Deriving Energy Intensity

The energy intensity model is constructed in a general equilibrium model replicating Leontief's final demand approach, which is estimated using the following basic I-O system of equations:

$$X = (I - A)^{-1} Y \qquad \text{..... (1)}$$

where X represent vector of gross output, $(I - A)^{-1}$ is the Leontief's inverse matrix (with I as identity matrix and A is the coefficient matrix) and Y is the vector of net final demand. In simple term, for every unit increase in production of food output (represent by X), a certain amount of input $(I-A)^{-1}Y$ is required for its production. Using this simple analogy, we can compute the interconnected input chains for each food industry. Next, we can compare the effect of energy prices in terms of direct and indirect effects and then sort their ranks from the highest to the lowest intensity.

The above-mentioned term “direct effect” refers to the initial results that emerge from requirements or inputs in production. The sum of direct and indirect inputs is normally called the indirect effects[4] (United Nations, 1999). In these direct and indirect effects, income is accrued as a result of the initial change in final demand. Spending increased income triggers another round of economic activity. This additional round of economic activity generates output, income and employment. The economic effects resulting from re-spending of accrued income are known as induced effects.

These induced effects, or as multiplier effects, allow for determination of the full effects or total impact resulting from any change in final demand. Assuming that the national economy is subdivided into food and non-food which can be read from the column entries, the energy increase can be read from the row-wise as in Table 1.

Table 1. Inter industry matrix of an I-O model

Item	*Purchasing sector: Food and Non-food*	Total Intermediate	Final Demand	Total Output
Producing sector: Energy	1 x_{11} $x_{12}\ldots x_{1n}$	W_1	Y_1	X_1
	2 x_{21} $x_{22}\ldots x_{2n}$	W_2	Y_2	X_2
	3 x_{31} $x_{32}\ldots x_{3n}$	W_3	Y_3	X_3
	…	…	…	…
	N x_{n1} $x_{n2}\ldots x_{nn}$	W_n	Y_n	X_n
Total Inputs	U_1 U_2 $U_3\ldots U_n$			
Primary Inputs	V_1 V_2 $V_3\ldots V_n$	V	V	
Total Production	X_1 X_2 $X_3\ldots X_n$	Y	X	

Source: Miller and Blair (1985)

Table 1 illustrates that both the food and non-food sectors’ final demand requirement for its output generates direct and indirect effects on the economy. We can see this inter industry interaction through the purchasing sector (row-wise). In this

[4] Inputs and effects are termed differently in this context. Inputs such as direct inputs can be in a form of energy directly use such as oil, gas, coal and gas at the initial point in the production processes. Indirect inputs are inputs releases from repercussions from the direct effect into other forms such as petrol products, electricity, etc., which in turn require various production processes and in turn requires again another cycle. Whereas, direct and indirect inputs is normally classified under indirect effects since both will mostly produce energy in the form of indirect effects from chains of processes. Reference: Handbook of I-O table compilation and analysis by United Nations, New York 1999. Series F, No.74.

arrangement the initial effect is the direct effect and is followed by induced effects. Similarly, the column-wise orientation constitutes energy as inputs used for producing food and non-food output. For example, in producing a targeted amount of goods and services, we have to plan inputs in the production process that include fuels as a direct energy and non-energy goods and services. The non-energy inputs again include some fuels and goods and services in their producing processes. These processes traces inputs back to primary resources; the first round of energy inputs or is called the direct energy requirement. Subsequent round of energy inputs comprise the indirect energy requirements.

In the I-O framework, the total energy requirement is obtained through the estimation of "energy intensity" in inter industries activities employing the conventional Leontief's inversed matrix. In the recent extensions of I-O energy analysis, more and more studies are focused on energy intensity measured in physical units. In summary, the energy intensity is measured in terms of how much direct and indirect effects of using energy as inputs in the production of food output.

3.4. Sectoral Price Effects

In order to examine sectoral price effects in the midst of rising energy prices, we employ the modified Leontief's price system (MLPS). The system assumed a general equilibrium environment where internal factors are unchanged and remaining prices in the oil industry are exogenously set in the equation $P_X = A'P + v + m$. When we assume P_X to be totally exogenous we are preventing any feedbacks onto energy use. In many EA countries, energy use would particularly be crude oil, natural gas and coal. Prices for these products are established in world markets (dominated by OPEC in the case of oil and Japan in the case of coal). To copy this exogeneity, we drop the P_X equation from the price system and thus, we partition the price of oil, P_X , into exogenous and endogenous divisions as follows:

$$\begin{pmatrix} P_X \\ P_E \end{pmatrix} = \begin{pmatrix} a_{xx} & \mathbf{A'}_{EX} \\ \mathbf{A'}_{XE} & \mathbf{A'}_{EE} \end{pmatrix} \times \begin{pmatrix} P_X \\ \mathbf{P}_E \end{pmatrix} + \begin{pmatrix} v_X \\ \mathbf{v}_E \end{pmatrix} + \begin{pmatrix} m_X \\ \mathbf{m}_E \end{pmatrix} \quad \text{... (2)}$$

where;

P_X = *price index for energy as an exogenous variable*;

$\mathbf{P_E}$ = (*n-1*) x *1* column vector of basic prices in the endogenous sectors;
a_{xx} = *input requirement of the energy sector from its own output*;
A'_{EX} = *1* x (*n-1*) row vector of the input requirement from *n-1* endogenous sector for the production of one unit of energy;
$\mathbf{A'_{XE}}$ = (*n-1*) x *1* column vector of input requirements from energy products sector for the production of one unit of output in each *n-1* endogenous sector;
$\mathbf{A'_{EE}}$ = (*n-1*) x (*n-1*) "square matrix" of the Leontief's domestic direct coefficients of the *n -1* endogenous sector;
v_X = *ratio of value added to the output in the energy sector*;
$\mathbf{v_E}$ = (*n-1*) x *1* column vector of value added ratio to output in the endogenous sector;
m_X = *ratio of imported inputs to output in the energy sector*;
$\mathbf{m_E}$ = (*n-1*) x *1* column vector of imported inputs ratio to output in the endogenous sectors; and
n = number of sectors i.e. 40 in our aggregation scheme.
Note: Italics to term for exogenous effect, non-italics for endogenous effect.

Next, we run equation (2) endogenously:

$$P_E = (I\text{-}A'_{EE})^{-1} A'_{XE} P_X + (I\text{-}A'_{EE})^{-1} (v_E+m_E) \qquad \text{….. (3)}$$

We use suitably aggregated sectors of the 2005 I-O table to simulate the impact of oil price rises by employing the MLPS. For simplicity, we use the 2005 OECD I-O tables with 48 sectors in selected EA countries. These tables provide the most specific sector decomposition that relates to oil classification, i.e. "energy". Thus in terms of specificity, MLPS analysis refers to the Mining and quarrying (energy) sector. These sectors represent crude oil or petroleum. This is suitable for our purpose since we need an exogenous sector that affects both the food and non-food sectors, although they generally do not use crude oil directly as inputs in their production.

3.4.1. Simulating Sectoral Price Effects

The MLPS works column-wise if we read from the I-O tables. Some caution should be taken with some basic I-O assumptions i.e. homogeneity of output, particularly on types of food, zero rates of substitutions between energy inputs, fixed proportions between input and output, absence of economies of scale and linearity of coefficient and final demand component. However, if the single input structure is violated, then the general rule is that choices made must to preserve the basis of the single input structure. The degree of aggregation adopted depends on many factors such as the purpose of study, availability of data, time and resources available. Detailed information is highly aggregated but, in general, the greater the degree of detail, the greater is the likelihood of substitution between sectors. However, the most desirable aggregation uses a commodity classification, which has a single input structure.

An example of how a price mechanism works can be shown by O'Connor and Henry (1975), who offer a simplified equation to portray price effects using the original Leontief's price equation, $P = [(I\text{-}A)^{-1}]' \; (\pi b)$. Although the MLPS is very much similar to this equation, the system is more varied as it provides endogenous and exogenous effects as the above-mentioned equation (3):

From the I-O tables we can the derive price of energy, P_E if we run equation (3) based on the following illustration diagram of *n-1* columns:

$$\underset{(nx1)}{PE} = \underset{(n\,xn)}{(I\text{-}A'_{EE})^{-1}} \; \underset{(n\,x1)(1x1)}{A'_{XE}\,P_X} + \underset{(nxn)}{(I\text{-}A'_{EE})^{-1}} \; \underset{(nx1)}{(v_E+m_E)}$$

$$\underset{(40x1)}{\begin{pmatrix} P_{E1} \\ \\ . \\ . \\ . \end{pmatrix}} = \underset{(40x40)}{\begin{pmatrix} a'ee_1 \\ \\ . \\ . \\ . \end{pmatrix}} \text{x} \underset{(40x1)}{\begin{pmatrix} a'xe_1 \\ \\ . \\ . \\ . \end{pmatrix}} \underset{(1x1)}{\begin{pmatrix} 1 \\ \\ . \\ . \\ . \end{pmatrix}} + \underset{(40x40)}{\begin{pmatrix} a'ee_1 \\ \\ . \\ . \\ . \end{pmatrix}} \text{x} \underset{(40x1)}{\begin{pmatrix} ve_1 \\ \\ . \\ . \\ . \end{pmatrix}} + \underset{(40x1)}{\begin{pmatrix} me_1 \\ \\ . \\ . \\ . \end{pmatrix}} \quad ...(4)$$

To endogenize the price system, we take out the Mining & quarrying (energy) sector, representing the exogenous energy sector, leaving the non-energy or endogenous sectors. The next step is to run the inverse on *(I-A'EE)* matrix and A'_{XE} multiply by P_x. This product will then be added to the multiplication of (*I-A'EE)* and (v_E + m_E) resulting with unity representing a balanced matrix. *P*x is then multiplied by two to simulate a double increase in energy price. The MLPS shows results of direct and indirect impact for both 2000 and 2005 with results on both value added and import share of output. We expect to gain some insight on EA countries' sectoral price effects and output generating capacity in this exercise.

3.5. Retail Price of Food

Unlike the above two models discussed in the earlier sections, the price-spread model is a short-run model which classifies 10-food-industries to estimate the impact of changes of input prices onto consumer food product prices. As a short-run model, it is assume that consumers do not respond to retail price changes, whilst food producers do not alter input proportions despite changes in relative input prices. Furthermore, output of each industry serves only as a final consumer of food products[5]. In our price-spread model, we compute 10 components of food industries in each EA country as categorized in their respective CPI to estimate price changes on retail price. Each firm of the respective 10 final food industries produces a single product by combining a farm commodity with a set of non-farm inputs in fixed proportions. In this model, consumer demand is fixed for all levels of retail price. These simplifying assumptions reduce the computation of a food price estimate to an evaluation of an accounting-type formula. This formula states that the percentage change in the retail price is a weighted sum of the percentage changes in input prices, with cost shares (e.g. from the Malaysian I-O tables, 2005) serving as weights:

$$P_R^* = P_F^* s_F + P_x^* s_x \qquad \text{..... (5)}$$

where s_F *and* s_x represent the cost shares of the food and non-food inputs, respectively, and where P_R^*, P_F^*, P_x^* denote the percentage changes in the retail, the food price, and the aggregate non-food price, respectively. The variable P_x is the food marketing cost index (FMCI), or the average price of the aggregate non-food input. The above formula asserts that a 1-percent increase in the FMCI leads to a s_x-percent increase in the retail price.

Energy is one of several non-food inputs used to produce food, and the price of energy is approximately about one-twelfth of non-food input prices used to construct the FMCI (i.e. P_x). Suppose that food is produced using a single food input and a single aggregate or representative non-food input, with a price equal to the FMCI. If this

---

[5] This assumption simplifies that each industry's output serves only at that respective final consumer of food product. Thus, we can examine each of the 10 components of food industry's retail price changes from increase in energy price.

single non-food input is produced from individual non-food inputs in fixed proportions, the retail price formula given by equation (5) above can be extended directly to:

$$P_R^* = P_F^* s_F + P_x^* s_x = P_F^* s_F + \boldsymbol{(P_E^* s_E + \sum_{i=3} P_i^* s_i)\, s_x} \qquad \ldots\ldots (6)$$

where s_E and s_i are the non-food cost shares of energy and the *i*th non-food input, and P_E^* and P^*_i are the percentage changes in energy and the other non-farm input prices, respectively. The sum in the parentheses of equation (6) represents the percentage change in the FMCI (i.e., P_x^*), and the shares of each term serve as weights on the individual input prices[6]. Equation (6) states that the percentage increase in the consumer price of food is the weighted sum of the percentage change in the price of the food ingredient, the energy price, and the other non-food input prices comprising the FMCI. At this point, it is convenient to describe the main difference between the price-spread and intensity models. The term, $P_E^* s_E$ in equation (6) is referred to as the direct effect because it denotes the energy cost increase incurred by producers of the aggregate marketing input[7].

$$\boldsymbol{\Sigma c P_i^* s_i}, \qquad (7)$$

The second term is referred to as the indirect effect because it measures the effect of a rising energy price on the costs of other inputs used in producing the marketing input. For example, because energy is used to produce food packaging, the cost of packaging will rise with higher energy prices. In a typical price-spread model simulation, the indirect effects would be zero since the price of energy does not affect the price of other marketing inputs. In a typical I-O model simulation, a change in the price of crude oil could affect the price of all other inputs used in the production of food.

