Price discrimination and limits to arbitrage: An analysis of global LNG markets

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Evolution of LNG market since 2000

Large growth in LNG volumes for several reasons

- Increased infrastructure investment (liquefaction & regasification)
- Larger LNG shipping fleet & lower transport costs

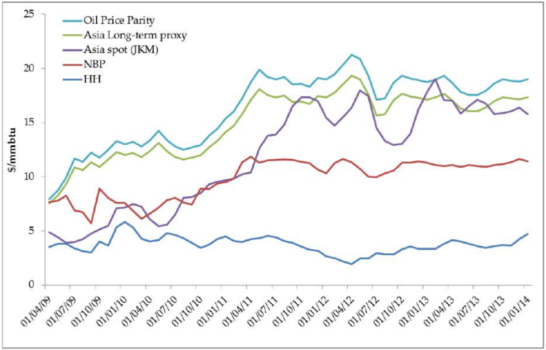
LNG connects previously separate geographies

- More flexible contracting between buyers & sellers
  - Ongoing shift away from bilateral long-term contracts
  - Short-term LNG $\uparrow$10-fold since 2000 (now $>$25% of total)
- Significant proportion of gas trade now between regions

$\Longrightarrow$ **Widespread conjecture of global gas price convergence**

Price non-convergence: Irrationality?

Some commentators argue LNG players acting "irrationally"



- Major exporters sell short-term LNG to both Asia & Europe
- Forgone profit = |Price differential| × Quantity sold to Europe?
  - Up to $100m *per day* for Qatar (Japan vs UK)

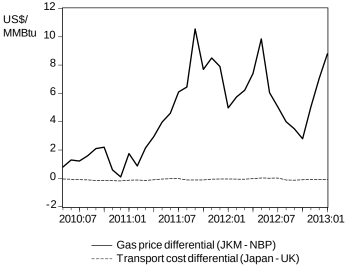
$\Longrightarrow$ **LNG exporters failing to engage in price arbitrage?**

An explanation based on transport costs?

Competitive model predicts netbacks equalized across markets

- Regional price differential = difference in transport costs

Figure: Qatar LNG short-term sales to Japan & UK



$\Longrightarrow$ **Competitive model cannot explain observed gas prices**

This paper: *Rationalizing LNG prices & trade flows with market power*

The special case of the US

Several reasons for recent US price divergence

1. Large-scale shale gas has pushed down US natural gas prices
2. Infrastructure reflects vision of US as major LNG *importer*

$\Longrightarrow$ US market largely isolated from the rest of the world

What if the US becomes a large LNG exporter?

- US & non-US prices will not necessarily converge (or netbacks)
- Any model of US LNG exports likely incomplete without market power
  - Recent model-based simulation for US Department of Energy: Incorporates general-equilibrium effects—but assumes that LNG producers do not respond strategically to US market entry...

A model of a profit-maximizing LNG exporter

Producer k's problem: Choose short-term exports to $M \geq 2$ export markets to maximize profits subject to any capacity constraint:

$$\max_{\{x_\ell^k\}_{\ell=1}^M} \Pi^k = \sum_{\ell=1}^M p_\ell^k x_\ell^k - C^k\left(\sum_{\ell=1}^M (x_\ell^k + y_\ell^k)\right) - \sum_{\ell=1}^M \tau_\ell^k x_\ell^k$$

$$\text{subject to } \sum_{\ell=1}^M (x_\ell^k + y_\ell^k) \leq \overline{Q}^k \text{ (with shadow value } \lambda^k \geq 0)$$

- **Producer k's demand** $p_\ell^k(x_\ell^k, y_\ell^k, X_\ell^{-k}, Y_\ell^{-k}; \boldsymbol{\theta}_\ell)$ in market ℓ
  - x_ℓ^k = k's short-term sales; y_ℓ^k = k's long-term commitments
  - X_ℓ^{-k} = others' short-term sales; Y_ℓ^{-k} = others' commitments
  - $\boldsymbol{\theta}_\ell$ = state of market ℓ (business cycle, prices of substitutes (coal, oil, etc.), demand shocks, weather, etc.)
- **Production costs** $C^k(\sum_{\ell=1}^M (x_\ell^k + y_\ell^k))$ for all $M \geq 2$ markets
- **Transport costs** τ_ℓ^k per unit of output sold to market ℓ

Fundamental condition for profit-maximization

Profit-maximization (nothing else) implies first-order condition

$$MR_i^k - MC^k - \tau_i^k - \lambda^k = 0 \text{ for market } i$$

$$\implies \quad MR_i^k - \tau_i^k = MR_j^k - \tau_j^k \text{ for any two markets } i \text{ and } j$$

(*Regardless of whether capacity-constrained or not*)

$\implies$ **Producer equalizes marginal revenues** (net of transport costs)

- **Equal marginal revenues does not imply equal prices**
  - Prices *optimally* far apart if demand conditions very different

A result on price differences across markets

Proposition *Profit-maximizing prices in any two export markets, i and j, satisfy*

$$\frac{(p_i^k - p_j^k)}{p_j^k} = \frac{\eta_i^k}{(\eta_i^k - 1)} \left[\left(\frac{1}{\eta_i^k} - \frac{1}{\eta_j^k} \right) + \frac{(\tau_i^k - \tau_j^k)}{p_j^k} \right]$$

where (η_i^k, η_j^k) are producer k's price elasticities of demand.

