

# DISSERTATION DEFENSE

## **Risk Management and Supply Chain Management in the Natural Gas and Global Liquefied Natural Gas Industry**

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Tuesday, April 22, 2008

10:00 a.m.

259 Posner Hall

My dissertation concentrates on several aspects of financial risk management and supply chain management in the natural gas and global liquefied natural gas (LNG) industry, including gas pipeline transportation, ocean LNG shipping logistics, and downstream storage.

Chapter one studies how to value U.S. natural gas pipeline network transport contracts as real options. It is common for natural gas shippers to value and manage contracts by simple adaptations of financial spread option formulas that do not fully account for the implications of the capacity limits and the network structure that distinguish these contracts. In contrast, we show that these operational features can be fully captured and integrated with financial considerations in a fairly easy and managerially significant manner by a model that combines linear programming and simulation. We derive pathwise estimators for the so called deltas and structurally characterize them. We interpret them in a novel fashion as discounted expectations, under a specific weighing distribution, of the amounts of natural gas to be procured/marketed when optimally using pipeline capacity. Based on the actual prices of traded natural gas futures and basis swaps, we show that an enhanced version of the common approach employed in practice can significantly undervalue natural gas pipeline network capacity relative to our model. This model also exhibits promising financial (delta) hedging performance. Thus, this model emerges as an easy to use and useful tool that natural gas shippers can employ to support their valuation and delta hedging decisions concerning natural gas pipeline network transport capacity contracts. Moreover, the insights that follow from our data analysis have broader significance and implications in terms of the management of real options beyond our specific application.

Motivated by current developments in the LNG industry, Chapter two studies the operations of LNG supply chains facing both supply and price risk. To model the supply uncertainty, we employ a closed-queueing-network (CQN) model to represent upstream LNG production and shipping, via special ocean-going tankers, to a downstream re-gasification facility in the U.S, which sells natural gas into the wholesale spot market. The CQN shipping model analytically generates the unloaded amount probability distribution. The spot price experiences both volatility and significant seasonality, i.e., higher prices in winter. We use trinomial lattice to model the price uncertainty, and calibrate to the extended forward curves. Taking the outputs from the CQN model and from a model of the dynamics of the spot price as stochastic inputs, we formulate a real option inventory-release model to study the benefit of optimally managing a downstream LNG storage facility. This allows characterization of the structure of the optimal inventory management policy. An interesting finding is that when it is optimal to sell, it is not necessarily optimal to sell

the entire available inventory. The model can be used by LNG players to value and manage the real options to store LNG at a re-gasification facility, and is easy to be implemented. For example, this model is particularly useful to value leasing contracts for portions of the facility capacity. Real data is used to assess the value of the real options to store LNG at the downstream re-gasification facility, and, contrary to what has been claimed by some practitioners, find that it has significant value.

Chapter three studies how important it is to model the shipping variability while valuing and managing a downstream LNG storage facility. The shipping model presented in Chapter two uses rolling forward method to generate the independent and identical distribution (i.i.d.) unloaded amount distribution in each decision period. To examine if the i.i.d. assumption is over-simplified, we propose a benchmark model using the simulation to represent the shipping process, and value the LNG storage over all sample path. We show that the model using the i.i.d. unloaded amount distribution provides a pretty good estimation of the storage value, and is also very good to obtain the optimal inventory control policy. We also test the performance of the model using constant throughput in the inventory release model. The model using the constant throughput is not as good as the one using unloaded amount distribution for the storage valuation purpose, but can be used to suggest the optimal inventory control policy especially when the ratio of supply arrival rate to storage size is high.