Since we wish to impose the same exogenous change on the two models, we include the indirect effects of energy increase in both model simulations. In particular, we used the I-O model's prediction of the percentage change in energy intensity whilst also using the FMCI in the price-spread model to estimate the effect of a doubling of the crude oil price. The price-spread model simulation suggests that a doubling of the price

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[6] The weights are the derived from averaging the inverse matrix of two main energy-related sectors'.
[7] $S_x\, P_F^* S_F$ is the direct effect of the energy price increase on the average cost of producing the food product.

of crude oil leads to a 1.483 percent increase in the FMCI in 2000. This predicted increase in the FMCI is used in the price-spread model simulations, whereas, the intensity analysis uses at least three energy sectors in its total impact.

3.6. Construction of Models

Table 1 is constructed by employing I-O analysis using selected EA data and information from the OECD I-O table 2005. The data from the I-O table is classified and aggregated according to the product lists in the EA's CPI. Using the inverse matrix table, we calculate intensity of each food industry using Crude oil, petrol & coal products and Electricity & gas by their input proportion. This estimate is used as a proxy for the total multiplier of energy for the whole economy. Next, the I-O table is used to produce the cost share of non-food and the average of energy price, or the FMCI. We take 10 food industries[8] from the I-O tables using the CPI classification and insert these figures into equation (6).

Table 2 summarizes the steps involved in using the price-spread model to compute an estimate of the effect of a 100 percent increase in the price of crude oil on the CPI for food at home. The non-food cost share is reported in column (1), and the 1.483 percent figure reported in column (2) is taken from the I-O model simulation from two energy sectors, mainly Petroleum products & coal and Electricity & gas, which serve as the total impact of energy multiplier in our model. Column (4) is the product of the three columns (1), (2) and (3), which individually represents the percentage change in the retail price of each industry. Column (3) reports the Department of Statistics (DOS) expenditure weight associated with each Food and Beverages industry.

3.7. Data and Measurement

This study uses secondary data, which is mostly sourced from OECD and various selected EA countries' statistical agencies, for example the Department of Statistics (DOS) in Malaysia and Singapore. The I-O based model primarily employs the Malaysian I-O tables 2005 published by the Department of Statistics in 2010. We also employ other data from statistics agencies to put up patterns on demand and

[8] Out of 11 food products in the CPI, we managed to classify 10 food industries, which were aggregated from the 120 by 120 sectors of the Malaysian I-O table, 2005.

consumption of petroleum products. Oil is classified under classification number 11100-01 includes crude oil, natural gas and coal in the Malaysian Classification of Products by Activity (MCPA) 2005 which is compliance to other international standards of classification. In line with the purpose of this paper we use Petroleum product & coal and Electricity & gas to proxy for energy prices. For 2005, since there are changes in classification, we use the transport sector's total effect to portray the nearest output multiplier of energy input price in terms of average and incorporate this as FMCI. The data and measurements used are tested for stability to ensure the robustness and validity of the analysis.

4. Results and Findings

4.1. Energy Intensity

The I-O analysis provides as a useful means to trace the footprints of energy use and related energy activities. It assists in determining direct and indirect energy utilization in the production chains of goods and services. Thus, the production target of goods and services can be met by combination of inputs, including fuels as one component, that produce direct energy and non-energy goods and services as another component. The non-energy inputs again include some fuels and goods as well as services for production processes. These effects ripple in the economic system forming total effects originating from an initial increase in the final demand. The initial effect or similarly called direct effect for the selected EA countries is as shown in the following Table 2.

Table 2 shows that energy use in terms of coefficient of direct energy effects that arises from an increase in final demand for selected EA countries in 2005. Take Japan for example, for every $1.00 increase in final demand for the output of food sectors, 2.4 cents worth of energy is required. An average of 4 cents is needed by Japan to produce non-food output. Thus, by ranking these direct energy use amongst EA countries, the highest energy use is found for Thailand in production of food and likewise for

Indonesia in non-food production. However, Indonesia has the lowest direct energy effect in food production with Malaysia has the lowest direct energy effect for non-food.

Table 2. Direct Energy in food and non-Food Production for Selected EA Countries, 2005 (by rank)

Direct energy in food and non-food production			
Country	**Food**	**Country**	**Non-food**
Thailand	0.0591	Indonesia	0.0768
China	0.0382	Thailand	0.0677
Taiwan	0.0359	China	0.0638
Korea	0.0313	Taiwan	0.0503
Australia	0.0277	Korea	0.0471
Malaysia	0.0264	New Zealand	0.0408
Japan	0.0243	Japan	0.0375
New Zealand	0.0145	Australia	0.0274
Indonesia	0.0112	Malaysia	0.0055

Table 3. Thailand's Total Energy Used in Producing Food for a $1 Increase in Final Demand in 2005

Energy input	Sector 4-Food products, beverages & tobacco	Sector 32-Hotels & Restaurants
2 Mining and quarrying (energy)	6.04	29.45
8 Coke, refined petroleum products and nuclear fuel	6.10	39.32
26 Production, collection and distribution of electricity	4.25	9.00
27 Manufacture of gas; distribution of gaseous fuels through mains	1.12	2.43
Average	4.38	20.05

We use selected energy sectors[9] as found in the 2005 OECD's I-O tables representing energy[10] in selected EA economies. The following total effect of energy intensity in Thailand is exhibited in Table 3. Holding other factors as constant, for every $1 of food output in the final demand, Thailand needs 6.04 cents of inputs from

[9] Specifically, sectors 2, 8, 26, 27

[10] Energy used varies between developed and developing EA countries with former used more secondary energy than latter which utilizes more primary energy like crude oil and natural gas. Thus, energy intensity in terms of primary energy for developed countries is maintained at low intensity. Nevertheless, one can aggregate this different energy level from the I-O table to obtain better results.

Mining & quarrying (energy), 6.1 cents from Coke, refined petroleum products and nuclear fuel, 4.25 cents from production, collection and distribution of Electricity, as well as 1.12 cents from Manufacture of gas and distribution of gaseous fuels through mains. Similarly, in order to produce non-food industry's output, Thailand need a higher amount of energy, on average 5 times greater than the requirement to produce food. Therefore, energy inputs are less intensively used in Thai food productions.

Table 4. Total Energy Intensity in Food and Non-food Production for Selected EA Countries, 2005

Country	Food	Country	Non-food
Taiwan	0.2677	China	0.3163
Thailand	0.2104	Taiwan	0.3138
China	0.1980	Thailand	0.2592
Korea	0.1613	Korea	0.2240
Indonesia	0.1488	Indonesia	0.2060
Malaysia	0.1048	Malaysia	0.1270
Australia	0.0960	Japan	0.1222
Japan	0.0844	Australia	0.0970
New Zealand	0.0815	New Zealand	0.0896

Table 4 shows that for every dollar increase in the final demand for food products will result in direct and indirect output of energy to increase by 26.8 cents in Taiwan. Taiwan has the highest average total energy impact in food production amongst the selected EA countries. New Zealand ranked lowest effect from energy increase of only 8 cents in production of food. Non-food production in China (31.6 cents) ranked the highest whereas New Zealand again had the lowest effect (9 cents) with energy increase.

These processes trace inputs back to primary resources. The first round of energy inputs, which is the direct energy requirement and the subsequent round of energy inputs comprise of indirect energy requirements. In the I-O framework, computing the total energy requirement is called measuring the "energy intensity" of industries which is analogous to computing the total energy requirement or Leontief's inverse of the traditional I-O model. In energy, I-O analysis more often are concerned with energy measured in physical units.

Table 5. Average Grand Total of Energy Intensity in Food and Non-food Production for Selected EA Countries, 2005

Selected EA countries	Average grand total for food and non-food
New Zealand	0.1132
Australia	0.1241
Malaysia	0.1319
Japan	0.1342
Indonesia	0.2214
Korea	0.2319
Thailand	0.2982
China	0.3082
Taiwan	0.3339

Assuming other things are fixed, Table 5 shows that on average New Zealand has the overall lowest energy intensity amongst the selected EA countries. It uses only 11 cents on average for both energy input costs in producing food and non-food amongst the EA countries. At 33.4 cents, Taiwan pays the most for its energy inputs amongst the selected EA countries and exhibits the most intense energy input utilization for each unit of output produced.

In summary, for every unit of food output there are variations of unit of energy inputs used by the EA countries' food industries in producing food and non-food output. This study reveals that selected EA countries like New Zealand used lower unit of total energy inputs in producing food compared to countries like Taiwan.

4.2. Sectoral Price Effects

In line with our second objective in examining the effects of energy price increases on sectoral performance, we focus our attention on how an exogenous increase in energy prices affects prices in other sectors. An exogenous increase in energy price directly and indirectly pushes up cost of production of food and non-food. The cost of production will be affected in terms of value-added and imported inputs. Based on the selected EA countries, we obtain interesting findings with regards to different value-added and imported input content per unit of output, which will finally affect their sectoral performance.

4.2.1. Case Study 1: Malaysia and Singapore

Malaysia and Singapore are very close proximity neighbours despite of their differences in economic structures and distribution networks. While Malaysia is endowed with arable land, labour and resources, Singapore at the other end comprise of a small island, lacking of labour and natural resources factors. Nevertheless, Singapore has built considerable human and physical capital-base to generate its economy's output. Although Malaysia is an oil-exporting country and Singapore mostly imports its energy need, similarly both were vulnerable to the increase in crude oil price. The following Table 6 illustrates this point.

Table 6. Total Effects of Increase in Oil Price for Malaysia and Singapore, 2005

Malaysia				**Singapore**			
Total effects	VA'* (I-A)	M'* (I-A)	M/ VA	Total effects	VA'* (I-A)-1	M'* (I-A)-1	M/V A
Food Crops	0.829	0.162	0.195	Food preparations	0.402	0.595	1.478
Vegetables	0.715	0.274	0.383	Bread, biscuits & confectionery	0.559	0.439	0.784
Fruits	0.828	0.161	0.195	Sugar, chocolate & related products	0.300	0.699	2.332
Poultry Farming	0.754	0.232	0.307	Oils & fats	0.240	0.759	3.155
Other Livestock	0.804	0.186	0.231	Dairy products	0.447	0.552	1.234
Fishing	0.747	0.224	0.300	Coffee & tea	0.408	0.590	1.444
Meat and Meat Production	0.721	0.257	0.356	Other food products	0.423	0.575	1.359
Preservation of Seafood	0.674	0.292	0.434	Soft drinks	0.484	0.513	1.061
Preservation of Fruits and Vegetables	0.652	0.324	0.497	Alcoholic drinks & tobacco products	0.568	0.426	0.751
Dairy Production	0.518	0.455	0.878	Food & beverage services	0.718	0.279	0.388
Oils and Fats	0.730	0.236	0.323				
Grain Mills	0.530	0.442	0.834				
Bakery Products	0.606	0.358	0.591				
Confectionery	0.453	0.528	1.165				
Other Food Processing	0.566	0.394	0.695				
Wine and Spirit	0.495	0.340	0.688				
Soft Drink	0.496	0.468	0.944				

Source: DOS, I-O Table 2005 and OECD
Notes: Highlighted M/VA is impact more than 1.0 index

The direct effect of value added and imports for both countries varies differently for each economy correspondingly. Malaysia, which is more resource-based economy compared to Singapore, exhibits a different magnitude of total effect across sectors, particularly in terms of effects having measures of coefficient which is greater than one (i.e. confectionery as highlighted). Singapore has seven food sectors scoring more than one and, including Oil & fats which is 3.16. More detailed information regarding direct and indirect effects can be found in Table 11, in Appendix 1.

In addition to Table 6, the subsequent Table 7 shows differences in the components of food industries from food crops to soft drinks for Malaysia, which were mainly focus on producing resource-based commodities like vegetables and fruits. Each food commodity is evaluated using direct and indirect effects with each owns a share of value-added, imports and relative imports over value added showing how it performed relatively in these two variables. In Malaysia, these ranked food commodities, particularly the resource-based food industry, has the highest rank followed by process-based commodities.

