Counteracting Strategic Behavior in Commodity Storage

Alan Holland[1], David C. Parkes[2], and Nicola Secomandi[3]

[1] Cork Constraint Computation Centre,
Department of Computer Science,
University College Cork, Cork, Ireland.
a.holland@4c.ucc.ie

[2] School of Engineering and Applied Sciences,
Harvard University, Cambridge, MA.
parkes@eecs.harvard.edu

[3] Tepper School of Business, Carnegie Mellon University,
5000 Forbes Avenue, Pittsburgh, PA.
ns7@andrew.cmu.edu

Storage capacity is a critically important asset for any firm engaged in trading voluminous commodities such as agricultural goods or fuel supplies. It can act as a strategic reserve to counteract supply uncertainty and ensure continuity of supply whilst the stored inventory is not exhausted. It can also be used in a tactical manner to buffer against price increases. Goods may be stored when supply exceeds demand (low prices) and later retrieved during periods of scarcity (high prices). Storage can be viewed as a *real option* that allows firms to sell inventory if the unit price increases [Thompson et al., 2009]. Storage is a particularly important buffer in markets where changes in supply or demand induce volatile price movements. For examples, price seasonality is very pronounced in natural gas markets because of inflexible production and increased demand during winter months. A lack of storage capacity compounds this problem. The capacitated warehouse problem for non-perishable goods occurs in many settings including pumped-hydro, oil and agricultural commodity goods [Secomandi, 2010]. It is of major economic significance, given the vast quantities of commodities stored in such warehouses. In regulated industries such as the energy sector there is often a legal requirement to offer third party access to storage leaseholders in a clear and transparent manner. This gives rise to the problem of coordinating the actions of self-interested agents that share a store whose injectability and deliverability may depend upon aggregate inventory levels.

We outline a research agenda that is focused upon the problem of managing third party access to commodity storage where multiple self-interested agents share space and flow capacity in a single physical store. To our knowledge, this is the first time that a scientific approach to optimising economic efficiency using computational mechanism design has been examined in this setting. The problem of strategic interaction in this setting arises due to the overall physical injection and withdrawal capacities depending upon the aggregate inventory levels. When the store is empty, the pressure in the store is low and it is easy to inject but difficult to withdraw gas (and vice versa when the store is full). Storage leaseholders that share space in a store would like their fellow leaseholders to behave in a manner that facilitates rapid injection and withdrawal during periods when they expect price movements to maximize expected returns. The inventory levels that leaseholders expect during the period directly influence the optimal injection and withdrawal plans. This introduces a dependency among the actions of fellow leaseholders and justifies the study of the strategic interaction that ensues [Holland, 2009].

Our research agenda addresses the rationale for strategic manipulation and involves a game theoretic analysis of equilibrium losses in a multi-stage game with self-interested agents. We aim to quantify welfare losses associated with myopic decisions made be self-interested leaseholders. We seek to quantify the harm that premature injection and withdrawal can impose on firms when compared to a social plan that aims to maximize aggregate welfare. This analysis is central to motivating the need for novel market mechanisms to internalize losses that ensue from exploitative strategies. Given the dynamic nature of trading policies in storage markets we plan to study extensive form games and use the subgame perfect equilibrium solution concept to estimate losses in different market settings where the physical parameters of stores vary. It is important to know whether fast stores that can be filled or emptied quickly are more sensitive to manipulation than slow stores. This knowledge could influence the investment decisions of storage operators.

Our agenda also includes a study of the computational challenges associated with calculating the joint optimal policy. This is important when constructing an approximately incentive compatible dynamic mechanism that is required for maximizing economic efficiency [Parkes et al., 2010]. We aim to examine whether key structural properties that ease the computation of an optimal policy in the single agent setting [Secomandi, 2010] continue to hold in a multi-agent setting, and hence facilitate the computation of a joint optimal policy. These properties can assist the computational feasibility of determining joint optimal policies.

We plan to focus our empirical analysis on a gas storage setting that exemplifies the challenges of commodity storage management. Natural gas storage is in very short supply compared to overall natural gas traded volumes due to the difficulty in constructing suitable underground storage facilities from depleted reservoirs, aquifers or salt caverns. An increase in the economic efficiency of natural gas storage facilities may have several notable side-benefits. It is widely regarded as the most environmentally friendly fossil fuel because it releases less carbon dioxide and other pollutants than oil or coal. A more efficient storage mechanism would help gas compete against coal in the market for domestic and commercial heating as well as for electricity power generation. Also, there is a strong correlation between the ability of an electricity network to support intermittent renewable energy and the gas-fired generation capacity. Gas-fired generators can react quickly and thus complement wind powered generation [Qadrdan et al., 2010]. A logical implication of a possible increase in the competitiveness of gas as a fossil fuel is that increased wind-powered generation can be supported should gas-fired generators become more numerous. A report from MIT provides an analysis of the future of gas as a fuel and considers such tensions in market dynamics [Group, 2011].

The importance of efficient economic mechanisms for commodity storage should be viewed in terms of the underlying significance of commodity markets to almost all economic activity. It is a domain that has many technical challenges related to the market volatility, operational constraints and non-trivial physical characteristics of storage facilities. We have identified a challenging research agenda that addresses computational sustainability issues related to commodity markets and improving the utilisation of scarce resources.

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