STRATEGIC MODEL OF LNG ARBITRAGE: ANALYSIS OF LNG TRADE IN ATLANTIC BASIN

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Abstract

We develop a two-stage model of the LNG market to determine the incentives to enter long-term contracts vs. spot trade and to understand the causes of new contract terms. First we study how LNG importers and exporters negotiate long-term supply contracts and make investments under demand uncertainty. Second we analyze spot trade when demand is known, capacities and long-term supplies are fixed. Importers with excess supply will resell to importers with higher than expected demand and compete with exporters if have the "flexibility option" included in their contracts. We find that the appearance of the "flexibility option" results from the value of investment cost and demand uncertainty level. We also establish the conditions for emergence of spot trade depending again on demand uncertainty and capital costs.

Keywords: strategic investment, bargaining, bilateral oligopoly
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1 Introduction

The role of LNG in natural gas markets becomes more and more prominent. According to the BP Statistical Review of World Energy (2008), the total export/import of LNG in the world increased by over 20% over the last two years, imports of North America rose by about 35%. This dynamics attracts growing attention to the LNG markets development. Loosely speaking, there are two major groups of players in LNG markets: upstream producers (exporters) and downstream traders (importers). Exporters enter bilateral long-term contracts with importers. Historically these contracts had "take-or-pay" clauses, defining the price a buyer is obliged to pay and the quantity the producer is obliged to deliver. Until recently contracts had destination clauses, not allowing importer to resell or divert LNG cargos. Yet, the contracts have changed considerably lately. First, short-term contracts and spot deals become a usual practice. Second, importers have got a right to resale excess volumes or return them to a seller at some fee. This opportunity is called in new contracts as "flexibility option". The two major reasons are called to be responsible for theses changes: demand/price uncertainty and reduction of capital costs.[1] At the very beginning LNG markets were isolated, e.g. Japanese market had no connection and relation to the markets in United States or in Europe. This allowed for a significant price discrimination, given that each market had its own mechanism of natural gas price formation and had some fixed demand. As the demand/price got more volatile, importers are often end up with much more or much less LNG than they need, this leads to rise or fall of prices. The flexibility option allows market players to benefit from arbitrage opportunities playing on price differential across regional markets. The growing literature discusses whether a global spot market is emerging, e.g Jensen (2004), Foss and Dietz (2005), Foss and Juckett (2005), and Charter (2007), and whether long-term contracts are to extinct.

The primary purpose of our study is to develop a model which will help us to understand how the global LNG trade will develop: what are the main factors affecting the market structure and the terms and the length of contracts, namely, will long-term contracts further prevail in the market, or will the spot trade get a dominant role; should we expect a stronger price correlation across the LNG importing regions or will the prices be further locally determined, what is the role of capacity costs and demand uncertainty? We develop an analytical model and test it using export/import data for the global LNG market, to examine how well we can explain the reality.

[1] See Weems (2006) for a detailed overview of changes in LNG contracting practice and possible causes.

To analyze the listed issues we build a stylized two stage model. It reflects the main features of the LNG market, of which the most important is that both exporters and importers of LNG are strategic player who may affect a market equilibrium. In the first stage, importers and exporters are involved in multilateral bargaining over long-term supply contracts and invest in capacities. We assume that bargaining is efficient: supply contracts are non-linear and complete with respect to quantities and prices. Importers buy LNG to cover their expected demand, the actual demand is known only at the second stage. If the observed demand exceeds the expectations, or if the price is happen to be higher, a local importer is willing to buy more LNG from exporters or other importers. If the actual demand is low, or the prices on other markets are more attractive, importers may be willing to resell the contracted LNG to other regions. Hence, the spot market is organized. A complexity of trade evolves because both importers and exporters may play as sellers in the second stage. We assume that the spot trade is organized as a double auction. LNG sellers send their bids to regional buyers, thus competing for supply. Buyers accept or reject these offers competing for sellers. The quantities traded as well as capacity investments are determined by the total profits, which are the sum of the annualized profit from long-term contracts and from the spot trade.

