Electricity Trade in a Regional Electricity Market:
Economic Efficiency and Welfare Implications

Youngho Chang[1] and Han Phoumin[2]

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Overview

There has been huge effort in connecting electricity markets across countries in Europe and Africa or states in the U.S. Such integration of electricity markets is expected to improve the efficiency of electricity markets and bring larger benefits to member countries of the integrated electricity markets. The Association of Southeast Asian Nations (ASEAN) has been trying to connect member countries' power grids in the region and integrate member countries' electricity markets in the region. ASEAN Power Grid (APG) is a good example of such integration effort.

Four member countries of the ASEAN, namely, Lao PDR, Thailand, Malaysia and Singapore jointly announced in 2014 a power integration project entitled "Lao PDR, Thailand, Malaysia and Singapore (LTMS) Power Integration Project (LTMS-PIP)" to examine the feasibility of power trade across. After examining related policy, legal and commercial issues, the four countries announced to initiate cross-border power trade up to 100 MW at the 38th ASEAN Ministers on Energy Meeting in November 2020. Following this announcement, Singapore has called for "Request for proposal to appoint electricity importer to import 100MW via the existing Singapore-Peninsular Malaysia interconnector for a two-year trial" in March 2021 (Energy Market Authority, 2021).

Bilateral electricity trade is a first step toward integrating electricity markets. European electricity market liberalization is considered the world's most extensive cross-jurisdiction reform of the electricity sector involving integration of distinct state-level or national electricity markets (Jamasb and Pollitt, 2005). An ASEAN power grid that links the energy resource-rich and the energy resource-poor countries could potentially play an important role in reducing the overall cost for the region to meet its growing electricity demand. Based upon an optimization study, eleven potential power grid interconnection projects in the ASEAN were selected for potential implementation through 2020, which appeared to a significant reduction in the cost of meeting the demand for electricity in the region as a whole (Chang and Li, 2013).

There has been a good body of research on how to promote cross-border power trade and what benefits it brings to the countries involved in the power trade in Africa (Odetayo and Walsh, 2021), in Central Asia (Qadir and Dosmagambet, 2021), in Northeast Asia (Otsuki et al, 2016), in North America (Siddiqui et al, 2020; Yuan et al, 2021), in South America (Agostini et al, 2019) and South Asia (Timilsina and Toman, 2016; Singh et al, 2018; Tortajada and Saklani, 2018). There are a few quantitative analyses of regional power market integration in ASEAN and a few qualitative studies focused on the institutional

[1] Corresponding author; School of Business, Singapore University of Social Sciences, Singapore; email: yhchang@suss.edu.sg
[2] Economic Research Institute for ASEAN and East Asia (ERIA), Jakarta, Indonesia; email: han.phoumin@eria.org

and policy aspects of regional development in relation with energy cooperation (Yu, 2003; Economic Consulting Associates, 2010; Yu et al., 2005; Watcharejyothin and Shrestha, 2009).

There have been studies on examining the welfare impacts of price equalization in energy market integration, relationship between energy market integration and efficiency of energy trade, infrastructure needs for trading electricity, possible benefits of hydropower projects in the lower Mekong River basin, and measurements of energy market integration (Kimura and Phoumin, 2014). Various benefits such as promoting renewable energy utilization, reducing consumption of fossil fuels and decreasing carbon dioxide emissions can be brought to the region through an integrated electricity market in the ASEAN (Chang and Li, 2015; Chang et, al, 2016; Chang et al, 2019; Chang and Phoumin, 2021a and Chang and Phoumin 2021b).

