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Chapter 2
Energy Security in Asia: The Case of Natural Gas

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Abstract Natural gas consumption in the future is expected to increase due to its low environmental impact, ease of use and rise in the number of natural gas-fired power plants. This chapter measures natural gas supply security in six Asian economies including Japan, Korea, China, India, Singapore and Thailand from 1996 to 2009. Disruptions to long term security of supply can be caused by inadequate investments in production and transmission infrastructure, lack of supply diversity and import dependency. A composite gas supply security index is derived from four indicators of security of gas supply, with a higher index indicating higher gas supply vulnerability. Results show that China and India are the least vulnerable in terms of natural gas security because of their significant domestic gas production and small share of gas in the energy mix. Thailand is the most vulnerable among the countries studied due to its high reliance on natural gas to power its electricity generation industry as well as its greater exposure to geopolitical risks. With these analyses, governments can target possible sources of supply disruptions and mitigate their effects. Diversification is highly encouraged to spread the risk across different import and energy sources.

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2.1 Introduction

The oil *shocks* in the 1970s demonstrated how vulnerable the world's economy was to supply interruptions and price volatility. In addition, the recent increases in energy prices, a steady rise in global energy demand, instability in energy producing regions and the threat of terrorist strikes against energy infrastructure have significantly led to a growing concern over energy security. Any energy infrastructure—oil, coal or natural gas—is often vulnerable to disruption by insufficient supply, accident or malice. Terrorism, technical mishap, or natural disasters that damage the energy system could be nearly as devastating as a sizeable war. Inadequate financial resources also increase vulnerability or insecurity by limiting supply, transmission, and reliability while increasing prices of energy imports adversely affect the macroeconomic balance of payments, contribute inflationary pressures, and displace other consumption and investment because short-term demand is inelastic. In the past, long term contracts between exporters and importers have been an important element of security of supply. However, in recent years long term contracts have not been an adequate assurance of uninterrupted deliveries.

Energy security has emerged as a major object of the energy policy agenda and policy makers have engaged in a wide ranging debate over how best to address future energy requirements. Along with this emergence, energy markets have moved towards strengthening regional co-operation and energy supplies and sources have become more diversified. There has also been a strong trend towards shorter contract terms or a considerable decrease in the length of contracts caused by either market-related or regulatory-related changes. Market changes due to government regulatory initiatives and the creation of competitive markets have led to this trend.

While many previous studies have focused on oil, this chapter provides evidence on security of natural gas supply in selected Asian countries. With the growing demand for gas, supply interruptions, increasing gas prices, transportation and distribution bottlenecks, and a growing reliance on imports over longer distances have rekindled a debate on gas security of supply. Extending the work by Cabalu (2010), this chapter proposes a composite gas supply security index (GSSI) which is derived as the root mean square of the scaled values of four security of gas supply indicators, for the period 1996–2009. The four security of gas supply indicators are interrelated and the GSSI derived from 1996 to 2009 provides a trend in the composite quantitative measure of gas security by taking into account the interactions and interdependences between the identified set of indicators. The GSSI captures the sensitivity of the Asian economies to developments in the international gas market, with a higher index indicating higher gas supply insecurity or vulnerability.

The existing literature does not identify a unique methodology that is factual, objective, unbiased, transparent and accessible, to assess and quantify energy security. However, it is important to provide metrics by evaluating a set of parameters and indicators to assess overall natural gas supply security in the six Asian economies of Japan, Korea, China, India, Singapore and Thailand, which together account for almost 64 % of the total gas consumption in the Asia–Pacific region in 2010 (BP 2011). It is important for future policy making to benchmark countries against quantified indicators and assess their gas security of supply weakness. This chapter is divided into six sections. The sect. 2 provides a brief background on the importance of energy security, particularly in natural gas and includes a discussion of the vulnerabilities in the natural gas system. The sect. 3 reviews related literature on energy supply security, particularly focused on identifying the various indicators used in the literature to indicate energy vulnerability while Sect. 4 derives a composite gas supply security index for the years 1996–2009 for the sample countries. Section 5 presents the results and analysis and the final section concludes.

2.2 Importance of Energy Security: The Case of Natural Gas

Natural gas has become an increasingly valuable resource. Its consumption is expected to increase significantly into the future because of its low environmental impact, ease of use and an increase in the number of natural gas-fired power plants. It is one of the fuels that drive the economy. The demand for it, as a replacement for more expensive, less environmentally-friendly and less efficient resources, has already increased significantly (Cabalu and Manhutu 2009). The world is dependent on natural gas for power generation. In 2010, it fulfilled around 24 % of the total global primary energy demand (BP 2011). OECD countries accounted for 49 % of gas use, transition economies, especially Russia, used about 19 % with developing countries accounting for the rest. Natural gas is forecast to be the fastest growing energy source by 2035, with global consumption rising by more than 52 % from 110.7 trillion cubic feet from 2008 to 168.7 trillion cubic feet in 2035. The emerging markets of Asia will be the centre of this growth where gas consumption is projected to triple by 2035 (EIA 2011).