Table 7. Malaysia: Direct Effect of Value Added Share by Rank, 2005

Food Sector	Value-Added
Food Crops	0.608
Vegetables	0.570
Fruits	0.557
Other Livestock	0.528
Fishing	0.502
Poultry Farming	0.483
Wine and Spirit	0.277
Preservation of Fruits and Vegetables	0.255
Confectionery	0.236
Preservation of Seafood	0.231
Bakery Products	0.202
Soft Drink	0.202
Other Food Processing	0.194
Meat and Meat Production	0.182
Dairy Production	0.162
Grain Mills	0.143
Oils and Fats	0.120

Source: Calculated from I-O Table 2005, DOS Malaysia

The resource-based orientation in food products are more widely spread in Malaysia, be it in supermarkets, flea markets and small stalls. The alternative, mechanization and food manufacturing, constitutes only a small portion of domestic output. Usually these manufacturing-based food processes contain inputs of high imported portion as shown by the highest contribution in the import column and high relative imports to value added, as in the third column of Table 6.

In terms of indirect effects, the Oils & fats industry and Meat & meat production sectors are mostly influenced by a double increase in oil price. This means that energy price shows substantial influence in the production of these food commodities. Surprisingly, Confectionery scores more than one and the highest total effects in the relative measure. This may be possibly brought about by greater spending on imported inputs.

There are 10 types of food commodities illustrated in the Singapore 2005 I-O Table. Food & beverages ranked the highest for the direct effect in value-added followed by Bread, biscuits & confectionery. Whilst, in terms of imports, Oils & fats ranked the highest followed by Sugar, the relative measure of import share over value-added shows that almost all commodities scored more than one, except for Alcoholic, Food & beverages and Bread. The indirect effect depicted that only Oils & fats have a relative measure greater than one. We also find that almost all of the total effects scored more than one, showing a high influence of inputs sourced from foreign or external markets.

Analysis: Interconnection and Integration between Malaysia and Singapore

As EA countries become more developed, the share of food inputs imported for food production increases. Thus, less developed countries have low import content but a more developed country such as Singapore has higher import content in its direct food production. In general, in terms of total effects, the share of inputs differs according to whether a country is more developed or less, having similar results to those found in UNIDO[11].

The direct and indirect effects have different magnitudes in the food industry. For Singapore, the attention has always been more on manufacturing-based products whilst Malaysia is still largely concentrating on resource-based products. As gaps between direct and indirect effects become widened, an efficient economy will aspire to higher end product development and value chains, leading to higher efficiency and integration.

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[11] *Source*: UNIDO Working paper 19/2009
Notes: UNIDO figures based on IDE I-O tables, 2009

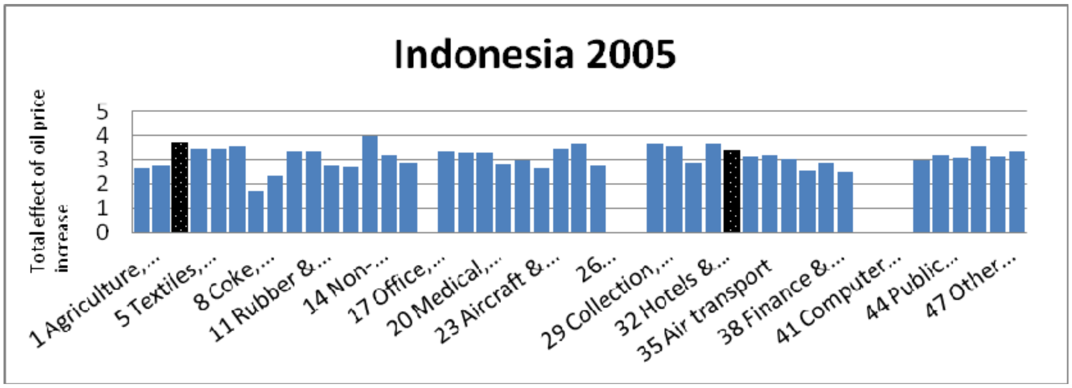
4.2.2. Case study 2: Indonesia, China and Japan

Analysis on performances of Indonesia, China and Japan in generating food and non-food products can be deduced by employing MLPS on their respective I-O Tables 2005. By 48 sectors into two dimensions: food products and non-food products, with beverages & Tobacco and Hotels & restaurant as food sectors and others as non-food sectors from the I-O tables. Next, we simulate interaction in endogenous price effects by making the energy sector i.e. sector 2 exogenous. Assuming other things fixed, for every increase in energy price, Japan generated a total effect of 4.898 for food and 3.61 for transport as shown in Figure 2 exhibiting a higher effect from increase in oil price.

Analysis: Performance of Indonesia, China and Japan

Figure 2 shows the total effect of energy increase in Indonesian food industry sectors. In sum, the total effect on food sector in Indonesia is bigger than China and Japan. This is also substantiated by the fact that for every unit increase of energy price; Indonesia generated a total effect of 3.73 for food and 3.71 for transportation which were higher than the average national effect of 2.72. Thus, again we found that energy used in food industries in developing EA countries is very sensitive to the increase in energy price.

Figure 2. Total effect of oil price increase on food and non-food for Indonesia, 2005



Source: Estimated from OECD I-O Table 2005

On average, total effect from a double increase in oil price has effects which are greater than average for developing countries, as shown in Table 8. Indonesia has effects in both food sectors of approximately 1.4 from its weighted average compared to only 1.0 and 0.7 for Japan. Thus, in contrast, these demonstrate that a double increase in energy price has less effect on energy resilient country like Japan.

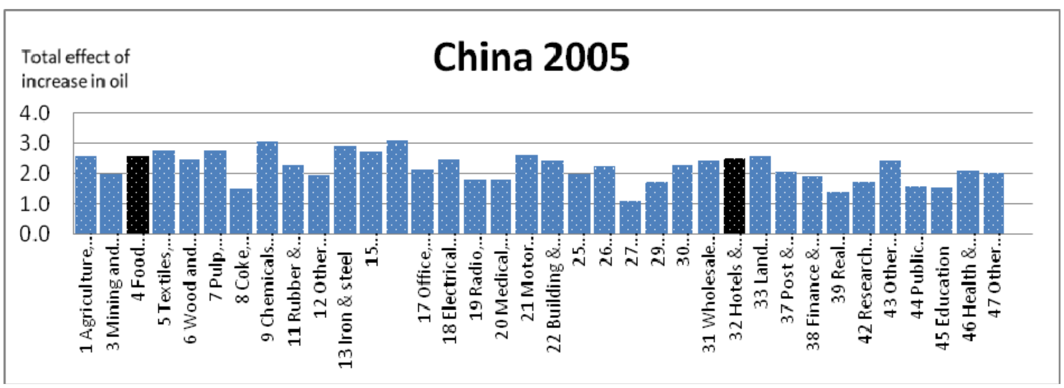
Table 8. Total Effect of Double Increase in Energy Price

Country	Sector 4 (1)	Sector 32 (2)	Weighted average (3)	Distance from average (4)	Distance from average (5)	Total (6)
Indonesia	3.73	3.71	2.72	1.4	1.4	1.0
China	2.57	2.52	2.22	1.2	1.1	1.0
Japan	4.90	3.61	4.88	1.0	0.7	1.0

Source: Estimated from OECD I-O Table 2005

This comparison between total effects of energy increase on food sectors are represented by sector 4 and 32 as shown in column (1) and (2) in Table 8. We measure vulnerability by the distance of total effect from the average. Thus, amongst the three selected countries, Japan showed the least distance from average portraying the least vulnerability from energy price changes.

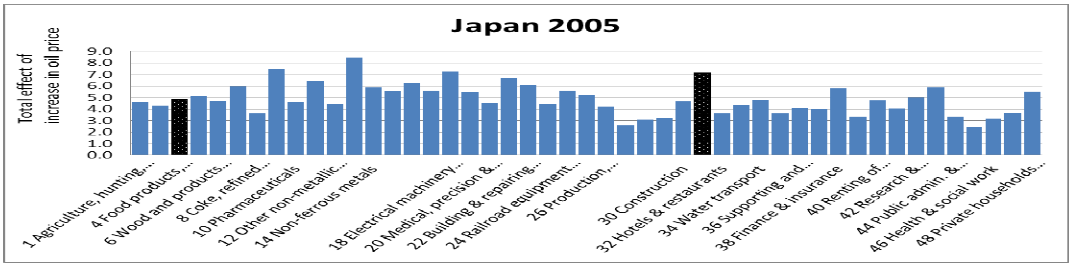
Figure 3. Total Effect of Oil Price Increase on Food and Non-food for China 2005



Source: Estimated from OECD I-O Table 2005

This is complemented by Figure 3, which exhibits the response of a doubling of oil price on food and non-food. Here, the Mining & quarrying (energy) sector is taken out as proxy to oil and we simulate an increase in food and non-food prices from its initial price endogenously. Food and non-food shares are implicitly determined by value added and imported an input, which varies amongst economies. Resilient economies have consistent performance in terms of value added creation and imported inputs during periods of energy price increase.

Figure 4. Total Effect of Oil Price Increase on Food and non-Food for Japan 2005



Source: Estimated from OECD I-O Table 2005

The total effect of energy increase is also positive in Japan. However, food sector 32, i.e. Hotels and restaurants, has a higher impact than food products and beverages of sector 4, showing imported inputs plays important role during oil price increase. In comparison with Indonesia and China, Japan has a higher impact in this sector showing there are considerable effects from increases in energy price.

4.3. Retail Price of Food Products

In this simulation, the retail price is determined by food and non-food cost share, FMCI and CPI weights using the price-spread model. By employing 10-food sectors from the Malaysian I-O tables of 2000 and 2005, we observed the following patterns:

i. The increase in the share of non-food, owing to the higher change in FMCI and CPI weight, resulted in an increased retail price, from 28% in 2000 rising to 36% in 2005.

ii. In 2005, the highest ranking food item is Food-away-from-home, which comprised of Restaurants and hotels. The change was approximately 12%, followed by Fish and seafood, 7%.

iii. Malaysia exhibits lower interconnectedness of energy use in marketing of food (as FMCI is higher) if FMCI is represented by Transport sector 2005 (1.49) than in 2000 (1.48). Thus, as transport has a higher index, it means that some marketing costs had increased in the midst of increasing oil prices.

Table 9. Retail Price of Food Products in Malaysia, 2000

Food Products	Share of non-food	FMCI	Change in PR	CPI Weight	CPI %	Retail Price
Rice, Bread, other cereals	0.378	1.4828	0.560431	4.6	0.046	0.026
Meat & meat products	0.733	1.4828	1.087133	2.9	0.029	0.032
Fish & seafood	0.961	1.4828	1.424701	4.5	0.045	0.064
Milk, cheese, & eggs	0.454	1.4828	0.673735	1.8	0.018	0.012
Oils and fats	0.313	1.4828	0.464125	0.6	0.006	0.003
Fruits & vegetables	0.588	1.4828	0.871543	3.7	0.037	0.032
Sugar, jam, honey, chocolate, & confectionery	0.356	1.4828	0.527323	0.7	0.007	0.004
Food products n.e.c	0.685	1.4828	1.015118	0.8	0.008	0.008
Food away from home	0.549	1.4828	0.814687	10.4	0.104	0.085
Coffee, tea, cocoa, & Non-Alcoholic Beverages	0.644	1.4828	0.954705	1.4	0.014	0.013
Sum/Total average				31.4		0.278

Table 9 shows that FMCI for Malaysia is lower in 2000 (1.48) than in 2005 (1.49) with both the petrol product and electricity and gas as weight. This may mean that a little increase will change marketing costs in the midst of increasing oil prices. Retail prices increased from 28 % in 2000 to 36% in 2005 illustrating that the country had experienced an increase in vulnerability as energy price affects through costs of production inputs, as in Table 10.

Table 10. Retail Price of Food Products in Malaysia, 2005

Food products	Share of non-food	FMCI *	Change in PR	Wt. CPI	CPI%	Retail Price
Rice, Bread, other cereals	0.761	1.49	1.13	4.40	0.044	0.050
Meat & meat products	0.845	1.49	1.26	2.90	0.029	0.036
Fish & seafood	0.963	1.49	1.44	4.50	0.045	0.065
Milk, cheese, & eggs	0.775	1.49	1.15	1.80	0.018	0.021
Oils and fats	0.623	1.49	0.93	0.60	0.006	0.006
Fruits & vegetables	0.742	1.49	1.11	3.30	0.033	0.036
Sugar, jam, honey, chocolate, & confectionery	0.855	1.49	1.27	0.60	0.006	0.008
Food products n.e.c	0.678	1.49	1.01	0.80	0.008	0.008
Food away from home	0.779	1.49	1.16	10.00	0.100	0.116
Coffee, tea, cocoa, & Non-Alcoholic Beverages	0.763	1.49	1.14	1.40	0.014	0.016
Sum/Total average				30.30		0.361

Source: Calculated from I-O Table 2005, DOS Malaysia

Amongst food items, food-away-from-home (0.116) shown at the last column of Table 10 has the highest percentage increase in response to an oil price doubling. This industry comprises of hotels and restaurants, which requires high oil inputs indirectly for transportation, food preparation, packaging, and other direct and indirect activities. Since oil price increases comprises a significant share of their production chains, the rise in oil price will certainly be felt by these industries and the price of products will increase if there are no change in composition of input.