In sum, there have been studies on power development and economic benefits in an integrated electricity market but how a bilateral or unilateral trade in an integrated regional electricity market has not been done. As a first step toward a fully integrated regional energy market, the International Energy Agency recommended a bilateral trade model (International Energy Agency, 2019). This study evaluates how bilateral power trade between two countries in the region affects the economic efficiency of the electricity markets. It takes a specific case of bilateral trade between Singapore and Malaysia under the LTMS-PIP setting. Apart from evaluating economic efficiency of the electricity markets in the two countries, it also draws welfare implications to the two countries and the ASEAN as a whole out of the cross-border power trade. This study is expected to present possible gains or losses in the economic efficiency of electricity markets in both countries along with a few policy recommendations for making individual country's electricity market more efficient. It is also expected to present how cross-border power trade would enhance the well-being of people in both countries involved in the cross-border power trade and any spillover effects to the ASEAN member countries.

Methods

This study adopts a dynamic linear programming framework in power generation first developed by Turvey and Anderson (1977) and later adapted by Chang and Tay (2006) and Chang and Li (2013). Using a dynamic linear programming framework in power generation and cross-border electricity trade, this study evaluates how bilateral power trade between two countries in the region affects the economic efficiency of the electricity markets. It also considers the cost of cross-border power transmission, transmission loss, carbon emissions from power generation and the carbon cost of power generation. The model is solved using General Algebraic Modelling System (GAMS).

A new country dimension is added to allow an international framework with cross-border electricity trade. The new model also adds the cost of cross-border power transmission as well as transmission loss into account. Carbon emissions from power generation as well as the carbon cost of power generation are explicitly considered. This study further modifies a cross-border power trade model developed by Chang and Li (2013) and Li and Chang (2015) to cater the bilateral power trade between Singapore and Malaysia.

The objective of the integrated power trade model is to minimize the cost of meeting demand for electricity in the ASEAN for the study period from 2018 to 2040. The cost has four components, namely capital cost, operation cost, transmission cost and carbon cost. The model explicitly represents the capital expenditure (CAPEX) and operational expenditure (OPEX) of a certain type of power generation, carbon emissions and cross-border transmission costs.

This study covers the ten member countries of ASEAN, which are Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. Technologies for power generation discussed in this study are coal, coal CCS, diesel, natural gas, natural gas CCS, hydro, small hydro, geothermal, wind, solar PV, and biomass. The period of this optimization simulation model is 2018 to 2040.

The key data required for this simulation study include existing capacities by the types of power generation that are mentioned above, the CAPEX and OPEX of these types of power generation, the load factor and life expectancy of each vintage of each type of power generation, the energy resources available for power generation in each country, the peak and non-peak power demand and duration of power demand of each country, projected growth rate of power demand, and transmission cost and transmission losses of cross-border power trade. For the detailed data and sources of data, this study adopts data used in Chang and Li (2013) and Li and Chang (2015) except the initial capacity. This study updated the initial capacity given in Chang and Li (2013) and Li and Chang (2015) using the data taken from ASEAN Centre for Energy (ACE, 2022) and IRENA (2020).

This study establishes two broadly defined scenarios. The first scenario is constructed with a hypothetical integrated electricity market in ASEAN where power trade between countries is unlimited. This scenario serves as a reference case. This study assumes the planned transmission grids in the ASEAN Power Grid is to be operating as scheduled and considers transmission costs and losses over the distance between countries in the calculation of total cost of meeting electricity demand in the region. This assumption presents the lower bound of the cost estimates.

The second scenario is constructed following Singapore's unilateral import of electricity from Malaysia. Singapore is assumed to import 100MW (at least 90MW) of electricity per year from Malaysia for the entire period. There are two specific cases in the second scenario – Singapore imports electricity only in peak period and both peak and nonpeak period, which are named "Import (peak only)" and "Import (peak/nonpeak)", respectively.

The results of the two scenarios present how Singapore's unilateral import of electricity from Malaysia affects the total cost of meeting electricity demand in Singapore and Malaysia. They also show whether and how the unilateral import of electricity influences Singapore's electricity trade with other countries in the region.

Results

Under the reference scenario, Singapore appears to supply electricity from its own capacity and import electricity from Vietnam during the peak period and from Malaysia during the nonpeak period. During the nonpeak period, Singapore appears to import electricity from a few neighboring countries such as

Cambodia a, Lao PDR, Indonesia and Thailand for some years, especially towards later period.

