AN ITERATIVE LINEAR PROGRAMMING APPROACH FOR MODELLING AGENT PROFIT MAXIMIZATION IN GAS MARKETS

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Overview

Since the introduction of the 3rd EU Gas directive, several trading hubs have been established across Europe, increasing competitiveness through the different systems. Traditionally, natural gas trading was limited due to a lack of infrastructures. However, with the new investments being carried out in different countries, this situation is changing. Therefore several studies are supporting natural gas as the fastest growing conventional source of energy.

Furthermore, there are several key drivers that are changing the overall picture, such as the globalization of the natural gas markets through LNG carriers, the concentration of suppliers, the production of shale gas in North America, and the reduction of Asian demand growth.

In this context, both market regulators and agents rely on models to make predictions and evaluate new rules. Therefore, the objective of this paper is to provide a tool that represents the strategic behavior of the different agents of the gas market and analyse the impact of market power in trading hubs of the downstream natural gas market. For this purpose, a novel approach by means of an individual profit maximization model combined with a trading hub using linear programming has been implemented. Finally, the proposed model will be applied to a case of study.

Methods

Mathematical approaches that realistically represent energy markets in multi-area structures have become gradually more complex. They are essential for regulators and market agents for planning operation and rules evaluation. The literature states that market equilibrium models are the most adequate tools to address this problem. However, these models present several difficulties when they are scaled up to a system-level approach.

The proposed methodology is built upon the GASCOOP model [1], which is capable of analysing the operation of real-sized gas systems by means of linear programming as modelling framework. More specifically, it encloses a detailed representation of a European gas system, being capable of evaluating the infrastructure operation, capacity contracts, long-term supply contracts and LNG carriers' schedules. Finally, the gas market is represented by an entry-exit access system.

The basic GASCOOP model is a system-level minimization of the overall costs. However, this methodology does not take into account the strategic behaviour of the agents trying to maximize their profits. To address this mater, the model has been improved to introduce an individual profit-maximization model.

Solving each agent individually has some issues that need to be handled. First, in the case that an agent is not capable of reaching a solution to its individual optimization problem, some slack variables are activated. These slack variables represent infeasible system operation situations and are cleared by the joint contribution of the rest of agents. Second, the bilateral contracts between agents are considered by establishing several rounds. In the first round, the agents that are supplied make their decisions and in the next rounds the agents that are suppliers adapt to these decisions until all the agents clear their position.

Another advantage of using linear programming is that, when the equations have been properly formulated, the dual variables of the equations reflect the marginal costs for each agent. More specifically, the dual variable of the balance equation of each zone evaluates the marginal price of gas. In a competitive market, the marginal price should reflect the clearing price of the market (in this case, the hub).

In this modelling approach, since the market price corresponds to a dual variable of the optimization problem, it cannot be used as a decision variable in the optimization problem and, hence, it is necessary to be set from outside. Inside the model, the hub is modelled as an alternative source or sink of gas with infinite liquidity at a price set from outside of the model. Therefore, it is necessary a strategy to explore several prices until a balance of sales and purchases is found.

To ensure the convergence of the algorithm, the proposed method is a search by bisection. Starting from an interval of search, bisection consist of evaluation the middle price between the boundaries selected. According to the mismatch between offer and demand, an upper or lower boundary is set, and a new price is evaluated in the middle of this updated search range. This process is repeated until the clearing price and the mismatch are below the selected tolerance.

Several improvements to increase the performance of this algorithm have been made. Instead of using generic initial boundaries, these are set by a first run of the model without hub. The initial boundaries are the lowest and highest marginal cost of all the agents. Furthemore, other approaches to find the clearing price such as derivative search and weighted average could increase the speed, but may not ensure the convergence. These methods could be combined with bisection in future work.

On the other hand, another application of this modelling approach is exploring the bidding curve of each agent by sweeping all the prices from the lowest to the highest. This allows having a complete overview of the behaviour of each agent and the bidding curve of the system, allowing to calibrate the results to match the results with the bidding offers of each agent in the liberalized market.

The main advantage of this methodology when compared to other modelling approaches is that it is based on an operation model of the gas system, ensuring the obtained hub prices reflect all the costs. Furthermore, by taking into account separately individual decisions of each agent, the clearing price obtained with the model should be close to the real clearing price of the hub.

Results

A case study has been developed to both evaluate the performance of the proposed solution and, at the same time, provide a summary of the Iberian gas market (MIBGAS). The case study takes into account different types of agents and the main infrastructures of the system such as LNG carriers, spot diversion and sell markets, regasifiers, pipelines, and storages.

Conclusions

An iterative mixed linear programming model for representing the strategic behaviour of the agents in gas energy markets taking into account the real operation of the gas system (LNG carriers, regasifiers, pipelines and storages) within the EU framework has been proposed. These models are important both for market regulators to evaluate new rules and for agents to take operation decisions and hedge risk under system stressful situations. To summarize, the main contributions of this paper are:

1. The proposal of an algorithm for the analysis of a trading hubs in a market power situation through a simplified modelling approach that is able to cope with real-size systems.

2. The proposal and analysis of a case of study that represents the Iberian system and evaluates the performance of the proposed solution.

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References

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