Energy markets in transition with a focus on LNG: Growing pains, new technologies and new trading arrangements

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Outline of Talk

- Economic growth and energy demand
- Technological change and fossil fuels
- Alternative energy technologies
- Modeling the transition process
- The future role of natural gas
- LNG market developments
- The value of long-term LNG contracts
- Indexing in long-term LNG contracts
TOPIC 1

Economic growth and energy demand
Economic growth and overall energy demand

- Access to modern energy is essential for economic growth
  - Access to non-human/non-animal energy sources was an essential ingredient in the industrial revolution
- Fossil fuels are relatively dense energy sources:
  - Gasoline 46.9 GJ/t by weight, 34.6 MJ/L by volume; Diesel 45.8 GJ/t, 37.3 MJ/L
  - Filling a car, flow rate is ~ 40 L/minute = 83 GJ/hour = 23 MW power plant output
  - Power of average human worker is about 75 W, so 2000 hours of work per year delivers 150 kWh = 540 MJ = energy in about 15 L of diesel
2011 TPE/capita versus GDP/capita

Source: Gapminder
TPE demand growth

Source: EIA
Higher growth tends to more unstable

Source: EIA
Growth and the pattern of energy use

- Economies tend to undergo a predictable pattern of energy use as they develop:
  - First, industrial and construction sector use grow most rapidly, especially via construction of infrastructure, which is very energy and material intensive
    - But industrial use eventually declines in *per capita* terms as economy matures
  - Commercial and residential energy use increase next
  - Rapid increase in energy use for transportation occurs later, and does not attain the growth rates of industrial or commercial, but...
    - Transportation eventually becomes the largest component of final energy demand
  - The share of primary energy used to generate electricity grows over time
  - Environmental concerns increase as people get wealthier, favouring natural gas especially at the expense of coal
Future sources of energy demand growth?

- Extraordinary feature of the recent episode: High growth combined with high population
  - Rapid Chinese growth stressed not only energy but also other commodity markets
- Sources of rapid economic growth:
  - Movement of labour from agriculture to industry
  - Investment in physical and human capital
  - Adoption of technologies from more developed economies
- Eventually countries converge to the long run growth path of the leading nations
  - Very high growth rates get more difficult to achieve as a straight numerical issue
  - Countries at the frontier can no longer take new technologies “off the shelf”
  - In particular, Chinese growth is unlikely to return to its previous highs
- Might India or SE Asia, which also have high populations move into the high growth phase?
Energy supply also affects growth

- In addition to economic growth affecting energy demand, energy availability, or especially lack thereof, can affect economic growth.
- Many major post-WWII recessions have been associated with a preceding, and apparently precipitating, constraint on energy supply.
- Major reasons for macroeconomic impacts of energy supply constraints:
  - Energy is an essential input.
  - More expenditures on energy imply less available for consumption or investment.
  - Energy/capital input ratios are relatively fixed in the short run.
    - Reducing hours of operation is the main short-run response to high energy prices.
    - If price changes are perceived as permanent, capital can be replaced with a more energy efficient alternative, but this is also disruptive in the macroeconomic sense.
  - Other attempts to economize on energy use also come at some economic cost.
TOPIC 2

Technological change and fossil fuels
Technological change and fossil fuels

- Despite repeated fears of exhaustion, technological change has continually uncovered new resources, reduced the cost of extracting “difficult” resources, and increased EUR from previously exploited sources
  - While total fossil fuel resources are finite, the known resource base is vast
  - Even the amount that could be recovered with current and reasonably foreseeable technologies is more than 2000 times current annual production
  - We will never “run out” of fossil fuels – rather at some point the remaining resources will cost more to extract than the cost of alternative energy sources
- The production of natural gas, and then light oil, from shale is just the latest “revolution” in fossil fuel technology
Increasing our reservoir contact by 1,000,000 fold has allowed pursuit of reservoirs with thousands of times lower perm.

