A New Paradigm for Natural Gas Pricing in Asia:

A Perspective on Market Value

Akira Miyamoto [1]

Chikako Ishiguro [2]

Oxford Institute for Energy Studies

February 2009

NG 28

[1] Executive Researcher, Energy Resource Business Unit, Osaka Gas Co.,Ltd.
e-mail:akira-miyamoto@osakagas.co.jp
[2] General Manager, Research Department, Osaka Gas International Transport Inc.
e-mail:cisiguro@osakagas.co.jp

ISBN
978-1-901795-87-5

Contents

Tables

Figures

Preface

The period since 2003 has seen wild swings in oil prices up to $150/bbl and back down to below $50/bbl. Because of the link between crude oil and LNG prices in the Pacific region, LNG price swings have been almost as dramatic, particularly in relation to prices of spot cargoes during 2007-08. The impacts on the major Pacific LNG importers have been severe and fundamental problems remain, even after the significant fall in oil (and therefore LNG) prices since mid-2008.

This paper questions the logic of continuing to price Pacific Basin LNG supplies on the basis of the Japan crude cocktail (JCC) and suggests that moving towards a netback market price would be beneficial in terms of retaining and expanding regional gas markets. Netback market pricing would produce much more differentiation of LNG prices in Asia because the energy markets in these countries are diverse in terms of fuel usage.

This paper is a welcome addition to the work on gas pricing carried out by the Natural Gas Research Programme, following previous papers on Europe by Stern (NG 19 2007) and on the United States by Foss (NG 18 2007).

We are extremely grateful to Akira Miyamoto and Chikako Ishiguro for writing this paper at a very critical time for gas and LNG pricing.

Jonathan Stern, Oxford
March 2009

Acknowledgements

We wish to express our gratitude to all the people who have helped to make the publication of this report possible. We particularly wish to thank Professor Jonathan P. Stern, the Director of Gas Research at the Oxford Institute for Energy Studies, who gave us the wonderful opportunity to publish this report, for his valuable advice and helpful suggestions. Special thanks are also due to Guangdong Dapeng LNG Company Ltd; Mr Xue Bo, Mr Song Lei, and Ms Lin Miao, who provided useful information and suggestions about China. This report also owes much to the invaluable advice made by Mr Ruchika Chawla from The Energy and Resources Institute in India. Also, we are grateful to Mr Yong Woon Kim from Korea Price Research Center for helping us by providing Korean price data. Finally, our thanks are due to Osaka Gas Co. Ltd, who gave us the financial support needed to write this report. The contents of the report, however, are our sole responsibility.

February 2009

1 Introduction

Propelled in part by rising awareness of environmental issues, natural gas consumption is growing strongly in the Asia-Pacific region; while annual world growth averaged 2.7 per cent over the ten years from 1997 to 2007, consumption in the region soared 5.9 per cent.[3] Trade in natural gas in this region revolves mainly around liquefied natural gas (LNG) which almost doubled from 61.73 million tons to 112.43 million tons over the same period.[4]

During this period, there has been strong growth in demand in existing LNG importers such as Japan and Korea, while the demographic giants of China and India are moving ahead with full-scale adoption of both pipeline gas (PNG) and LNG. Natural gas markets in Asia may thus be said to have expanded enormously.[5]

Regarding recent trends in the energy markets, however, the escalation of crude oil prices in the years following 2004 appeared to show no sign of stopping, and the West Texas Intermediate (WTI) price approached US$150/barrel in mid July 2008. This caused LNG prices under existing long-term contracts, which are linked to crude oil prices, to rise sharply. However, crude oil prices then fell steeply, and it is likely that the prices will remain around $30–50/bbl during 2009, due to the very weak demand caused by the global economic recession.

As the supply and demand situation in the international LNG market tightened during the high oil price period it became entirely a seller's market, and short-term and spot prices also went up sharply. As a result, price competitiveness of natural gas compared with other energy sources began to change in the domestic energy markets of Asia. In the Japanese city gas sector, for example, gas was no longer price competitive in areas – such as cogeneration and air conditioning – where it competes with electricity, which is relatively less affected by

[3] Statistical Review of World Energy 2008, BP.
[4] GIIGNL statistics
[5] For details of market trends at the national level, see Stern (2008).

movements in crude oil prices. Demand has thus begun to falter seriously.[6] As well as the rise in LNG prices under existing contracts, large price increases have been finalized in negotiations for new term contracts. While a rise in short-term and spot prices may have to be accepted as a temporary phenomenon, revising the price formulae adopted to medium- and long-term term contracts in order to push up prices, will lead to:

- a long-term deterioration in price competitiveness of natural gas against other energies, and
- a negative impact on the development of the natural gas market.

This will have an adverse effect on the structure of overall demand for energy over the next two to three decades and should be regarded as an extremely serious issue[7].

Although the natural gas market has grown steadily, both globally and in Asia, due to the advantages natural gas offers in terms of energy security and the environment, countries such as Japan and Korea remain highly dependent on oil, while the demographic giants of India and China are heavily dependent on coal. Expanding the use of natural gas is thus undoubtedly an extremely important option from the point of view of medium- to long-term energy policy. In this context, it is crucial that market conditions which allow natural gas to develop autonomously are developed and maintained, and particularly, that natural gas pricing will be the key to the achievement of such a market environment.

As we shall see in the next section, it is becoming clear that the conventional crude oil

[6] As of late December 2008, although crude oil prices have fallen to around $30/b (WTI spot price), a reversal of changes in demand structure has yet to be observed mainly because energy consumption has been significantly affected by the economic recession. The demand situation might change, in the context of price competitiveness, relations between natural gas, and other fuels, but changes in pricing of various energies during the high oil price period should be taken into account as described in this paper. For details see Akira Miyamoto, *Natural Gas in Japan*, in Stern (2008), p.p.146–51.

[7] As this report was completed in January 2009, LNG spot prices have fallen considerably, but evidence of any decrease in LNG prices in long-term contracts has yet to be observed. Judging from the current market environment in which oil prices are low and natural gas demand is shrinking rapidly, LNG prices are likely to decrease in the short term, but these market trends are beyond the scope of this report.

price-indexed method used to determine LNG prices in Asia is becoming increasingly inappropriate and illogical.

In order to explore this issue in greater depth, the primary objective of this report is to estimate the ‘natural gas netback market value’ based on the prices of fuels with which natural gas actually competes in the end-use markets of each of the key LNG importing countries of the Asian region (Japan, Korea, Taiwan, India, and China). The way in which this market value and the actual LNG transaction price relate to the presently most commonly used crude oil price-indexed formula is then investigated. This is followed by brief observations on the future direction of LNG prices in the Asian region.

2 Changes in the environment for LNG pricing in Asia

Before proceeding to the main subject of this report, we first explain the problem of the declining rationality of LNG pricing in the region.

As is well known, Japan, which was the first Pacific LNG importer, has a large market, and has served as Asia's LNG price maker. Japan first began importing LNG, with imports from Alaska in 1969, and the price of LNG was initially determined by means of a fixed price system based on the project's costs. As imports from Southeast Asian countries such as Brunei, Indonesia, and Malaysia subsequently expanded, and oil prices soared following the first oil crisis in 1973, LNG prices came to be determined by an oil price-indexed method that was the model for today's price formulae.[8] At the time, oil accounted for an overwhelming 77.4 per cent of Japan's primary energy supply, and as oil's share of consumption for power generation and city gas feedstock (the main areas of consumption of LNG) were also high, at 71 per cent and 49 per cent[9] respectively, the oil price-indexed method had a compelling logic.

This price formula, which links the price of LNG to the average c.i.f. price of crude oil imports arriving in Japan (referred to below as the 'JCC (Japan Crude Cocktail) price'),[10] was also adopted by Korea and Taiwan when they began importing LNG. The same formula has

[8] Regarding LNG prices in Japan, see Miyamoto in Wybrew-Bond and Stern (2002), pp. 129–30.
[9] In the case of power generation, coal 8.4 per cent, oil 74.4 per cent, natural gas 2.2 per cent, hydro 15.9 per cent, and nuclear power 2.4 per cent. In the case of city gas feedstock, coal 25.5 per cent, oil 49.2 per cent and natural gas 25.2 per cent. Source: Energy Balance Table of FY 1973 published by MITI.
[10] For details of the JCC price formula see Stern (2008), pp. 405–9

more recently been adopted in emerging markets such as China and India.[11]

However, over the course of long term changes in the energy market, LNG price competitiveness has, in practice, also been modified by adjusting the slope and the constant term of the formula, to reflect conditions in the energy market at any given time. For example, among the technical means employed to maintain a proper relationship (not only from the point of view of price competitiveness) between LNG and other energy sources, has been the introduction of an S-curve concept.[12] This acts as a 'protector' for the sellers during periods when crude oil prices are severely depressed, and for buyers during the periods when they climb unpredictably steeply. Also, China and India, which are highly dependent on coal and (particularly in the case of India) which have artificially low domestic gas prices, have introduced a ceiling price. Basically, however, market fundamentals have been reflected in the price level at the time of negotiations between sellers and buyers, and the slope and constant term of the price formula have been determined through negotiation so that the price level is lower when the supply and demand situation eases, and higher when it tightens.

Logically, however, this price formula determines the price of LNG based on the crude oil price, and such an approach makes less sense if the relationship between LNG and crude oil (or oil products) weakens.

Looking at long-term trends in energy markets, it is apparent that progress towards adopting alternative energy sources to oil has been made, particularly by developed countries, following the two oil crises of the 1970s; in Japan, too, the presence of oil in the primary

---

[11] In the context of the concept of the pricing formula first introduced in Japan in the 1970s, it may be irrational that Asian countries other than Japan have introduced the same type of pricing formula using the 'JCC price' which would be applicable only to the Japanese market. However, it is possible that one of the main reasons why the JCC price has been applied in other Asian countries is that there was no alternative 'marker price' for long-term contracts acceptable to both sellers and buyers.

