# Multiagent Model of Stabilizing of Petroleum Products Market

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Abstract: The problem of developing of multi-agent models of stability in market prices of petroleum products is presented. The problem of price stabilization occurs due to external factors: the result of sudden changes of crude oil on world markets or exchange rate changes. In addition the market price dynamics is also influenced by internal factors such tacit collusion sellers. Shown the theoretical possibility to reduce of asymmetry in prices through the use stabilization fund of petroleum products, which the public body can use at the moment when there is a of price jump through the sale of petroleum products by stable prices.



## 1 INTRODUCTION

The behavior of fuel prices has a global impact on the whole economy of a particular country. Increases in fuel prices automatically lead to higher prices of commodities with high demand and transportation services. The result is the decrease in purchasing power and reduction in profitability of companies, especially those with energy-intensive production.

The expenses for petroleum products are involved in the consumer market prices; transportation costs also affect the prices of all goods of consumer market.

This question is particularly important in emerging economies, especially in such countries as Ukraine, where practically immediate reaction of all industries to changing prices occurs. This factor affects not only the economy, but also the social situation of the general public and political processes in it.

The modern market of oil products in Ukraine is characterized by the large number of economic entities, acting alone or co-operating, in conditions dissimilar to classical equilibrium markets. In this market the main sources of equilibrium disturbance are external factors, primarily world prices of crude oil and exchange rates. Due to non-stationarity of these factors and cooperative actions of market agents, prices of petroleum products, including retail gasoline prices, are changing daily.

Retail gasoline prices in Ukraine depend on many factors; the main ones are the national currency fluctuations, changes in world oil prices, the activities of oil producing and refining companies, oil traders, government policy etc. Thus, the problem of finding the mechanism for stabilizing oil prices arises. The ways of price stabilization – from direct administrative methods to the market-based approaches – have long been known. This paper deals with the mechanism for smoothing oil price shocks through targeted interventions of oil products, provided by the state, in moments of disturbance in fuel prices threatening to destabilize the market.

## 2 RELATED WORKS

The intensive research of price dynamics in the oil market as well as research of multi-agent approach to modeling price competition in oligopolistic markets was held over the last 20 years. The asymmetry of prices for petroleum markets in different countries was studied in (Bacon, 1991), (Borenstein et al., 1992); (Matt Lewis, 2003), (Veremenko and Galchinsky, 2010); (García, 2010).

In (Kephart et al., 2000); (Tsvesovat and Carley, 2002); (Happenstall et al., 2004); (Levin et al., 2009); (Ramezani et al., 2011) the possibilities and properties of applying multi-agent approach to modeling the competition in oligopolistic markets were explored.


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# 3 MODEL

In oligopolistic markets, the decisions of each firm don't only affect their own profit but also the profit of their competitors. Therefore, firms react to the actions of their competitors and in every decision the companies consider not only the direct impact on their income, but also the reaction effects of competitors. This so-called oligopolistic interdependence lays the foundation in modeling the market behavior as a multi-agent system. There are several reasons for choosing the multi-agent approach, although the game theory was about to be chosen as the theoretical basis. However, for games with more than two players the results of the game theory approach are far from building a constructive design scheme. Even in games with no coalitions there is no exact algorithm for finding equilibrium in general, because it is very difficult to consider the real constraints on the strategy of all players analytically. For coalition games claim the existence of equilibrium was not even proven, so we will find the solution of the problem in another way, with the agent modeling method.

Let us determine the following factors in the model:

- Consumer - a vehicle with the driver. It is characterized by the type of fuel being used and fuel tanks capacity, the use of fuel per 100 km, the frequency and range of travel, the propensity to traveling and saving money.
- Gas Station - a gas station that provides services to consumers and the companies, which buy fuel for their vehicles. It is characterized by the volume of containers for storage, type of fuel, its availability, and geographical location.
- Refinery station, which is characterized by type of fuel it produces, volumes of containers for storage, fuel prices.
- Country is an agent that displays activity of the state and sets a number of rules for the market functioning and import-export operations.
- Trader is a mediator between refineries and gas stations. Sells fuel in bulk, making transportation to the appropriate object. Characterized by means of transportation and storage facilities for fuel.

The environment also holds information about the concentration and location of agents in the country, the transport grid, grid with railroad connections.

Each agent has its own program behavior based on finite-state machines, which describes its condition and the conditions of transition from one state to another.

Each agent can communicate with any other agent through the messaging mechanism. Thus the «consumer», that is within visibility range of certain agent of a «station» will be able to receive notice of the price on its fuel. Similarly «station» agents will be able to receive data available in the region traders and their prices. Also, each agent has a specific set of actions with which he manipulates the state of the environment. For example, for the «consumer» agents they are: go (move around the environment), refuel and wait. In case of failure of any agent to act in the market (the agent goes bankrupt) he is removed from the model. Similarly, agents may also enter the model. Inputs for the model are:

$$\{M, PZ, PN, LOC, S\},$$

where

$PZ_t^m$ - For purchases of fuel by network S in t time;

$PN^m$ - The original retail price of network m;

$LOC_k^m$ - The location of station k of network m;

$S_{i,j}$ - Number of consumers of fuel in the square with coordinates (i,j);

$M$ - The number of retail networks;

The main mechanism for the distribution of fuel consumed is the function of demand, taking into account not only for a particular network, but also the maximum possible demand.

$$D = \begin{cases} D_{max} \cdot N_{AZS}^i, \\ A - Bp_i + C\sum_{j \neq i} p_j \end{cases}$$

The model of agents' behavior relies on rule-based algorithm, proposed in [1]. Variables and logical conditions were added in the implemented algorithm to model collusion between the agents. The collusion is valid until significant changes happen in the agent's input parameters.
In account of this it is possible to make an algorithm for the agent:

1. Set the price specified in the preceding period
2. Collect data for neighbors
3. Get prices for fuel
4. Get on the environment of consumers for the current period
5. Determine the cost of 1 liter fuel, taking the fixed costs into account
6. Forecast fuel demand, given the cost of fuel, the current price and the price of neighboring agents to forecast demand for fuel

7. Check messages from neighboring agents for available collusion suggestions.
8. Decide on pricing, using a set of rules.
9. Put the price set in the next period.