Source: Mike Vincent, “Five things you didn’t want to know about hydraulic fractures”
Increased energy efficiency

- Increased end-use energy efficiency also extends fossil fuel resources
  - By allowing the same energy services to be produced with less primary energy input, fossil fuel resources are exploited more slowly
  - Costs of production then will not rise as fast
  - This is a version of the “green paradox”
  - Technologies increasing substitution between different fuels also extends resource life
- Other innovations – most especially the production and long-distance transmission of electricity – have increased the value of energy services
- Economic growth beyond middle income levels also tends to reduce the energy intensity of GDP
  - This is simply the result of the changing composition of GDP toward sectors – especially services – that are less energy intensive
  - This, as more countries become high income, economic growth can continue without requiring the same increases in energy input
TOPIC 3

Alternative energy technologies
Non-fossil fuel energy technologies

- Fossil fuels currently supply more than 90% of the world’s primary energy
- Nuclear power and hydroelectricity supply more than 8%
- Other modern non-fossil energy sources are used mainly as a result of subsidies
  - Example: The DSIRE database currently lists 28 US Federal policies and 2,613 policies at the state and local level (including Washington DC) promoting renewable energy and energy efficiency technologies
- While these other sources are called “renewable” in practice they also are limited in supply
  - The energy source (basically sunlight) that is converted to energy services by sources such as wind, solar or hydroelectricity is essentially unlimited
  - However, suitable sites for constructing harvesting infrastructure are limited in supply
Renewables – cost disadvantages

- Relative to combined cycle gas turbines, the per kW of capacity capital cost of
  - onshore wind is about 2x
  - offshore wind is about 4x
  - solar is about 5.5x
- Low average capacity utilization for renewables further raises costs per kWh
- Renewables also often need transmission upgrades
  - These also are used at a low capacity factor
Example generating plant cost calculations \((r = 0.075)\)

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Renewables – other issues

- Wind power output fluctuates frequently and substantially
  - For wind speeds 10–30 km/h, output varies as the cube of wind speed (next slides)
  - Ancillary services are needed to maintain network stability
  - Added thermal plants then are not used when the wind blows
  - Also peaking gas turbines are less efficient and more costly than NGCC plants
  - Curtailing base load thermal plants reduces their efficiency and can raise pollution

- In many locations, wind also is strongest off-peak, weakest in peak hours
  - A large fraction of wind capacity increases the chance of inadequate capacity at peaks

- Best sites for wind and solar are often remote from major consuming locations
  - Expensive new transmission lines with low capacity factors are needed

- Wherever wind has been forced into the network via subsidies and mandates we have seen substantial rises in prices and deterioration in supply quality

- Wind and solar farms also have a large land and environmental impacts
Example Turbine Power Curve (225 kW rating)
Wind production SE Australia 14/10/15
Wind production SE Australia 15/10/15
The “valley of death” for new energy technologies

- Claimed paucity of funding for commercializing new technologies relative to funds for basic R&D
- Discussions typically focus on remedial policies
- Why are apparently profitable opportunities ignored?
Previous explanations for the valley

- Informal justifications include:
  - Information spillovers that make it hard to capture benefits of R&D
  - Information asymmetries, uncertainty about viability, and financial and product market volatility that make it hard to “sell” the project to investors
  - Higher costs of early plants make initial prototypes unprofitable even if the technology would be viable in the long run (an “infant industry” argument)
  - Inability to use many assets (especially intellectual property, patents) as collateral

- But one would think that most of these problems would be more severe at the “discovery” phase than at the “new product development” stage

- A 2009 paper argues that a “non-economic” motivation (public subsidies) for R&D at stage 1 alone can lead to more stage 1 than later stage projects
  - Actually, more subsidies for stage 1 research could be efficient if more basic research has more extensive spillovers that are hard to monetize