Natural gas is also becoming an increasingly global commodity. In the past, gas tended to be used in the region where it is produced because of the relatively high transport costs. However, technical developments have led to a drastic reduction in gas liquefaction and transport costs making liquefied natural gas (LNG) competitive with traditional pipeline gas. The rapid growth in LNG use and its greater flexibility has started to create a global market for gas. In 2010, more than 30 % of the global natural gas supply was internationally traded with LNG shipments showing strong growth, well above the ten-year average and making up more than 30 % of total export volume (BP 2011). The remaining share of gas sold on the world energy market is distributed via gas pipelines. The imbalances between supply and demand drive international trade in natural gas. On the one hand are northeast Asian countries (i.e. Japan, Korea, Taiwan and China), which held just over 1 % of world reserves in 2010 but accounted for almost 8 % of the demand.

On the other hand, the Middle East (particularly Iran and Qatar) and Russia had around 65 % of the world's reserves and accounted for around 25 % of the demand in 2010 (BP 2011).

In 2010, more than 11 % of the Asia–Pacific primary energy consumption was based on natural gas. Gas market requirements are mostly met through imports, more than 85 % of which is LNG from Malaysia, Brunei, Indonesia, Australia and the Middle East. Japan and Korea are almost entirely dependent on LNG imports for their gas supplies. In Japan and Korea, imported gas exchanges are based on long term contracts of 20–25 years and indexation clauses where the gas price is directly linked to the price of crude oil, including relatively strict clauses such as take-or-pay clauses which require importers to pay for the gas even if their deliveries are interrupted. In Australia and New Zealand, prices are set by gas-on-gas or gas-on-coal competition (IAEE 2007; IEA 2007; BP 2011).

Short-term security of gas supply is the ability to maintain gas supply despite exceptional demand and difficult supply conditions. Disruptions to supply may be due to physical or economic factors. Physical disruptions can occur when gas supply is exhausted or gas production is stopped. Economic disruptions can be caused by dramatic gas price fluctuations which in turn, are due to physical disruptions or unanticipated price changes associated with speculative reaction to potential disruption. Long-term security of gas supply on the other hand, is the ability to ensure that future gas demand can be met by a combination of domestic and imported gas supplies. Disruptions to long term security of supply are caused by inadequate investments in production and transmission infrastructure, lack of supply diversity and risks associated with import dependency which are geopolitical in nature. Gas-importing countries have started to examine potential responses to disruptions to ensure security of gas supply (Dolader 2003; Costantini et al. 2007).

2.3 Energy Security and its Indicators

To date, the literature on assessing energy security has concentrated on oil and mostly on industrialized countries. A number of studies have tried to develop a set of energy supply security indicators to account for both short- and long-term disruptions. Although a number of indicators have been proposed in the literature, there is no consensus on a set of relevant indicators. As a result, time series data to directly assess trends in energy supply security are not readily available and policymakers have therefore relied on a number of parameters associated with energy security to inform decision making.

Jansen et al. (2004) studied the energy supply security issue in the European Union by constructing four long-term energy security indicators based on the Shannon diversity index applied to eight primary energy supply sources (coal, oil, gas, modern and traditional biofuels, nuclear, renewables and hydropower). The indicators accounted for supply security aspects such as diversification of energy sources in energy supply, diversification of imports with respect to imported energy sources, political stability in import sources, and the resource base in import sources.

Similarly, Costantini et al. (2007) grouped indicators of supply security into two categories: dependence, and vulnerability represented in physical and economic terms. The distinction between dependence and vulnerability was made and in their study, the physical dimension of dependence was represented by indicators such as percentage share of net import of oil and gas in total primary energy supply and the share of European oil and gas imports in world oil and gas imports while the physical dimension of vulnerability was calculated in terms of the degree of supply concentration in trade and production using the Shannon-Weiner diversity index, percentage share of oil used in transportation, and percentage share of electricity produced with gas. In terms of the economic dimension of dependence and vulnerability, the value of oil and gas imports and oil and gas consumption per dollar of GDP respectively, were estimated. These indicators of the European energy system were analyzed under different energy scenarios.

In a study by de Jong et al. (2007), a model was developed for reviewing and assessing energy supply security in the European Union, on the basis of pre-agreed criteria. It used two quantitative indicators and some qualitative considerations. The first quantitative indicator, the Crisis Capability (CC) Index dealt with the risk of sudden unforeseen short-term supply interruptions and the capability to manage them. The second indicator, the Supply/Demand (S/D) Index covered present and future energy supply and demand balances. Qualitative considerations included multilateral measures for securing overall producer/consumer relations and safeguarding vulnerable transport routes for oil and gas.