Since the price-spread model requires multiple and detailed data for food and non-food share, FMCI and CPI, we could not complete simulations for other EA countries. We hope this subsequent exercise is able to be extended in the near future.

4.4. Summary of Findings on Energy Intensity:

a. Energy intensity varies amongst EA countries. An increase in energy price has direct and indirect effects on energy inputs used in food and non-food production. The more intense energy is utilized, the higher the risks of coping with higher energy price. This ultimately relates to measures enacted by EA countries to cope with energy price increases that escalate production costs in the course of producing food and non-food output;
b. Low energy intensity economies as found in developed countries use less energy as inputs in the production of food and non-food as they are more efficient and diversified in energy types. Over and above this, their production sectors also have higher output generating capacity; and
c. Energy intensity analysis can be a basis for investigating policies related to efficiency, planning alternative energy inputs and expanding output capacity.

Sectoral Price Effects:

a. Relative prices across sectors of the EA economy performed differently. Increased in the energy price generates more costs in terms of generating value added and importing input in producing food and non-food output. This has consequences on policies concerning interconnectedness of energy inputs along food and non-food corridors.

b. Food productions in developed EA countries are lower than average total effect, nevertheless, these sectors generate greater value added. Thus, they are more resilient to energy price increases;
c. In contrast, developing EA countries' food productions are higher than total effect, however, generate less value added; and
d. Agricultural-based countries with low technology have low value-added. Thus, local value added has limits in using new techniques.

Retail price:

a. A rise in energy prices has direct and indirect effects on EA economies. The lower an economy's energy inputs, the lower the effect from energy price increases. Additionally, such economy's have greater potential in nurturing efficiency and diversification with lower food intake and thus exhibit smaller effects in retail prices;
b. The price-spread effects in terms of energy use, non-food costs share and CPI differ across food items; and
c. The higher the effect of an increase in the oil price, the greater the retail price. This occurs through channels of food marketing such as transportation, packaging and so on.

5. Conclusions and Recommendations

Productive integration transpires if the production process is composed of fractions with different resource use intensities, since the productivity of a firm will increase in allocating each fraction in locations where its most intensively used resource is abundant. The productivity gains from fragmentation are large if resource endowments are sufficiently different in both countries; hence a firm can optimize their energy intensive production process using non-intensive energy techniques of production of a developed country.

Energy interconnection can act as catalyst towards higher productivity even during an increase in energy prices as found in the case of Malaysia and Singapore. The case study showed that there is huge potential to interconnect activities that enhance competitiveness and comparative advantage on food and non-food industries. In the case study of Indonesia, China and Japan, we found that as countries with different input intensity and output generating capacity, can interconnect their activities by closing their gaps in lowering their trade barriers such. Although a less developed country will be at a disadvantage, however if integration is more widespread they will become more efficient and diversified by sharing new technologies.

In this light it is recommended to deepen EMI activities that could maintain output and productivity even in the wake of oil price increase by:

- Emulating consistent energy policies in mitigating energy efficiency gains with energy diversification in line with intensities of energy utilization in EA countries;
- Obtaining productivity gains from fragmentation/clusters, as measured by interconnectedness. These are large if resource endowments, especially energy, are sufficiently different and can be integrate between countries. Hence, a firm can locate a less energy intensive plant in an energy resources abundant country, which will allow more efficient food production; and
- On investment plans, an unbalanced growth strategy should be embark amongst EA countries by selecting the main player and highest value added producer of food industries with highest efficiency to lead investment plans in bolstering for higher energy growth and at the same time encouraging for consumption of more efficient and cleaner fuels.

In a dynamic and changing food and non-food industry of the EA economy; energy intensity, capacity and value chains of production measures how efficient, interconnected and integrated a country to a region. This assists in driving efficiency and expanding output, especially in times of energy price increase. In this continuous effort of building capacity, interconnectedness amongst chains of production is critical in crystalizing integration.

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Appendix A. Energy intensity results for selected EA countries

Table 11. Direct and Indirect Effects of Oil Price Increase for Malaysia and Singapore, 2005

Malaysia

Direct effects	VA	M	M/VA
Food Crops	0.608	0.092	0.151
Vegetables	0.570	0.197	0.346
Fruits	0.557	0.074	0.133
Poultry Farming	0.483	0.041	0.085
Other Livestock	0.528	0.040	0.076
Fishing	0.502	0.107	0.213
Meat and Meat Production	0.182	0.068	0.373
Preservation of Seafood	0.231	0.104	0.448
Preservation of Fruits and Vegetables	0.255	0.159	0.623
Dairy Production	0.162	0.266	1.649
Oils and Fats	0.120	0.061	0.512
Grain Mills	0.143	0.332	2.324
Bakery Products	0.202	0.147	0.724
Confectionery	0.236	0.416	1.760
Other Food Processing	0.194	0.188	0.969
Wine and Spirit	0.277	0.198	0.717
Soft Drink	0.202	0.260	1.288

Singapore

Direct effects	VA	M	M/VA
Food preparations	0.228	0.463	2.029
Bread, biscuits & confectionery	0.323	0.251	0.775
Sugar, chocolate & related products	0.180	0.608	3.385
Oils & fats	0.129	0.611	4.725
Dairy products	0.246	0.361	1.468
Coffee & tea	0.207	0.420	2.032
Other food products	0.219	0.401	1.829
Soft drinks	0.260	0.311	1.198
Alcoholic drinks & tobacco products	0.256	0.227	0.888
Food & beverage services	0.411	0.150	0.365

Malaysia

Indirect effects	VA	M	M/VA
Food Crops	0.221	0.070	0.3148
Vegetables	0.145	0.077	0.5284
Fruits	0.271	0.087	0.3230
Poultry Farming	0.271	0.190	0.7028
Other Livestock	0.276	0.146	0.5272
Fishing	0.245	0.117	0.4781
Meat and Meat Production	0.540	0.189	0.3509
Preservation of Seafood	0.443	0.189	0.4261
Preservation of Fruits and Vegetables	0.397	0.165	0.4169
Dairy Production	0.356	0.188	0.5290
Oils and Fats	0.610	0.174	0.2858
Grain Mills	0.387	0.110	0.2854
Bakery Products	0.404	0.212	0.5247
Confectionery	0.217	0.113	0.5185
Other Food Processing	0.372	0.206	0.5524
Wine and Spirit	0.218	0.142	0.6510
Soft Drink	0.294	0.208	0.7083

Singapore

Indirect effects	VA'*(I-A)-VA	M'*(I-A)-M	M/VA
Food preparations	0.174	0.131	0.754
Bread, biscuits & confectionery	0.236	0.188	0.797
Sugar, chocolate & related products	0.120	0.091	0.758
Oils & fats	0.111	0.148	1.332
Dairy products	0.201	0.191	0.949
Coffee & tea	0.201	0.169	0.840
Other food products	0.204	0.174	0.854
Soft drinks	0.224	0.202	0.902
Alcoholic drinks & tobacco products	0.312	0.199	0.639
Food & beverage services	0.307	0.129	0.419

Source: DOS, I-O Table 2005 and OECD
Notes: Highlighted results constitutes M/VA coefficients of more than 1.0

CHAPTER 11

Calibrating the Mix of Electric Power Generation Types

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The shift in electric power generation types has gained attention in the context of climate change and more recently by the devastating nuclear fallouts in the aftermath of the Japanese earthquake. On the one hand, shifting away from fossil fuels to renewable energy sources would mitigate greenhouse gas emissions; on the other hand shifting from nuclear to fossil fuels is an immediate response to urgent situations. The shift of electric power sources will have economic impacts on production, consumption, and international trade. To capture the quantitative impacts through economic linkages, we implemented simulations with a global CGE model and database by asking the question: what would be the economic impact of shifting source of power generation away from nuclear in Japan? Simulation results show that reductions in the use of nuclear for electric power generation could have profound negative impacts on the economy.

1. Introduction

The main objective of this report is to shed some light on the following question: what would be the economic impact of altering the type of electric power generation from nuclear to fossil fuels? In the aftermath of the East Japan earthquake hitting northern Japan in March 2011, an immense tsunami devastated the nuclear power plants in Fukushima, leaving the affected region under radiation risk and with power shortages. It seems unlikely that the level of support for the use of nuclear to generate electric power not only in the Tohoku region but also in other parts of Japan can be maintained, thereby motivating this research.

Originally motivated by climate change concerns, this report intended to address the same question of altering the mix of electric power generation but in the opposite direction of shifting from fossil fuels to hydro, nuclear, and other renewable energy sources. By replacing the use of fossil fuels in power generation for other energy sources, the shift was expected to contribute toward greenhouse gas abatement.

Either way of the shift in electric power generation will have economic impacts on production, consumption and international trade across the world. Industries purchase electrical supply services as a vital input into their production activities, while they are competing over the primary factors of production such as labor and capital. Households are also purchasing electrical supply services as well as other goods and services. Suppose there is a change in the price of electrical supply resulting from a shift in the mix of power generation types. The change in price will cause further changes in the demand for intermediate and primary factor inputs by industries and the final demands by consumers. Consequently, these domestic changes will have effects on international trade.

To quantitatively address the economic linkages and channels affecting industries and households across countries, we will rely on a global Computable General Equilibrium (CGE) model and its database. With this global CGE model and database we can conduct computational experiments and describe the linkages of the world economy within a coherent accounting framework. We implemented two sets of simulations by asking the following question:

What would be the economic impact of shifting the sources of power generation away from nuclear in Japan?

Simulation [A]: Reduce the electric power generated by nuclear in Japan;

Simulation [B]: Reduce the electric power generated by nuclear in Japan while maintaining the overall generation level by substituting it by fossil fuels.

Suppressing the use of nuclear power in simulation [A] will lead to a fall in supply of electricity, and I will examine how far economic activities in Japan would be curtailed. In simulation [B], electric power generation based on fossil fuels will fill the gap caused by the cut in nuclear. The extent to which substitution would mitigate the negative impacts on economic activities is considered.

In the next section, we briefly describe the global CGE model and database used in this study, and the data extension process of incorporating different types of electric power generation into the database. Design for the simulation experiments and their results are explained in the third section, followed by summary and policy implications.

Before we proceed to the following section, it is very important to make a few cautionary notes. First, this report is not about the natural disaster and its economic consequences. Rather, we are focusing only on the smooth shift between electric power generations, assuming no damage to existing physical infrastructure. Relating to this point, secondly, this report is not about the economic cost of recovery from the loss caused by the natural disaster.

2. GTAP Model, Database, and Extension

The main aim of this report is to analyze the economic impacts of shifting the electric power generation from nuclear to fossil fuels. For quantitative evaluation of such impacts our choice of applied economic model is a multi-sector multi-region CGE model. To capture intersectoral linkages among industries and consumer in a country as well as international trade flows, it is reasonable to use a multi-sector multi-region comparative static CGE model. The widely used platform for this type of CGE analysis is the Global Trade Analysis Project (GTAP) database and modeling framework (Hertel, 1997; McDougall, 2000; Narayanan and Walmsley, 2008).

The comparative static GTAP model has features of perfect competition, constant returns to scale production technology, a representative regional household, and bilateral international trade with transport margins and differentiation by place of production. Each industry produces their output of goods and services based on the constant return to scale technology by using the inputs of intermediate goods, skilled and unskilled labor, capital, land, and natural resource. Intermediated goods are produced domestically or imported from abroad. Each country is endowed with labor, capital, land, and natural resource, and these primary factors of production do not move across a country's border. A representative regional household in each country decides the allocation of expenditures on private, government, and future consumption.