The discounted total cost for the ASEAN appears to increase a little. This is due to the unilateral import of electricity is a deviation from the efficient and least cost solution of the simulation model of electricity trade in the ASEAN under a hypothetical integrated electricity market for which no disruption or a foul play in supplying electricity. The discounted total cost for the ASEAN appears to increase, but the impacts of the unilateral import of electricity on the two trading countries are different.

The unilateral import of electricity from Malaysia seems not to affect the discounted total cost for Singapore but for Malaysia. This is mainly due to the fact that Malaysia has to deviate from the most efficient and least cost solution for supply and export of electricity to meet Singapore's unilateral import of electricity. The negative impact appears to deepen when the unilateral import of electricity from Malaysia applies to both the peak and nonpeak period.

Conclusions and Policy Implications

This study considers how Singapore's unilateral import of electricity from Malaysia affects the discounted total cost of meeting electricity demand in the ASEAN by adopting a simulation model of electricity trade in the ASEAN context as well as for Singapore and Malaysia.

This study draws a few policy implications. First, Singapore's unilateral import of electricity from Malaysia appears not to affect the discounted total cost for Singapore but Malaysia. It is good to develop policies that lead the two countries to determine how to share the possible increases in the cost.

Second, the results of the simulation model appear to verify that a unilateral import of electricity from Malaysia may lead to an inefficient and non-least cost outcome. These results suggest that it is good to review if any bilateral electricity trade agreements are nested in the efficient and least cost outcomes.

Third, the simulation results of Singapore's unilateral electricity import from Malaysia show a bilateral electricity trade regime could be inferior to a full-pledged cross-border power trade regime. This suggests moving away from a bilateral electricity regime to a full-pledged cross-border power trade regime as early as possible would benefit both countries.

The trial of the bilateral electricity regime appears to help the two involved countries identify the areas to be strengthened, fixed or improved. It is good to reflect these points in developing and moving to the full-pledged cross-border power trade regime.

The assumption of a hypothetical integrated electricity market is a bit optimistic. The results from the simulation of the hypothetical integrated electricity mark may not represent the realistic features of electricity trade in the region. It is good to consider how to share the transmission costs and losses among the trading countries in a more realistic and equitable manner.

References:

Agostini, C.A., A.M. Guzman, S. Nasirov and C. Siva (2019), 'A Surplus Based Framework for Cross-Border Electricity Trade in South America', *Energy Policy*, 128, pp.673–84.

ASEAN Centre for Energy (ACE) (2022), https://aseanenergy.org/work/data-statistic/

Chang, Y. and Y. Li (2013), 'Power Generation and Cross-Border Grid Planning for the Integrated ASEAN Electricity Market: A Dynamic Linear Programming model', *Energy Strategy Reviews*, 2(3), pp.153–60.

Chang, Y. and Y. Li (2015), 'Renewable Energy and Policy Options in an Integrated ASEAN Electricity Market: Quantitative Assessments and Policy Implications', *Energy Policy*, 85, pp.39–49.

Chang, Y. and H. Phoumin (2021a), 'Harnessing Wind Energy Potential in ASEAN: Modelling and Policy Implications', *Sustainability*, 13, 4279.

Chang Y. and H. Phoumin (2021b), 'Curtailed Electricity and Hydrogen in Association of Southeast Asian Nations and East Asia Summit: Perspectives from an Economic and Environmental Analysis', *International Journal of Hydrogen Energy*, (forthcoming).

Chang, Y. and T.H. Tay (2006) 'Efficiency and Deregulation of the Electricity Market in Singapore', *Energy Policy*, 34, pp.2498–508.

Chang, Y., Z. Fang and Y. Li (2016), 'Renewable Energy Policies in Promoting Financing and Investment among the East Asia Summit Countries: Quantitative Assessment and Policy Implications', *Energy Policy*, 95, pp.427–36.

