World Gas Trade Model: Some Implications for South Korea

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Overview and motivation

Worldwide, the demand for natural gas is rising:

Key reasons for the demand increase:
- Environmental pressure for cleaner fuels
- Wholesale electricity market competition raised the demand for smaller scale electricity plant, which CCGT satisfied

The share of gas may continue to rise:
- Gas may supply transport fuel needs (GTL, oil shale, fuel cell)
- A possible contrary influence is that coal gasification, solar, hydro and/or nuclear power, perhaps assisted by falling costs of HVDC, could displace gas in electricity generation

Source: EIA
Overview and motivation

- South Korea began importing gas in 1986, but gas was < 5% of Korean primary energy demand until 1994 and is now > 10%

- South Korea will face more competition for LNG supplies
  - There is high growth in energy demand in China and India
  - Declining North American and North Sea reserves with increasing demand has stimulated actual and planned LNG import
  - Falling LNG shipping costs have expanded the options for suppliers

- World gas supply potential is large, but:
  - It is concentrated in areas remote from markets
  - Production and transport infrastructure is required
  - Prices need to rise in real terms to finance the investments
  - Unstable political regimes may make investments unattractive

- Russia could be a big supplier of natural gas to both Europe and Asia, making developments there critical

- The Rice World Gas Trade Model, based on economic and geological fundamentals, can be used to examine political and economic influences on the world market for natural gas
Rice World Gas Trade Model

- Model framework: Market Builder from Altos Partners
  - The model calculates equilibrium prices and quantities across a fixed number of locations and time periods
    - In each period, gas is produced or transported until there are no opportunities for profitable arbitrage across locations
    - Producers schedule production to eliminate profitable arbitrage across time periods
    - Supplies isolated from markets, or in areas lacking infrastructure, earn lower rents and are extracted last
    - Consumers shift the timing of demand in response to anticipated changes in prices

- The supply data is based on the USGS World Resource Assessment updated with latest reserve revisions

- The econometric model for forecasting demand was developed using
  - EIA International Energy Outlook 2004,
  - IEA World Energy Outlook 2002 and
  - World Bank data on population and economic growth

- The demand for natural gas is related to:
  - The level of economic development (GDP/capita)
    - Following Medlock and Soligo (2001), energy demand increases with GDP/capita but at a decreasing rate
    - But the natural gas share in primary energy demand also increases with development
  - Population
  - Country-specific effects reflecting, for example, resource endowment or climate
  - Prices (wholesale industrial $/BTU) of natural gas, oil and coal
Backstop technology

- Future supply possibilities are important because expected future prices affect current supply and price

- The estimated demand elasticity reflects historical substitution possibilities, not possible future ones
  - Technological change is difficult to predict, but
    - IGCC, nuclear and renewable sources provide sources of electricity supply that compete with natural gas
    - DOE says IGCC is competitive at $4 per mcf of gas (2004 prices)
    - Gasification of coal may also satisfy other uses of natural gas

- We assume that, starting in 2030, demand is lost to new technologies at prices above $5 with up to 2.5% lost at $5.50 and 5% lost at $10
  - Each year, the proportion of demand vulnerable to the backstop at each price above $5 increases until in 2040 all base case demand could be satisfied at a price of $10
More detail on supply

Regional resource potential of

- associated and unassociated natural gas resources,
- both conventional and unconventional gas deposits in North America and Australia (CBM), and
- conventional gas deposits in the rest of the world

was assessed in three categories:

- proved reserves (2003 Oil & Gas Journal estimates)
- growth in known reserves (P-50 USGS estimates)
- undiscovered resource (P-50 USGS estimates)

Cost estimates for North America (including Canada and Mexico) were applied elsewhere based on geological characteristics

- The North American estimates (developed by Altos & USGS) include:
  - capital cost of development,
  - operating and maintenance costs, and
  - cost changes by region and deposit type as resources deplete
Example cost of supply curves

Comparative Cost of Supply Curves for Selected Regions

Cumulative Reserve Additions (Quadrillion BTU)