[12] For details of S-curve formula, see Stern (2008), pp.405–9.

energy supply has been significantly reduced.[13] Oil is therefore losing its position as the primary energy resource, in sectors other than transport, in developed countries which have made progress in diversifying their energy supplies, a trend that has been strengthened by the high level of crude oil prices since 2004, and the view that oil will become a specialized transportation fuel is emerging. In Asia, too, energy sources other than oil – such as coal and nuclear power (or secondary electric power) – are increasingly becoming the main competitors to natural gas in the economies of Japan, Taiwan, and Korea; while in emerging markets such as China and India, dependence on coal remains high.

The concept of linking LNG prices to crude oil prices was originally based on the assumption that LNG's main competitor would be crude oil.[14] In view of the above changes in market conditions (including market expansion), however, the price formula for each contract expresses the short and medium-term price levels agreed by buyer and seller, reflecting the market fundamentals at a given time, and the 'philosophy of competition' incorporated in the price formula would appear to be already weakened. It is therefore to be hoped that the markets will migrate to a new pricing approach that can simultaneously reflect market fluctuations, while ensuring the price competitiveness which will allow future growth of natural gas markets.

Below, we shall first examine the rationality of the present pricing system from the point of view of competition between energy sources in each market by estimating the netback market value (NMV) of natural gas.

[13] The share of oil in the primary energy supply decreased from 77.4 per cent in FY 1973 to 47.9 per cent in FY 2006. Source: The Energy Data and Modeling Center, Japan.
[14] Japanese electric utilities which first became large buyers of LNG in the 1970s at that time burned significant quantities of crude oil to generate power.

3 Approaches to market value and preconditions

3.1 Definition of Netback Market Value (NMV)

European readers will be familiar with the NMV concept derived from, and indexed to, the prices of alternative fuels in a specific market.[15] The main difference between NMV and the methodology used in this paper is that in Europe the concept refers to the market of a specific company, whereas the methodology in this paper is applied to a national market.

The NMV of natural gas in a country is given by

$$\mathbf{NMV = \Sigma(WF_{\mathit{i}} \times \mathit{P_i}) - \mathit{C}}$$

where

NMV: Market value of natural gas in a country

WF: Weighting factor for competing fuel based on consumption of natural gas by sector and competing fuel's share

P: Price of competing fuel concerned

C: Domestic cost of supply of natural gas (including terminal cost, etc.)

The WF is given by

$$\mathbf{WF = NGS \times CES}$$

where

NGS: The segment's share in the total natural gas consumption

[15] NMV in a European context is defined and discussed at length in Stern (2007).

The main segments are power generation use in the energy conversion sector and industrial use, commercial use, residential use, and feedstock use in the final consumption sector. However, the segments were created according to the actual state of consumption of natural gas in each economy. Note that while the segments were determined so that their shares (NGS) summed to 100 per cent, certain segments with low shares were combined with others according to circumstances.

CES: This signifies the market shares of competing energies in a consumption segment. It is calculated by identifying the competitors to natural gas and using the ratio of this competing energy to the total supply (excluding natural gas) of competing energies. Energies that clearly do not compete with natural gas are excluded.

Concept of ***P***

Retail price[16] of competing energies in each consumption segment (see Appendix 2 for details).

Concept of ***C***

Estimated cost of supply from terminal to transportation and distribution in each economy (see Table 1 for details).

The netback market value of natural gas for Asia as a whole, or NMV(ALL), is expressed by

$$\mathbf{NMV(ALL)} = \Sigma \mathbf{NMV}_i \times S_i$$

where

[16] Prices for end users

NMV: Natural gas market value in a given economy

S: The market share of each country in the total natural gas consumption of all the economies

3.2 Supplementary explanation of data

Table 1. Supplementary explanation for calculation of supply cost

	Basic approach
Japan Korea Taiwan	Calculation of terminal cost and domestic supply cost, and calculation of cost for electric power use and city gas use Conversion of this cost to weighted average based on proportion of volume handled by electric utilities and city gas utilities
India	Estimated based on cost data for the Dahej Terminal and others
China	Estimated based on cost data for the Guangdong LNG Terminal and others

4 Competition between natural gas and other energy sources in retail markets (explanation of WF)

Below, we outline the competition which natural gas faces from other energy sources in each market, as it is this that serves as a basic prerequisite for estimating the market value of natural gas. Table 2 classifies and aggregates the weighting factors (WF defined in Section 3) into coal, oil, and electric power, thus showing which energy source competes most strongly with natural gas.

From this it can be seen that the main competitor to natural gas in the Asian market is coal-based energy, which accounts for approximately 50 per cent of consumption in the five countries as a whole. This is because the segment with the highest share of natural gas consumption in four of the five economies (China being the exception) is power generation, which accounts for 78 per cent in Taiwan, 60 per cent in Japan, 45 per cent in India, and 43 per cent in Korea, and coal is the main competitor to natural gas in the segment. Moreover in China, despite the low level of consumption of natural gas for power generation, coal's high share of final consumption in segments such as industrial use put it in a highly competitive relationship with natural gas.

The next strongest competitors to natural gas are oil-based energy (approximately 40 per cent) and electric power (slightly under 10 per cent). These are mainly competitors in the industrial, commercial, and residential sectors, though the state of competition in each of the five economies varies according to the state of development of their city gas and electric power industries, and to the existence of considerable differences in usage. For example, in

China and India, city gas industries are at the development stage, and the use of city gas in the residential, commercial, and industrial sectors has also yet to develop to any extent; furthermore, use of natural gas in cities is still low, on average. For reference, projected figures for the state of competition in the two economies once natural gas use has expanded somewhat are shown in Table 3. Taken in conjunction with figures from Tables 2, this indicates that, up to around 2015, there is unlikely to be much change in the overall competitive relationship of natural gas with other energy sources, even if use were to expand in the power generation and city gas segments in these economies. It should be noted that the high level of competition with oil-based energy in India at present is due to the large proportion of natural gas consumption accounted for by fertilizer feedstock,[17] in which segment natural gas competes mainly with naphtha.

For reference, over 90 per cent of natural gas consumption in Japan in 1979, when the second oil crisis occurred, competed with oil-based energy, which gives some indication of just how dramatically the state of competition of natural gas with other energy sources has changed over the subsequent three decades.

[17] Fertilizer feedstock use presently accounts for a high proportion (34 per cent) of total natural gas consumption.

Table 2. State of competition of natural gas with other energy sources in Asia

Competing energies	Japan		Korea	Taiwan	India	China	Asia
	FY1979	FY2006	2006	2006	2005	2005	2005/6
Coal	0.057	0.496	0.447	0.732	0.552	0.570	0.506
Oil	0.909	0.407	0.458	0.202	0.408	0.284	0.403
Electric power	0.034	0.097	0.095	0.066	0.040	0.146	0.091

Note: The figures for Asia as a whole are the products of the proportions of LNG imports multiplied by the WF for each economy.

Source: Authors' estimate based on energy balance tables (for details, see Appendix 1)

Table 3. Estimate of Weighting Factors for India and China in 2015

Competing energies	India	China
Coal	0.576	0.580
Oil	0.366	0.282
Electric power	0.058	0.138

Source: estimated based on energy balance data in IEA, *World Energy Outlook 2007* Reference Case

The weighting factors used to calculate the actual NMV for each economy are shown in Appendix 1. These were estimated based on the energy balance for each economy (cited from statistics generally recognized as reliable in each economy). However, energy usage differs considerably according to region, and various obstacles to quantifying the state of competition among energy sources while ensuring consistency between economies exist. Therefore, we calculated the weighting factors based on the following premises. The segments of consumption used to analyse competition with natural gas, and to assess compatibility with the retail price structure for each energy source, were:

- generation by electric utilities and private power plants in the energy conversion sector,

- industrial use,
- commercial use,
- residential use,
- feedstock use (for fertilizers, etc.)

It should be borne in mind, however, that we depart from this classification in certain cases due to differences in the energy balance formats in the different economies.

- In the power generation segment, stations are operated differently depending on their individual features e.g. including nuclear and hydroelectric power. Furthermore, at the level of individual electric utilities, it is normal for utilities to draw up an individual operating plan for each plant in order to optimize supply capacity,[18] which consequently makes it extremely difficult to quantify the concept of natural gas competition in a manner that reflects actual use. Given that our objective is to ascertain the state of competition of natural gas in macro terms, the weighting factors are determined assuming the competitors to natural gas are coal-fired and oil-fired plants, which are generally operated in a relatively similar manner.
- In relation to electric power in the final consumption sector, the weighting factors were calculated excluding consumption for uses where there is clearly no competition with natural gas, such as motive power and lighting. Where statistics on energy consumption by use are not available in general, estimates were made based on sources such as qualitative surveys of energy use.[19]
- As far as India is concerned, despite heavy use being made of non-commercial energy sources, the weighting factors were calculated considering only commercial energy sources.

[18] In Japan, for example, the typical approach is to use nuclear power for base load, coal for base to middle load, natural gas-fueled thermal power for middle to peak load, and oil for peak load only.
[19] The data are from published survey findings. Regarding Korea, China, and Taiwan, estimates are based on qualitative comparison with the state of energy use in Japan. (For details, see Table A6.)

5 Netback Market Value of natural gas (NMV) in each economy

The following analysis is based on eight years of data from January 2000 to December 2007, during which time the price of crude oil (JCC) fluctuated between US$19.3/bbl (January 2002) and US$90.7/bbl (December 2007). It should be borne in mind that the period of even higher oil prices from January 2008 is excluded from the analysis as data was not available.[20] As described in Section 1, however, crude oil prices have fluctuated dramatically during the most recent five years; the conditions for LNG pricing during the extremely high oil price period from the fourth quarter of 2007 to the middle of 2008 may, in particular, be a special period that can be viewed in a completely different way from the present situation.

5.1 Summary of findings of NMV in each economy

Korea

Among the five economies studied, Korea has the highest NMV. In the Korean energy market, the proportion of competition with natural gas of oil-based energy is the highest of the five economies at 0.458. This is thought to be due to the relatively higher share of petroleum products, which reflected the increase of crude oil prices more straightforwardly compared with other economies.