A number of studies have focus on assessing energy vulnerability. Kendell (1998) explores the meaning and value of measures of import vulnerability as indicators of energy security, in particular, oil security in the United States. While measures of oil import dependence showing the extent of a country's imports may be of interest, they offer a limited indication of energy security. Gupta (2008), APERC (2007), and UNDP (2007) also examine the relative oil vulnerability of oil-importing countries on the basis of various factors. Using a principal component technique, individual indicators such as domestic oil reserves relative to total oil consumption, geopolitical oil risk, oil intensity, cost of oil in national income and the ratio of oil consumption in total primary energy consumption are combined into a composite index of oil vulnerability. Percebois (2007) clarifies the distinction between vulnerability and energy dependence and presents a coherent set of indicators including import concentration, level of energy import value in output, risk of blackout in the electricity sector, price volatility, exchange rates, and industrial and technological factors that are used to analyze energy vulnerability. Gnansounou (2008) defines a composite index of energy demand/supply weaknesses as a proxy for energy vulnerability. The index is based on several indicators such as energy intensity, oil and gas import dependency, CO_2 content of primary energy supply, electricity supply weaknesses and non-diversity in transport fuels. The assessment of the composite index is applied to selected industrialized countries. In 2008, the

World Energy Council (2008) identified threats to the European economy which could lead to potential energy crises and suggested solutions for facing related key challenges. The study also developed a number of indicators to assess the level of different types of vulnerability, as well as the overall vulnerability of a country or region, including threats to physical disruption and higher energy prices.

The design of a composite index of energy security has been undertaken in previous studies. A composite vulnerability index was developed by the World Energy Council (2008) to benchmark and monitor European countries' respective efforts to cope with long-term energy vulnerability. Similarly, de Jong et al. (2007) designed state-of-the-art indices of energy security risk (i.e., the Crisis Capability Index and Supply/Demand Index) which are oriented towards a comprehensive and analytical representation of the energy supply chain. However, the shortcoming of these approaches is the use of subjective-opinion-dominated weighting systems and scoring rules where the weights and the rules are based on expert judgments. In response to this shortcoming, Gnansounou (2008) proposes an alternative method which is objective-value-oriented and statistics-based. Gnansounou defines the composite index as the Euclidean distance to the best energy security case represented by the zero point. The Euclidean distance is standardized in order to get a value between 0 and 1. Following the more objective methodology proposed by Gnansounou, Cabalu (2010) develops a composite gas supply security index for selected Asian countries for the year 2008. This chapter extends this previous study by calculating an annual gas supply security index for the period 1996–2009 for net gas importing countries in Asia.

2.4 The GSSI for the Asian Gas Market

In line with the analysis made in Cabalu (2010), four distinct security of supply indicators are selected for this study: gas intensity (G_1), net gas import dependency (G_2), ratio of domestic gas production to total domestic gas consumption (G_3) and geopolitical risk (G_4). These indicators are chosen to be the most common indicators calculated in the prior literature which have direct relevance to security of natural gas supply.

G_1 is measured as the ratio of gas consumed in an economy to gross domestic product (GDP). It is the amount of natural gas needed to produce a dollar's worth of goods and services and provides an indication of efficient use of gas to produce the economy's output. *Gas intensity* (G_1) is calculated as:

$$G_{1j} = \frac{GC_j}{GDP_j}.$$

The gas intensity of GDP of country j (G_{1j}) is measured as the ratio of total natural gas consumed in country j (GC_j) to GDP of country j (GDP_j) and expressed as cubic meters per unit of GDP or m^3/GDP. The country's output of goods and services is measured by inflation-adjusted GDP.

The relative indicator for country j associated with G_1 (φ_{1j}) is estimated as:

$$\varphi_{1j} = \frac{G_{1j} - \mathrm{Min}(G_1)}{\mathrm{Max}(G_1) - \mathrm{Min}(G_1)}.$$

The relative indicator, φ_{1j} results in projection of G_{1j} in the interval [0, 1]. A low value of φ_{1j} means that country j is less vulnerable or less insecure to supply shocks compared to other countries in the study.

G_2 is expressed as the ratio of net imported gas consumption to total primary energy consumption. *Net gas import dependency* (G_2) is calculated as:

$$G_{2j} = \frac{GM_j}{TPEC_j}.$$

The gas import dependency of country j (G_{2j}) is represented by the ratio of net imports of natural gas in country j (GM_j) to total primary energy consumption in country j ($TPEC_j$) expressed as a percentage.