- Alaska
- Qatar
- Saudi Arabia
- Iran
- West Siberia

Sources: USGS, EIA, author calculations
Technological change in mining

Technology Curves in the Resource Extraction Industries
Percentage of Initial Cost

Source: Adapted from "Balancing Natural Gas Policy" National Petroleum Council, 2003
Linking supply with demand
Representing transport networks

- The model examines a world market of expanding depth and geographical extent
- North American, European pipeline networks are now the main transport systems
  - LNG is only about 5% of world demand, but is important in Japan & Korea, and increasing elsewhere
- To allow calculations, supplies and demands are aggregated into discrete “nodes”, parallel pipes are aggregated into a single link, and minor distribution and gathering pipes are ignored
- Transport links are inherently discrete
  - We allow many potential pipeline links including ones that have been discussed and others that might appear profitable at prices calculated in initial iterations of the model
  - A hub and spoke representation is used for LNG to allow many potential trading partners
    - While bilateral contracts now dominate LNG trade, the market is becoming more flexible
    - Decreasing distances between suppliers and customers increases arbitrage opportunities
    - Contracts are financial arrangements that do not necessarily constrain physical trades
      - Contracts can be fulfilled by swap agreements as increased market depth increases trading options
- The model chooses new or expanded transport capacity from supply sources to demand sinks based on:
  - capital costs of expansion, and
  - operating and maintenance costs of new and existing capacity
EIA published cost data for 52 pipeline projects

Using this data, we estimated a regression relating specific capital cost (annual cost per unit of capacity) to project characteristics

- Project cost is raised by:
  - Length of the pipeline
  - Crossing mountains
  - Moving offshore or crossing a lake or sea
  - Developing in more populous areas

- Higher capacity reduces per unit costs as a result of scale economies
LNG transportation network
LNG costs

- Consulted a variety of sources (including a 2003 EIA report and industry contacts)

- Shipping costs split into a fixed capital cost for ship development plus operating costs of:
  - 2.25% of fixed cost of development
  - fuel use during transit (0.15% per day)

- Liquefaction costs are a fixed cost ($4.11/mcf/yr) plus a variable feed gas cost (model calculated)

- Regasification costs vary by location (primarily because land costs vary)
## Indicative LNG Costs

Price required for expansion, including capital costs but excluding feed gas cost

<table>
<thead>
<tr>
<th>Route</th>
<th>Liquefaction</th>
<th>Shipping</th>
<th>Regasification</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinidad to Boston</td>
<td>$ 0.82</td>
<td>$ 0.25</td>
<td>$ 0.69</td>
<td>$ 1.75</td>
</tr>
<tr>
<td>Trinidad to Lake Charles</td>
<td>$ 0.82</td>
<td>$ 0.32</td>
<td>$ 0.21</td>
<td>$ 1.35</td>
</tr>
<tr>
<td>Algeria to Boston</td>
<td>$ 0.82</td>
<td>$ 0.45</td>
<td>$ 0.69</td>
<td>$ 1.96</td>
</tr>
<tr>
<td>Algeria to Lake Charles</td>
<td>$ 0.82</td>
<td>$ 0.63</td>
<td>$ 0.22</td>
<td>$ 1.66</td>
</tr>
<tr>
<td>Nigeria to Lake Charles</td>
<td>$ 0.82</td>
<td>$ 0.77</td>
<td>$ 0.22</td>
<td>$ 1.81</td>
</tr>
<tr>
<td>Qatar to Lake Charles</td>
<td>$ 0.82</td>
<td>$ 1.17</td>
<td>$ 0.23</td>
<td>$ 2.22</td>
</tr>
<tr>
<td>Qatar to Baja</td>
<td>$ 0.82</td>
<td>$ 1.32</td>
<td>$ 0.28</td>
<td>$ 2.41</td>
</tr>
<tr>
<td>NW Shelf to Baja</td>
<td>$ 0.82</td>
<td>$ 0.99</td>
<td>$ 0.27</td>
<td>$ 2.07</td>
</tr>
<tr>
<td>Norway to Cove Point</td>
<td>$ 0.82</td>
<td>$ 0.57</td>
<td>$ 0.36</td>
<td>$ 1.74</td>
</tr>
</tbody>
</table>