Taiwan

The economy with the lowest NMV is Taiwan. This is attributable to the extremely high (0.732) proportion of competition with natural gas of coal-based energy in the Taiwanese

[20] A brief observation for the period after January 2008 is described in the last part of section 7.

energy market. This is because natural gas is mainly used for power generation (78 per cent), and its main competitor in this segment is coal (88 per cent).

India

While NMV in India rose rapidly during the high oil price period, this is affected by the aforementioned high proportion of use of naphtha for fertilizer feedstock as a competing fuel. However, India's fertilizer sector receives priority when allocating cheap, domestically produced natural gas (PNG) as a matter of government policy,[21] and is also the recipient of huge government subsidies. When considering the market value of LNG in India, therefore, it is necessary to take proper account of these special features of Indian energy policy.[22]

China

In China, as well, where the level of competition with coal-based energy is comparatively high, the NMV of natural gas rose during the high oil price period. One reason for this is that domestically produced PNG is used as fertilizer feedstock (and as a result, the WF of the segment is relatively high) and in this segment, as in India, natural gas is in a competitive relationship with naphtha. Another contributing factor is the higher level of competition with relatively more expensive electric power compared with other energies in the industrial segment, which accounts for the largest proportion of natural gas consumption.[23] It is necessary to bear in mind, however, that actual consumption of natural gas was still low in China during the period under analysis, and that due to the late commencement of LNG imports in June 2006, it was mainly domestically produced PNG that defined the weighting

---

[21] Domestically produced natural gas is classified into Administered Price Mechanism (APM) gas and non-APM gas, and cheap APM gas is supplied on a priority basis to the fertilizer and power generation sectors.

[22] Concerning the level of NMV, for example, one might argue, at first glance, that procurement of high-priced LNG might be possible. Over the long term, however, sustained procurement of high-priced LNG would not be feasible because subsidies would become too great and are intended to be removed gradually by the Indian government's policy that favours a transition to a market economy.

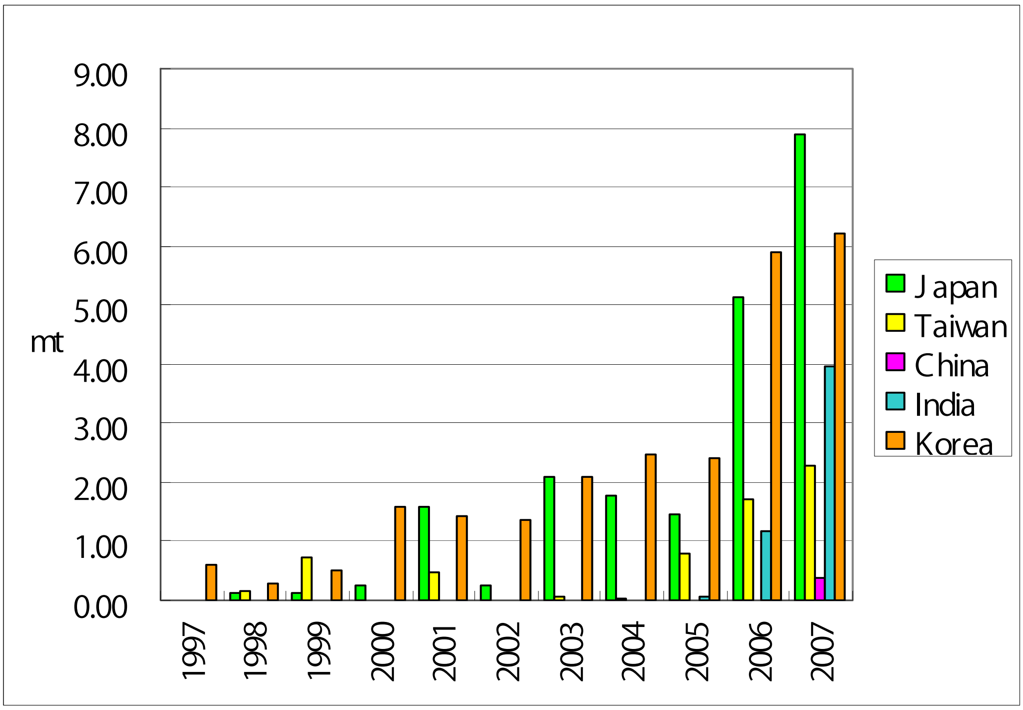
[23] These are the findings according to the statistics. However, further more detailed research is required to confirm whether these results are an accurate reflection of reality.

factor at the time of our survey.

Japan

Turning to Japan, NMV was at approximately the same level as in Korea during the low oil price period from 2000 to around 2004. However, during the high oil price period thereafter, the level of increase was low, and linkage to the crude oil price was small. Although due in part to the lag in the passing on of costs in the retail price of petroleum products, the stagnation and downward movement of electric power prices (contrary to the upward trend in oil prices) as a result of market liberalization appears to have had a major impact.[24]

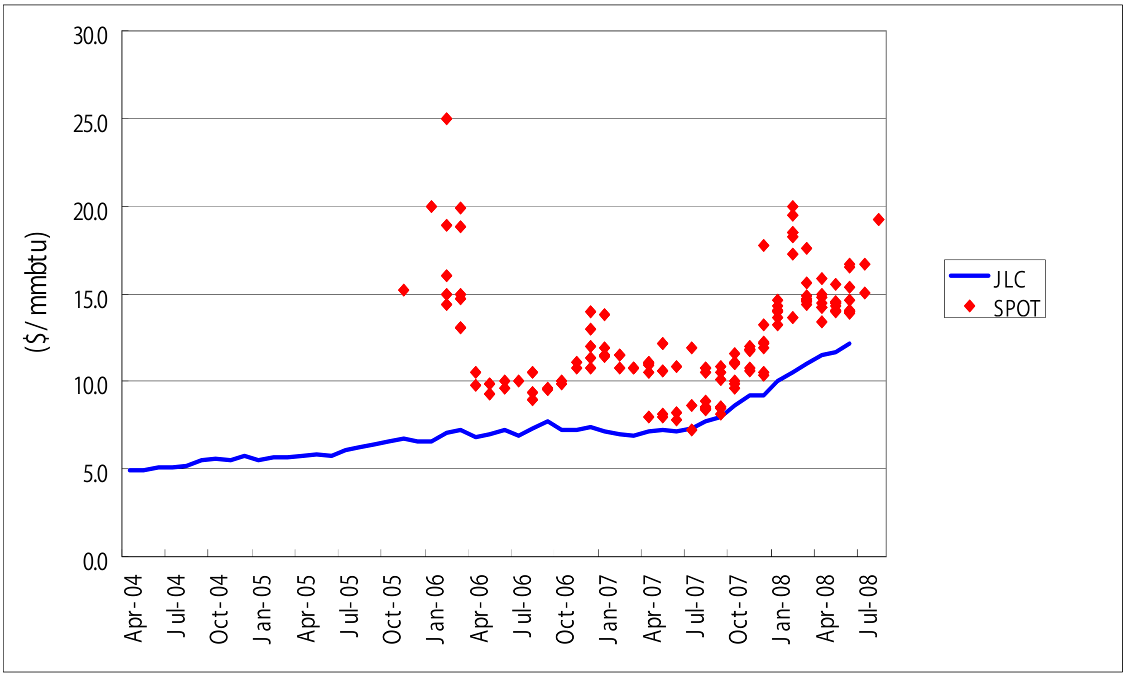
Figure 1. Short-Term & Spot LNG Transactions in Asia



Source: GIIGNL statistics

[24] For details, see *Natural Gas in Asia*, Stern (2008), pp. 146–7.

<u>Figure 2. LNG Prices in Asia; Spot transactions vs JLC</u>



Source: Custom Statistics of Japan

5.2 Analysis of NMV from the perspective of relationship to JCC[25] and LNG import prices

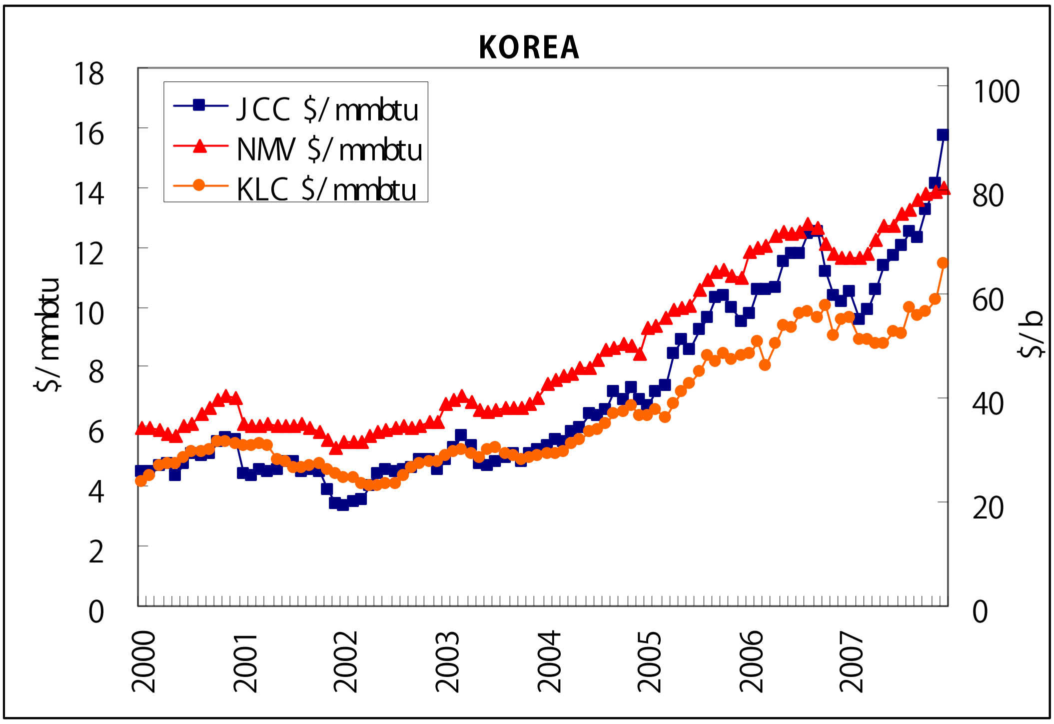
Below, we consider the NMV in each economy from the point of view of the relationship with the JCC price and actual LNG import price.

