Chapter 9

An Integrated Asian Natural Gas Market: Potentials and Policy Implications

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December 2011

This chapter should be cited as
Chang, Y. and Y. Li (2011), 'An Integrated Asian Natural Gas Market: Potentials and Policy Implications', in Kimura, F. and X. Shi (eds.), *Deepen Understanding and Move Forward: Energy Market Integration in East Asia*. ERIA Research Project Report 2010-25, Jakarta: ERIA. pp.237-265.

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:

$$\text{Transportation costs} = ptc_{ij} \cdot xp_{ij} + ltc_{ij} \cdot xl_{ij} \tag{4}$$

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[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:

$$\sum_j (xp_{ij} + xl_{ij}) \le y_i \quad \text{(Supply constraint, country } i\text{)} \tag{5}$$

$$\sum_i (xp_{ij} + xl_{ij}) \ge z_j \quad \text{(Demand constraint, country } j\text{)} \tag{6}$$

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

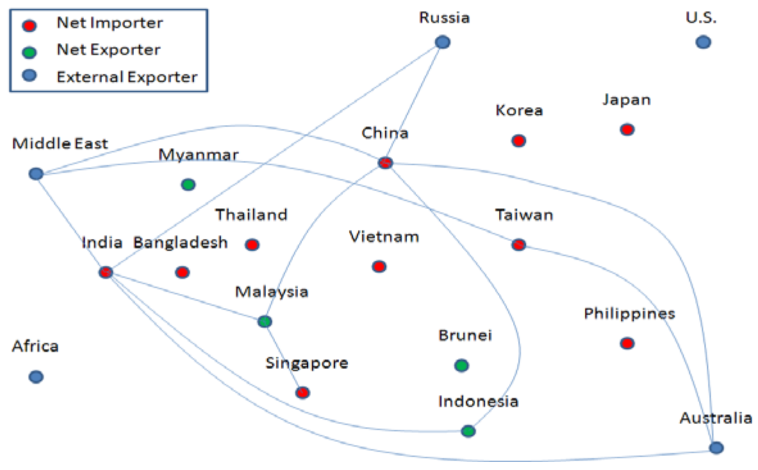
The comparison between Table 6 and Table 7 leads us to the following observations: First, in the integrated and competitive market, China and India will need to reduce their total consumption, and meanwhile cut off most of their LNG imports except that from Guinea. This is driven both by their willingness 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%.

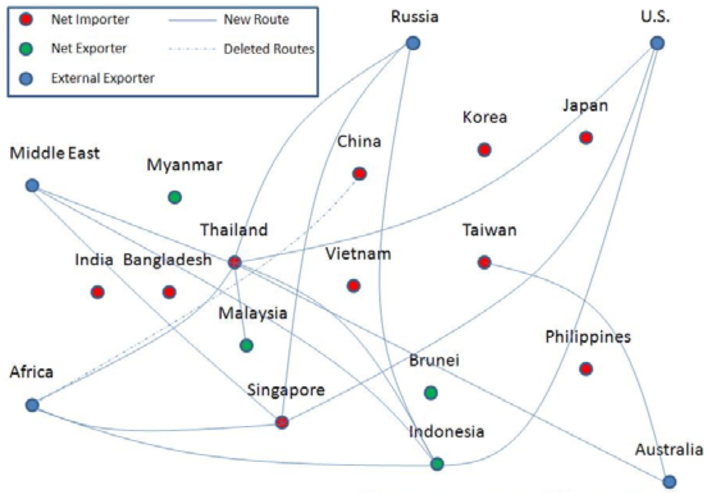
Figure 1. Inefficient Trade Routes removed from the Current Trade Pattern after optimization