Chang, Y., J. Lee, W.X. Ang and J.Y. Chua (2019), 'Energy Market Integration in ASEAN: Locational Marginal Pricing and Welfare Implications', *Journal of Asian Economic Integration*, 1(1): pp.48–72.

Economic Consulting Associates (ECA) (2010), *Greater Mekong Subregion (GMS) Transmission & Trading Case Study*. London: Economic Consulting Associates, Ltd.

Energy Market Authority of Singapore (2021), 'Request for Proposal to Appoint Electricity Importer to Import 100MW via the Existing Singapore-Peninsular Malaysia Interconnector for a 2-Year Trial', 5 March 2021. (www.ema.gov.sg › Imports › EMA-RFP-Electricity-Imports-20210305)

International Energy Agency (IEA) (2019), *Establishing Multilateral Power Trade in ASEAN*. Paris: International Energy Agency.

International Renewable Energy Agency (IRENA) (2020), *Renewable Power Generation Costs in* 2019.

Jamasb, T. and M. Pollitt (2005), 'Electricity Market Reform in the European Union: Review of Progress toward Liberalization and Integration', *The Energy Journal*, 26, pp.11–41.

Kimura, F. and H. Phoumin (2014), *Energy Market Integration in East Asia*: *Energy Trade, Cross Border Electricity and Price Mechanism*, ERIA Research Project Report 2013, No.29, Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).

Li, Y. and Y. Chang (2015), 'Infrastructure Investments for Power Trade and Transmission in ASEAN+2: Costs, Benefits, Long-Term Contracts and Prioritized Developments,' *Energy Economics*, 51, pp.484–92.

Odetayo, B. and M. Walsh (2021), 'A Policy Perspective for an Integrated Regional Power Pool within the Africa Continental Free Trade Area', *Energy Policy*, 156, 112436.

Otsuki, T., A.B. Mohd Isa, and R.D. Samuelson (2016), 'Electric Power Grid Interconnections in Northeast Asia: A Quantitative Analysis of Opportunities and Challenges', *Energy Policy*, 80, 311–29.

Qadir, S. and Y. Dosmagambet (2020) 'CAREC Energy Corridor: Opportunities, Challenges, and Impact of Regional Energy Trade Integration on Carbon Emissions and Energy Access', *Energy Policy*, 147, 111427.

Siddiqui, S., et al. (2020) 'Integrated North American Energy Markets under Different Futures of Cross-Border Energy Infrastructure', *Energy Policy*, 144, 111658.

Singh, A., T. Jamasb, R. Nepal, and M. Pollitt (2018), 'Electricity Cooperation in South Asia: Barriers to Cross-Border Trade,' *Energy Policy*, 120, pp.741–48.

Timilsina, G.R. and M. Toman (2016), 'Potential Gains from Expanding Regional Electricity Trade in South Asia', *Energy Economics*, 60, pp.6–14.

Tortajada, C. and U. Saklani (2018), 'Hydropower-based Collaboration in South Asia: The Case of India and Bhutan,' *Energy Policy*, 117, pp.316–25.

Turvey, R. and D. Anderson (1977), *Electricity Economics*: *Essays and Case Studies*, Baltimore and London: The Johns Hopkins University Press.

Watcharejyothin, M., and R.M. Shrestha (2009), 'Effects of Cross-Border Power Trade between Laos and Thailand: Energy Security and Environmental Implications,' *Energy Policy*, 37, 1782–92.

Yu, X. (2003), 'Regional Cooperation and Energy Development in the Greater Mekong Sub-region,' *Energy Policy*, 31, 1221–34.

Yu, Z., B.H. Bowen, F.T. Sparrow, V. Siriariyaporn, and L. Yu (2005), 'Integrated Energy Resources Planning for the ASEAN Countries and Southern China', *Oil, Gas & Energy Law Intelligence*, 3(4), 1–12.

Yuan, M., K. Tapia-Ahumada, and J. Reilly (2021), 'The Role of Cross-Border Electricity Trade in Transition to a Low-Carbon Economy in the Northeastern U.S.', *Energy Policy*, 154, 112261.