[25] For details of JCC, see *Natural Gas in Asia*, Stern 2008, pp. 405–9.

Korea

In Korea, where NMV is the highest of the five economies, NMV exceeds JCC throughout almost all of the period under analysis. Although the average import price of LNG in Korea (KLC) is relatively high compared with the average import price of LNG in Japan (JLC), it is less than NMV throughout the period as, due to the effect of the S curve, it is less than JCC during the high oil price period. While JCC hit a high of US$90/bbl during the period under analysis, even oil-equivalent LNG may be considered to be competitive against competing energies up to around this level. In the case of Korea, the volume procured through spot transactions and short-term contracts has increased sharply in the past few years due to rising demand not being fully covered by term contracts, and by having low storage capacity compared to the large scale of seasonal variation. While Korea needed to make expensive spot and short-term cargo purchases to ensure stable supply (see Figure 1), relatively expensive LNG was still competitive in Korea in comparison with other economies (Figure 3).

Figure 3. NMV of Korea



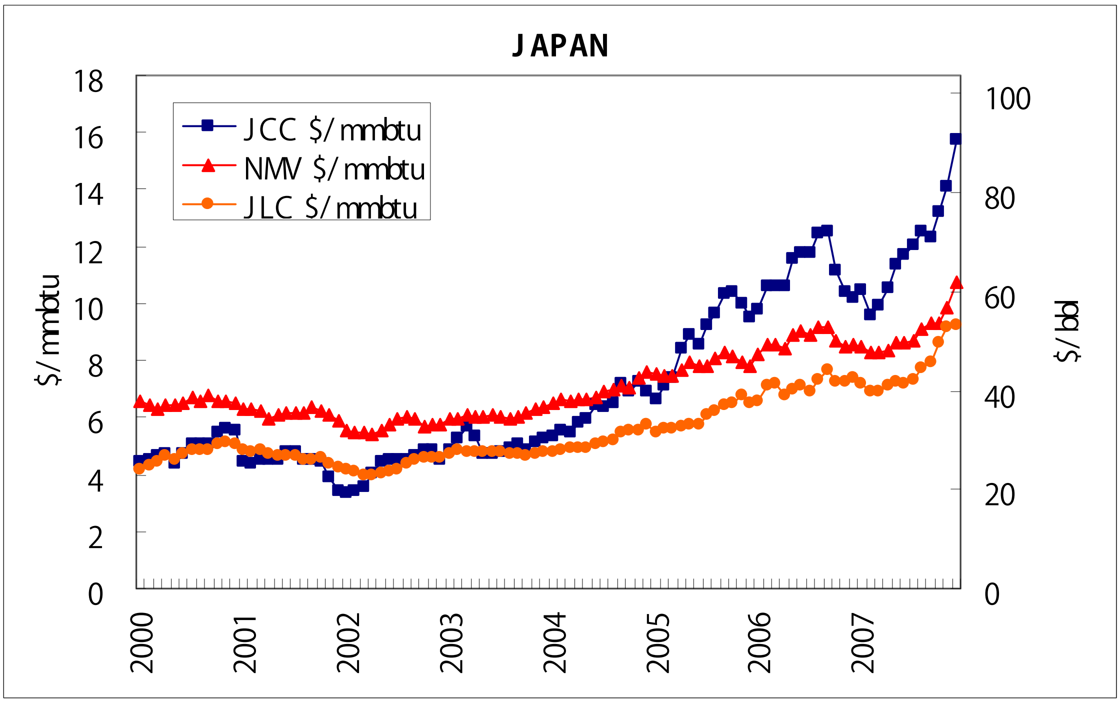
Japan

In Japan and China (Figures 4 and 5), by contrast, NMV exceeds JCC during the low oil price period, but is less than JCC during the high oil price period.

In the case of Japan, JCC is higher than NMV when the oil price exceeds approximately US$45/bbl. In other words, if the LNG price had been raised on a par with the crude oil equivalent, LNG would already have lost its price competitiveness (overall) in the high oil price period during the same period of analysis.

Looking at the relationship between the average import price of LNG (JLC) and NMV in Japan, JLC was less than NMV, and LNG which was competitive from a macro perspective was procured throughout the period.[26]

Figure 4. NMV of Japan

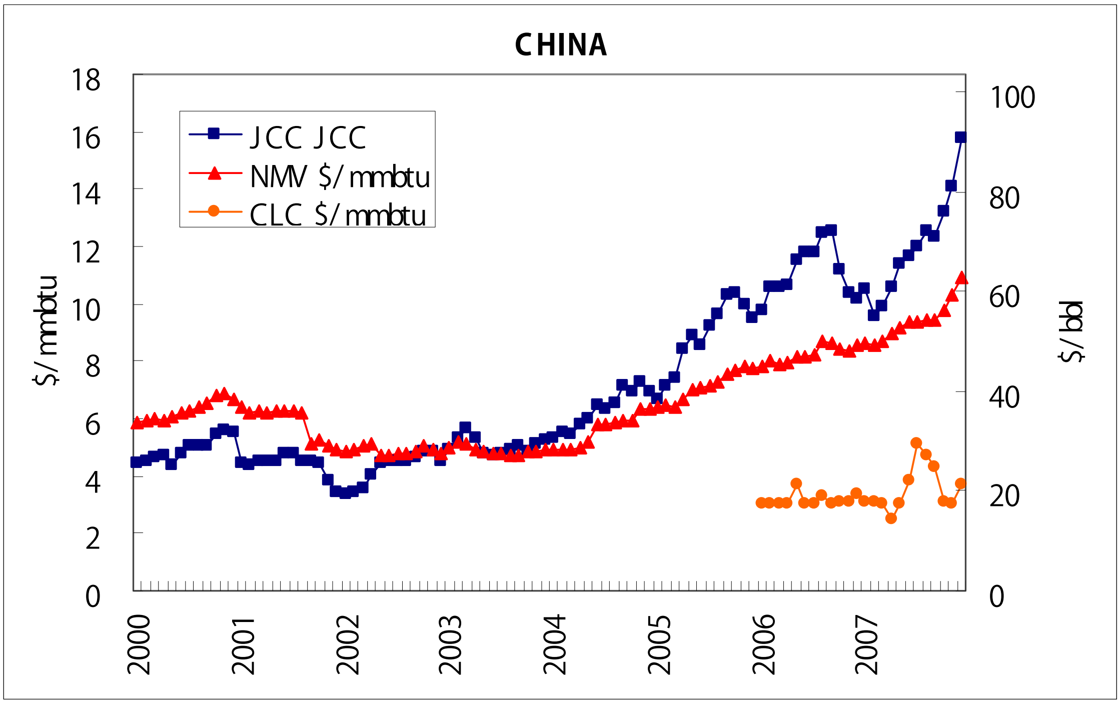


[26] This only holds true for a JCC price of up to US$90/bbl during the period under analysis and does not apply from 2008, during which WTI has exceeded US$140/bbl.

China

Viewed from the same perspective, the price level at which oil-equivalent LNG would lose its price competitiveness in macro terms in China would be approximately US$28/bbl. Regarding the LNG import price in practice, the long-term contract for Guangdong LNG purchased from the Australian North West Shelf (NWS) project adopts a price-capped price formula and, as the price level is sufficiently low, the average import price of LNG in China (CLC) including relatively expensive spot cargoes[27] procured during the period is significantly below NMV, as shown in Figure 5 .

Figure 5. NMV of China



[27] For example, in 2007, China imported several cargoes from Oman, Algeria, and Nigeria and their prices were around $8–9/mmbtu; in 2008 it imported spot cargoes and signed up long term contract cargoes at oil prices much higher than this.

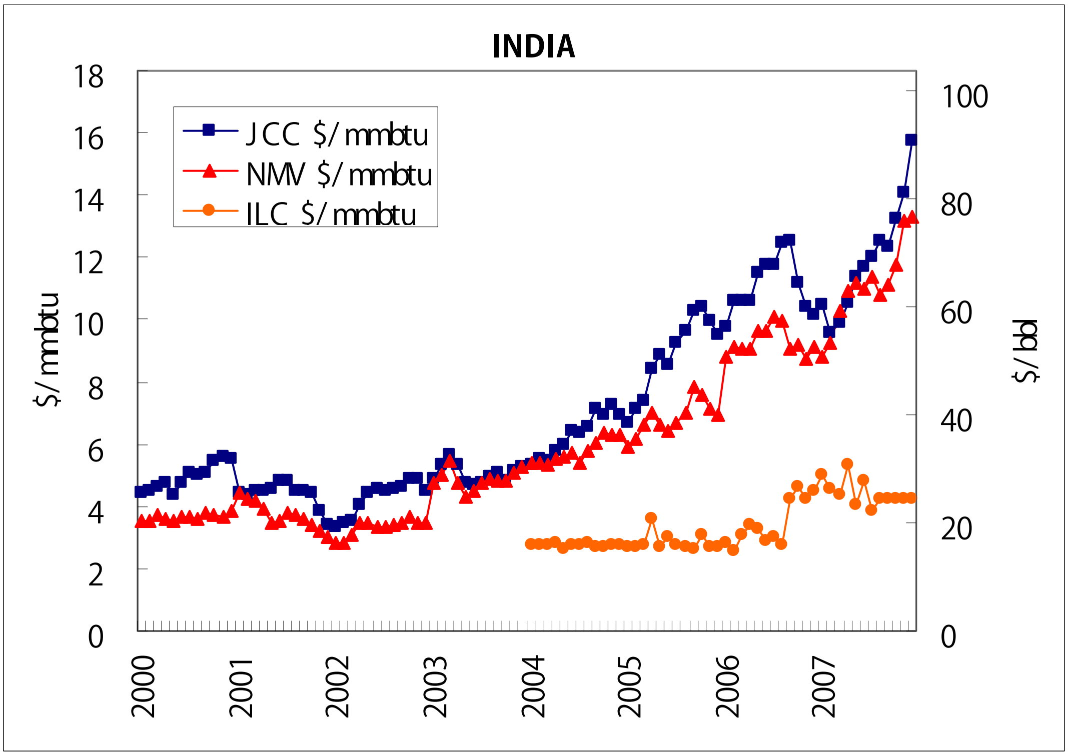
India

In the Indian market, NMV hovered a little below JCC during the period under analysis. As previously noted, however, it is hard to evaluate price competitiveness based on NMV precisely because, in the Indian market at present, energy prices (including natural gas) are subject to government control, and various subsidization policies are employed according to industry. Nevertheless, it is quite possible that the NMV estimated here is an overestimate and that the competitive LNG price level is considerably lower.[28] The actual imported LNG price is determined, as in the case of China, by a price-capped formula in the form of a long-term contract, and the average price level is also sufficiently low.[29] Although significant numbers of high-priced spot cargoes were purchased in 2007 and 2008,[30] the average import price, as the figure shows, remained below NMV.