Similarly, the relative indicator for country j associated with G_2 (φ_{2j}) is estimated as:

$$\varphi_{2j} = \frac{G_{2j} - \mathrm{Min}(G_2)}{\mathrm{Max}(G_2) - \mathrm{Min}(G_2)}.$$

The above adjustment transforms the indicator to the [0, 1] interval with the value of 0 being assigned to the country with the lowest value of the selected security of supply indicator and least vulnerable and the value 1 is assigned to the country with the highest value of the selected indicator and hence most vulnerable.

G_3 is measured as the ratio of domestic gas production to total domestic gas consumption. Domestic production is a better indicator of the country's capacity to cope with short-term supply disruption than domestic reserves as production excludes gas from stranded reserves which cannot be tapped immediately. *Ratio of domestic gas production to total domestic gas consumption* (G_3) is calculated as:

$$G_{3j} = \frac{GP_j}{GC_j}$$

where GP_j is domestic natural gas production in country j and GC_j is total natural gas consumed in country j.

This indicator, unlike the first two, is negatively related to gas supply vulnerability or security. A high value for G_3 means that country j is less vulnerable or less insecure to supply shocks compared to other countries in the study. To accommodate this negative relationship, the relative indicator for country j associated with G_3 (φ_{3j}) is estimated as:

$$\varphi_{3j} = \frac{\text{Max}(G_3) - G_{3j}}{\text{Max}(G_3) - \text{Min}(G_3)}.$$

The above adjustment transforms the indicator to the [0, 1] interval with the value of 0 being assigned to the country with the highest value of the selected security of supply indicator and least vulnerable and the value 1 is assigned to the country with the lowest value of the selected indicator and hence most vulnerable.

G_4 represents the exposure of an economy to political risk and is measured on the basis of two factors: diversification of gas import sources and political stability in gas-exporting countries. *Geopolitical risk* (G_4) is largely determined by the degree of diversification of gas import sources and the associated political s tability of these sources. Jansen et al. (2004) suggests a methodology for quantifying such risk using the adjusted Shannon diversity index. The following formula describes this index.

$$S = -\sum_i (h_i m_i \ln(m_i))$$

where:

S = Shannon index of import flows of gas, adjusted for political stability in exporting country i;
h_i = extent of political stability in exporting country i, ranging from 0 (extremely unstable) to 1 (extremely stable); and
m_i = share of gas imports from country i in total gas imports.

The relative indicator for country j associated with $G_4(\varphi_{4j})$ is estimated as:

$$\varphi_{4j} = \frac{\text{Max}(G_4) - G_{4j}}{\text{Max}(G_4) - \text{Min}(G_4)}$$

Like φ_{3j}, this indicator is negatively related to gas supply vulnerability or security which means that a lower value for G_4 suggests high vulnerability to supply shocks or a worse gas supply situation (i.e., high insecurity). The above adjustment transforms the indicator to the [0, 1] interval with the value of 0 being assigned to the country with the highest value of the selected security of supply indicator and least vulnerable and the value 1 is assigned to the country with the lowest value of the selected indicator and hence most vulnerable.

The data on GDP are taken from the World Economic Outlook Database (IMF 2010). Data for natural gas—domestic production, domestic consumption and trade movements in volume terms were taken from BP Statistical Review of World Energy (2010, 2011). In this study, the percentile rank of an exporting country in the World Bank's Worldwide Governance Indicators for political stability for various years is used to determine h_{i} (Table A.1). Table 2.1 presents estimates of the four security of supply indicators of the selected six net gas-importing countries in Asia from 1996 to 2009.

High gas intensity of GDP results in larger adjustment costs and impacts on gas supply security in the event of natural gas supply shocks. In addition, the higher the share of imported gas in total energy demand the more vulnerable an economy is to international gas developments. Diversification of supply sources, particularly politically stable supply sources also reduces the risk and vulnerability to disruption. Dependence on domestically-sourced gas supply is preferred over imported gas, as it avoids geopolitical uncertainties. In addition, the larger domestic gas reserves relative to consumption or the larger domestic production capabilities a country has, the smaller are the likely impacts on gas security.

It is difficult to quantify a country's overall gas supply security using individual indicators and it is even more difficult to synthesize different indicators. To facilitate comparison or aggregation of several indicators, it may be better for these to be expressed in the same units. To do this, for each of the four security indicators, a relative indicator φ_i, was estimated which was used to compute a composite index—the gas supply security index (GSSI). The relative indicators are estimated by using a scaling technique where the minimum value is set to 0 and the maximum to 1. The value of 0 is assigned to the country with the least vulnerability or insecurity to supply disruptions and the value 1 is assigned to the country with the most vulnerability to supply shocks. Table 2.2 presents calculations for the relative indicators which are scaled values of the four security of supply indicators.