- Another issue: why energy but not pharmaceuticals or IT, for example?
TOPIC 4

Modeling the transition process
A model of the transition process

- In a recent paper, we use a dynamic intertemporal model to calculate an efficient transition between energy sources
- The model distinguishes several types of investment:
  - R&D into both fossil fuel and non-fossil energy technologies
  - Capital is used to produce final output, with energy services as another essential input
  - Energy services are produced using two types of non-substitutable capital
- We assume learning by doing and explicit R&D are both needed to reduce the cost of new non-fossil energy production
  - Such a “two factor” learning model has been estimated for progress in solar and wind and other energy technologies
- Technological progress in fossil fuel technology makes it harder for non-fossil alternatives to compete
The valley of death in this model

- The early stage of development largely involves cost reductions through R&D expenditure and learning.
- The “commercialization” phase involves building physical capital to supply energy services using the new technology.
- Capital used to produce energy services from fossil fuels is a sunk cost, so it will be used so long as the energy price covers short-run operating costs.
- Until fossil fuels are abandoned the energy price is less than even the operating costs of the alternative energy technology.
- Investment into R&D and development of new technologies starts long before the technologies are deployed commercially.
- Furthermore, the new technologies will be used to supply energy services before the energy price is sufficient to cover their long run costs.
  - The full long-run costs are not covered until some time after fossil fuels are abandoned.
- Big difference between energy and IT or pharmaceuticals: only energy requires large investments in infrastructure to deliver final product after the R&D phase.
An “optimal energy crisis”

- The transition path between technologies that we calculate is efficient
- That path involves an “energy crisis” – slower economic growth and especially reduced consumption and a lower standard of living – around the time $T$ of transition between fossil and non-fossil energy sources
  - As the cost of fossil fuel production begins to rise, it becomes optimal to invest more in fossil fuel R&D (including new field development) to keep costs under control
  - Also as $T$ approaches, substantial investment in infrastructure to supply energy services from non-fossil sources is required
  - It also becomes more worthwhile to accelerate R&D investment into alternative energy technologies as $T$ approaches
  - Investment into fossil fuel energy supply infrastructure ceases before fossil fuels are abandoned at $T$, but this limits the supply of energy services and hence final output
  - The cost of energy services has to rise dramatically to cover the full long-run cost of alternative energy supply infrastructure and incentivize the investment required
  - Spending on energy and investments, and constrained output, reduce consumption
Real price of energy
Output growth rate
Consumption/output ratio

years

0.7
0.68
0.66
0.64
0.62
0.6
0.58
0.56
0.54
0.52
0 20 40 60 80 100 120
TOPIC 5

The future role of natural gas
A “golden age of gas”?  

- Barring a breakthrough in alternative energy technology, fossil fuels are likely to dominate energy production for many more decades.
- However, many expect natural gas to grow faster than coal or oil.
- Natural gas has much lower emissions than other fossil fuels – especially coal.
  - Controlling “conventional” pollutants from coal is already raising costs.
  - CCS and gasification as strategies to keep coal competitive?
- The resource base for natural gas is huge – especially if one includes hydrates.
- Even if renewables subsidies continue, wind and solar generation tend to require more natural gas as backup.
  - Time of day pricing to smooth the load curve is a possible alternative approach.
Natural gas in transportation?

- For transportation, gasoline and diesel have higher energy density than CNG and are easier to handle than LNG.
- Nevertheless, LNG may be used more widely in truck fleets, rail, and especially shipping, in part because of the relative environmental benefits.
- Natural gas is already indirectly used in transportation via oil sands and ethanol production, and in the form of electricity.
- Electric cars also have some advantages over internal combustion engines:
  - Advantages in braking and idling.
  - Generating plants are more energy efficient than internal combustion engines.
  - But batteries currently have low energy density.
  - Vehicle choice versus driving choices in multi-vehicle households.
TOPIC 6

LNG market developments
Increasing spot and short-term LNG trades

Source: GIIGNL
Increasing numbers of LNG traders

Source: GIIGNL
Spot trading is related to the number of importers

Source: GIIGNL

\[ \text{SpotFrac} = 0.187 \ln(\text{Regas}) - 0.590; \quad R^2 = 0.9370 \]
Average LNG shipping distance