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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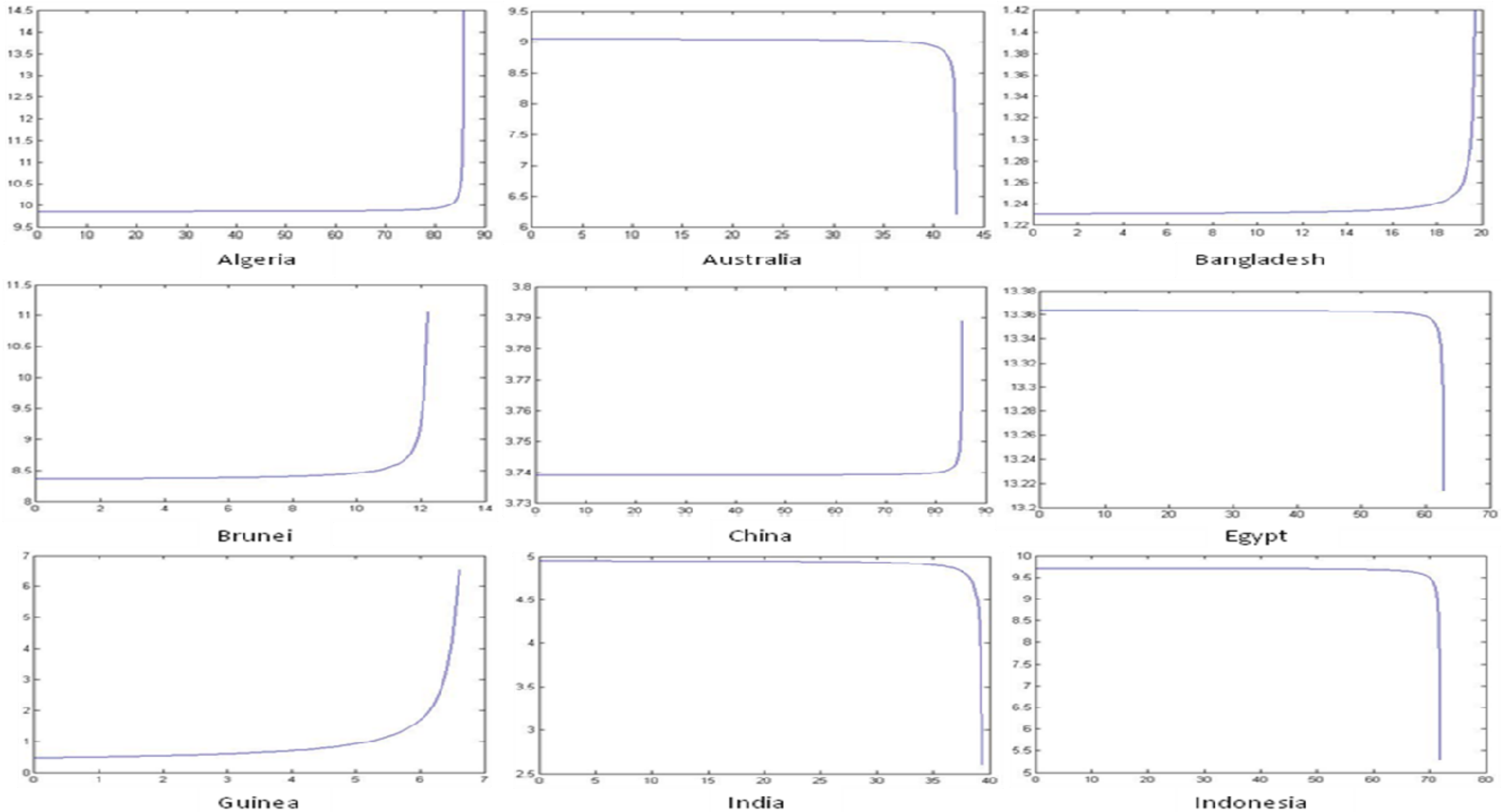
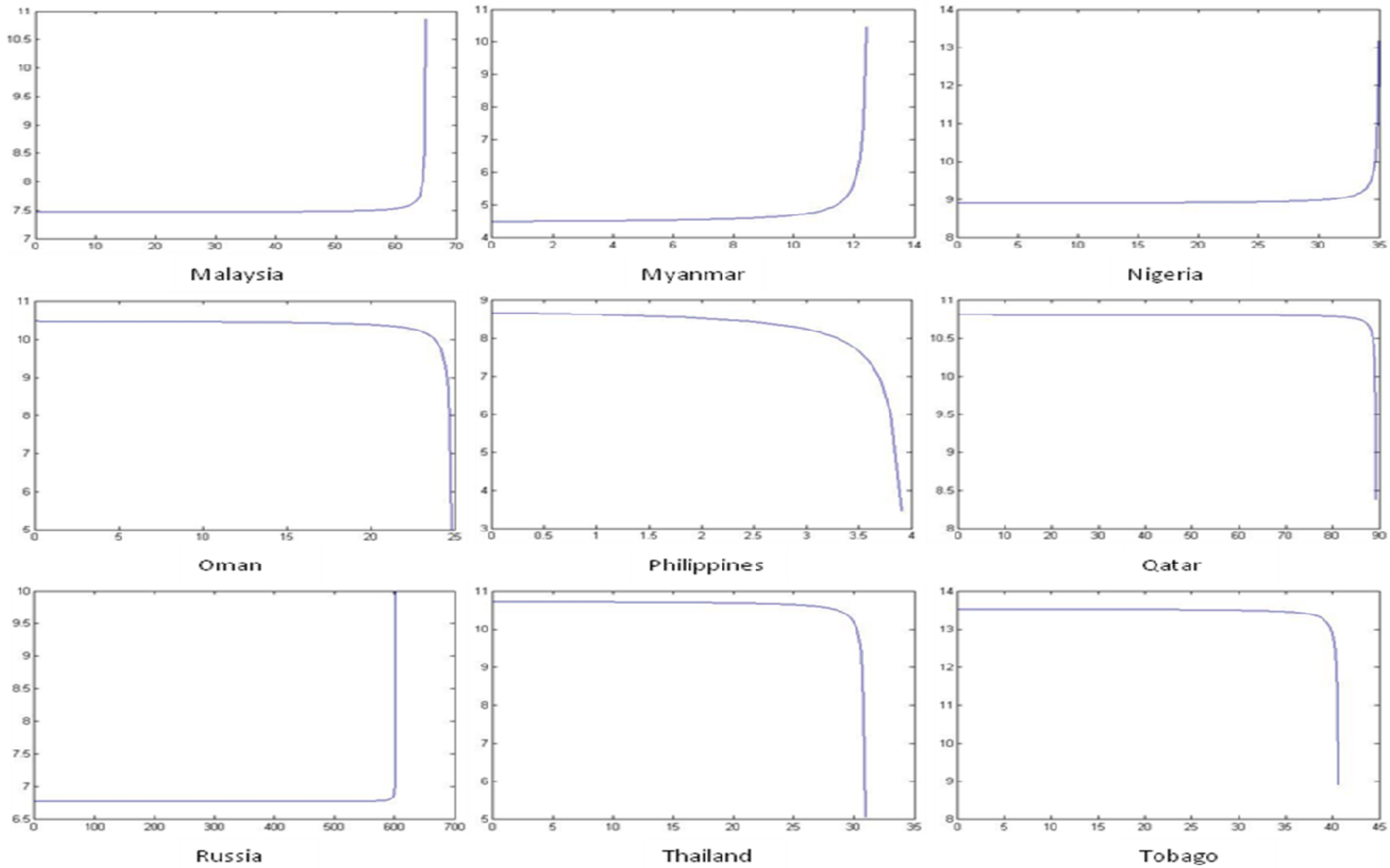
Appendix A. Estimated Marginal Cost of Suppliers