The gas supply security index (GSSI) is derived as the root mean square of the four relative indicators or scaled values of the four security of supply indicators.

$$\mathrm{GSSI_j} = \sqrt{\frac{\sum_{i=1}^{4} \phi_{ij}^2}{4}}$$

The various relative indicators of gas security are interrelated and the GSSI derived provides a composite quantitative measure of gas security by taking into account the interactions and interdependences between the identified set of indicators. The GSSI captures the sensitivity of the Asian economies to developments in the international gas market, with a higher index indicating higher gas supply insecurity or vulnerability.

2.5 Empirical Results

The GSSI is estimated for six Asian net gas-importing economies: Japan, Korea, China, India, Singapore and Thailand, on an annual basis from 1996 to 2009. The final values of GSSI for the sample net gas-importing countries in Asia are plotted in Fig. 2.1.

In the sample, China appears to be the least vulnerable country in the event of a natural gas supply disruption. Except for the period 2005–2008, China consistently registered the lowest GSSI where its major strengths are the indicators G_1, G_2 and

G_3. China is rich in energy resources, particularly coal. Gas use in China is still small and is significantly less than the use of other fossil fuels. Coal and oil resources are utilized more extensively than natural gas for power generation and industrial development purposes. Natural gas generally occupies a very small share (4.0 % in 2010) in China's energy mix but is expected to double by 2030 (Komiyama et al. 2005; APERC 2008).

China's major gas fields are located in the western part of the country, making transport to eastern demand centers difficult. The use of domestic gas production was initially limited to areas near production sites such as in Sichuan, Liaoning and Heilongjiang Provinces, where low cost gas is possible. However, with recent increases in infrastructure investments on pipeline construction such as the West–East pipeline to transport inland domestic gas, demand for natural gas has increased. Between 2005 and 2008, China's natural gas consumption increased by 23.8 % and it became one of the world's top ten countries in terms of natural gas consumption. This coincided with the period when China became relatively vulnerable. At the same time, LNG imports also started and its import dependence increased rapidly due to a substantial rise in demand. This growth was driven mainly by the increased use of gas for power generation, feed stock in chemical fertilizer production and to operate oil and gas fields. Recent developments such as the increased residential consumption due to penetration of city gas, together with the urbanization of cities have also led to the significant increase in demand. In addition, the Chinese government through policy and regulation has encouraged the use of natural gas as a source of 'cleaner energy' and a substitute for oil and coal. While some of the rising demand will be fulfilled through increases in domestic production, a large portion has come from pipeline and LNG imports. Due to geographical accessibility, the small amount of imported LNG goes to southern provinces along the coast like Guangdong and Fujian (Higashi 2009).

In 2010, China had 14 import sources compared to one import source in 2006. However, most of the additional import sources are politically unstable which explains China's relative poor performance on G_4. China received its first-ever LNG cargo in mid-2006 under a long-term contract with Australia. Australia remains China's major source of LNG. Its second terminal in Fujian started receiving cargoes from Indonesia in 2008. Another re-gasification terminal in the Shanghai area started to import LNG from Malaysia in 2009. In the northern inland areas of China, natural gas supply has been sourced from Qatar, Siberia, Turkmenistan, Sakhalin and Sakha.

India ranks as the second less gas-vulnerable country in the sample. For the period, 1996–2009, India's natural gas security generally improved through time as shown by a downward trend in its GSSI. The strength of this country is in G_2 indicating a relatively low gas import dependency, and to a less extent in G_1 for having low gas intensity. In India, natural gas is a minor fuel in the overall energy mix representing only 10.6 % of total primary energy consumption in 2010. In that same year, India's natural gas imports represent just over 2 % of its energy mix and hence not reliant on imports. With coal as the major source of energy for power generation, gas intensity of the economy's GDP is low. However, opportunities exist for gas in reducing regional air pollution and providing peaking power. For the fertilizer sector, significant opportunities exist to import cheap fertilizer; thereby reducing domestic gas demand, but political constraints will likely buoy gas demand. Industrial consumers will benefit from increased supplies of LNG to replace expensive liquid fuels, but cheap coal remains the dominant fuel for many industrial applications (Jackson 2007).

However, India's consumption of natural gas has risen faster than any other fuel. The power and fertilizer industries are the key demand drivers for natural gas. With domestic gas production only large enough to satisfy almost three-quarters of its domestic gas consumption, India's domestic natural gas supply is not likely to keep pace with demand. Despite major new natural gas discoveries in recent years, the country will have to import more, either via pipeline or as LNG. With an increase in the demand for and supply of natural gas and with many new players entering the market, the Indian government's Petroleum and Natural Gas Regulatory Board Act of 2006 has promoted competition among market players and stabilized natural gas supply (Thacker 2006).