Sources: Author calculations based on GIIGNL and VesselDistance.com
Recent evolution of spot natural gas prices

Source: Platts
US LNG Imports/Marketed production

Source: US Energy Information Administration (EIA)
Japanese LNG imports: Long-term contract and other

Source: GIIGNL
Other recent developments

- LNG swaps and other spot trades increasingly exploit arbitrage opportunities
- Many regasification terminals are adding storage capacity to support arbitrage
- Expiration of long-term contracts for some early liquefaction developments has created spare capacity and without a need to finance large investments
  - More of their output is being sold short-term and spot
- Many recent contracts have greater volume flexibility, destination flexibility, and less than 100% off-take commitments by buyers
- After the EU restructuring directive of 1998 (promoting competition in EU gas markets), the Commission found destination clauses anti-competitive in 2001
  - This stimulated re-export of cargoes and increased destination flexibility
- Growth of “branded LNG” sourced from many sellers and sold to many buyers
Effects of US developments on LNG trade

- The first few US terminals are proposing exports under a tolling arrangement
  - Typical feed gas price 115% of Henry Hub and liquefaction fee $3–3.50/mmbtu
  - Several buyers will add the LNG to their global portfolio
- Some proposed facilities are smaller and more modular than traditional trains
  - For example, Elba Island (which also has output assigned to Shell’s global portfolio)
  - LNG Ltd Lake Charles terminal using a more energy efficient less capital intensive process
- Future co-location of regasification and liquefaction facilities in the US with pipeline connections to a deep market will facilitate short-term arbitrage
Summary comments on recent developments

- More elastic natural gas supply and demand curves will reduce price volatility
- Intermediaries providing hub services and having access to storage will allow more effective price arbitrage, further reducing price variability
- The gap between spot prices available to importers and exporters also will decline as market liquidity rises
- Spot market trades from parties to contracts should continue to increase
- Greater use of spot and short-term trading may favor lower capital cost projects
- Growth in spot trading may reduce volumes under contract and raise spot market participation, further raising spot market liquidity
- Long-term contracts will also become more flexible to allow parties to better exploit the optionality of spot and short-term trades
- There are compelling reasons for retaining oil prices as the main indexing variable for long-term contracts, but limited use of gas price indexes from deep natural gas markets might provide some risk diversification benefits
TOPIC 7

The value of long-term LNG contracts in an uncertain environment
Explanations for long-term contracts

- We focus on two main explanations for the desirability of long-term contracts:
  1. The hold-up problem
  2. Securing a lower cost of finance by reducing cash flow variability
- Commercial parties emphasize the risk sharing benefits of contracts, but the academic literature has focused on the hold-up problem
- The academic literature has also focused on the efficiency benefits of take-or-pay clauses in long-term contracts
The hold-up problem

- This can occur when trading partners make large up-front investments dedicated to the trade partnership.

- Once investments have been made, the counter-party has an incentive to bargain for prices that cover operating costs but do not yield a competitive return on the capital.
  - This can also apply to re-negotiating an indexation formula.

- The problem can become more acute if some information is known only to one party, so the rents associated with the relationship are not public knowledge.

- Contracts often allow more quantity adjustments than price adjustments.
  - Price adjustments are zero-sum, while quantity adjustments leave the other party with alternative avenues for making up lost profits.
Rent in the contracting relationship

- Parties in a long-term contract tend to be better matched to each other than to outside parties.
- The next best price for the buyer $p_M$ and the next best price available to the seller $p_X$ will vary randomly.
- While the two contracting parties generally are better off trading with each other that may not always be true.
- The contract price will tend to be toward the top of the $p_X$ distribution and the bottom of the $p_M$ distribution.
Take or pay clauses

- In the situation illustrated, the importer would prefer to buy spot rather than honour the contract.
- But it would be efficient to buy from the exporter since they would both be better off trading at a price between $p_X$ and $p_M$ than both using the spot market.
- A take-or-pay clause requires the importer to make the exporter “whole”, that is pay $p - p_X$ to the exporter, if the contracted volume is not taken.
- Then the buyer would choose to not take delivery only when $p_M < p_X$ in which case this is efficient.
- But the take or pay clause also leads to a transfer from the buyer to the seller in situations like the one illustrated.
Long-term LNG contracts and project financing