The contribution of the paper is manyfold. First of all we develop a model of bilateral oligopoly, with both buyers and sellers playing strategically, and investigate the impact of the possibility to resell and incentives to invest. The literature on bilateral trade is limited, though is growing and comprises mainly on theoretical studies. Since Galbraith (1952,1993) it is recognized that large or small in number buyers possess some power to restrain the market power of sellers and can negotiate lower prices. This power is referred to as countervailing power. Recently, there has been a surge of research aimed to study industries where several upstream players, e.g. producers, and a number of concentrated downstream players, e.g. buyers or retailers, negotiate supply contracts. Such industries, where both up- and downstream players behave strategically are referred to as "bilateral oligopolies". A growing body of literature on "bilateral oligopoly" derives the power of each player in the market endogenously exploring the bargaining between buyers and sellers. Various studies examine the impact of horizontal and vertical concentration, entry of new players, and investments in efficiency (e.g. Horn and Wolinsky (1988), von Ungern-Sternberg (1996), de Fontenay and Gans (2002), de Fontenay and Gans (2004), de Fontenay and Gans (2005), Bjrnerstedt and Stennek (2001), Inderst and Wey (2003)).[2] Multilateral negotiations with many rounds and various protocols have been explored, yet

[2] A comprehensive literature review with the details of the concept can also be found in Snyder (2005).

to our best knowledge they neglected the role of arbitrage or possibility to resale. Besides, the works on applied analysis of bilateral trade are scare, see for example Snyder (1999), McAfee and Hendricks (2008), Ellison and Snyder (2002), Dobson and Waterson (1997), and because of the industry complexity and lack of data, they do not solve for investment problems. The availability of data and the limited number of the market player in the LNG market at the end of 90'ies allow us to contribute to the applied studies on bilateral oligopoly and multilateral contracting.

Current paper also contribute to the increasing amount of studies on LNG market, e.g. BSA (2008), Ruester (2008), Hayes (2008), Bellman (2006), Ruester and Neumann (2008), and Jensen (2004), that investigate different aspects of the trade. like arbitrage opportunities, price convergence conditions, price forecasting problems, and organization of the spot trade. Our work among a few others provides not an econometrical, statistical, or descriptive, but rather structural approach to the analysis of the market players' behavior. We also suggest to look not just at price and investment problems, but also making an attempt to understand the rationale behind the short-term vs. long-term contracts and explain the "optionally" term in contracts, allowing the importers to resell or divert their LNG cargos.

The paper is organized as follows. In the next section we develop an analytical model describing the LNG market. In section 3 we solve the model for a six players case. In section 4 we discuss our approach to the calibration of the model. In section 5 we provide the results of the calibration. We build a market forecast and discuss its robustness. Section 6 concludes.

2 Model

The setup of our model reflects the main features of the global LNG trade. The presented model is rather complex and cannot be solved analytically in its most general form. We use a two-stage game to depict some dynamics in decisions and relations of the market players. In the first stage the market players, namely exporters and importers, make their long-term decisions: they invest in capacities and sign long-term supply contracts. In the second stage, capacities and contractual terms are fixed and the players are engaged in the spot market game. Throughout the game we assume that the players are rational and maximize their expected profit. We solve the game backwards. Our objective is to determine the pricing and contracting strategy of sellers, investment incentives, and trade allocation between long-term and spot market.

Basic assumptions

We denote importers of LNG as $i \in I$. We assume that each importer represents some geographical region with independent demand for natural gas.[3] Loosely speaking, importers serve as an intermediate tier in the LNG supply chain, they buy natural gas from producers and resell it to the local retailers and/or to final consumers. We assign to each importer a demand function $D_i(p)$, which reflects the willingness to pay for LNG observed by importers.[4] We assume that ex ante all the players know only the expected demands. The exact demand is learned by each region only ex post before the spot trade starts.

The second group of players is represented by the major LNG producers or exporters $e \in E$. Exporters are described by their supply functions: $c_e(q)$. In general, supply costs depend on the distance to the market, so we use a double subscript $c_{ei}(q)$ to reflect this fact. The long-term marginal cost curve of each exporter is a common knowledge, yet in the short-run due to unexpected circumstances and production specificity, each exporter knows only a probability distribution of his rivals' costs.