The bulk of India's natural gas production comes from the western offshore regions, especially the Mumbai High basin. The onshore fields in Assam, Andhra Pradesh, and Gujarat states are also major producers of natural gas. In 2010, around 24 % of supply came from imported LNG. Currently, there are two re-gasification terminals located on the Western coast of India, Dahej and Hazira. The Dahej terminal is being supplied from Qatar under a long term contract, supplemented by spot cargoes from other sources. A possible source of supply for the Hazira terminal is Australia's Gorgon LNG project. In 2012, India will have two more import terminals, Dabhol-Ratnagiri and Kochi (EIA 2012).

One interesting result is Thailand's natural gas supply vulnerability. Between 1996 and 1998, Thailand was ranked third least vulnerable country, after India. However, between 1999 and 2009, Thailand became the most vulnerable among the country sample. The sources of insecurity come from G_1 to G_4. Thailand's heavy reliance on natural gas to power 70 % of its electricity generation accounts for its vulnerability in G_1. Thailand's high gas intensity is facilitated by a relatively well-established natural gas regulatory framework where third party access in gas transmission is quite developed and means the existence of non-discriminatory access to the gas transmission system based on tariffs reflecting costs that provide a fair and reasonable rate of return (Chandler and Padungkittimal 2008). In addition, despite efforts to diversify sources of natural gas imports, a substantial amount comes from Myanmar, increasing the country's vulnerability due to its exposure to geopolitical risks. The government aims to reduce Thailand's dependency on natural gas for power generation as stipulated in the Power Development Plan for 2007–2021 (EIU 2010). However, heavy government subsidy of electricity to residential users may make this improbable in the next few years. Thailand's strength lies in G_3. Natural gas production has improved due to several developments particularly at the Arthit field in the Gulf of Thailand and the Malaysia–Thailand Joint Development Area. The construction of a third national gas pipeline in the Gulf of Thailand was finished in 2007 further expanding natural gas production (EIU 2010).

Table 2.1 Individual gas security of supply indicators 1996–2009

Country	Years	G_1 (m3/\$)	G_2 (%)	G_3 (%)	G_4
China	1996	0.02	−0.15	108.79	0.49
	2000	0.02	−0.25	111.01	0.00
	2004	0.02	−0.11	104.51	0.00
	2009	0.03	0.15	96.02	0.67
India	1996	0.05	0.00	100.00	0.06
	2000	0.06	0.00	100.00	0.00
	2004	0.05	0.69	91.75	0.02
	2009	0.06	2.42	75.68	0.71
Japan	1996	0.01	11.17	0.00	0.99
	2000	0.02	12.75	0.00	1.09
	2004	0.02	13.41	0.00	1.13
	2009	0.02	16.96	0.00	1.27
Singapore	1996	0.02	4.27	0.00	1.04
	2000	0.02	4.48	0.00	0.74
	2004	0.06	13.32	0.00	0.62
	2009	0.07	14.31	0.00	0.34
South Korea	1996	0.03	6.77	0.00	0.47
	2000	0.04	9.02	0.00	0.85
	2004	0.04	11.92	0.00	0.94
	2009	0.04	12.81	0.00	1.10
Thailand	1996	0.10	0.00	100.00	0.00
	2000	0.18	2.35	92.21	0.00
	2004	0.20	8.07	74.83	0.00
	2009	0.23	7.86	78.81	0.00

Source Authors' calculations
Note G_1 gas intensity, G_2 net gas import dependency, G_3 ratio of domestic gas production to total domestic gas consumption, G_4 geopolitical risk

Korea shows a relatively stable trend in its GSSI from 1996 to 2009. G_1 and G_4 are as its major strengths. To reduce the economy's dependence on imported oil, Korea introduced LNG in the 1980s to power its natural gas based city gas to the residential sector. Since then, natural gas use has grown rapidly. Korea relies on imported LNG for most of its natural gas, though it began producing a small quantity from one offshore field in 2004. Korea is the second largest importer of LNG worldwide accounting for 15 % of total LNG imports in 2010. The bulk of Korea's LNG imports come from a much diversified group of sources which explains its strength on G_4. These 17 import sources include, among others, Qatar, Indonesia, Malaysia, and Oman, with smaller volumes coming from Trinidad and Tobago, Algeria, Nigeria, Belgium, Egypt, Brunei Darussalam, and Australia, and occasional spot cargoes from elsewhere. Korean natural gas demand is shared almost evenly between the electricity sector and the residential heating sector, with a smaller amount consumed in petrochemical plants. With demand growing at an average annual growth rate of 8.4 % between 2003 and 2010, Korea continues to sign contracts for additional supplies, though most of the new LNG term contracts