Sources:
2. Various Industry Consultant Reports
Technological change in LNG

- LNG transport, liquefaction, and regasification capital and O&M costs are expected to decline
  - Rates of change in the model are based on a statistical fit to WEIO rates

Selected price projections

![Graph showing selected price projections for different cities over a range of years, with a source citation at the bottom: RWGTM, Hartley and Medlock (2005).]
European and US supply shrinks, to be replaced by Russia and Middle East

Source: RWGTM, Hartley and Medlock (2005)

Backstop constrains demand growth
Demand projections

Source: RWGTM, Hartley and Medlock (2005)
Natural gas trades

Source: RWGTM, Hartley and Medlock (2005)
LNG exports to come from higher risk sources

Source: RWGTM, Hartley and Medlock (2005)
LNG imports to be dominated by Asia & North America

Source: RWGTM, Hartley and Medlock (2005)
South Korea - pipeline gas displaces LNG in the Reference Case

Source: RWGTM, Hartley and Medlock (2005)
Some implications of the Reference Case

- Russia becomes a major force in the global gas market
  - Russian pipeline gas continues to be important for Europe
  - Russia also becomes a major supplier of natural gas to China, Korea and Japan
    - Japan continues to import LNG as the high cost of a national gas grid is prohibitive
    - Ultimately, gas is also piped east from West Siberia
    - Korea shifts to pipeline gas from Russia and stops importing LNG
    - In consequence, Seoul prices fall from approximating Tokyo prices to approximating Beijing prices
  - Russia also enters the LNG market possibly supplying the US
    - “Net-back” prices in Russia have to be equilibrated

- Over the period from 2002-2040 Australia, Qatar and Indonesia are the largest suppliers of LNG (>40% of total), but in 2040 Iran, Russia and Saudi Arabia join Australia and Qatar to supply more than 60% of LNG exports

- Russian pipeline gas exports to Europe and Asia make Russia the dominate exporter overall

- Other long-haul international pipelines are constructed
  - The trans-Saharan pipeline (Nigeria to Algeria) is constructed in 2012
  - India imports Iranian gas via pipeline from 2020
  - Europe also imports gas from the Middle East via Turkey in substantial amounts from 2020
  - A pipeline from West Siberia to East Siberia is constructed in the mid 2030’s to supply NE Asia

- North America becomes a major importer of LNG
  - Alaska gas serves only to replace declines in other North American production having no dramatic impact on prices
  - Gas prices in the US eventually exceed prices in Japan
  - Russia, Middle East, Australia retain low gas prices

- South American gas is consumed primarily in South America
  - Trinidad LNG export growth is limited to the near term, but Venezuela is significant later
  - Brazil imports Bolivian and Venezuelan supplies
  - Argentina imports Bolivian supplies and becomes an LNG importer

- A backstop technology is implemented almost everywhere by 2040, but is used most heavily in the US, western Europe and Japan
Will Russia Continue to Increase its Oil and Gas Exports?

Sustainable Russian export growth depends on removing major bottlenecks in

- Eastern Siberia
- Northern route to Barent’s Sea for ocean bound movements by ultra large tankers
- Bypass to Bosporus Strait

State control in pipeline sector unlikely to change
Problem of financing – state funds and higher tariffs unlikely to be enough
Outside investors?
State Stabilization Fund?
Putin reasserting government control over Russia’s natural resources

- Philosophy dates back to late 1990s
- Believes in a mixed system of state and private ownership in assets but state protecting the interests of the nation
  - Since early 2004, new appointments of like minded officials to cabinet, presidential administration and state oil and gas firms
    - Many have background that includes service in state security organs
- Sea change likely to affect business model for Russian industry
  - New round of redistribution of petroleum assets
  - Corporate responsibility a la Russe; need to follow “unwritten rules” to succeed in Russia
  - These rules involve limits to Western involvement and Western style management
  - Kremlin decides export routes
Geopolitical Trends

1. Russia actively being courted by U.S., China, Japan, Europe
   - Kremlin as a moderator of global prices?

2. Kremlin’s plans for industry reorganization is dampening level of increase by disrupting speedy implementation of plans to remove infrastructure constraints or if it causes a slow down in capital expenditures and project development