Table 1. Sector Aggregation

No.	Code	GTAP 57 Sectors
1	GrainsCrops	Paddy rice; Wheat; Cereal grains nec; Vegetables, fruit, nuts; Oil seeds; Sugar cane, sugar beet; Plant-based fibers; Crops nec; Cattle,sheep,goats,horses; Processed rice.
2	MeatLstk	Animal products nec; Raw milk; Wool, silk-worm cocoons; Meat: cattle,sheep,goats,horse; Meat products nec.
3	ForestFish	Forestry; Fishing.
4	Coal	Coal.
5	Oil	Oil.
6	Gas	Gas.
7	OthMinerals	Minerals nec.
8	ProcFood	Vegetable oils and fats; Dairy products; Sugar; Food products nec; Beverages and tobacco products.
9	TextWapp	Textiles; Wearing apparel.
10	LightMnfc	Leather products; Wood products; Paper products, publishing; Metal products; Motor vehicles and parts; Transport equipment nec; Manufactures nec.
11	HeavyMnfc	Petroleum, coal products; Chemical,rubber,plastic prods; Mineral products nec; Ferrous metals; Metals nec; Electronic equipment; Machinery and equipment nec.
12	Util_Cons	Gas manufacture, distribution; Water; Construction.
13	TransComm	Trade; Transport nec; Sea transport; Air transport; Communication.
14	Electricity	Electricity.
15	OthServices	Financial services nec; Insurance; Business services nec; Recreation and other services; PubAdmin/Defence/Health/Educat; Dwellings.

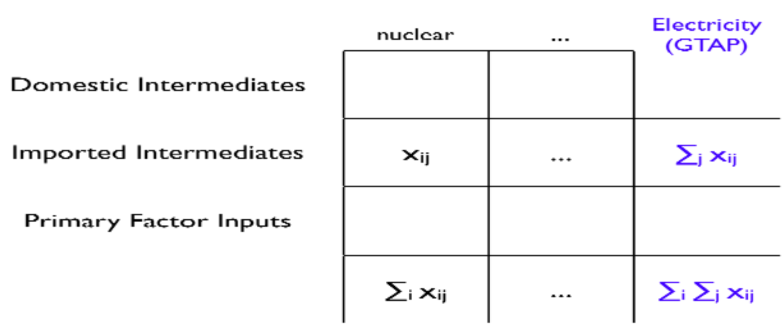
Source: GTAP Database v.7.1.

The GTAP database used in this report is the version 7.1 database, which records all the domestic and international economic transaction flows for 57 industrial sectors accross 112 countries / regions in the world, benchmarked in 2004. Table 1 shows the mapping from the original 57 sectors to the aggregated 15 sectors studied in this report. Electrical supply service, “Electricity” in the code, is one of the 57 industries stored in the GTAP database, but there is no distinction between electric power generation types such as nuclear, fossil fuels, and other.

The electricity sector in the GTAP database can be viewed as an aggregate of different power generation types so that it is possible to disaggregate the original electricity sector into sub-sectors of nuclear, fossil fuels, and other. As electrical supply services are produced from both domestic and imported intermediates as well as primary factor inputs, these production inputs need to be split into sub-sectors. A similar split of database is required for electrical service supply in households' consumption, other industry's intermediate use, and international trade.

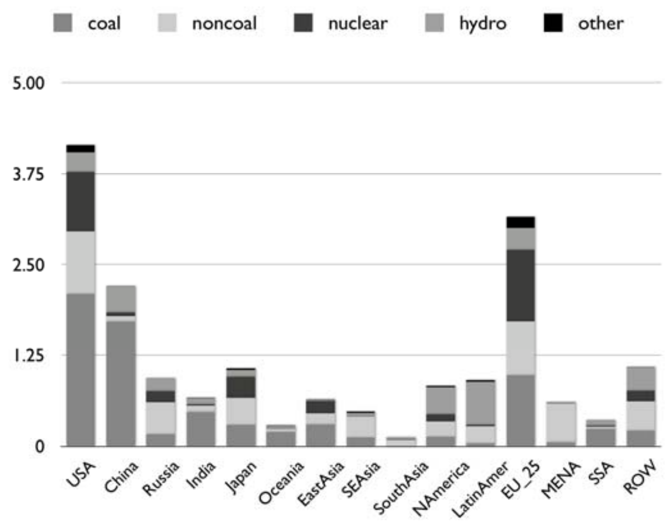
Figure 1 shows an idea of splitting the original GTAP electricity sector into sub-sectors. While subscript *i* stands for an input to the production, subscript *j* stands for a sub-sector, either nuclear, or fossil fuels, or others. As we summed over the sub-sectors, it is clear that the original input data of electricity will be recovered for all the input cells. Given these add-up conditions as constraints, the software SplitCom (Horridge, 2005) implemented the disaggregation process along with the additional data information from IEA (2008), EIA (2008), and Japanese input-output tables for 2005 by Statistics Bureau in Japan (SB, 2009).

Figure 1. Split Electricity



Splitting the electricity sector in GTAP v.7.1 database into sub-sectors has been performed for 112 countries, and the splitting results are shown in Figure 2 for selected countries. There is considerable regional variation in the overall level of electric power generation, with the US, China, and EU_25 having the highest levels. The size of coal-based power generation in China is almost equivalent to the US, but its share in the overall generation is overwhelmingly dominating. Following the US and EU_25, the use of nuclear power is proportionally significant in Japan.

Figure 2. Electric Power Generation by Type, 2004 (PWh)



Source: Author’s estimates from IEA, EIA, SB.

Computed for the EAS countries, Table 2 reports the share of power generation types in total production. Among EAS members, Japan and Korea rely substantially on nuclear, whereas China only utilizes nuclear to a minor degree. The use of fossil fuel predominates in power generation amongst EAS countries. The large number observed in Laos for other energy sources is mainly driven by hydro-electricity.

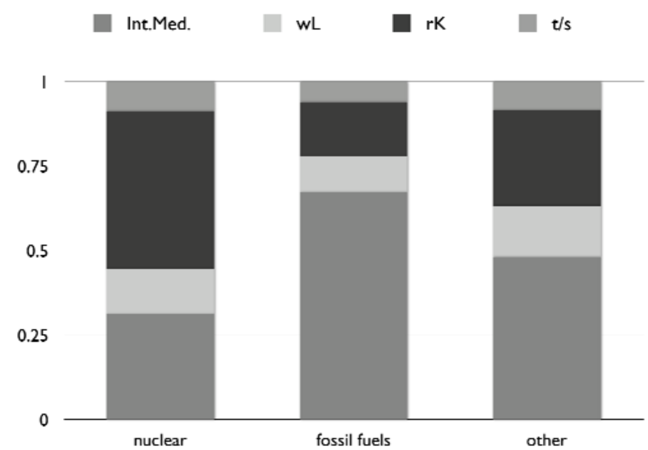
Table 2. Share of Electric Power Generation Type in EAS (%, 2004)

	Fossil	Nuclear	Other
Japan	62.6	26.5	11.0
Korea	63.0	35.7	1.3
China	81.5	2.3	16.2
Cambodia	96.3	0	3.7
Indonesia	86.4	0	13.6
Laos	3.2	0	96.8
Myanmar*	57.1	0	42.9
Malaysia	92.9	0	7.1
Philippines	66.3	0	33.7
Singapore	100.0	0	0
Thailand	93.0	0	7.0
VietNam	61.6	0	38.4

Note: * Weights are computed but not used in GTAP Database v7.1.

Source: Author's estimates from IEA, EIA, SB.

Figure 3. Cost Structure of Electric Power Generation by Type in Japan



Source: Author's estimates from SB.

Figure 3 illustrates the cost structure of electric power generation by type in Japan, estimated from the input-output tables in 2005. Total generation cost breaks down into four categories; intermediate input cost (Int.Med), labor cost (wL), rental cost (rK), and tax or subsidy (t/s). It is clear that nuclear power generation has a large rental cost share whereas fossil fuel power generation relies heavily on intermediate inputs. These variations in the cost structures imply that different power generation types would have different impacts on the rest of economy after a shift in the mix of electricity generation.

3. Simulation Experiments and Results

The comparative static GTAP model and database version 7.1 are used to run comparative static simulations with the software GEMPACK (Harrison and Pearson, 1996) and RunGTAP (Horridge, 2008). Two sets of simulation experiments with four different levels of changes are implemented:

Simulation A1: Cut the use of nuclear in electric power generation by 5%

A2: Cut the use of nuclear in electric power generation by 10%

A3: Cut the use of nuclear in electric power generation by 15%

A4: Cut the use of nuclear in electric power generation by 20%

Simulation B1: A1 + increase the use of fossil fuels to substitute for nuclear

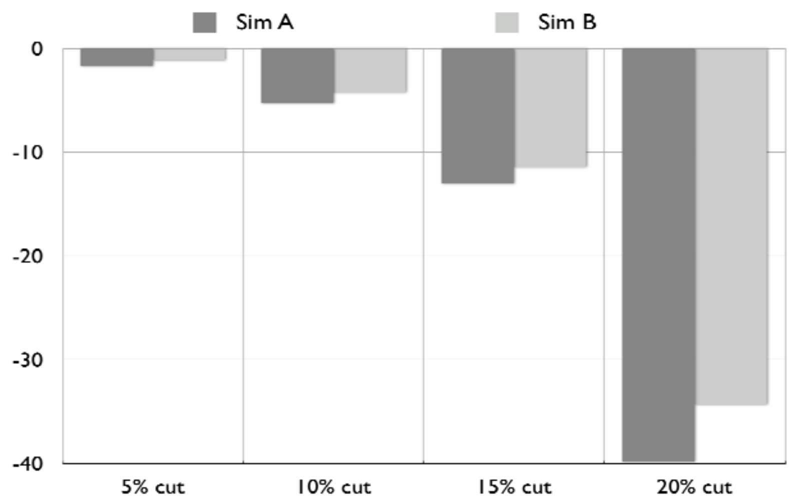
B2: A2 + increase the use of fossil fuels to substitute for nuclear

B3: A3 + increase the use of fossil fuels to substitute for nuclear

B4: A4 + increase the use of fossil fuels to substitute for nuclear.

In simulation A, reductions of the use of nuclear in Japan are simulated to varying degrees. In simulation B, fossil fuels filling the electrical supply shortage caused by a cut in nuclear use. In cutting the level of nuclear-based power generation, the model is configured to allow the sub-sectors to make losses / profits while their generation activities are controlled by the simulation settings. Consequently, as a caveat, this configuration would introduce a breach in equilibrium conditions. Therefore, the simulation results should not be taken as a full equilibrium response to the exogenous shocks but they are rather coarse estimates in the process recovering to the full equilibrium conditions.

Figure 4. Impact on Real GDP in Japan (US$, billion)



Source: Author’s simulation results.

As Japan reduces power generation from nuclear, then real Japanese GDP would be negatively affected. Figure 4 illustrates the negative impacts on real GDP in Japan. The deeper the cut in nuclear use for power generation, the larger the negative impact on real GDP. The substitution of fossil fuels for nuclear in simulation B was not sufficient to mitigate these negative impacts. If nuclear-based power generation in Japan was reduced by 20 per cent without any replacement, then the real GDP in Japan would decrease by approximately 40 billion US dollars, almost equivalent to one per cent of GDP evaluated in 2004. Table 3 reports the impacts on real GDP in percent terms.

Table 3. Impact on Real GDP in Japan (%)

	5% cut	10% cut	15% cut	20% cut
Simulation A	-0.04	-0.11	-0.28	-0.86
Simulation B	-0.02	-0.09	-0.25	-0.74

Source: Author's simulation results.

Recall from Figure 3 that the cost structure of nuclear-based power generation has relatively high share of rental cost. Once the use of nuclear is suppressed, then the primary factor demands for physical capital would be weakened, leading to lower rental price in Japan. The lowered rental price implies that the expected rate of return would diminish so that the resulting fall in investment negatively contributes to real GDP.

4. Summary and Policy Implications

The shift in electric power generation types has gained attention in the context of climate change and more recently by the devastating nuclear fallouts in the aftermath of the earthquake. On the one hand shifting away from the fossil fuels to renewable energy sources would mitigate green house gas emissions, on the other hand shifting from nuclear to fossil fuels is immediate response to recent events.

The shift in electric power sources will have economic impacts on production, consumption, and international trade. To capture the quantitative impacts through economic linkages, simulations with a global CGE model and database were analysed. As simulation results showed, reductions in the use of nuclear for electric power generation could have a large negative impact on the economy.

Given the variations in types of electric power generation across countries, it is desirable in policy formulation to design an appropriate mix of electric generation types based on existing facilities and feasibly planned future investments. Also, given the variations in cost structures of power generation, the economic consequences of shifting amongst different types would differ considerably.

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CHAPTER 12

Substitute of Nuclear Energy Supply-A Strategic Policy Decision for Asia[1]

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Asian energy policy makers are now in the cross road of defining the future direction of the region's long term energy scenario which can strike a balance between economic development, energy supply security and climate change mitigation due to the Fukushima nuclear accident in Japan. Though there are certain drawbacks and constraints on mainstream utilization of renewable energy at a large scale, renewable energy seems much clearer for Asian countries, especially for the developing countries considering the risks and damage associated with the nuclear energy. This study demonstrates feasibility of no-nuclear energy supply scenarios as well as potential benefits of renewable energy based future energy supply path from the perspectives of electricity supply cost and total cost of energy supply to the market. This study shows the possibility for Japan, India and China to satisfy future energy demands without nuclear energy. Further, this study demonstrates potential benefits of focusing more on renewable energy development than other fossil fuel based energy resources for having a sustainable, affordable and reliable energy supply in these countries. Renewable energy's expensiveness should not be a constraint for its development and promotion in the regional market.

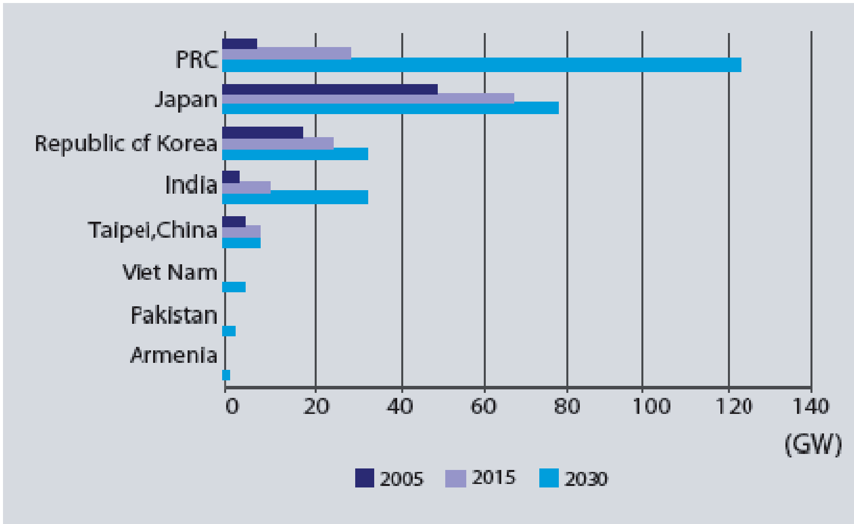
[1] The base model and its Reference case are developed and maintained by KanORS/KanLo. See www.KanORS-EMR.org/DCM/TIAM_World for details. It is also recognized here the valuable contribution of Dr. Amit Kanudia in terms of setting the technical details of the model and its calibration. We are also thankful to our IGES colleagues Dr. Takeshi Kuramochi and Ms. Takako Wakiyama for providing us Japanese renewable energy data and also for providing several technical comments on the findings.

1. Background

Asian energy supply is in a critical juncture now in the context of triple goals of the region: economic development, poverty eradication to achieve the millennium development objectives, and environmental protection with reduced emissions. Asia is now the growth hot spot with its expected GDP growth rate at around 6-7% per annum and energy demand growth rate at 4-5% per annum (ADB, 2009). In spite of relatively rich reserves of coal, natural gas and crude oils, the energy system of this region as a whole is dependent on fossil fuel imports from the world market, particularly from politically vulnerable Middle East countries. This situation is undesirable from the energy security perspective. Emissions risk is another concern for Asian countries. Although only the Annex-I countries like Japan under the Kyoto target are currently constrained by GHG emissions internationally, more and more non-Annex-I countries such as China, India and Indonesia start serious consideration in setting emission reduction targets. This emission constraint further casts doubt in sustainability of the current imported fossil fuel dependent energy scenarios in Asia.

Against this background, nuclear energy has been envisaged as an important energy supply source in the region with its multipurpose benefits including lower cost, less pollution and reduced import dependence. As a matter of fact, major Asian countries like Japan, Korea, China, and India have pursued the nuclear energy development programs to increase the share of nuclear power supply in the national energy mix. Japan has already implemented nuclear energy program with certain pioneering technologies while China, India and other countries are in the process of developing the program with various multilateral and bilateral technology transfer processes. As shown in Figure 1, by the year 2030 the total installed capacity of nuclear power generation in these regions is expected to be around 250 GW from 70GW at 2005 level.

Figure 1. Existing and Planned Nuclear Power Plant Capacity



Source: ADB, APEC 2009

However, the Fukushima Daiichi nuclear accident in March 2011 compelled to critically review this rosy picture of nuclear technology. The most critical lesson from the Fukushima Daiichi accident is the fact that potential scale of damages from nuclear power accidents is essentially unforeseeable and immeasurable. The damages not only cross over the national boundaries but also affect generation together. The German government led by Chancellor Merkel immediately takes this lesson very seriously. Merkel administration convened the Ethics Committee in addition to the existing Nuclear Safety Commission (RSK) for the consultation on the nuclear and future energy issues, and based on the conclusion of the Ethics Committee it was decided to completely phase out nuclear power in Germany by 2021[2] So far, there is not much repercussion after the Fukushima accident among Asian countries (except for Japan) in terms of their nuclear energy program, but the debate has been raised in many cases to reconsider the option with additional dimensions of civilian safety and damage cost liability sharing among the stakeholders. Whatever be the outcome of these debates, the

[2] One of the major recommendation of the Ethics Committee was “Technologies of which risk is immeasurable and uncontrollable are negative assets to the future generations”. Source: Ethics Commission for a Safe Energy Supply (2011) "Germany's Energy Transition: A Collective Endeavour for the Future" (http://ecojesuit.com/wp-content/uploads/2011/06/The_Phase_Out_of_Nuclear_Energy_is_Ethically_Demanded.pdf)

policy makers are now facing tremendous challenges to envisage a balanced energy supply outlook for the countries amidst nuclear energy uncertainties and to seriously reconsider future energy scenarios with taking the lessons from Fukushima Daiichi accident.

In this regard it is important that Asia is endowed significant amount of renewable energy resources which are mostly untapped so far due to financial and technological barriers. It has been estimated that the total renewable energy supply potential in major Asian countries is largely many fold of the existing total electrical power generation in the countries as shown in Table 1.

Table 1. Renewable Energy Generation Potential in Asia

Countries	Total RE potential (Gwh)	Actual RE Generation in 2005 (Gwh)	Total Electricity Generation, 2005 (Gwh)
Brunei	154	0	2,707
Indonesia	421,684	6,229	112,730
Malaysia	58,094	0	89,247
Philippines	327,996	12,692	63,166
Thailand	34,312	2,018	131,839
Viet Nam	165,946	1,232	53,798
China	529,373	5,942	1,846,836
Japan	1,132,265	15,907	1,054,596
Korea	18,718	0	368,022
Total	2,688,541	44,020	3,722,940

Source: Romero et.al 2010

2. Research Goal and Objectives

Taking the lessons from Fukushima Daiichi nuclear accident seriously, it seems wise to diversify the scope of future alternative energy scenarios including no-nuclear scenarios. This study aims to demonstrate feasibility of no-nuclear energy scenarios in the future as part of such efforts. This study assumes two alternative assumptions about major substitutes of nuclear power, i.e. conventional fossil fuels and renewable energies. As mentioned in the previous section, Asia has so far utilized only a fraction of renewable potential, and huge untapped resources are lying idle in the region. Therefore, our scenario setting also tries to demonstrate that renewable energy is an economically viable solution which can satisfy the dual targets of emissions reduction and energy security via energy import control at a reasonable economic cost.

Towards the above goal, this study estimates the impacts of the two alternative scenarios to phase out nuclear energy supply in Japan, China and India by indigenous renewable energy, by energy efficiency improvement and by rigorous energy conservation along with use of advanced technologies in energy generation and reducing emissions.

The impacts are assessed based on the following indicators associated with the cost of supply, environmental impacts, and energy security implications:

Nationwide CO2 emissions

Total energy system cost

Electricity supply cost in the country

Electricity supply mix

3. Methodological Approach

The TIMES Integrated Assessment Model (TIAM-WORLD) is a technology-rich model that integrates the entire energy/emission system of the World, divided in 16 regions, including the extraction, transformation, trade, and consumption of a large number of energy forms. India, along with Japan and China are represented as individual regions in this model. The model contains explicit descriptions of more than 1500 technologies and several hundreds of commodities in each region. TIMES' economic paradigm is the computation of a inter-temporal partial equilibrium on energy and emission markets based on the maximization of total surplus, defined as the sum of suppliers and consumers surpluses. The detailed technological representation of the energy system of TIAM-World allows the computation of energy flows, prices, technology uses, net greenhouse gas emissions and concentrations.

3.1. Scenario Assumptions

The TIAM model in the study used the energy service demand projections based on the projections of various demand drivers like GDP, per capita GDP, population, number of households, sectoral growth rate etc. The following Table 2 shows the basic assumptions for various energy demand drivers mentioned above and used in this model[3].

Table 2. Macroeconomic Drives Used for Service Demand Projection Unit 2050 (CAGR[4])

Macroeconomic Drivers (Annual Growth Rate)	Japan	China	India
GDP	0.50%	4%	4%
GDPP (GDP per capita)	0.68%	3%	3%
GDPPHOU (GDP per household)	0.23%	3%	3%
HOU (No. of household)	0.25%	1%	1%
PAGR (Agr growth rate)	-0.01%	4%	4%
PCHEM (Chem sector growth rate)	0.36%	4%	4%
PISNF (Iron & Steel sector growth rate)	0.43%	4%	4%
POP (Population growth rate)	-0.14%	0.3%	0.7%

Sources: Authors' estimation based on IMF Projection of World Economic Outlook 2010.

In energy systems analysis, final energy demand variation gets reflected in the system's supply side and vice versa. As a matter of partial equilibrium model, the TIAM model endogenously determines the prices of energy that flows through a particular energy process based on the given costs of that particular energy production, supply and other activities. Thus primary energy prices are important in this model which finally determines the demand and supply equilibrium. The basic assumptions are shows in the figure below:

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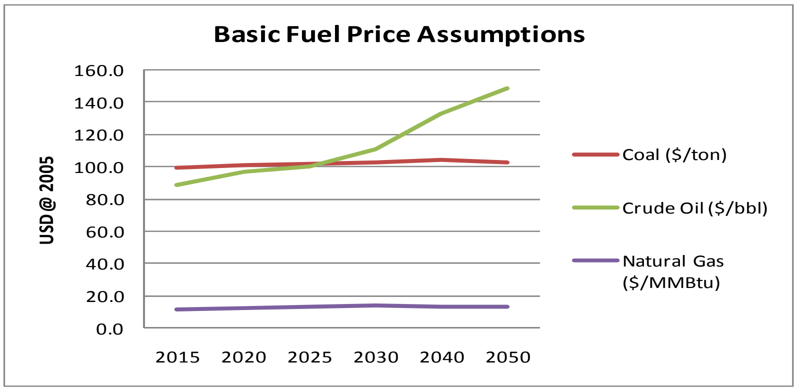
[3] This study assumes pessimistic economic growth of the world viewing the current economic condition and considering the uncertainty of long term high growth prospect especially for China and India.
[4] CAGR is the compounded annual growth rate which is taken over the period of 2005 and 2060.

Figure 2. Primary Fuel Prices



Sources: Model determined fuel price projection using production data from IEA.

The costs of technologies are also very important for this study as they determine the final technological intervention in the system. The following table shows the reference case cost comparison between different renewables mainly solar and wind. Here the 2050 cost projection is assumed to be affected by the learning a curve experience where the cost decreases by around 3% every next year of the previous year [Ct = Ct-1* 0.97] for Japan. For China and India the costs are reducing at the rate of 2% per annum for solar technologies and 1% for wind technologies.

Table 3. Reference Case Technology Investment Cost Comparison

Unit: USD/KW

RE Technology	JAPAN		CHINA		INDIA	
	2005	2050	2005	2050	2005	2050
Solar PV_Grid	6900	1750	5300	1340	5300	1340
Solar PV_Off-Grid	8000	2000	6300	1570	6300	1570
Wind On-shore_Grid	4000	1000	1100	1000	1100	1000
Wind Off-shore_Grid	8000	2000	2700	1700	2700	1700
Wind On-shore_Off-Grid	5000	1250	1300	1200	1300	1200

Source: Data has been drawn from the TIMES Integrated Assessment Model (Version 4.3.3) base data which are primarily collected from IEA and other external sources including MoEJ for Japan.

3.2. Scenarios

Scenarios have been created to follow the research objective of demonstrating the benefits and costs of renewable energy dependent path over the fossil fuel dependent path under the nuclear energy phase out condition by 2050. The fundamental assumption of this study is nuclear phase out by 2050 from all these case study countries.

1. **Reference Energy Scenario (REF)**: This is the business as usual scenario. This scenario assumes continuation of pre disaster energy supply policy. However, this scenario inherently emphasizes nuclear energy supply in the mix. For Japan it is expected to be reaching around 40% of total electricity by 2050 and for India and China, nuclear energy supplies are expected to be reaching around 20-25% of total electricity supply in the market under this reference scenario. This scenario also assumes no fundamental technology changes which can affect the energy systems as a whole.
2. **Fossil Fuel Dependent Scenario (FF Dependent)** : This is fossil fuel dependent scenario with gradual phase out of nuclear energy supply in the total electricity supply mix by 2050. This scenario assumes that Japan, China and India will gradually phase out its nuclear energy supply completely by 2050 with replacement of fossil fuels. The share of nuclear power in total electricity generation is assumed decreasing from 30% in 2009 to 0% in 2050 for Japan and for China and India it is assumed decreasing from their respective current level to 0% by 2050. This scenario also assumes that the renewable energy supply is maximum up to 10% of total electricity supply in the system by 2050. This scenario assumes energy efficiency improvement of between 5-10% and energy conservation of around 15% across the sectors of the economy and energy utilizing activities and processes. Energy efficiency improvement is assumed taking place in the energy conversion processes where primary energy is getting converted to usable energy (oil refinery and power plants) and in all other energy utilizing processes in the system. For the energy conversion processes we have used the maximum limit of 5% improvement which is at the higher side of the world average of 3 to 6% by 2030.
3. **Renewable Energy Dependent Scenario (RE Dependent)**: This is renewable energy dependent scenario with gradual phase out of nuclear energy. This scenario also assumes energy efficiency improvement of between 5-10% and energy conservation of around 15% across the sectors of the economy and energy utilizing activities and processes. In addition to the assumption of gradual phase out of nuclear energy in the Fossil Fuel Scenario, this scenario assumes to have certain

market policies in place like FIT and/or mandatory minimum RE supply to achieve target level of minimum renewable energy share of 40% (15% from wind and 25% from solar) by 2050 with gradual escalation. The following table (Table 5) shows the assumption of solar and wind energy penetration ratio in the total electricity supply mix until 2050. As different countries have different levels of renewable energy potential and capacities to produce electricity and also different levels of total electricity demands, we used the percentage reduction target rather than absolute target. This approach helps us to avoid the computation problem of magnitude difference for same variables in different countries.

Table 4. Solar and Wind Energy Penetration Ratios

Technology	2020	2030	2040	2050
Wind (on-shore & off-shore)	5%	10%	12%	15%
Solar (PV/CSP)	10%	15%	20%	25%

Geothermal energy is assumed to be restricted in all cases of electricity supply especially in Japan (maximum up to 10% by 2050) based on the assumption of continuation of the current regulatory restrictions which hinder its development in Japan. Moreover, biofuel utilization (biodiesel and bio-ethanol) in the transport sector is also assumed maximum of 5% by 2050 in all cases. This assumption is based on the understanding of the global decline in biofuel production and its availability in the international market for trade.

3.3. Simulation Setting

We compare two nuclear phase-out scenarios (REN and SFF-LR) under the same amount of emission reduction. First we estimated the amount of emission reduction under REN scenario, and use this amount as the benchmark emission reduction level. Table 5 below shows the benchmarking emissions reduction compared to the reference case for each country and for each milestone year.

Then this benchmark emission reduction level is given to the model as constraint for the fossil fuel dependent scenario.

Table 5. Benchmarking CO_2 Emissions Reduction for Each Country

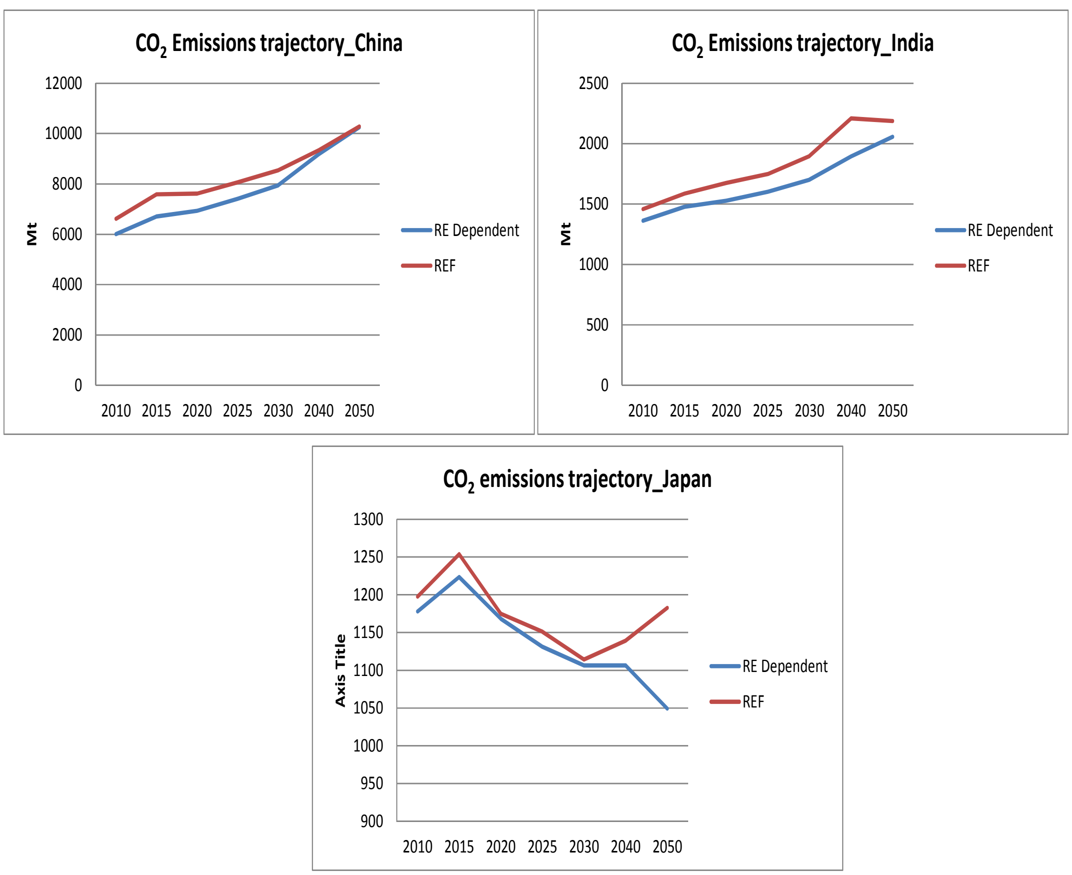
Country	2020	2030	2050
China	-9%	-7%	-0.4%
India	-9%	-10%	-6%
Japan	-1%	-1%	-11%

4. Results and Discussion

4.1. CO2 Emissions Pathway for Renewable Energy Dependent Scenario

Figure 3 below shows the total CO2 emissions trajectory for Japan, China and India under the reference and renewable energy dependent scenarios.

Figure 3. Cumulative CO_2 Emissions Trajectory for Japan, China and India



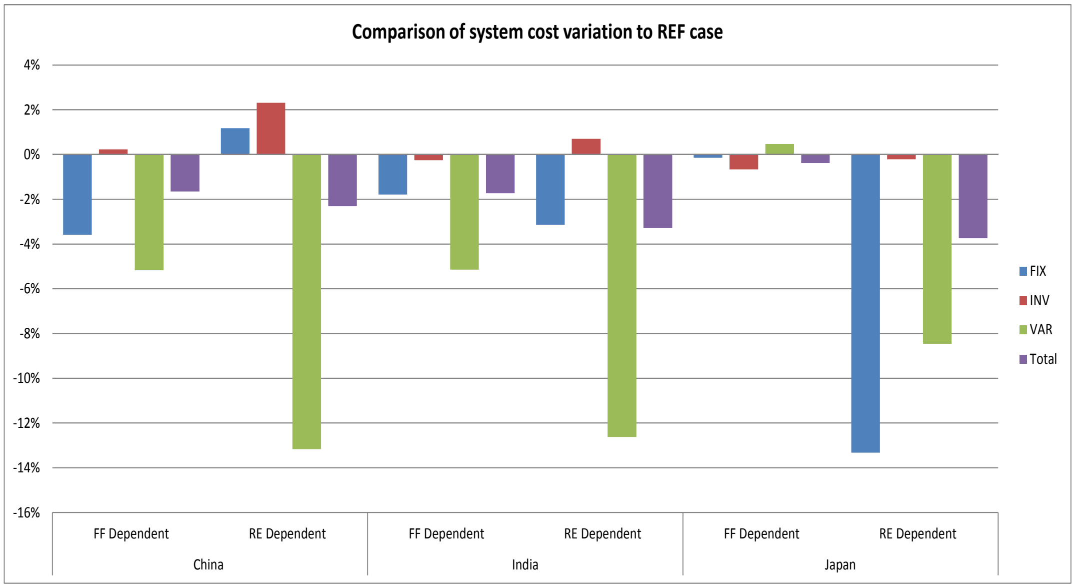
The renewable energy dependent path can contribute to the maximum of 11% total national CO_2 emissions reduction from the electricity sector compared to the reference case by the year 2050 and by 17% compared to the base year 2005 in Japan. For China and India, CO_2 emissions are increasing at a rapid rate until 2050 under the reference case scenario. By 2050 the CO_2 emissions could be doubled in China (102% increase) and around 1.7 times for India (76% increase). Nevertheless, renewable energy dependent path can restrain this massive growth in emissions to some extent. In this study, CO_2 emissions reduction is benchmarked for the fossil fuel dependent scenario for level playing comparison of the two scenarios under the condition of no-nuclear supply by 2050.

4.2. Impact on total system costs

The system cost is the net present value of the total annualized cost of energy supply and consumption in the system discounted at 5% rate over the period of time between 2005 and 2050. The total cost includes fixed cost, new investment costs and variable costs. The fixed cost is the overhead expenditures of the energy production units like power plants which mainly cover all sorts of rents, wages and salaries and interest payments for debts. Investment cost is for new construction of energy extraction, production and consumption facilities which is the major cost to the system. The variable costs include the fuel costs along with operation and maintenance costs which are linked to the level of production of each unit of energy.

The total system cost impact comparison demonstrates that renewable energy dependent path is in general economically better off for all the countries like Japan, China and India compared to the fossil fuel dependent path (See Figure 4) under the condition of certain level of CO_2 emissions reduction. As a consequence, the countries can ripe the benefit of reduced energy use and its corresponding effect on import reduction. Being the net energy importers, Japan, China and India can get the benefits of such energy import reduction. This result further corroborates the importance of renewable energy for the long term sustainable energy planning for Asia.

Figure 4. System Cost Variation to REF Case Under Different Scenarios



4.3. Impact on Electricity Price

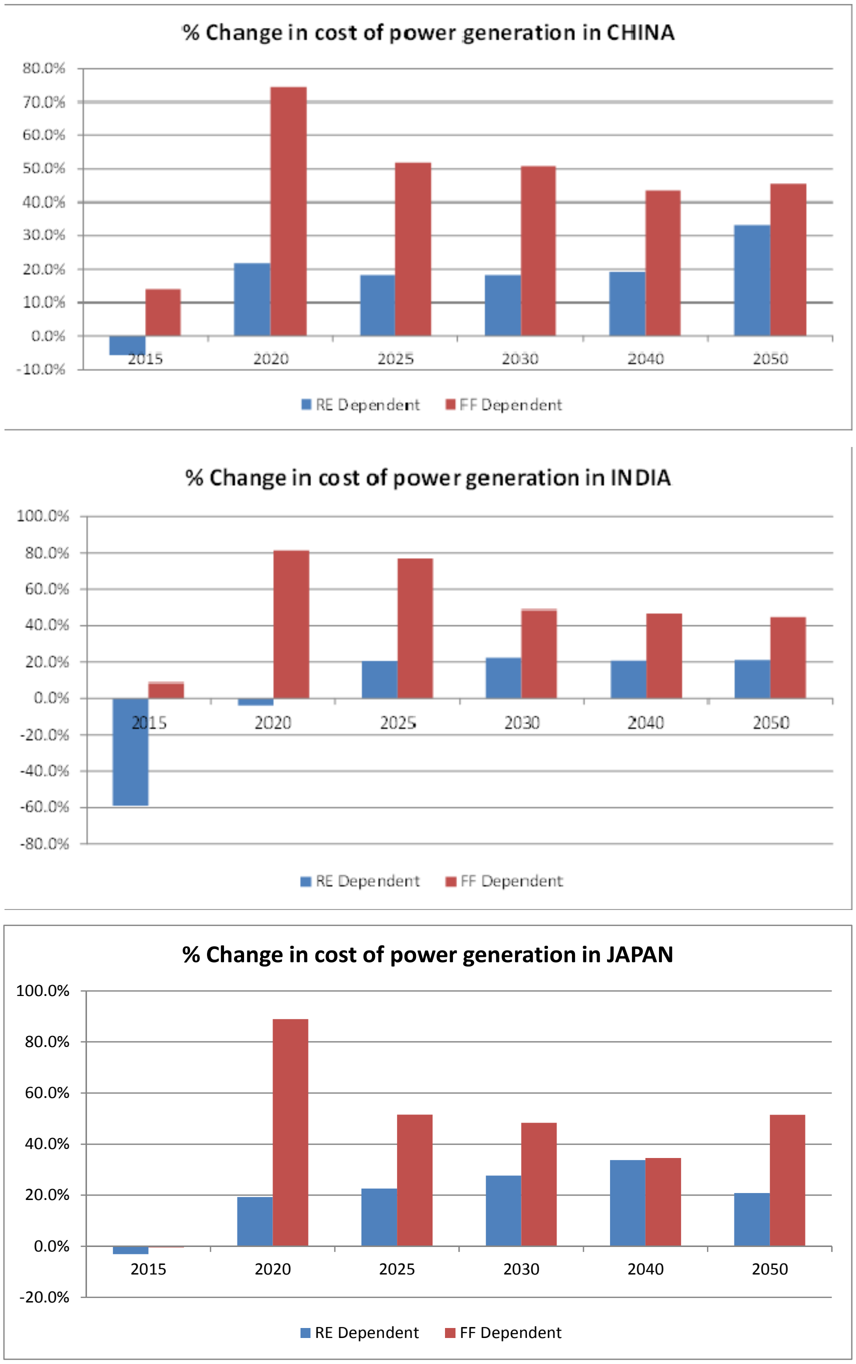
For investigating the consumer prices of electricity, we estimate the variation in cost of production of electricity in the power plants. This cost is the marginal cost of per unit of electricity generation. For the sake of simple understanding we took the mean of these marginal prices for all six different time slices[5] of the year. Figure 5 shows changes in electricity generation cost under different scenarios in each country.