Setup of the game: Stage I

In the first stage, *ex ante*, importers and exporters negotiate long-term supply agreements and make projections on future spot trade to ensure stable revenue to cover the annual capital costs. Let the supply contracts, also called Sales and Purchase Agreements (SPA), have a form of "take-or-pay" contracts.[5] By their nature these contracts are non-linear and contain a pricing formula which relates the price for LNG to the price of its substitutes, e.g. oil products and natural gas. Another feature of the long-term contract which has been recently introduced is a flexibility option, also called "optionally". The inclusion of the option into a contract allows a buyer to resell or divert LNG cargos. The price of "optionally" is defined in various ways with the main condition that the supplier should not be worse off with it than without. Thus, if an importer resells his LNG in other region with higher prices, he usually has to share his profit with his supplier.[6] The same situation can be represented as cargo diverting, which means that LNG goes to a new buyer directly

[3] We will go into details in the next section, when the model is calibrated. In general our assumption can also be justified as in Inderst and Wey (2003) and de Fontenay and Gans (2005).

[4] Historically, LNG is considered to be a "marginal" fuel, which is more expensive than other natural gas sources. Therefore we assume that LNG is used to satisfy the residual demand.

[5] The ordinary "take-or-pay" contract defines the price the buyer is obliged to pay for, even if he does not takes it, and the quantity the seller must deliver.

[6] See Charter (2007) for examples.

from seller. In this case a buyer may still be asked to pay some fee, a part of the contracted price (costs of loading, transportation, capital, etc.). Often ex ante contracts determine the upper and lower bound of the resale fee for a buyer to guarantee non-negative profit for an exporter.

As for investments, we distinguish investments in supplier's capacity k_e, that includes investments in exploration, production, lignification, and shipment, and the option to build regasification, storage and distribution capacities on the buyer side k_i.[7]. Thus k_i determines how much LNG buyer i can accept and process. Unless it is said otherwise, we assume that importers and exporters invest in their capacities individually, in other words investments are non-contractable.

We model bilateral contract negotiations among the exporters and importers as a game in a characteristic function form, assuming that in the equilibrium every importer negotiates with all the exporters.[8] We describe the game by the value function $v : S \to R$ which assigns to every possible coalition, a set of interconnected trading partners $S \subseteq E \cup I$ some value. We define this value as a maximum trade surplus, i.e. the sum of consumer surpluses for $i \in S$ plus the sum of producer surpluses for $e \in S$.

$$v(S; k_I, k_E) = \max_{p^*} \left[\int_{p^*}^{\bar{p}^{max}} \sum_{i \in S} E[D_i(p)]dp + \int_0^{p^*} \sum_{e \in S} c_e^{-1}(p)dp \right]$$
$$\text{st. } E[D_i(p)] \leq k_i \text{ and } \sum_{i \in S} c_{ei}^{-1}(p) \leq k_e$$

$E[D(p)]$ is the expected long-term demand for LNG, $c^{-1}(p)$ is the inverse marginal cost function, p^* - is a surplus maximizing price, and $\bar{p}^{max}$ is the expected price at which the aggregate demand is zero: $D_{I \cap S}(\bar{p}^{max}) = 0$.[9] The first summand in (**??**), the integral of the aggregate demand over the price, is the aggregated consumers' surplus for the importers in the coalition. The demands are summed under the condition that they give positive or zero values for a given price and that demand of each importer cannot exceed his receiving capacity. The second summand, the integral of the aggregate supply costs, gives the aggregated producers' surplus. Again the costs cannot be negative and

[7]We assume that exploration, production, lignification, and shipment capacities are compliments and define the final supply capacity of an exporter as $k_e = \min[k_{exploration}, k_{production}, k_{lignification}, k_{shipment}]$

[8]Note that such assumption, however, does not implies that each importer has a contract with each exporter.

[9]Naturally, we assume that demand as well as supply costs cannot be negative, e.g. for any i for any $p \geq \bar{p}_i^{max}$ such that $D_i(\bar{p}_i^{max}) = 0$ the quantity asked is equal to zero $D_i(p) := 0$.

the total supply from each producer cannot exceed the production capacity. Hence, we obtain maximization problem (**??**) the solution of which depends on capacity constraints. We reflect this fact by adding capacities to the list of variables, with $k_I = (.., k_i, ..)$ and $k_E = (.., k_e, ..)$. We assume that ex ante exporters do not intend their LNG for reexport, i.e. importers can not buy quantity exceeding their capacity.[10]