- Long term contract is “bankable” because it makes cash flows less volatile
- This in turn allows increased leverage, and reduces the cost of project finance
  - We assume the net benefits of debt are approximated by corporate tax benefits alone
- The total amount of debt is limited by a “value at risk” type constraint:
  - After-tax cash flows to importing and exporting parties are random
  - The constraint requires an upper bound on the probability that the after-tax cash flow will not be sufficient to service the debt in any given year
- Key findings:
  - Contracts can allow trade where it would not otherwise be supportable
  - General increases in spot prices are indexed 85–90%
  - Contracts are more valuable when there is “rent” in the relationship
  - Parties may limit long term contract volumes to allow more flexibility to exploit profitable spot market trades
  - Increased spot price variability generally raises the benefits of long-term contracts
TOPIC 8

Indexing in long-term LNG contracts
Indexing in long-term contracts

- Energy *relative* prices tend to be much more stationary than the prices of individual energy commodities
  - For demand, energy content is the dominant determinant of value, although energy density, ease of handling, environmental effects and other attributes are relevant
  - For supply, resources that can be used to produce natural gas in particular can also be used to produce oil and relative output shifts in response to relative prices
- Many studies have shown that *oil* prices tend to be the *most exogenous* energy price in markets where both prices are free to fluctuate independently
- *Natural gas* prices are the *most volatile* fossil fuel price (next slide)
- US natural gas prices have looked more attractive recently because the foreign exchange value of the $US has affected the oil/gas price ratio
  - After US LNG is traded, US gas prices may be a less attractive index to Asian buyers
- Other spot natural gas markets need to become sufficiently deep and liquid to reduce risks to investors in these large capital intensive projects
- Indexing to natural gas hub prices may exchange geographical basis differentials for commodity basis differentials
Relative volatilities of Henry Hub and Brent

Source: Author calculations based on data from the US Energy Information Administration (EIA)
Long-run relationship requires relative heat rates and the foreign exchange value of the $US to be included to be stable.
Within sample fit of dynamic model

- Adjustment to long-run error is approximately 6% per month
- Unexpected inventory changes have about 2x the effect on prices as expected ones
- HDD and CDD deviations and major hurricanes have expected effects on $\Delta \ln(p_{NG})$
Relationship of JKM to other fuel prices

Data sources: Platts and EIA
The co-integrating (long-run) coefficient $\beta$

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Restricted long-run equations

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The Speed-of-adjustment coefficients $\alpha$

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<td>65</td>
</tr>
<tr>
<td>$\Delta$RFO</td>
<td>-0.003 (2.27)</td>
<td>0.020 (3.19)</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Impulse response functions: Model D

LNG→LNG

RFO→LNG

coal→LNG

Brent→LNG

LNG→RFO

RFO→RFO

coal→RFO

Brent→RFO

LNG→coal

RFO→coal

coal→coal

Brent→coal

LNG→Brent

RFO→Brent

coal→Brent

Brent→Brent
Concluding remarks

- Energy is of fundamental importance for economic growth
- The energy industry has experienced tremendous technological change and this has kept fossil fuels as the lowest cost energy source for a long time
- The transition to alternative energy sources is costly and will take time
  - Forcing it with subsidies and mandates is imposing substantial welfare costs
  - We should distinguish subsidizing research into new technologies versus subsidies/mandates for the deployment of new technologies that are not yet competitive
- Natural gas is a favored fuel in the short and intermediate run
- LNG is growing relative to pipeline gas supplies, but the LNG market is also undergoing rapid change as it makes natural gas more of a globally traded good
- The capital intensity of LNG projects leaves a role for long-term contracts but spot and short-term trading, and flexibility in contracts, are all increasing
- While there are good reasons for indexing to oil prices, other indexes are possible and have some desirable features