A feature shared by the emerging markets of China and India is that while LNG is, by international standards, imported comparatively cheaply under long-term contracts with ceilings on the maximum price, domestically produced gas is supplied at relatively low prices. From this, it may be surmised that additional high-priced spot purchases serve only marginal demand. Had the LNG price been raised to the same level as the crude oil price, LNG would have lost its price competitiveness (overall) during the high oil price period. Maintaining consistency between domestically produced PNG and LNG prices, is a significant policy challenge for the two countries, and could become a serious difficulty.

[28] This can also be explained by the fact that cheap domestically produced PNG is supplied on a priority basis to the electric power and fertilizer sectors, which are the main sectors of consumption of natural gas.
[29] According to customs statistics, the average of imported prices (c.i.f.) of cargoes from Qatar in 2007 was around $ 3.67/mmbtu.
[30] For example, in 2007, India imported spot cargoes from Malaysia, Oman, UAE, Trinidad, Algeria, and Nigeria at a price level of around $ 7–9/mmbtu. In 2008, it procured several spot cargoes at more than $20/mmbtu while our analysis does not cover this period.

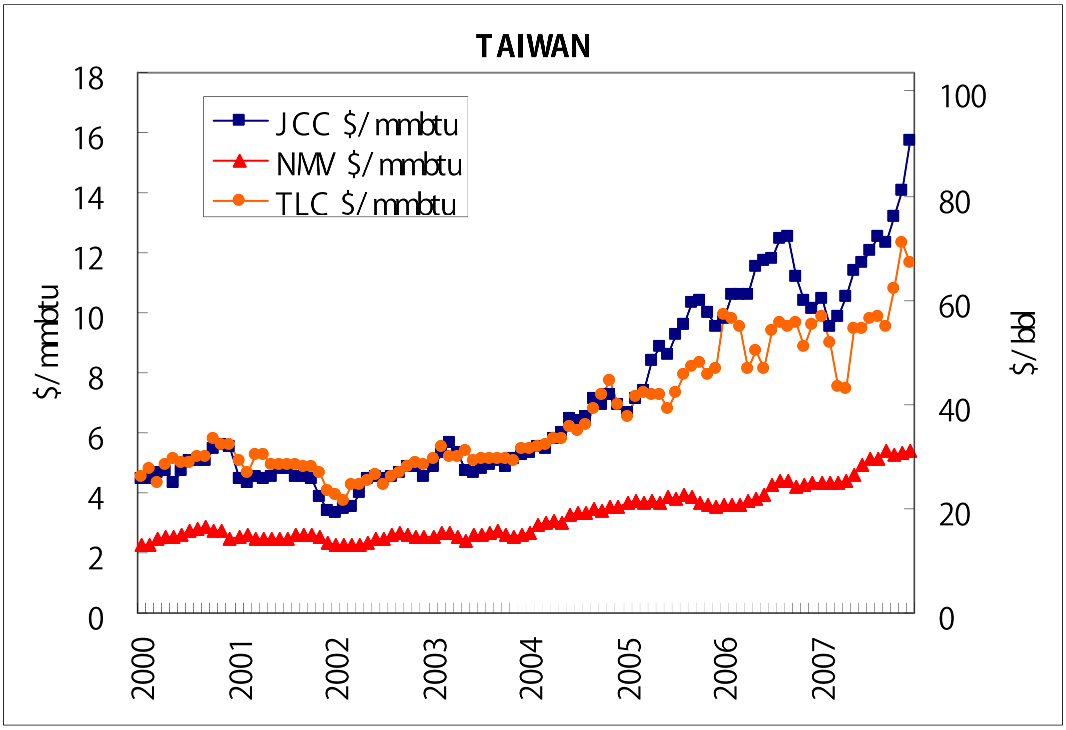
Figure 6. NMV of India



Taiwan

Finally in the Taiwanese market, NMV is substantially below both JCC and the actual average import price of LNG in Taiwan (TLC). As noted above, this is due to the extremely large share accounted for by power generation. Rather than being an issue of price competitiveness between energy sources therefore, it is more a matter of national energy policy. One is nevertheless forced to conclude, however, that the LNG import price is very high in relation to market value.

Figure 7. NMV of Taiwan



A comparison of the NMV for the five economies as a whole, based on the weighted average according to proportion of natural gas consumption, reveals that whereas NMV is slightly higher than JCC during the low oil price period, the positions are reversed when JCC exceeds US$40/bbl and NMV falls below JCC. It may be noted that when the JCC price was US$90/bbl (US$15.7/mmbtu) in December 2007, NMV was US$11.5/mmbtu, a difference of approximately US$4.2/mmbtu (see Table 4).

Table 4. NMV and JCC in each country

JCC $/bbl	NMV $/mmbtu					
	JAPAN	KOREA	TAIWAN	INDIA	CHINA	ASIA
20	5.7	5.3	2.3	2.9	4.8	5.3
30	6.4	6.8	2.7	4.4	5.6	6.2
40	7.0	8.4	3.2	5.9	6.5	7.1
50	7.7	9.9	3.7	7.4	7.3	8.0
60	8.4	11.5	4.1	8.9	8.1	8.9
70	9.1	13.0	4.6	10.4	8.9	9.8
80	9.8	14.6	5.1	11.9	9.8	10.7
90	10.4	16.1	5.6	13.4	10.6	11.5

6 Evaluation of NMV when using JCC-indexed formula

Next, we consider the relations between the actual market value of natural gas and JCC when NMV is expressed by the JCC-indexed price formula ($Y = A \times X + B$) – widely used at present for LNG transactions in the Asia-Pacific region.

where

Y: NMV expressed in cents/mmbtu

A: Slope

X: JCC price expressed in $/bbl

B: Constant

Figure 8 shows the natural gas NMV for each economy as a linear function of the JCC price using least squares approximation. For reference, the figure also shows the line in the case where LNG is the JCC calorific value equivalent, and the line for NMV in Asia as a whole (calculated based on the average weighted according to the proportions of LNG imports).

First, in the case where LNG is the JCC calorific value equivalent, the slope (*A*) of the line according to the price formula $Y = A \times X$ (where *X* is the JCC price expressed in $/bbl) is approximately 17.4. If the NMV for Korea is expressed by the same price formula, slope (*A*) is approximately 15.5, there is a strong linkage with the crude oil price; among the five markets, this is closest to the JCC equivalent slope.

Indian NMV is similar to Korea's, with slope (*A*) being almost the same at 15.0. Considering the impact of subsidies and the two-tier pricing of domestic PNG,[31] however, one would have expected a realistic NMV of LNG to have had a lower slope value.

The slope of the line representing NMV in China is 8.3, indicating that the linkage to crude oil price is considerably weaker than that in Korea and India. The Chinese slope value is higher than that of Japan (6.8) which is somewhat surprising in terms of the realities of the two markets. As the state of competition with existing PNG is largely reflected in the weighting factor for NMV in China (described in Section 1 above), however, one would expect a lower slope value, and to coincide better with the reality of interfuel competition in the market i.e. greater competition with coal in the power generation sector and competition with naphtha in the fertilizer sector.

The 6.8 inclination of the line representing NMV in Japan largely coincides with the approximately 7.0 slope in the case that Japan's LNG import price (JLC) is expressed by the same type of price formula during the same period. While more detailed analysis is required to determine what to make of this finding, it may nevertheless be concluded that, as far as the period under analysis is concerned, LNG was imported at a price commensurate with the market value.

Finally, the slope for NMV in Taiwan is 4.7, which indicates that linkage with crude oil price is the smallest. This is attributable to the price of coal, which is natural gas's main competitor.

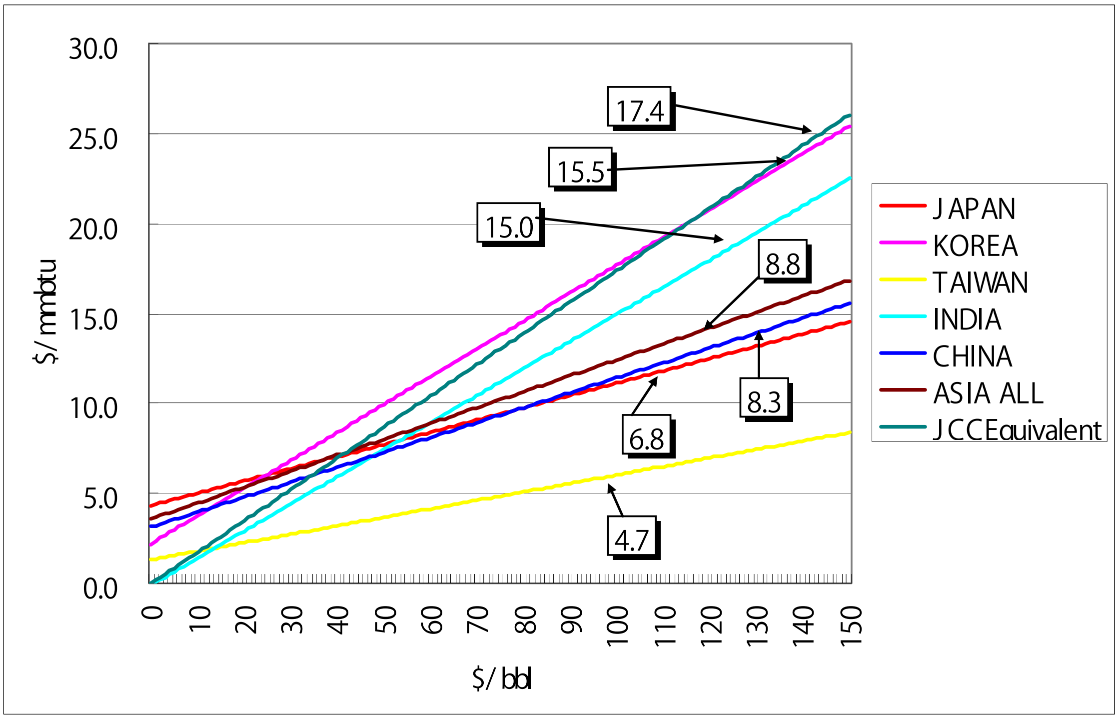
---

[31] For details, see footnote no. 21

In addition, it might be possible to divide the current natural gas markets into three groups in terms of NMV/JCC linkage, namely, the first group being India and Korea, the second, Japan and China, and finally Taiwan. Even though we can not explain the result of this grouping by a rational logic (as it is affected by too many factors), the important point is that it is extremely difficult to apply the current pricing formula as the price setting mechanism in the region.

It may be noted in passing that when the weighted average of the NMV for Asia as a whole, which is calculated based on the proportional volumes of LNG imports, is expressed by the same formula, slope *A* is approximately 8.8.[32]

Figure 8. NMV described by the current LNG Price Formula linked to JCC



Note: Figures in box for each line are 'the slope (*A*)' calculated when NMV is expressed in cents/mmbtu and JCC price is expressed in $/bbl

[32] The slop for NMV calculated as a weighted average based on proportional natural gas consumption is approximately 9.7. As the ratios for India and China go up and the ratio for Taiwan, which has a smaller slope, goes down, the slope is somewhat greater than where the weighted average is calculated based on proportional LNG imports.

The key points to note concerning the above findings are as follows. A comparison of the weighting factors of Japan and Korea reveals only a small difference, with Japan around five points higher for the proportion of competition with coal-based energies; Korea is around five points higher for the proportion of competition with oil-based energies. There cannot therefore be said to be any major difference at the macro level in the state of competition of natural gas. If the NMV of natural gas is expressed by the crude oil price-indexed method, however, slope *A*, which expresses the proportion of linkage with the crude oil price, differs markedly (15.5 for Korea compared with 6.8 for Japan). In other words, even though the competitive relationships of energy sources in the two countries closely resemble one another at the macro level, domestic energy retail prices have a major impact on NMV.[33] In order to ensure the price competitiveness of natural gas, therefore, it is necessary to properly consider the significance of the slope based on the crude oil price-indexed formula as described in the next section.

[33] i.e., differences in the absolute level of retail prices and the linkage of retail prices to oil prices affect NMV.

7 Design of LNG pricing in Asia

In light of the above analysis, we briefly consider in this section how natural gas should be priced in Asia.

While the present analysis has concerned the five main consumers of natural gas in Asia, these five natural gas markets are independent entities rather than a network linked by trunk pipelines and other infrastructure. It is therefore quite natural that gas should trade at different prices in these markets, and one should certainly not expect there to be a single natural gas price in Asia. Despite growth in LNG spot transactions globally, LNG can not act as a 'complete adjuster' of supply and demand for natural gas between markets. It remains impossible to obtain a price convergence effect solely through arbitrage transactions in LNG, which still retains contractual rigidities – such as the prohibition on reselling.

If the natural gas market is to be made more flexible by LNG trading, as is now being intensively debated, it has to be understood that LNG will only be able to function as an international commodity like petroleum if much larger numbers of LNG liquefaction and regasification terminals with free entry and exit are built, allowing LNG to adjust supply and demand between natural gas markets. In other words, as long as the supply of LNG under long-term contracts is inflexible, reality shows that differences in long-term contract LNG prices will inevitably exist (even though this should not be the case). As for spot cargoes of LNG, given the concept of 'the law of one price', and that market price should be determined at any point in time, it is incomprehensible that prices should depend on the market into which they are sold. As at present, there thus arises the anomaly that if economy A with purchasing power continues to buy high-priced spot cargoes, LNG that is procured on a spot basis will be supplied to economy B, which has a completely different market structure (and/or pricing system) from economy A, only as a marginal energy source. The problem of such price disparities between markets will not be eliminated unless gas markets in these countries are physically integrated. Because that issue is beyond the scope of this study, it is excluded from our discussion below as to how natural gas should be priced in Asia.

Observation of the five major importing countries addressed in this paper illustrates that devising an ideal approach to natural gas pricing for the entire Asian region is extremely difficult, partly because the markets are all at different development stages and partly because they are not physically integrated.[34] Accordingly, this report now investigates approaches to replace the current pricing system for the Asian region, which is becoming increasingly irrational. Specifically, we examine LNG pricing based on a common rationale, to ensure the autonomous development of individual natural gas markets while recognizing the differences between them.

We begin by summarizing the irrationality of the present natural gas pricing system, which is linked to crude oil prices. As explained above, there is no doubt that the significance of oil expressed by the present pricing formula has drastically changed, since the sectors where natural gas competes with oil have greatly diminished since the time when LNG was initially introduced. Moreover, there is also a global trend towards concentration of oil in the transport sector.[35] This means that oil's position in the stationary sector will steadily decline, further undermining the grounds for linking LNG prices to oil prices.

[34] There is an argument that, for example, there is a possibility that markets among some countries could be physically linked by an international pipeline. In the authors' view, however, market integration harmonizing natural gas pricing will not occur in the region for the foreseeable future.
[35] Probably the price of oil will affect the speed of this trend.

When the market value of natural gas is expressed by the crude oil price-indexed formula, the movements of other energy prices also become linked, to some extent, to crude oil prices. Thus at a glance one tends to view the correlation between NMV and crude oil prices as comparatively high.[36] It is important to remember, however, as demonstrated by the cases of Japan and Korea above, that there may still be large differences in slope *A* in relation to the correlation between NMV and crude oil prices, even when the weighting factors bear a close numerical resemblance to each other at the macro level. Therefore, in the majority of countries, the current pricing formula is losing its original aim, which was to accurately reflect the competition which natural gas faced in the national energy market. The mistake lies in this very concept of erroneously defining slope *A* under the current formula as the proportion of linkage to crude oil prices (i.e. as the weighting factor).

To reiterate, the crude oil price-indexed method adopted when LNG was first introduced in Japan was originally based on the idea of ensuring price competitiveness against the major fuel against which gas competed in the energy market. However, now that energy market conditions have changed dramatically, using the existing formula to determine LNG prices from a correlation with crude oil prices has become 'an empty numbers game', since the resulting prices fail to reflect the NMV. In short, the original philosophy behind the formula is no longer valid because market conditions have changed and market value (as shown in the previous section) is no longer based on crude oil.

Then what would be a more rational approach to pricing LNG in Asia, than the present crude oil price-indexed formula?

[36] The correlation may be regarded as being strong, based on the coefficient of correlation between crude oil prices and the NMV estimated here.

In theory, at least, Asian gas prices could be determined by the supply and demand of LNG, since there is a considerable amount of LNG traded and consumed in the region. In reality, however, it is extremely difficult to introduce such a pricing method at present, because there are various obstacles in terms of commercial, infrastructural, and other obstacles to natural gas trading in the region[37].

First let us examine whether the Anglo-American model, which determines import prices based on price signals from the domestic market, can be applied to Asia (even though there is little feasibility of implementing this model in the short term). Fundamentally, the Anglo-American model requires the development of a transparent, liberalized, and competitive natural gas market. Looking at the present conditions, however, the main consuming countries in Asia are still at the stage of examining how to develop industrial structures and market systems required to upgrade their supply infrastructures and to stimulate vibrant domestic trading.

In Korea, where national trunk line networks have been established and considerable amounts of LNG are imported, it can be said that the country has some similarity to European countries in terms of market environment. However, introducing the Anglo-American model to Japan, which is the region's largest LNG trader, would require the resolution of numerous issues – starting with improvements to pipelines and other infrastructure, and systems for free trading – before a suitable market environment could be created. This could take at least ten years. In addition to this situation, the biggest obstacle is the reluctance of all utilities in the

[37] As noted above most LNG is traded on long-term contracts with destination clauses. There are technical obstacles for free trade, such as ship–shore adjustment, heat contents of LNG and so on. However, the most important barrier is that almost all players involved in LNG trade in the region are unwilling to introduce pricing based on spot prices of LNG.

regions to contemplate a spot market as the basis of LNG pricing. There are also a great many obstacles to introducing the Anglo-American model in China, which has an abundance of domestically produced PNG and the potential for PNG import projects. In addition to the fact that the Chinese energy market remains largely under government control, China would have to build up its infrastructure and the market systems of its electric power and city gas industries. None of these will issues be resolved in the short term.

However, there is a basic problem that major players are opposed to the introduction of the Anglo-American model. Even having addressed the practical issues, the extent to which the countries of Asia, which have a significant dependence on foreign energy sources, would advance the liberalization of their energy markets is still far from clear. Because of the post-2007 volatility of energy prices, followed by the financial crisis which has spread from the USA to markets worldwide, governments of Asia may now take an even more cautious stance toward the liberalization of their energy markets.[38] Consequently, we conclude that the likelihood of applying the Anglo-American pricing model in Asia is extremely low at present.

Another possibility would be to adopt a netback pricing system based on market value, an option that extends the original philosophy behind the current crude oil-linked pricing formula. Pricing under the market value netback system is extremely rational, in that it maintains the price competitiveness of natural gas by adopting energy price markers appropriately, reflecting the competitive conditions of natural gas and other energy sources in end-user markets. Considering the process whereby other energy sources are replaced by natural gas, for the Asian region – where the development of natural gas has recently compared with most other OECD countries – the netback system has the particular advantage

[38] In Japan, for example, there was a drastic change in energy policy after the 9/11 incident in 2001, and since then, energy market liberalization has been put on hold. For details, see Stern (2008), pp.116–18.

of incorporating an evolving market value mechanism into gas pricing.