The solution of the problem (**??**) for the set of all the players $I \cup E$ gives: (i) the total profit in the LNG market $v(I \cup E; k_I, k_E)$, the volume of the long-term market: $q_i^l = \min[E[D_i(p^*)], k_i]$ for all $i \in I$, and the supply by each exporter $q_e^l = \min[\sum_i c_{ei}^{-1}(p^*), k_e]$. To determine a surplus obtained by an individual importer and each exporter we have to solve the game $(v, E \cup I)$. We employ the general solution concept of Shapley (1953) - the Shapley value, to determine the bargaining outcome. The Shapley value, denoted as ϕ, is calculated as a probability weighted sum of marginal contributions a player to all possible coalitions. The value can also be considered as an aggregate worth of a given player for the market:

$$\phi_j(k_I, k_E) = \sum_{S: j \notin S} Pr(S) \left[v(S \cup j; k_I, k_E) - v(S; k_I, k_E) \right] \tag{1}$$

where $Pr(S) = |S|!\,(|N| - |S| - 1)!/|N|!$ is the probability of coalition S. Generally speaking, the Shapley value determines how the total surplus from the trade is distributed among the market player, all being treated as strategic players. The advantage of our approach is that we consider both the competition over the long-term supply among importers as well as exporters. In other words we represent the market as a bilateral oligopoly. The solution defines how the market profit is distributed among buyers and seller, with the relative shares of the total surplus signaling the relative market power of each player, based on the market structure. Besides, the Shapley value allows to account for the price indexation and hence, quantify the profitability of long-term contracts

We choose the Shapley value as a solution concept because it is the only rule for allocation of gains from multilateral cooperation, which fulfills a set of reasonable criteria: efficiency, symmetry, monotonicity (see Shapley (1953) and Young (1985)). Moreover, the Shapley value is also the unique rule with so called "balanced contributions": for any two players i and j it is true that i loses as much if j withdrew from the game, as j loses if i withdrew. Hence, if any player objects the Shapley allocation by pointing out the damage he can impose on another player through a boycott of cooperation, his opponent

[10]This assumption can also be justified, that the "diversion" of LNG cargos, i.e. resale or return of the bought LNG does not requires a special permission from the government. In contrary, to resale an importer needs a license, which is usually not obtained before the LNG receiving terminal is built.

can always counter the argument (Myerson (1980)).[11] The Shapley value has axiomatic foundations and can be derived both as a solution to a cooperative game as well a non-cooperative game (Perez-Castrillo and Wettstein (2001)). Finally, the Shapley value was originally derived as a solution for a complete information game, yet Harsanyi (1963), Thomson (1982), and Perez-Castrillo and Wettstein (2001) show how the Shapley value can arise as a Pareto optimal allocation in the games with incomplete information, when players have incentives to unilaterally misrepresent their valuations.

As follows from (1), the expected payoff of each player depends on his own capacities as well as on capacities of all the other players. Hence, when a player makes his investment decision in the first stage he has to take into account the investment strategies of all the players. We will use a Cournot-Nash solution concept to take this into account. Yet, to find equilibrium investments we must also the consider how capacities will affect the second stage profits.

2.1 Stage II

In the second stage, *ex post*, importers and exporters are involved in spot trade. We define the spot trade as less than one-year period contracting, including the agreements on LNG cargo diverting and resold. Many experts argue that the main driver for the increase in spot trade is price volatility and demand uncertainty across the regions. To study to which extent this is true we incorporate into our model some uncertainty in future demand and allow for maximum price difference in regions. At the beginning of the second stage the uncertainty of demand is resolved and importers learn the actual demand and the regional maximum willingness to pay p_i^{max}. Given the realization of the demand, we will distinguish two groups of importers: "low" and "high".[12] By "high" we mean importers who underestimated their demand and would like to buy more LNG. We refer to importers as "low" if they have overestimated their demand and wish to resell or divert a part of their LNG and get refund. We will not discuss here the importers who have bought as much LNG as needed to saturate their demand. Those importers will not take part in the spot trade.