The printed form should be completed and signed by one author on behalf of all the other authors, and sent on to the secretariat either by normal mail, e-mail or fax.

## 4 MARKET SIMULATION

The basis of the algorithm is the set of rules for changing prices, which also contains rules for checking the usefulness of the collusion. The main indicator, appearing in the rules is $P_{\text{int}} = \frac{\sum_{i=1}^{n} \frac{p_i}{l_i}}{\sum_{j=1}^{n} \frac{1}{l_j}}$, where $p_i$ is price of agent i in the neighborhood, and $l_i$ is the distance between this agent and the i-th agent.

The numerical constants for price change rates were determined basing on real data in the studied region and on the characteristics of prices asymmetry. For this purpose the initial values based on expert judgments were taken and then specified through minimizing the residual function with the help of Nelder-Mead method on a set of historical data in Kyiv region for the period 2010-2011.

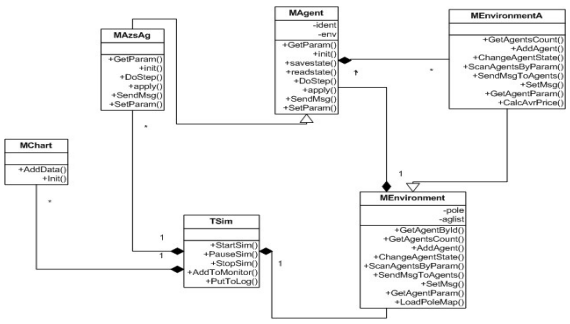


Figure 1: The class diagram in UML notation.

The diagram of classes shows, that the main class which provides the entire program is the class TSim. It is a kind of the experimental abstraction, and it includes instances of the agent model classes. Agent model is represented by two classes: MAzsAg and MEnvironment. According to the paradigm of agent modeling, MAzsAg is a software agent which can receive messages, react to the environment changes and interact with other agents through the environment. MEnvironment class is the agents' environment which provides their identification, messaging and performs a mechanism for interaction between agents and between agent and environment.

## 5 EXPERIMENTAL RESULTS

Since the agent-based model relies on the interaction between retailing petroleum products networks, it is firstly needed to consider the opportunity for the state to intervene in the retail market in order to prevent collusions between the agents. Thus, the state petroleum retail network can be considered as such regulator. Taking into account, that the oligopolists have significant market shares, the state-owned market share, sufficient for the desired effect on the market, must be determined.

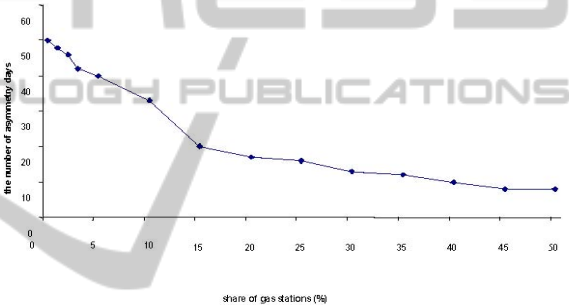


Figure 2: Dependence of the length of the return prices to normal levels of the market share of the state regulator.

As you can see, the effect is noticeable when the market share exceeds 15-20%. Further increase in market share slightly increases this effect. In respect that that the cost of a public network can be quite high (the cost of building a gas station is estimated at 0.5 million.), the regulator may be too expensive. Analysts estimate the total costs could reach up to $2 billion. These costs are currently estimated as too high in order to implement.

Due to the fact that it is difficult to enact the above-mentioned type of controller, government can bring such regulator to the wholesale market. Given that during the jump in prices some retailers do not have enough fuel, the state can sell their stocks to reduce the effects of the shock. Thus, signing contracts with the network stations and having their margin on the sale of petroleum products restricted, is a way to indirectly affect the price situation in the market.

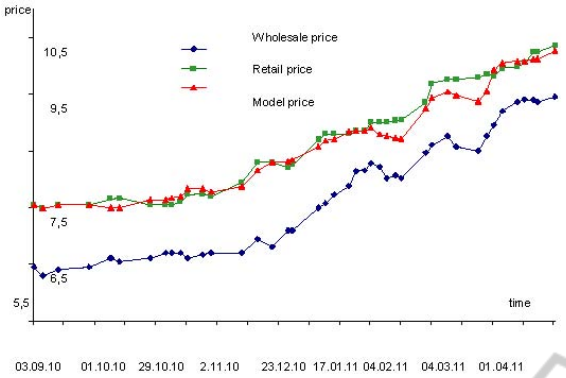


Figure 3: The behavior of the gasoline prices with regulation and without.

So the state can enter the wholesale market with stabilization reserve during the prices' jumps and sell fuel under contracts to station networks, which have demand for fuel. The need for profitability of such fund should be taken into account. To evaluate the effectiveness of control, the scheme, rearranged in Figure 3, can be used. The comparison of price without regulator and with the presence of the regulator clearly indicates the effect of stabilization.

## 6 CONCLUSIONS

The results indicate that basing on the proposed multi-agent model, the implementation of the regulator, which can effectively reduce the level of asymmetry in oil prices, is possible in principle. The state agency, acting not administratively, but through market-based control methods, might play a role of such regulator. Further research in this area should be aimed at clarifying the mechanism of influence on prices by the state regulator.

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