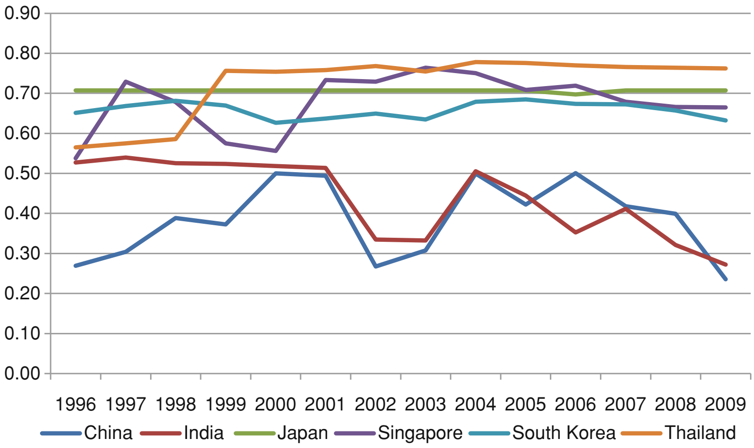
Table 2.2 Relative indicators of security of supply in selected net gas-importing countries in Asia

Country	Year	φ_1	φ_2	φ_3	φ_4
China	1996	0.09	0.00	0.00	0.53
	2000	0.03	0.00	0.00	1.00
	2004	0.04	0.00	0.00	1.00
	2009	0.06	0.00	0.00	0.47
India	1996	0.46	0.01	0.08	0.94
	2000	0.26	0.02	0.10	1.00
	2004	0.21	0.06	0.12	0.98
	2009	0.20	0.14	0.21	0.44
Japan	1996	0.00	1.00	1.00	0.05
	2000	0.00	1.00	1.00	0.00
	2004	0.00	1.00	1.00	0.00
	2009	0.00	1.00	1.00	0.00
Singapore	1996	0.08	0.39	1.00	0.00
	2000	0.02	0.36	1.00	0.32
	2004	0.25	0.99	1.00	0.45
	2009	0.24	0.84	1.00	0.73
South Korea	1996	0.14	0.61	1.00	0.55
	2000	0.12	0.71	1.00	0.22
	2004	0.16	0.89	1.00	0.17
	2009	0.13	0.75	1.00	0.13
Thailand	1996	1.00	0.01	0.08	1.00
	2000	1.00	0.20	0.17	1.00
	2004	1.00	0.61	0.28	1.00
	2009	1.00	0.46	0.18	1.00

Source Author's calculations
Note φ_1 is the relative indicator or scaled value for G_1 (gas intensity); φ_2 is the relative indicator or scaled value for G_2 (net gas import dependency); φ_3 is the relative indicator or scaled value for G_3 (ratio of domestic gas production to total domestic gas consumption); φ_4 is the relative indicator or scaled value for G_4 (geopolitical risk)

in the past few years with Yemen, Malaysia and Russia include more flexibility for the purchaser in terms of the ability to lower volumes if necessary. To ensure a stable supply of gas, Korea is also increasing LNG storage capacity at its four existing terminals (BP 2011).

Between 1996 and 2000, Singapore's GSSI fluctuated but this trend was to stabilize thereafter. Singapore's gas security of supply profile is relatively weak on G_2 and G_3 particularly during the tumultuous years. The absence of domestic gas production combined with high domestic gas consumption makes Singapore relatively vulnerable to natural gas supply disruptions. Its consumption has risen rapidly in recent years owing mostly to government programs aimed at reducing carbon dioxide and sulphur emissions and encouraging the use of natural gas for power generation and petrochemical production (EIA 2007). In 2008, natural gas accounted for almost 15 % of Singapore's total primary energy demand. Singapore relies entirely on imports to meet its natural gas requirements which are mainly



Source Based on author's calculations

Fig. 2.1 Gas security of supply index of selected net gas-importing countries in Asia (1996–2009). *Source* based on author's calculations

used for power generation and petrochemical production. Around three-quarters of Singapore's fuel demand for electricity production comes from natural gas. With gas representing such a large share of electricity production energy needs, diversification of supply is an important issue. All of Singapore's piped natural gas imports come from Malaysia and Indonesia via four offshore pipelines. However, in 2010 Singapore LNG Corporation Pte Ltd awarded a contract for the engineering, procurement and construction of Singapore's first Liquefied Natural Gas import terminal. The terminal will be a critical component of Singapore's energy infrastructure to ensure diversification of its gas supply sources and enhance its energy security. It will have an initial capacity of 3.5 million tonnes per annum and is targeted to be ready for start-up by year 2013 (EMA 2010).