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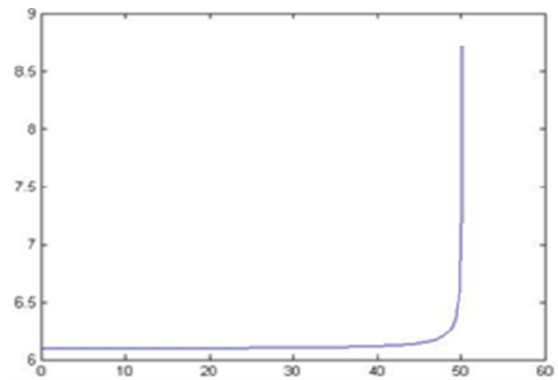
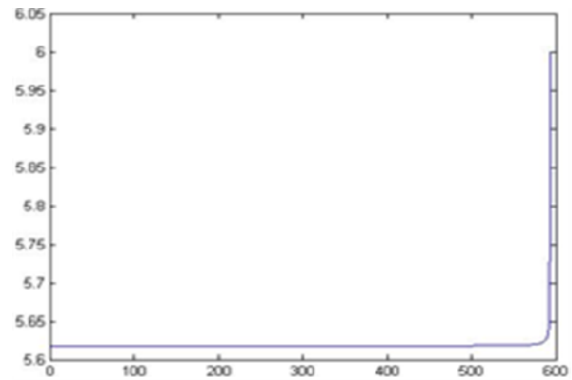
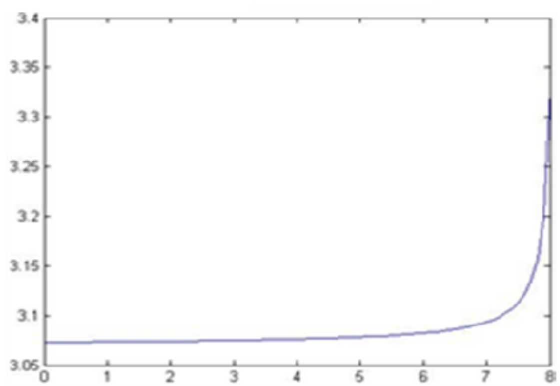
Oman
Philippines
Qatar
Russia
Thailand
Tobago