The results show that under both nuclear phase-out scenarios, electricity price is expected to be higher than the reference case but the price differences are gradually reducing towards the end of the simulation time. This decline is observed mainly due to the reduced investment costs and other overhead cost reduction happening due to full depreciation of the power plants capital investment costs, full paid up of debts and liabilities etc. Nevertheless, 2020 to 2030 is expected to be the costliest time period for the consumers in terms of electricity price escalation. The results also show that fossil

[5] Time slices are lined to the seasonal electricity load patterns in Japan and divided into six categories like summer day, summer night, winter day, winter night etc. The marginal cost of generation of electricity in a perfect competitive market condition varies between each time slice due to different supply mix shows the mean of all the marginal costs over a year to demonstrate the trend of overall cost variation of the electricity generation.

fuel dependent path generates electricity at the higher cost compared to the renewable energy dependent path.

Figure 5. Changes in Electricity Generation Cost Under Different Scenarios



4.4. Impact on Electricity Supply Mix

Figure 6(a) and 6(b) show the electricity supply portfolio in the countries until 2050 under the reference case and under two dependency path scenarios. These supply mixes are endogenously determined under the given constraints of no nuclear supply, energy efficiency improvement and conservation of certain level, minimum renewable energy supply etc. These supply mixes indicate how the RE and FF dependent paths under certain CO2 emissions reduction constraint can influence countries' long terms energy scenarios compared to the reference case.

This result indicates that in the fossil fuel scenario, coal will be the single largest fuel sources for power generation in China and India while for Japan, coal and natural gas together are the major sources of power generation.

Figure 6(a). Reference Case Electricity Supply Mix for The Countries

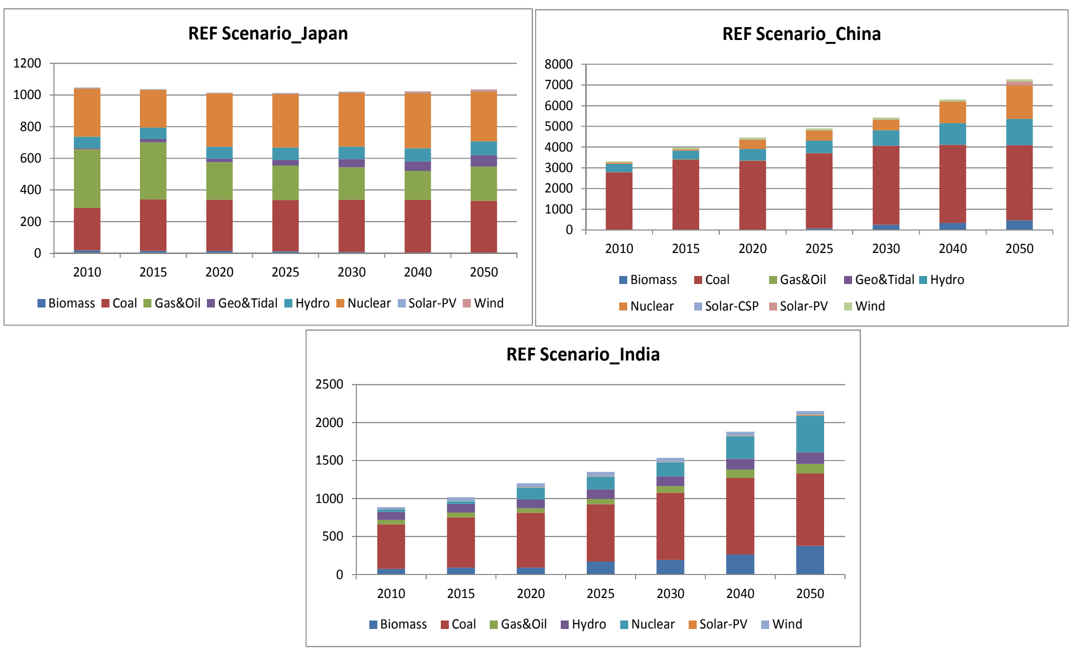
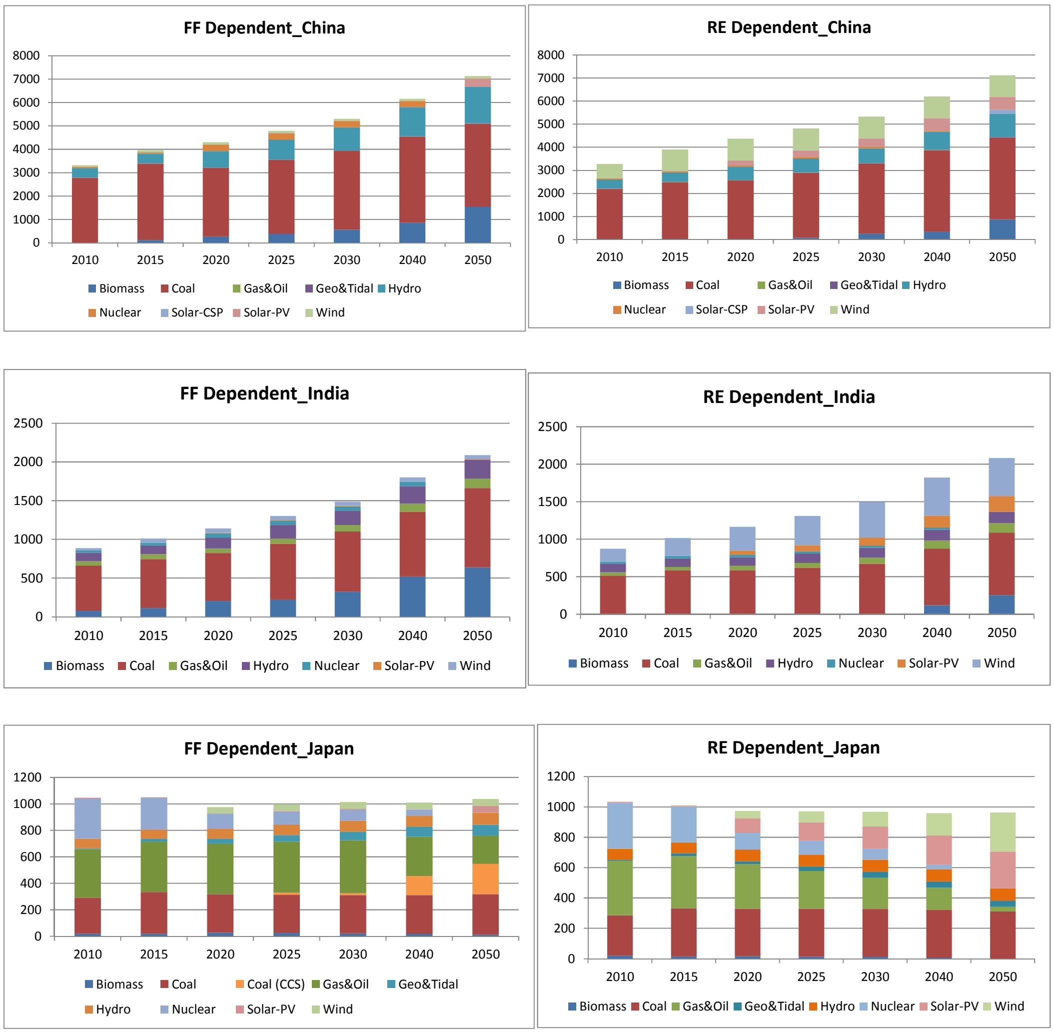


Figure 6(b). Electricity Supply Mix for The Countries Under Different Scenarios



Under the fossil fuel dependent path, CCS technology is required to achieve the same level of emissions reduction as the renewable energy dependent path. It is observed that this advanced technology is becoming an option after 2030 and rapidly increasing in the share. This further indicates that Japan has to make trade-off between the advance technologies like CCS which are yet to be commercially available and solar and wind technologies which are already commercially available. In Japan, the fossil fuel dependent path may lead the country more towards investment uncertainties with newer technologies.

In China, solar CSP technology is expected to be coming up in the market during the later stage of the time horizon when other technologies are utilized fully. Another important aspect of nuclear phase-out scenario for China and India is lesser utilization of hydro power in the supply mix for the renewable energy scenario compared to the fossil fuel dependent scenario. Similarly biomass based energy generation is reduced under renewable energy dependent compared to the fossil fuel dependent path in China and India both.

5. Discussions

Compared to the renewable energy dependent path, the fossil fuel dependent path appears costly in the long run in Japan, China and India when given the same level of emissions reduction. Benefits of renewable energy are multifarious and observed in terms of total system cost and electricity generation cost.

In Japan, the renewable energy dependent path could be even clearer provided the indigenous geothermal potential is allowed to be harnessed significantly. So far its utilization is restricted under the legal protection of forest conservation. But given the nature of geothermal energy which is primarily suitable for base load power supply, Japan may need to consider appropriate utilization of this resource especially under the nuclear phase out planning. Geothermal energy can partly address the technical problem of intermittency of renewable energy and grid instability indeed.

Electricity price is expected to increase under both the nuclear phase-out scenarios in all three countries, but the renewable energy dependent path will have lesser increase than the fossil fuel dependent path. This also indicates reduction of imported energy use (variable cost) in the renewable energy dependent path. The myth of renewable energy utilization i.e. higher cost implication to the consumers seems doubtful. It may be relevant to raise priority of renewable energy with other objectives like better environment, risk free energy supply and sustainable future of the country.

Coal is expected to be dominating the supply under nuclear phase-out scenarios at least until 2050 in the three countries. There is a trade-off observed here between the advanced technology like CCS and renewable energy in Japan. The risk of investment can play a crucial role in this context. Investment risk in CCS needs to be evaluated against risks in renewable technologies like solar and wind under long term nuclear phase-out energy scenario analysis.

6. Recommendations and Way Forward

Based on the above findings, this study recommends that Asia needs to focus more towards its indigenous energy resources like renewable energy rather than looking for something which is not of its own like nuclear energy and or fossil fuel based technologies, to have sustainable future with reasonable economic development which can support basic human needs for all. It is recommended to develop and promote indigenous renewable energy resources for the developing countries in Asia to the maximum possible level with all technical and financial support from developed countries like Japan. Nuclear energy may be expected to solve the problem of higher cost of energy, environmental pollution and maintaining certain economic growth rate assuming no accidental threat, but it will ultimately make the region dependent on other countries for nuclear fuel supply, technology support, maintenance of power plants, and even for decommission of power plants. This is political problem to be seriously considered, in addition to the nature of risks associated with nuclear technology revealed by the Fukushima nuclear plant accident.

To significantly increase the share of renewable energy in energy mix, there are technical challenges to ensure grid supply stability. This issue cannot be covered by the employed methodology of this study. Additional work and more advanced modeling technique need to be used to address this issue. Furthermore, the model does not pose much importance on the demand sector of energy in this study, which is an important component of the energy system analysis and assumed a general range of demand elasticity to its own price between 10 to 20% across the demand sectors. Sector specific demand elasticities are more appropriate in this case. In addition to that, the study also lacks in sensitivity analysis of price changes of various primary energies which could be of further interest of the readers.

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