The spot reservation price p_i^{max} is observable for all $i \in I$ as well as the approximate total

[11] For further discussion of the application of the Shapley value in the supply chain analysis see Hubert and Ikonnikova (2003) and Cachon and Netessine (2004)

[12] Further on, to avoid confusion, discussing the second stage we will talk about buyers and sellers instead of importers and exporters, because it may happen that an importer will become a seller at the second stage.

demand Q_i.[13] Thus, the players may find out whether a given importer i has overestimated or underestimated his demand and derive his spot demand q_i^s, which is the residual demand left unsatisfied by long-term contract $Q_i - q_i^l$. Buyers with positive residual demand compete for sellers on the spot market: sellers are more attracted to the market where they expect higher marginal revenue, i.e. where the marginal willingness-to-pay is higher and the probability to sell (to be the lowest cost seller) also higher. On the other hand, sellers compete to supply buyers. The seller offering a lower price is winning. Recall we have two subsets of sellers: importers-sellers and exporters. An importer-seller is obliged to pay for the whole q^l even though he does not need all the quantity. In this case he would be willing to sell his excess supply on other markets. The incentive compatibility would require the price on that other market to be at least as high as to cover transportation costs and a premium for the opportunity to resell. This premium is the fee paid to the seller for the resale. Exporters have to cover their transportation and operational cost $c_e(q) = \sum_i \theta_{ei} q_{ei}$. We assume costs are a private values but have a common probability distribution known to the market players.

To model the described trade we use the modeling approach by Friedmand (1991) and Spulberg (1995) and express the expect profit of a seller from a "double auction"-like trade as

$$\begin{aligned} \pi_e(k_I, k_E) &= \sum_{i \in I} \pi_{ei}(k_I, k_E) = \max_{p_{ei}} \sum_{i \in I} Pr(win|p_{ei}) \cdot q_i^s \cdot (p_{ei} - c_{ei}(q_i^s)) \qquad (2) \\ &= \max_{p_{ei}} \sum_{i \in I} (1 - F_i(p_{ei}(c_{ei})))^{n_i - 1} \cdot q_i^s \cdot (p_{ei}(c_{ei}) - c_{ei}) \\ & s.t. \;\; q_i^s + q_i^l \leq k_i, \quad \sum_i (q_{ie}^s + q_{ie}^l) \leq k_e, \quad p_{ei} \leq p_i^{max} \end{aligned}$$

The first multiplier in (2) is the probability to win if a seller set a price p_{ei} for importer i, it is expressed through $F_i(p_{ei}(c_{ei})$ – the cumulative probability, the degree $n_i - 1$ is the number of sellers offering LNG to buyer i.[14] We solve (2) with respect to the price for each importer. Thus, a seller will derive the optimal pricing given the number of competitors and the distribution of their costs. We assume sellers supply importers in the descending order of expected marginal profit.

[13]For example, the Henry Hub spot price for natural gas is observable, as well as the price in the European spot market in Zeebrugge, see Jensen (2004).

[14]In our analytical solution for the sake of simplicity and in order to derive the dependence on the number of competitors, we take that all the sellers have the same probability distribution of costs, which differers only across the markets. In our empirical analysis, however, we will take the product of individual cost distributions $(1 - F_{e_1 i}(c_{ei})) \cdot (1 - F_{e_2 i}(c_{ei})) \cdot ...$

From the first order conditions $\frac{d\pi_e}{dc_{ei}} = 0$ we obtain that the optimal price as:

$$p_{ei} = \frac{1}{h(c_{ei})(n_i - 1)} + c_{ei} \tag{3}$$

where $h(c)$ is the hazard rate, or the probability to fail to win the auction. Hence, if all the constraints are not binding the price is determined by the costs of the seller c_{ei} and the number of competitors. For the sake of simplicity we do not solve the Lagrangian function here, though we do so in our numerical calculations. Then, we obtain that actually the price also depends on capacity constraints and reservation price on the buyer's market. The first summand in the price expression can also be interpreted as a mark-up. The higher the cost of a seller is, the higher the chance to lose the auction, and hence, the smaller the mark-up the seller will ask. The mark-up is also negatively depend on the number of competitors: the higher the competition the smaller the mark-up is. Thus, the formula for the price is very intuitive and confirms the fact that on the LNG spot market the sellers set prices based on their netback values.