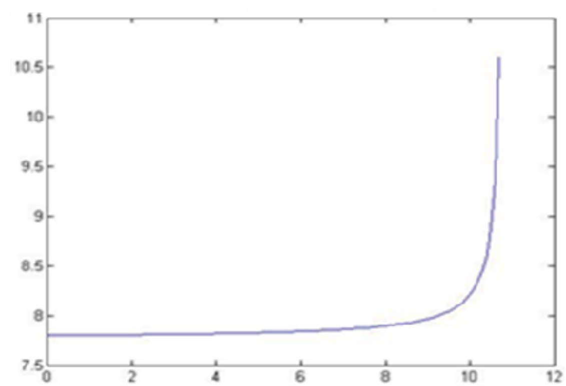
UAE



USA

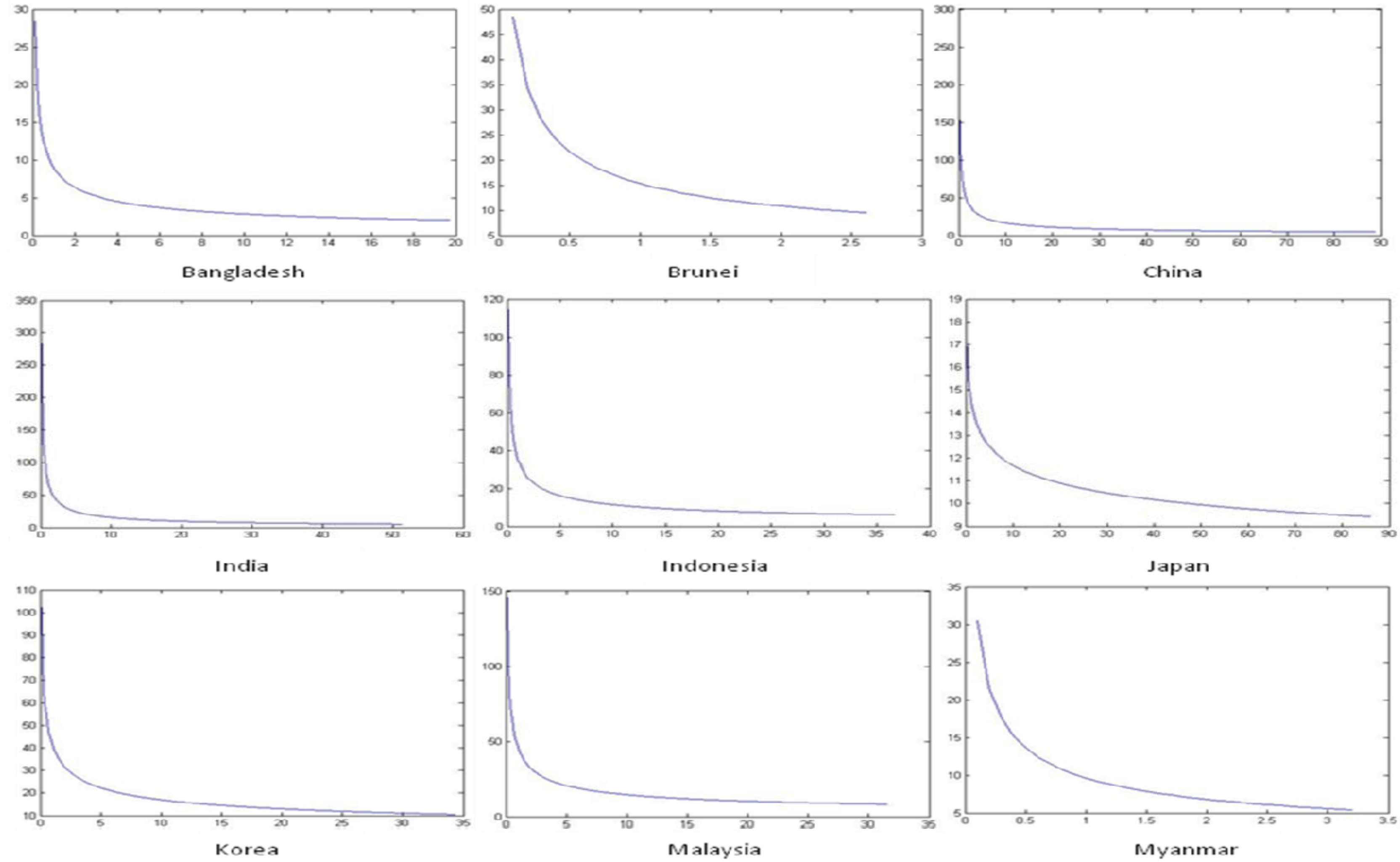


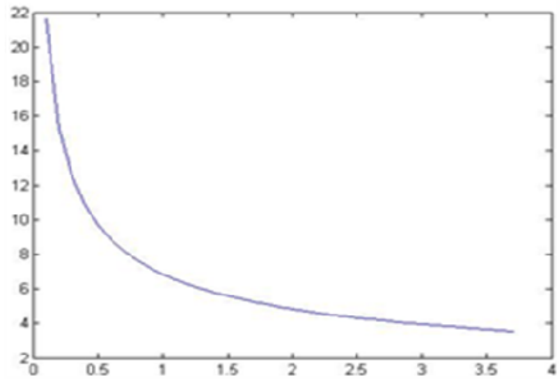
Vietnam



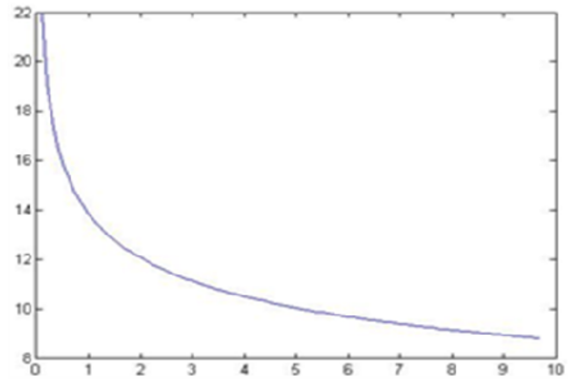
Yemen