- **Simple-yet-general result** on price differences across markets:
    - Weak assumptions on demands and costs
    - No assumptions on mode of competition
        - e.g., perfect competition, Cournot-Nash, monopoly, dominant firm

Key point: *Market power easily rationalizes observed prices*

Four special cases of the model

1. **Perfect competition** ($\eta_i^k \to \infty$ and $\eta_j^k \to \infty$)

$$\Delta p_{i,j}^k = \Delta \tau_{i,j}^k$$

2. **Symmetric transport costs** ($\tau_i^k = \tau_j^k$)

$$\Delta p_{i,j}^k > 0 \iff \eta_i^k < \eta_j^k \implies \text{sign}(\Delta p_{i,j}^k) \neq \text{sign}(\Delta \tau_{i,j}^k)$$

3. **Symmetric demand elasticities** ($\eta_i^k = \eta_j^k = \widehat{\eta}^k < \infty$)

$$\Delta p_{i,j}^k = \frac{\widehat{\eta}^k}{(\widehat{\eta}^k - 1)} \Delta \tau_{i,j}^k \implies \text{var}(\Delta p_{i,j}^k) > \text{var}(\Delta \tau_{i,j}^k)$$

4. **Weak-and-near & strong-and-far market** ($\eta_i^k < \eta_j^k$ and $\tau_i^k \geq \tau_j^k$)

$$\Delta p_{i,j}^k > 0$$

$\implies$ *Relative demand conditions matter* (in addition to transport costs)

Applying the result to LNG markets

Asian LNG prices recently much higher than in Europe. Why?

Asian markets: "Low" price elasticities

- Fukushima sharply increased Japanese LNG import demand
- More generally, greater concerns about "security of supply"

European markets: "High" price elasticities

- Since 2011 significantly higher imports of coal from US
- More generally, better substitution possibilities to pipeline gas

Numerical example: Let $\tau_i^k \approx \tau_j^k$, $(\eta_i^k, \eta_j^k) = (2, 9) \Longrightarrow p_i^k / p_j^k \approx \frac{16}{9}$

- In general, no *unique* pair (η_i^k, η_j^k) to rationalize (p_i^k, p_j^k)

NB. None of these arguments valid under perfect competition

Estimating producer-specific demand elasticities

Various ways to estimate producer-specific elasticities:

1. **Econometric methods**
   - Estimate η_i^k using time-series data on prices & quantities
2. **First-order conditions**
   - If not capacity-constrained, then $\eta_i^k = p_i^k / [(p_i^k - \tau_i^k) - MC^k]$
3. **Model of competition**
   - If Cournot-Nash competition, then $\eta_i^k = \eta_i / s_i^k$
     - η_i = *market-level* price elasticity of demand
     - s_i^k = market share of producer k in market i
     - $\left.\begin{array}{c} \eta_i = \frac{1}{2} \text{ \& } (s_i^k, s_j^k) = (25\%, 5\frac{5}{9}\%) \\ s_i^k = s_j^k = 10\% \text{ \& } (\eta_i, \eta_j) = (\frac{1}{5}, \frac{9}{10}) \end{array}\right\} \implies (\eta_i^k, \eta_j^k) = (2, 9)$

NB. Limited data availability for LNG markets...

Case study: Price-cost margins for Qatar

Inputs (prices & costs)

IEA estimates: Indicative unit cost for production, liquefaction & regasification = \$3.00/MMBtu (in 2008 US\$)

$\Longrightarrow MC^k = 3.90$ (for 2012) & not capacity-constrained ($\lambda^k = 0$)

- **Japan**: Price $p_i^k = 16$ & transport cost $t_i^k = 2.10$
- **UK**: Price $p_j^k = 9$ & transport cost $t_j^k = 2.15$

Results ("market power")

Define price-cost margin $L_i^k \equiv \left[(p_i^k - t_i^k) - MC^k\right] / p_i^k$

- **Qatar-to-Japan**: $L_i^k \simeq 63\%$
- **Qatar-to-UK**: $L_j^k \simeq 33\%$

$\Longrightarrow$ **Significant mark-ups to both markets, twice as high for Japan**

Limits to arbitrage: LNG buyers

- **Contractual constraints**
  - Some destination restrictions persist despite greater flexibility
  - LNG exporters may restrict resale onto commodity exchanges
- **Shipping capacity**
  - Larger LNG fleet—but only small proportion is uncommitted
  - Shipping market unable or unwilling to provide transport
- **Vertical issues**
  - Redirecting cargo forgoes LNG buyer's downstream surplus
  - Complex ownership arrangements along LNG supply chain

Limits to arbitrage: Third-party traders

JP Morgan Cazenove 2012 LNG industry report

> *"The entry barriers to LNG trading are surprisingly high—new entrants require more than just experienced traders and trading systems.*
>
> *They must have access to cargoes, but the market's liquidity is typically held captive by the LNG liquefaction owners/upstream suppliers who are understandably very reluctant to release volumes for traders to trade with. Traders must also have access to shipping, either via owned vessels or the charter market.*
>
> *Furthermore, certain ships can unload at certain terminals (e.g., many import terminals cannot accommodate Q-Max vessels). This can make it even more difficult to efficiently connect volumes to buyers."*

- **Other arbitrage considerations**: Time, risk, units, market power

Looking ahead: Impact of greater price arbitrage?

- **Theory literature on third-degree price discrimination**
  - "Uniform pricing" versus price discrimination $\Longleftrightarrow$ Unconstrained pricing versus perfect & costless arbitrage
    - Consumer typically benefit in aggregate but some lose
    - Monopoly worse off but oligopoly may be better off
    - Welfare impact ambiguous—depends on fine details
- **Application to LNG markets currently very limited**
  1. Unrealistic market structures (monopoly or price-setting duopoly)
  2. All markets remain served despite increased arbitrage
  3. Producers have identical marginal cost for each market
  4. No long-term contracts or complex ownership structure
  5. No dynamic perspective on incentives for investment