After we have found the optimal price for each market, we substitute it into (2) and find the expected profits for each market π_{ei}. We assume that a seller first goes to the market promising the highest return.

$$\pi_e(k_I, k_E) = \sum_{i \in I} (1 - F_i(p_{ei}(c_{ei})))^{n_i - 1} \cdot q_i^s \cdot \frac{1}{h(c_{ei})(n_i - 1)}$$

We notice that the price as well as the profit of each seller in each market depends on the distribution of sellers across markets, in its turn the distribution depends on the expected profits. Then, $\max_i \pi_{ei}(n)$ defines the spot market which seller e enters if he assumes the initial distribution of sellers is $n = (.., n_i, ..)$. If the resulting distribution $\tilde{n}$ obtained this way differs from n a new maximization $\max_i \pi_{ei}(\tilde{n})$ is solved to find the equilibrium distribution. Hence, we apply Cournot-Nash equilibrium concept to solve the game and determine the expected payoffs of the sellers.[15]

On our next step we derive the expected profit for buyers, which we later use to derive the shadow price of additional quantity contracted under long-term. The expected profit of a buyer depends on his maximum willingness-to-pay which determines the marginal profit for a seller. The buyers with a higher willingness-to-pay are more attractive to seller and hence, have a higher probability to have their demand satisfied. This intuition

[15] In principle there can be a tier in a search for a fixed point. We break it by taking the highest of the two closest by the vector of payoffs $\tilde{n}$.

is reflected in the following expected profit expression:

$$\pi_i(k_I, k_E) = \int_{p_i^{min}}^{p_i^{max}} \int_{p}^{p_i^{max}} q_i^s dp\, dF_i(p)$$
$$\simeq q_i^s p_i^{max} - q_i^s \int_{p_i^{min}}^{p_i^{max}} p dF_i(p)$$
$$= q_i^s p_i^{max} - \int_{c_i^{min}}^{c_i^{max}} [\frac{(1-(1-F_i(c_{ei})))}{f(c_{ei})(n_i-1)} dc + c dF_i(c_{ei})]$$
$$\approx q_i^s p_i^{max} - \frac{1}{2} c_i^{max} \frac{n}{n-1} \quad (4)$$

here by $F_i(p)$ we mean the sellers' price distribution for the given market i, we express this distribution as in case of sellers through the distribution of sellers' supply costs. In the first line the integral gives the consumer surplus with respect to the expected price p. The first integral allows to calculate the expected consumer surplus given the minimum expected bid p_i^{min}. To calculate the integral we first substitute the equilibrium price for a given market, then, we assume that the average cost for a market is a half of the maximum cost. This allows us to obtain an explicit expression for the consumer profit and analyze what affects it.[16] We find that buyers benefit from the increase in the number of competitors on the market and lower supply cost.

3 Overall game, flexibility option pricing

The total expect profit of a player is defined as a sum of the short-term profit and the long-term profit. We have defined the procedure to calculate short-term and long-term profits $\{(\phi_i, \phi_e), (\pi_i, \pi_e)$ and now proceed with the issue of "flexibility option" choice and pricing. To this end we introduce a new function $H(Q_i) = Pr(Q_i \geq q_i^l)$ which is the cumulative probability distribution of the actual demand or the probability that the actual demand exceeds the quantity contracted. We introduce a "flexibility option", which is a refund in case a buyer does not need a part of the contracted volumes, by a refund rate r. Then, the total expected profit of a buyer is

$$\Pi_i = \phi_i + H(Q_i)\pi_i - (1 - H(Q_i))(1 - r)\pi_{ii} \quad (5)$$

[16] We take the mentioned assumptions for illustrative purpose to explore analytically the relation between consumer profit, number of players on the market, costs distribution, etc. However, for our numerical calculations we solve the integral give the estimated demand and price distribution.