Appendix B. Estimated Demand Function of Countries in the Region

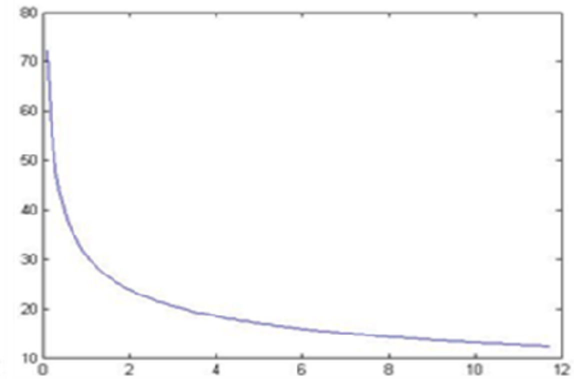




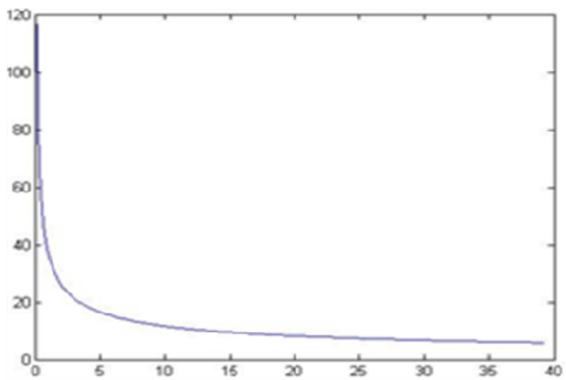
Philippines



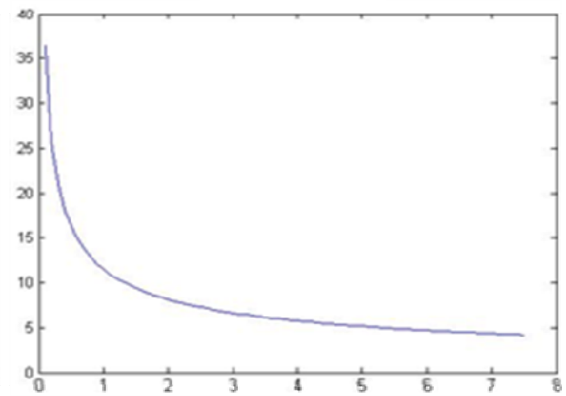
Singapore



Taiwan



Thailand



Vietnam