Specifically, under this netback system, natural gas prices would be determined through a price formula linked to coal, petroleum products (fuel oil, kerosene, naphtha, etc.), and retail electric power prices, considering the competitive conditions of natural gas on each country's energy market. This concept was originally introduced to the classic European long-term pricing formula.[39] Pricing under this method reflects energy market values which would be more rational than the current crude oil price-indexed method, in the sense that the netback method ensures the autonomous development of each country's natural gas market.

On the other hand, we can expect the following issues regarding a netback system based on market values to be raised.

(*a*) Natural gas import prices would still vary from country to county under the netback system (as under the current crude oil price-indexed formula) because of energy market differentials among the consuming countries of Asia.

(*b*) The netback system would not improve the issue of dual pricing (as under the current crude oil price-indexed formula) since a large gap could still exist between prices under each country's term contracts and spot prices, as was the case in 2007–8.

(*c*) In cases like Japan where natural gas imports are conducted by electric power and city gas utilities, which have different cost structures, different industries (or different importers) may find it difficult to reach a consensus on actual import prices.

(*d*) The introduction of the netback system could be considered unrealistic in that it is unlikely to be particularly acceptable to sellers if (as seems possible) it would lead to lower prices.

[39] For details, see Stern (2007).

As for (*a*), as explained above, unless the markets of Asia become integrated, it will remain difficult to resolve the price differentials between individual markets, regardless of what pricing formula is adopted. Even under the Anglo-American pricing model, the fundamental problem of inter-market basis risk remains, since a natural gas price index could not be adopted as a common price across Asia.[40] One way to resolve this under a market value netback system is to calculate a weighted average of the natural gas market prices in the main importing countries of Asia and use this to derive the appropriate price for the entire Asian region. We can leave the choice of accepting price differentials between countries, or aiming toward a common Asian price with some restraints, as an issue for future consideration.

Turning to (*b*), there will always be price differentials between term contract prices and spot prices, provided that long-term contracts remain the norm for natural gas trading, which is the case because of the vast initial investments required for large-scale LNG and pipeline projects. What is clear, however, is that in Asia, it is virtually impossible from a financing perspective to launch any new LNG liquefaction or large-scale pipeline projects using international LNG market spot prices as the basis for investments.[41] Therefore, while some sort of pricing which can take future risk into account is certainly required for long-term contracts, we conclude that buyers and sellers have no choice but to accept the differential between spot and long-term contract prices, arrange optimal procurement portfolios, and take measures to avert risk, as long as spot prices continue to be determined by the international supply–demand balance at any given point in time[42].

---

[40] That restriction might no longer apply if all Asian countries were to adopt the Anglo-American pricing model in their own markets.
[41] However, in the 2000s, several LNG receiving terminals have been built without long term LNG contracts.
[42] In the Atlantic region, LNG spot prices are generally determined by the actual supply and demand. In the Asia-Pacific region, however, prices seem to be considerably affected by factors other than the supply and demand, as shown in Figure 2, in which we can observe an extremely wide range of spot prices during almost the same period. The reasons for such situation are supposed to be that spot transactions are not transparent, and

As noted in (*c*), there are cases – such as the electric power and city gas industries in Japan – where different industries would theoretically have different natural gas market prices because they operate in different market segments, and those market segments have a different market value for natural gas. In such circumstances, natural gas is imported individually by electricity and city gas utilities, whose cost structures are completely different. Consequently a single netback price for all of Japan would not be comfortable for both industries and that is why the Europeans developed NMV based on the individual importing company's market portfolio. Because the netback formula reflects market prices, greater integration of the entire Japanese energy industry, beginning with importers, is logical for the consistency of the domestic natural gas chain pricing structure. In other words, we should note the possibility that the netback price formula may not function on a national basis, since in countries with a large number of importers, the commercial positions of individual utilities cannot be reflected by a uniform market value.[43] It is thus also important to note that the market value netback pricing formula involves the structure of the energy industry, market liberalization, and other market institutions. Nevertheless, these factors only concern a single nation's industrial policy and market systems, and cannot be considered a fundamental obstacle to international natural gas pricing.

Finally, we would like to respond to (*d*) as follows. There will be always an argument as to which pricing formula, namely the existing one or an alternative such as the proposed netback pricing formula, will create more profit for sellers or buyers? A simple answer is illustrated in Figure 8; if we compare the LNG price equivalent to JCC prices (green line) with the estimated NMV of Asia as a whole (brown line), the former price is lower when the

---

utilities in the regions, which are extremely sensitive to security of supply, tend to ignore economics in case of supply shortage.

[43] In the case of Europe, it is possible when it is contractually linked to the market of buyers.

JCC price is around $42/bbl and conversely, the latter is lower when the JCC price rises above this level. During the period from January to July of 2008 when oil prices reached nearly $150 (although this period is not included in our analysis) it could easily be imagined that not only the NMV of Asia as a whole, but also of individual countries including Korea,[44] would be substantially below the LNG price equivalent to the JCC price. Therefore, it is highly likely that sellers will want a pricing formula that reflects crude oil prices straightforwardly, because of a consensus that from the long-term point of view, oil prices will rise substantially above the $30–50/bbl levels of early 2009.

At the same time, however, it should be remembered that in such circumstances, LNG virtually lost its competitiveness against energies other than oil products. For the time being, we foresee no changes to the basic structure whereby long-term contracts remain the main format for international natural gas trading in Asia. In principle, the price levels of these long-term contracts should ensure the price competitiveness of natural gas in each market. With the sudden rise in energy prices, however, the supply–demand balance for LNG temporarily tightened, creating a one-sided seller's market, and the market environment was not conducive to negotiations for long-term contracts between buyers and sellers during the high oil price period. We should note that, in response, structural changes in natural gas demand,[45] are already beginning, as one would easily recognize from the developments during the global oil crises of the 1970s. Moreover, future aggregate energy demand is projected to flatten, with the promotion of energy efficiency policies not only in industrialized, but also in developing nations, as tighter environmental restrictions – to counter global warming for example – are enforced. Meanwhile, there is also a very high likelihood that continued high prices for oil-based energy would further accelerate the

[44] We can find such a trend in Figure 3.
[45] For example, refer to Japanese natural gas demand trends described in the first section of this report.

conversion to nuclear power and to biomass, solar, wind power, and other renewable energies. Thus, the existing pricing formula would be an obstacle for the long-term development of the natural gas market in Asia as shown by what happened during the high oil price period.

The post-July 2008 Collapse of Oil Prices

In addition, we would like to add some observations for the period following July 2008, when crude oil prices rapidly fell to around $30–50/bbl. It is difficult to conclude what has happened in the end user market, because total energy consumption is declining due to the deep economic recession. In addition, there is always a time lag between changes in crude oil prices and end user energy prices, even if these have a direct linkage (as in the case of LNG). Also, in many countries, the pricing of electricity and/or oil products was adjusted to reduce the impact on consumers or energy companies during the high oil price period.

Thus in early 2009, we are in a chaotic situation, but the following point seems essential; even if the JCC price remains at the current level ($30–$50/bbl), the relationship between JCC and NMV will be changed (from the results of our analysis) because price competition between energy sources has changed considerably due to revisions on energy pricing including LNG[46] which were implemented during the high oil price period. Therefore, the quantitative result of our analysis cannot be applied to future market conditions. However, we want to stress here that even if our estimated NMV was equivalent to LNG prices used in actual transactions, particularly during the low oil price period, this happened by chance. The existing LNG price formula can never express an appropriate NMV because the formula has not and can not reflect competition between natural gas and other energies accurately.

[46] LNG prices for existing projects have been revised upward and those for new projects were concluded at higher price levels; in addition, the S curve has been removed in many of these contracts. As for other energies, city gas and electricity retail pricing have been revised (or are under revision) in Japan and other countries, and the pricing of oil products is being revised in almost all countries.

Consequently, from a long-term perspective, we repeat that it is important for both buyers and sellers that natural gas prices should reflect rational market prices. To conclude, the introduction of a netback market value pricing system, based on the energy products with which gas competes in the Asian region, may be considered a more rational alternative to the present pricing system.

8 Conclusion

In this paper, we have analyzed the situation regarding the market value of natural gas in the Asian region. As noted in the text, crude oil prices have fluctuated wildly in 2008, and the energy market is going through a major transition. Internationally, strengthened measures against global warming are being discussed, and the resulting shift to nuclear power and renewable energy sources, and accelerated development of clean coal technologies could change the role of natural gas in long-term energy supplies. Nevertheless, over the next 20–30 years, natural gas will undoubtedly continue to grow as a core energy source in the Asian region.

While the use of natural gas is thus expected to develop further in Asia, the irrationality of the present system of LNG pricing must be recognized, and the time has undoubtedly come for the majority of all players involved in the LNG chain, to consider a more appropriate and logical pricing solution.

In the present analysis, it has only been possible to discuss some of the most basic issues in relation to the future direction of pricing. The key point to note, however, is that a discussion of LNG pricing in the Pacific typically commences with the traditional price formula, and is deeply immersed in the debate on the coefficients and intercepts of the formula. It is important that all those involved in the LNG business take a step back from the position of negotiations between buyers and sellers to begin discussion of logical pricing of LNG, and it is hoped that this report makes its own small contribution to that debate.