to avoid cumbersome notations for time being we skip the argument (k_I, k_E), by p_i^l we denote the per-unit price defined by the long-term contract. The expression above implies that the flexibility option covers any volume. The first summand shows that a buyer have to pay for his long-term contract in any case. Yet, if he is covered through the flexibility option, then in the case of low demand a seller allows to return the excess LNG and pays back some refund. We determine this second case loss as a loss of a profit on the own market $\pi_{ii} := \pi_e|_{c_{ei}=0} = (q_i^l - Q_i) \cdot p^*$ if the consumers would demand $q_i^l - Q_i$ at price p^* minus a part of this profit which is compensated by a seller. We derive the minimum refund rate under which a buyer will be indifferent to buy or not to buy the flexibility option:

$$r = 1 - \frac{H(Q_i)\pi_i}{(1 - H(Q_i)\pi_{ii}} \qquad (6)$$

We have obtained a very intuitive result. First of all we notice that $r > 0$ only if the expected loss due to the low demand exceeds the expected gains from high demand. In other words, a buyer will buy insurance, i.e. flexibility option, only if he expects he has negative expectations. Then, $r = 0$ when the expected loss and gain are equal. Only when an expected loss from contracting more exceeds the expected gain will a buyer be willing to insure himself and buy the "flexibility option".

This leads us to the conclusions about the rope of the demand uncertainty in contracting. Keeping the expected values the same, we find that a buyer with higher dissection and cumulative probability shifted to the right end has stronger preferences for the refund: if for the same Q_i the probability $H(Q_i)$ is decreasing r increases. Otherwise, if dispersion of expected demand is small and $H(Q_i)$ increases, than r gets smaller.

4 Example

In this section we provide a numerical example demonstrating the approach and providing the intuition of theoretical results. The example is taken out of this Online proceedings, but its complete version is presented in Ikonnikova and Volkov (2009), there an empirical results are shown to support the theoretical findings. There we narrow our focus to three buying regions: USA, UK, and "Spain", where "Spain" is a representative for the continental Europe. As for the seller side, we look at three representative exporting regions: Algeria, Nigeria, Trinidad and Tobago.

5 Conclusions

Current paper makes a first attempt to understand and explain the developments on the global LNG market. To reflect the major features of the market, which are the long-term contracts with flexibility option and spot trade, we apply a two stage model. At the first stage players involved in the negotiation of long-term contracts, at the second stage they may take part in commodity exchange - like spot regional trade. At both stages we consider the market as a bilateral oligopoly. At the first we allow player to compete both in prices and quantities considering non-linear efficient contracts. At the second stage we assume price competition in regional markets as well as across regions.

We calibrate our model using the market data and solve for the market equilibrium under various assumptions numerically. We examine the results to understand whether our simplified model can provide intuition and explain the major changes in the market.[17] From theoretical model we derive that higher uncertainty in demand will make buyer more opt to buy "flexibility option". The price of this option will depend on uncertainty of demand of other buyers and on valuation of these buyers. Thus, low valuation buyers with little demand uncertainties may buy long-term contracts only, as the demand uncertainty increases these buyers are more interested to buy "flexibility option". High willingness to pay buyers with low uncertainty will also buy long-term contracts and get advance-purchase discounts. As the uncertainty in demand of high willingness to pay buyers increases they are more attracted to "flexibility". In ultimate case, high value buyers will switch to spot market. The fact that they are high value buyer with comparison to other buyer will increase their probability to buy LNG from other regions and hence, makes them less vulnerable to demand uncertainty. Moreover we determine the equilibrium spot price as a shadow price of investment which determines whether sellers/buyers invest more.

At present the LNG markets are still comparatively small, less than 15% of the world natural gas trade. The number of pivotal players is also small. To calibrate our model we use the data on estimated past demands in the regions, supply costs, on the LNG price, delivered volumes, re-exported (diverted) cargoes. We make some approximation and consider only the larger players of the interregional trade. We consider African LNG producers, Algeria, Qatar, Nigeria, and Trinidad & Tobago. As the buyers we consider the regions of USA, UK, Spain, France. We obstruct from other LNG market players deriving residual demand and supply functions for corresponding players. Our empirical

[17] For the calibration procedure and results see the full version of the paper posted on beg.utexas.edu/ikonnikova.

study supports the idea that to which extent the market is covered by the long-term contract and how much by spot deals is determined by the uncertainty of the demand and production and investment costs. For example, as the last decade the costs decrease we observe increase in the spot market size. In addition, as the uncertainty in prices in all the LNG buying regions increases the more buyer enter contracts with "flexibility option".

The intuition of the second stage trade is the following: the smaller the demand and the more capacities available are in the market, the higher surplus the buyer gains and the lower profit the seller earns. The preliminary results also show that long-term contracts can be beneficial if capacities in the spot market are scares and that the spot market grows if demand and prices are high.

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