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Natural Gas Game facing Low-carbon Transition Scenarios on America Gas Exportation Strategies with Agent-based Modelling

Yingjian Guo

Department of Chemical Engineering, Centre for Process Systems Engineering, Imperial College London

Natural Gas is low carbon emission fossil fuel, hence is crucial in Energy Transition Phase. Supply exporters play game to benefit optimally from their gas resources. [1]

After its shale gas boom, America developed aggressively in its Liquefied Natural Gas (LNG) projects and is expected to bring on-line large volumes of gas which may lead to global gas glut. [2]

This work investigates America's future exportation strategies facing the low-carbon transition agenda and the reaction of other exporters towards America's LNG expansion.

Agent-Based Global Natural Gas Model

General description: Multi-period model studying global gas import-export relationships

Agents: Supply agents - Export Regions & Demand agents - Import Markets

Transmission routes: Pipeline & LNG Structure: Two-modular structure

MEM: single time-period Market Equilibrium Module & IEM: Future-forward Infrastructure Expansion Module

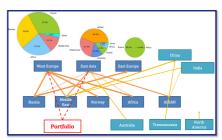


Figure 1: Global Natural Gas Trade

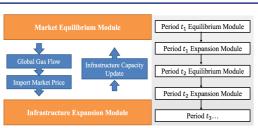


Figure 2: Model Structure and Modular Sequential Flow

Market Equilibrium Module

Supply agent: Each optimizes its own gas sale profit & Demand agent: Price-Demand relationship Method: Mixed Complementarity Problem - Simultaneously optimize all players' objectives Results: Gas Flow & Price - Game theoretic Nash-Cournot Equlibrium in each time period t

$$\sum_{j \in D} \left[SALE_{i,j,t}^{PIPE} \left(\pi_{j,t} - C_{i,t}^{PRD} - C_{i,j,t}^{PIPE} - C_{_EX_{i,j,t}}^{PIPE} \right) + SALE_{i,j,t}^{LNG} \left(\pi_{j,t} - C_{i,t}^{PRD} - C_{i,j,t}^{LNG} - C_{_EX_{i,j,t}}^{LNG} \right) \right]$$

Infrastructure Expansion Module

Demand - Supply Contracting Section: Confirm future contracts on import request and supply economic evaluation.

Contractual Based Expansion Section: Expand to fulfil contract required infrastructure capacities

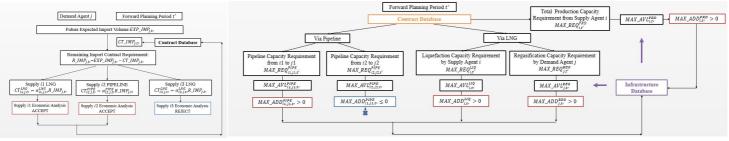


Figure 3: Demand-Supply Contracting Section Algorithm (Left) & Contract-based Capacity Expansion Section Algorithm (Right)

Case Study on America Gas Exportation Strategy Scenario A: North America stays Conservative for contract agreement and capacity expansion Scenario B: North America Aggressively agrees on contract request and expand exportation capacities Import market analysis: Supply agent analysis: Similar total import in both cases Middle East, Norway, Russia Lower Russia & Middle East shares Lower total export, especially to West Europe if US aggressive market if US being aggressive. Norway not affected too much **North America** Fast Asia Generally not affected Total around 100 BCM/yr exportation, to West Russia's share decreases slightly Higher total import in ScenB Europe (50%) as the largest buyer, followed by China East Asia (25%) and China (20%) US aggressive takes Russia's share US grabbed Middle East shares, but India Africa, Australia, ASEAN, Transcaucasia generally small amount Not too much affected Liquefaction capacity analysis: North America Conservative – 20 BCM/yr Aggressive – 125 BCM/yr North America share in total LNG trade Other export regions react to US's aggressive behaviour, and investless i Liquefaction plants Russia has 40 BCM/vr lower in ScenB Middle East has 24 BCM/yr lower Norway has 20 BCM/yr lower

- 1. Agent-based model incorporating short-term Nash-Cournot equilibrium and long-term contract-driven expansion, allowing import and export imperfect foresight and decision flexibilities
- 2. Russia and Middle East's shares in West Europe markets would decrease in 2040 if US export LNG aggressively. But they consider US's strategy and invest less to control gas oversupply and keep prices at economic levels
- 3. Though being aggressive, America's share in total LNG trade peaks in 2040 and then stays steady afterwards.

Reference

[1] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014. Washington, DC: U.S. Environmental Protection Agency; 2016. [2] Key World Energy Statistics. International Energy Agency; 2015.

Contact: yg915@ic.ac.uk