Game of Timing in Gas Pipeline Projects Competition: Simulation Software and Generalized Equilibrium Solutions*

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Abstract

Many models of energy market development and decision-making processes take into account the competition between energy suppliers, and the theory of games is an appropriate tool to study these problems.

This chapter is devoted to numerical analysis and modification of the game-theoretical gas market model developed by Klaassen, Kryazhimskii, and Tarasyev. We describe a software G-TIME elaborated for this purpose and the results of a simulation and sensitivity analysis on the data of the Turkish gas market. The last section deals with the notion of a generalized Nash equilibrium, which seems to be useful for taking risk and uncertainty into account. The research is based on approaches and methods developed in [1–10].

1 Model Description

Most models of gas pipeline projects competition deal with investment plans of large natural gas exporters to a specified gas market. Several papers are devoted to the market of Western Europe, and some papers concern the Turkish and

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Asian gas markets. A game-theoretical model of competition between two gas pipeline projects called *the game of timing* has been proposed in [10].

The pipelines are expected to operate in the same market. Players 1 and 2 are associated with the investors/managers of projects 1 and 2, respectively. Assuming that the starting time for making investments is 0, we consider the "virtual" positive commercialization times of projects 1 and 2 (i.e., the final times of the construction of the pipelines), t_1 and t_2. Given a commercialization time, t_i, player i $(i = 1, 2)$ can estimate the cost, $C_i(t_i)$, for finalizing project i at time t_i.

At any time $t > 0$, the gas price and cost for extraction, transportation, distribution and transit fees determine a *benefit rate* for each player. When one of the players solely occupies the market he gets *an upper benefit rate*, b_{i1}. When another player enters the market both of them get *a lower benefit rate*, b_{i2}, which is lower than the upper benefit rate since the appearance of another competitor decreases the market price:

$$b_{i1}(t) > b_{i2}(t).$$

We stress the dependence of benefit rates on competitive commercialization time and write

$$b_1(t|t_2) = \begin{cases} b_{11}(t) \text{ if } & t < t_2, \\ b_{12}(t) \text{ if } & t \geq t_2 \end{cases}.$$

Similarly, a commercialization time t_1 of project 1 determines *the benefit rate* of player 2 as

$$b_2(t|t_1) = \begin{cases} b_{21}(t) \text{ if } & t < t_1, \\ b_{22}(t) \text{ if } & t \geq t_1 \end{cases}.$$

The total benefit for each player is determined by the following equalities:

$$B_1(t_1, t_2) = \int_{t1}^{\infty} b_1(t|t_2)dt, B_2(t_1, t_2) = \int_{t2}^{\infty} b_2(t|t_1)dt,$$

and the total profit as

$$P_i(t_1, t_2) = B_i(t_1, t_2) - C_i(t_i).$$

We assume that the functions $b_{ij}(t)$ $(1, j = 1, 2)$ are continuous and monotonically decreasing and the above integrals are finite. Figures 1 and 2 illustrate a typical behavior of the graphs of the functions introduced above.

According to the standard terminology of the game theory, a strategy t_1^* of player 1 is said to be the best response of player 1 to a strategy t_2 of player 2 if t_1 maximizes the payoff to player 1, $P_1(t_1, t_2)$, over the set of all strategies of player 1, t_1:

$$P_1(t_1^*, t_2) = \max_{t_1 > 0} P_1(t_1, t_2).$$