Although Japan's GSSI indicates relatively high vulnerability to supply shocks, its trend has been consistently stable for the period 1996–2009. Japan's security of supply profile is relatively weak on G_2 which is a measure of net import dependency, and G_3 which is the ratio of domestic production to domestic consumption of natural gas. Like Korea, Japan does not have significant domestic natural gas reserves or production, and gas is imported in the form of LNG. Of the total primary energy consumption in 2010, approximately 17 % is imported natural gas. Japan's demand for natural gas has been growing at an average annual growth rate of 3.1 % between 2000 and 2010. This is due mainly to the revision of the Gas Utility Industry Law where there has been increased competition in the industry as market entry and prices have been deregulated. In 2010, Japan imported almost 99 % of its gas requirements and this was met entirely by LNG. LNG imports into Japan comprised 31 % of total world LNG trade, coming mostly from Indonesia, Malaysia, Brunei Darussalam, Australia, and Qatar. Natural gas is mainly used for electricity generation, reticulated city gas and industrial fuels. Since Japan has placed priority on the stable and secure supply of LNG, Japanese LNG buyers have been in general paying a higher price than buyers in Europe or the United States under the long-term take or pay contracts with rigid terms on volume and price. Japan lacks a national pipeline network which could interconnect its consuming areas. The possibility of a significant disruption at one LNG terminal in Japan poses a potential supply vulnerability issue.

2.6 Conclusion

Many factors determine gas vulnerability of an economy. Domestic production, gas efficiency usage, volume and sources of gas imports are very crucial in determining an economy's vulnerability. The analysis in this chapter highlights inter-country differences in individual and overall indicators of gas security which means that country differences exist with respect to vulnerability to natural gas supply disruptions. This implies that governments need to develop policy responses that directly address individual countries' weaknesses to enable them to handle natural gas supply disruptions. Policy measures should reduce the probability of supply disruptions occurring and the costs of disruptions. For instance, India and China are relatively less vulnerable to supply disruptions compared to other countries in the sample because of their significant domestic gas production and small share of gas in their energy mix. This means that the two countries do not have to rely on gas imports for energy generation.

Governments could implement various measures to better cope with supply disruptions and significantly mitigate their effects. For instance, gas import dependence has risks associated with price volatility, natural disaster, political blackmail and terrorism. Imported gas supplies are either pipeline bound or sea bound LNG. These transit options are both exposed to risks but it is the degree of having viable alternative options that defines security of supply. When gas imports depend dangerously on too few sources, it raises a concern whether this is compatible with a sensible policy goal of gas supply security. This concern is exacerbated when taking geopolitical considerations into account. Hence, diversification of gas import sources is encouraged. Other diversification measures include fuel-switching and diversifying energy mix. Diversification in fuel types and sources would reduce the costs of supply disruptions by spreading the risks across different import and energy sources. As Percebois (2006) and Reymond (2007) summed it up, a country which imports the majority of its gas at a sustainable cost and ensures the security of supply by well-diversified and politically-stable sources will not be vulnerable.

Governments also have the option of reducing overall gas dependence by improving gas efficiency through research and development and adoption of technologies that reduce gas consumption or increase the efficiency of gas use, technologies that facilitate gas exploration and production, and alternative processing technologies such as gas to liquids plant. To enhance natural gas supply security, it is also important that investments in domestic gas exploration and production activities are encouraged though joint venture projects and that gas trade routes and sea lanes remain open and secure.

Appendix

Table A.1 Political risk rating of selected gas-producing countries, selected years

Country	Political stability			
	1996	2000	2004	2009
Algeria	0	4	9	13
Australia	81	90	83	76
Bahamas	81	86	79	78
Bahrain	21	49	47	41
Belgium	90	82	75	74
Bermuda	..	69	77	72
Brunei	92	91	96	95
Cambodia	10	22	30	25
Canada	79	85	78	85
China	33	36	39	30
Denmark	95	96	86	86
Egypt	17	34	20	25
Equatorial Guinea	19	41	32	43
Finland	96	100	99	96
France	78	74	63	66
Germany	92	91	71	77
Hong Kong SAR, China	44	75	80	82
India	15	25	24	13
Indonesia	15	6	6	24
Iran	24	32	17	8
Ireland	88	97	90	84
Italy	75	78	62	65
Japan	75	83	83	83
Korea, North	6	41	38	35
Korea, South	42	48	59	52
Kuwait	44	64	53	59
Malaysia	58	52	58	47
Myanmar	13	9	14	7
Netherlands	95	99	84	83
Nigeria	8	10	5	4
Norway	94	97	93	92

(continued)

Table A.1 (continued)

Country	Political stability			
Oman	58	76	75	75
Pakistan	9	16	6	0
Philippines	25	20	12	11
Qatar	55	82	78	89
Russia	16	24	17	22
Saudi Arabia	26	47	20	33
Singapore	73	81	87	90
Sweden	94	96	96	88
Switzerland	96	98	92	92
Thailand	48	60	33	15
Trinidad and Tobago	57	49	46	45
United Arab Emirates	70	73	68	81
United Kingdom	77	79	61	55
United States	78	87	51	59
Yemen	14	11	5	2

Source World Bank (2009). Political risk ratings range from 0 for high risk to 100 for low risk

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