APPENDIX 1

Table A1. Weighting Factor (Japan)

Sector	Share (*A*)	Competing fuel	Competition Factor (*B*)	**WF＝ (*A*)×(*B*)**
Power Generation	0.60	Steam coal	0.76	**0.456**
		Crude oil	0.09	**0.054**
		Fuel oil C	0.15	**0.090**
Industrial & Private Power	0.21	Steam coal	0.19	**0.040**
		Fuel oil C	0.18	**0.038**
		Fuel oil A	0.09	**0.019**
		Diesel oil	0.03	**0.006**
		Kerosene	0.07	**0.015**
		LPG	0.11	**0.023**
		Electricity	0.33	**0.069**
Commercial	0.08	Fuel oil A	0.54	**0.043**
		Kerosene	0.51	**0.012**
		LPG	0.21	**0.017**
		Electricity	0.10	**0.008**
Residential	0.11	Kerosene	0.53	**0.058**
		LPG	0.29	**0.032**
		Electricity	0.18	**0.020**

Table A2. Weighting Factor (Korea)

Sector	Share (*A*)	Competing fuel	Competition Factor (*B*)	**WF＝ (*A*)×（*B*)**
Power Generation	0.43	Steam coal	0.88	**0.378**
		Fuel oil C	0.12	**0.052**
Industrial	0.15	Steam coal	0.18	**0.027**
		Fuel oil C	0.19	**0.029**
		Diesel oil	0.12	**0.018**
		LPG	0.07	**0.011**
		Electricity	0.44	**0.066**
Residential & Commercial	0.42	Coal	0.10	**0.042**
		Fuel oil C	0.08	**0.034**
		Diesel oil	0.18	**0.076**
		Kerosene	0.38	**0.180**
		LPG	0.19	**0.080**
		Electricity	0.07	**0.029**

Table A3. Weighting Factor (Taiwan)

Sector	Share (*A*)	Competing fuel	Competition Factor (*B*)	**WF＝ (*A*)×（*B*)**
Power Generation	0.78	Steam coal	0.88	**0.686**
		Fuel oil	0.12	**0.094**
Industrial + Private Power	0.10	Steam coal	0.46	**0.046**
		Fuel oil	0.22	**0.022**
		LPG	0.03	**0.003**
		Electricity	0.29	**0.029**
Commercial	0.03	Fuel oil	0.40	**0.012**
		Diesel oil	0.34	**0.010**
		LPG	0.07	**0.002**
		Electricity	0.19	**0.006**
Residential	0.09	LPG	0.66	**0.059**
		Electricity	0.34	**0.031**

Table A4. Weighting Factor (India)

Sector	Share (*A*)	Competing fuel	Competition Factor (*B*)	**WF＝ (*A*)× (*B*)**
Power Generation	0.45	Steam coal	0.95	0.428
		Naphtha	0.05	0.023
Industrial	0.20	Steam coal	0.62	0.124
		Fuel oil	0.14	0.026
		Diesel oil	0.03	0.006
		LPG	0.01	0.002
		Electricity	0.20	0.040
Residential	0.01	Kerosene	0.47	0.005
		LPG	0.53	0.005
Fertilizer	0.34	Naphtha	1.00	0.340

Table A5. Weighting Factor (China)

Sector	Share (*A*)	Competing fuel	Competition Factor (*B*)	**WF＝ (*A*)× (*B*)**
Power Generation	0.12	Steam coal	0.96	**0.115**
		Fuel oil	0.04	**0.005**
Industrial	0.47	Steam coal	0.50	**0.235**
		Fuel oil	0.09	**0.042**
		Diesel oil	0.10	**0.047**
		Electricity	0.31	**0.146**
Residential	0.22	Coal	0.69	**0.152**
		LPG	0.31	**0.068**
Fertilizer	0.19	Coal	0.36	**0.068**
		Naphtha	0.64	**0.122**

Table A6. Data Sources for WF

	Statistics
Japan	Energy Balance Table FY2006 by The Energy Data and Modeling Center
Korea	Energy Balance Table 2006 by Korea Energy Economics Institute
Taiwan	Energy Balance Table 2006 by Bureau of Energy, Ministry of Economic Affairs
India	Energy Balance Table FY2005 in TERI Energy Data Directory & Yearbook 2007
China	Energy Balance Table 2005 in China Energy Statistical Yearbook 2007

Figure A1. NMV Comparison

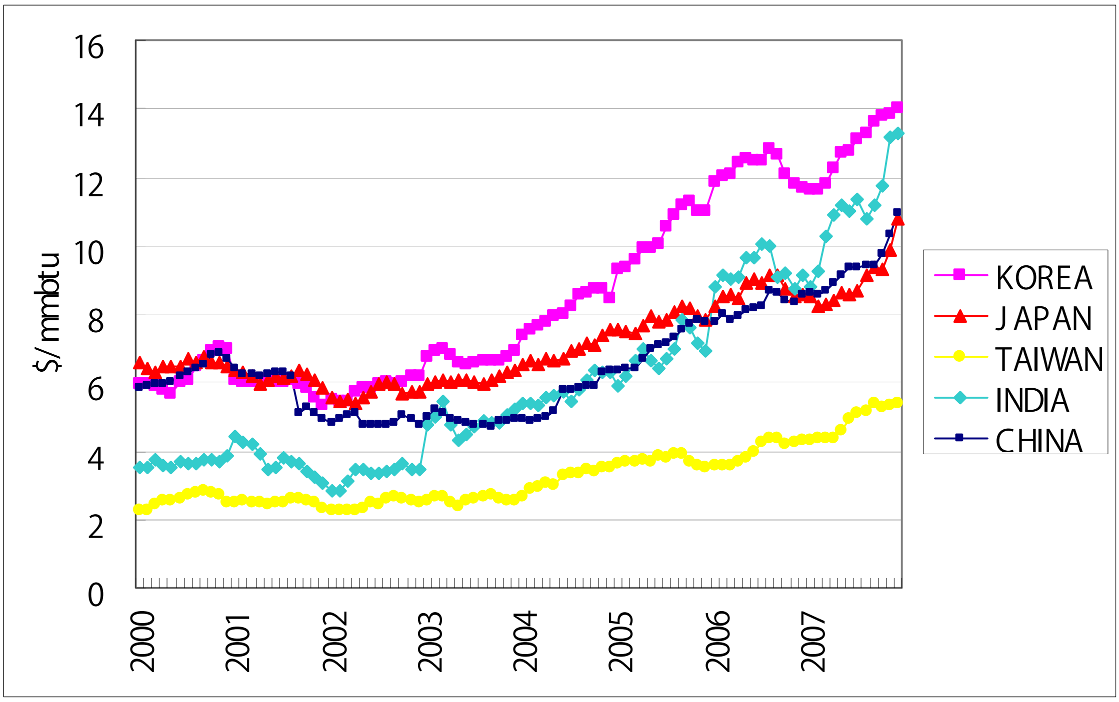
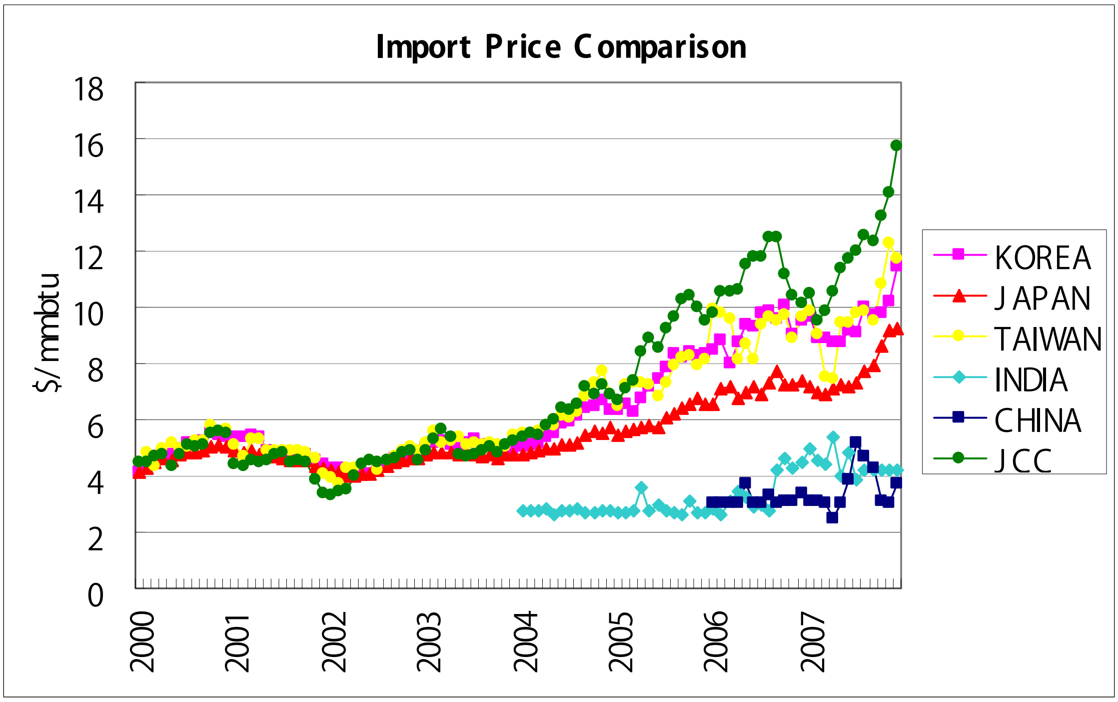


Figure A2. LNG Import Price Comparison



APPENDIX 2 Price Data*

Table A7. Price Data

State	Energy	Data Sources
Japan	Oil Products	'Price Data for Construction Cost Estimating' by Economic Research Association
	LPG	'Price Data for Construction Cost Estimating', The Oil Information Center website
	Electricity	Price Data published by METI, Power Utilities website
	Coal	Asset security reports of power utilities, Trade Statistics of Japan
Korea	Oil products	'The information on Commodity Prices' by Korea Price Research Center
	Electricity	'The information on Commodity Prices' by Korea Price Research Center, Korea Energy Economics Institute website
	Coal	'The information on Commodity Prices' by Korea Price
Taiwan	Oil products	CPC Corporation website
	Electricity	Bureau of Energy, Ministry of Economic Affairs, Taiwan Power Company website
	Coal	Directorate General of Budget, Accounting and Statistics, Taiwan Power Company website
China	All	Data submitted to authors by an energy company in Guangdong province
India	All	Data submitted to authors by Infraline Energy

BIBLIOGRAPHY:

Stern, J., (2007), *Is There A Rationale for the Continuing Link to Oil Product Pricing in Continental European Long-Term Gas Contracts?*, Oxford Institute for Energy Studies.

Stern, J., (ed.) (2008), *Natural Gas in Asia, The Challenges of Growth in China, India, Japan and Korea*, OIES/Oxford University Press.

Wybrew-Bond, I. and J. Stern, (eds) (2002), *Natural Gas in Asia, The Challenges of Growth in China, India, Japan and Korea,*, OIES/Oxford University Press.