3. Russia worried about fate of eastern regions
   - Emigration a demographic threat to Russia’s sovereignty
   - Fears of splintering of oil-rich distant regions
   - Wants to use East Siberian resources to spur local economic develop; many in the Kremlin take a Russia first attitude towards energy resources

4. Energy as key plank to Russia’s diplomacy in Asia
   - Russia wants to speed up integration process with Asia Pacific but pipeline routing remains an economic and diplomatic problem, but political/diplomatic problems surrounding the routing question remain to be tackled
Two scenario analyses

1. Pipelines from Nahodka & NE China through North Korea are blocked
   - Political relations with North Korea prevent them
   - An undersea pipeline to South Korea from China can still be built
   - Connections between South Korea and Japan are also permitted, but these are too expensive to use

2. Russia to China pipelines also don’t get built
   - Political difficulties may also prevent this development
   - We also rule out the pipeline from Uzbekistan to China
     - It otherwise provides an indirect route for gas sales from the Volga-Urals region in Russia to China
   - Sakhalin pipeline to Japan still is possible
No North Korea pipes: LNG and China pipeline share South Korean market more equally
No North Korea pipes: Changes in Selected Prices

No North Korea pipes: Major Supply Changes
Russian output declines most, but effects are worldwide
No North Korea pipes: Major Demand Changes
Higher prices stifle South Korean demand, and in general lower prices stimulate demand elsewhere
No North Korea pipes: Major Changes in LNG Supply
More Sakhalin gas is now exported as LNG, beating out other LNG from Australia and Saudi after 2030
No North Korea pipes: Major Changes in LNG Demand
Higher Korean LNG demand reduces LNG consumption in other Pacific Basin importers, especially Japan
China & Korea pipes off: Effects on Korean Supplies

LNG beats a potential Sakhalin-Japan-Korea pipe
China & Korea pipes off: Changes in Selected Prices

[Graph showing changes in selected prices over time for various locations: Henry Hub, Beijing, Tokyo, Buenos Aires, Zeebrugge, Delhi, Seoul. The graph includes data points for years 2002 to 2038, with price values ranging from -$1.0 to $1.5.]
China & Korea pipes off: Major Supply Changes
Now higher overall LNG demand allows main LNG exporters (Australia, Iran, Qatar, Indonesia) to expand
China & Korea pipes off: Major Demand Changes
Now Chinese demand decline exceeds the Korean one; remaining Pacific Basin importers are again adversely affected
China & Korea pipes off: Major Changes in LNG Supply
Again Sakhalin LNG exports rise, but now the overall LNG market expands enough that few LNG exports decline
China & Korea pipes off: Major LNG Demand Changes
Increased LNG demand in Korea and China displaces demand in other Pacific Basin importers

[Bar chart showing LNG demand trends from 2002 to 2038 for various regions including South Korea, Japan, China, US Pacific, Mexico Atlantic, Europe, US Atlantic, Canada, and Remaining Asia Pacific.]
Some implications of the Results

- In the coming worldwide market for natural gas, political disturbances in one area have global effects.

- The results illustrate the key role Russia will play in the future world gas market:
  - Russia not only has a lot of gas.
  - It also is strategically placed to ship gas either east or west and hence in a position to arbitrage between European and Asian markets.
  - Toward the end of the horizon, Russia also becomes a significant exporter of LNG, thus helping to solidify the link between LNG prices and pipeline gas prices around the world.

- North America and the Middle East also link Pacific and Atlantic gas markets:
  - Middle East producers can export LNG east or west, and also can ship gas via pipeline to Europe or the Indian sub-continent.
  - In North America, if Pacific Basin gas prices rise, more Atlantic Basin LNG is imported and the arbitrage point moves toward the west coast.

- A final point more specific to the Korean experiments is that Japan is a close competitor to South Korea for Pacific Basin LNG and increased Korean demand raises Japanese prices.
References for further information

Details on the construction of the model can be found in the paper:


Other scenarios are discussed in the companion paper:


The model of economic development and energy demand is explained further in:
