Long-term contracts and efficiency in the liquefied natural gas industry

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Introduction:

Many countries with limited gas reserves rely on imported liquefied natural gas (LNG) to meet their energy needs. The market for LNG has traditionally been characterized by long-term bilateral contracts of up to 20 years between buyers and sellers, though the spot market has been slowly growing over time. The goal of this paper is to study whether the current trading arrangement, with trade dominated by long-term contracts, is efficient. We examine how the size and thickness of the market affects the optimal mix of contracts and spot and ask whether the efficient outcome will be reached in the absence of policy intervention.

Long-term contracts involve a fundamental trade-off between efficiency of investments and efficiency of allocation. Contracts facilitate efficient levels of irreversible investments made by sellers faced with hold-up risk (Williamson, 1979). In the LNG industry, an exporter must construct an export terminal that typically costs between $4-$15 billion and at least 4 years to build. A seller making this investment without a contract risks being exploited in ex-post negotiations. This can happen because the buyer may demand a much lower price, or the buyer may choose to buy from a different source, forcing the seller to search for buyers on the spot market. Anticipating this, in the absence of a long-term contract, the seller will under-invest. Thus, contracts are needed to incentivize efficient long-run levels of investment.

In the short run, though, contracts can impede the ability of the market to respond effectively to demand fluctuations, resulting in significant misallocation of gas. Allocative efficiency requires that LNG be sold to buyers with the highest willingness to pay (net of shipping costs). However sellers who are contractually obliged to fulfill their contracts may not be able to respond to unexpected changes in demand. Figure 1 illustrates how this can result in significant and systematic spot price differentials across regions, especially when the LNG market is tight. A particularly striking illustration of this is the period between mid-2011 and end-2013, when there was a large spike in Japan's LNG demand following the Fukushima nuclear disaster. Asian spot prices remained an average of $5/MMBtu higher than European prices during this period. The price differential persisted for over two years despite the possibility of arbitrage: this is because LNG arbitrage is costly both due to high shipping costs and due to technological constraints that make it difficult to store LNG for more than a few days. As Figure 2 shows, during this period Europe continued to import significant amounts of LNG, mostly under contracts. If exporters had fewer contractual commitments during this period, they would likely have sold more LNG to Asia and less LNG to Europe, resulting in a more efficient allocation of gas.

Thus there is an inherent trade-off between hold-up risk (which is improved by contracts) and short-run misallocation (which is worsened by the use of contracts). Whether contracts are welfare-improving depends on which of these two effects dominates. To understand the linkage between contracts and efficiency, the paper will develop and estimate a structural model of investment, contracts and trade in the LNG industry. We will use the model to quantify the effect of long-term contracts on trade flows, prices, and investment. By simulating the path of investments and trade in a counterfactual scenario where firms face restrictions on the duration of contracts, we will assess the welfare effects of long-term contracts.

A key mechanism we explore is that the size and thickness of the market affects this trade-off between hold-up risk and short-run misallocation. As the market becomes thicker, the risk of hold-up decreases as there are more potential trading partners. At the same time, the potential misallocation from relying on long-term contracts worsens: when there are many buyers, it is more costly to remain tied to one buyer, since the option value from selling on the spot market to the buyer with the highest willingness to pay increases with the number of buyers. As such, as the market grows thicker, it becomes efficient to switch

away from long-term contracts. In the LNG industry, a large number of buyers and sellers have entered the market in the last decade, and the share of spot and short-term sales in LNG trade has increased from 12% in 2004 to 28% in 2015. However, the bulk of LNG trade is still carried out under long-term contracts. Why is that the case, given the potential efficiency gains from switching to spot trade?

The hypothesis proposed in this paper is that there is a tension between overall welfare, and the incentives facing individual buyers and sellers. When the market is large enough, everyone has a joint interest in switching from long-term to short-term contracts. However if most existing buyers and sellers are locked into existing long-term contracts, no new buyer or seller has an incentive to make the switch: conditional on other players having signed long-term contracts, the best response is to also sign a long-term contract. In effect, the act of signing a long-term contract leads to a thinner spot market and imposes negative externalities on firms not party to the contract. Thus long-term contracts can potentially persist even when they are socially inefficient. To empirically test this mechanism, we plan to run a second counter-factual experiment where firms are forced to simultaneously re-negotiate their existing contracts. We will then test whether the firms are able to coordinate onto a different equilibrium that involves more use of the spot market, and whether such an equilibrium is welfare-improving.

Related Literature:

The paper is related to several strands of literature. We build on the literature exploring the relationship between contracts and market efficiency. The seminal paper by Allaz and Vila (1993) shows that if the spot market is imperfectly competitive, forward contracts improve efficiency. These efficiency gains have been found to be substantial for electricity markets: Ito and Reguant (2016) show that the use of forward contracts in the Iberian electricity market reduces deadweight loss from market power by 60%, while Bushnell, Mansur and Saravia (2008) find that production costs in US electricity markets would be 45% higher without long-term contracts and other vertical arrangements. Our contribution to this literature is to show that in spatially differentiated markets with high transport costs, contracts can result in spatial misallocation and hence may not necessarily be efficiency-improving.

We also contribute to the literature on asset specificity and long-term contracts. The transactions cost literature (for example, Williamson (1979)) argues that in the absence of contracts, asset-specific investments are subject to the hold-up problem. Long-term contracts remove the possibility of an ex-post holdup by either the buyer or the seller, and therefore lead to more efficient ex-ante investments. Joskow (1985) carried out one of the first empirical tests of this theory by studying contracts between coal mines and electric utilities in the US, showing that the greater the degree of asset-specificity, the longer the duration of contracts. This literature suggests that growth in the market size and depth can reduce the usage of long-term contracts: for example, Hartley (2015) predicts that increased LNG market liquidity is likely to lead to increased reliance on spot and short-term trades. The structural model that we will develop in our paper provides a way to empirically test this hypothesis. In addition, though, we highlight the fact that the transition from long-term contracts to spot trade can be impeded by coordination difficulties, even when it is socially optimal to make the switch. The idea the long-run equilibrium can involve an inefficiently high usage of long-term contracts builds on the literature on globalization and vertical integration. McLaren (2000) and Grossman and Helpman (2002) develop theoretical models to study how firms choose whether or not to vertically integrate with their suppliers. They show that as the market becomes thicker, it becomes optimal to switch from vertical integration to outsourcing. However, the outcome where firms remain vertically integrated is one of the possible equilibria even in a thick market, since when every other pair is vertically integrated, no one supplier-firm pair has an individual incentive to deviate.

Data:

The empirical analysis will draw on historical data on the global LNG market, most of which I have already collected from various industry sources. The primary requirement is data on individual LNG contracts, including contract quantity, year during which contract was signed, contract duration, and information on the buyer and seller. This data is available for the period 2004-2016 both from Bloomberg and from annual industry reports provided by the GIIGNL (The International Group of

Liquefied Natural Gas Importers), whose members encompass nearly every LNG import terminal in the world. Some contract features, though, are confidential: this includes the pricing formula, the take-or-pay share, and any destination restrictions or diversion clauses. Investment data, for both seller and buyer terminals, is obtained from the GIIGNL. We observe the start-up year, capacity and owner/operator for every export and import terminal built between 2004 and 2016. GIIGNL also provides data on yearly LNG trade flows for each country pair, broken down into long-term flows, short-term and spot trade flows, and re-exports. Finally, we obtain data on LNG spot prices and shipping costs between 2006 and 2016 from Waterborne Energy.

Model and Estimation:

There are N_i sellers, indexed by i, and N_j buyers, indexed by j. At the beginning of period t, buyers know only their expected demand for LNG in period t and all future periods. Sellers and buyers play a three-stage game in each period t. In Stage 1, each seller-buyer pair (i, j) decides whether to sign a long-term contract, with price p^c_{ij} and volume q^c_{ij} determined by Nash-in-Nash Bargaining. It is crucial that sellers have not yet committed to making new investments during this stage, and thus can credibly use the threat of not investing to extract higher prices from buyers. We allow a seller to bargain with multiple buyers, and a buyer to bargain with multiple sellers: in practice an export venture will typically sign contracts with 2-4 buyers, depending on their planned capacity.

In Stage 2, once contracts (if any) have been signed, sellers decide how much capacity k_i to add. Finally in Stage 3, period t demand shocks are realized. For contracted buyer-seller players, trade takes place at the agreed price and volume. Uncontracted quantities are traded on the spot market, which we model as a static Cournot game with capacity constraints. Buyers can also choose to sell excess quantities on the spot market. Unlike contracted flows, spot trading flows are determined only after demand shocks are unobserved, and thus in principle can respond to demand fluctuations. This is the key difference between spot trade and contracted trade, and implies that holding contracts and investment fixed, short-run efficiency is maximized by the use of spot trade.

We will structurally estimate this model in two steps. The first step is to estimate the static Cournot model of short-run trade flows, taking contracts and investment decisions as given. From the estimated trade flow model, we will derive buyer and seller payoffs, which will depend both on their own investments and contracts as well as the industry distribution of contracts and investments. The second step is to use these estimated payoff functions as well as data on contracts and investment to estimate the dynamic model of bargaining and investment (Stages 1 and 2 of the above model). This will draw on the recent literature in empirical industrial organization on estimating models of firm bargaining: see, for example, Crawford and Yurukoglu (2012) and Ho and Lee (2017).

The estimated model will be used to conduct several counter-factual experiments to explore the relationship between contracts and efficiency. First, to examine the long-run efficiency consequences of long-term contracts, we will simulate equilibrium investment and trade under a policy where firms are not allowed to sign new contracts exceeding one year in length, and compare overall welfare under this scenario with welfare under a benchmark scenario where firms are free to sign contracts of any duration. Second, to test whether efficiency is impeded by dynamic coordination difficulties, we will simulate investment, contract choices and trade in a scenario where firms are forced to simultaneously renegotiate all of their existing contracts. The idea is to see whether firms are able to coordinate into a different equilibrium that involves greater use of the spot market and less reliance on long-term contracts, and quantify the ramifications for total welfare.

Deliverables:

By the end of the fellowship year, I plan to complete a research paper that empirically assesses the relationship between efficiency and long-term contracts, how the size and thickness of the market affects the optimal mix of contracts and spot trade, and whether the efficient outcome will be reached in a dynamic equilibrium.

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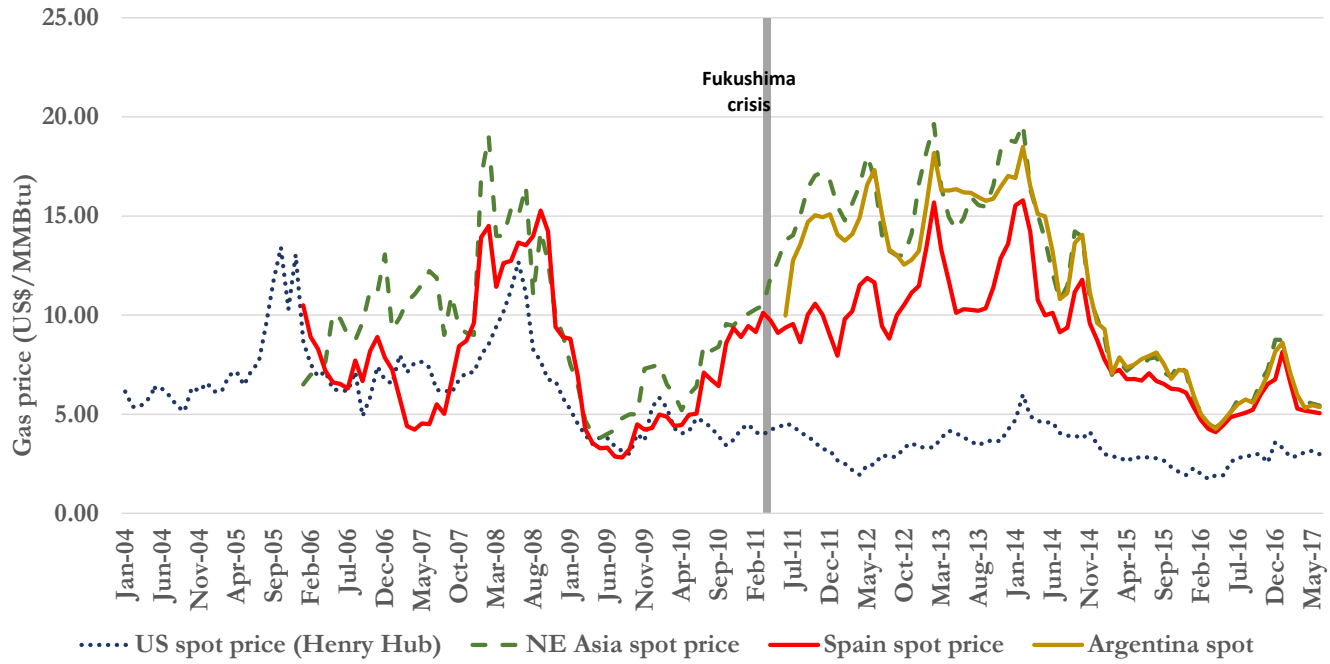
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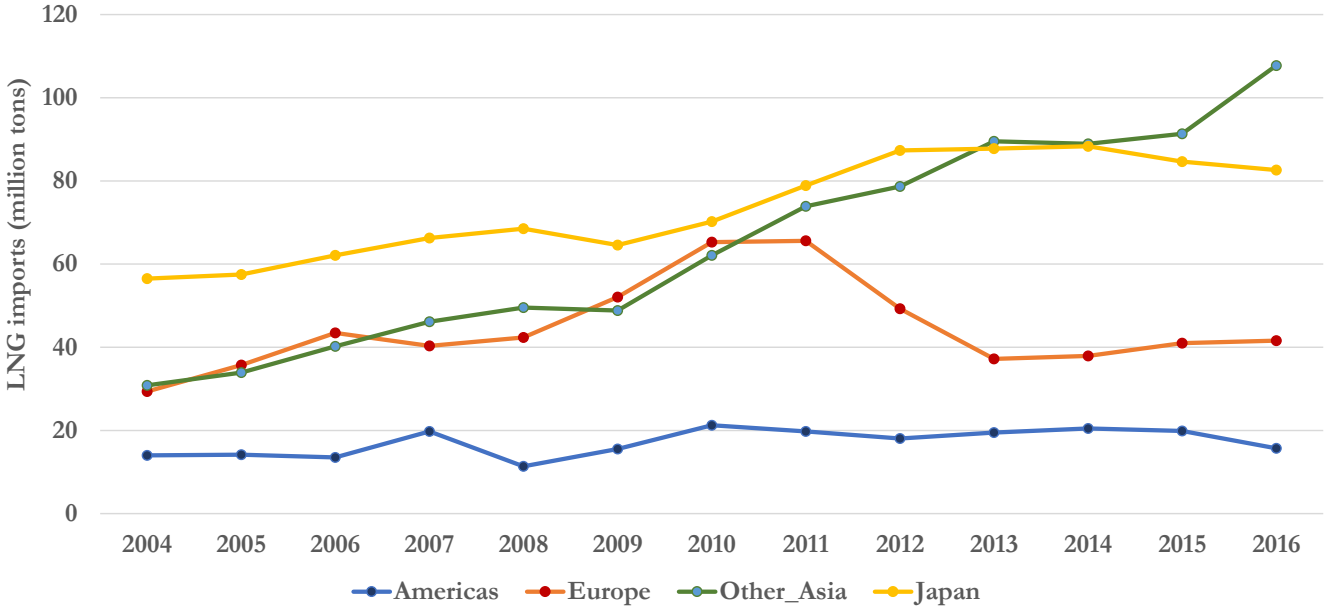
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Figure 1: LNG spot prices in major importing regions



Source: Argus, Reuters, Waterborne, FRED.

Figure 2: LNG Imports, 2004-16



Source: GIIGNL

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EDUCATION

Doctoral Program in Economics, Cornell University, 2014 – Present

Bachelor of Social Sciences in Economics, National University of Singapore, 2007-2011.
Double Major in Political Science. First Class Honours.

WORK EXPERIENCE

2011-2014	Analyst, Energy Studies Institute, Singapore.
2009	Intern, Economic Research Group, Dhaka, Bangladesh.

SCHOLARSHIPS, HONORS AND AWARDS

2016	The Louis Walinsky Fund in Economics Outstanding Teaching Award (in Honor of Professor Herbert Joseph Davenport)
2007-11	Dean's List (six semesters).
2008-09	Special Book Prize (Political Science).

WORKING PAPERS

"Air Pollution, Health Spending and Willingness to Pay for Clean Air in China." (with Panle Jia Barwick, Shanjun Li and Deyu Rao).

SEMINARS AND CONFERENCE PRESENTATIONS

"Traffic Congestion and Consumer Spending," Association of Environmental and Resource Economists (AERE) Summer Conference, Pittsburgh, USA, June 2017.

"Industrial Policy and China's Shipbuilding Industry." China Research Days Conference, Cornell University, October 2016.

"Farsighted Fuzzy Coalitions in an Economy with Multilateral Negative Externalities." Australian Agricultural and Resource Economics Society Conference, Port Macquarie, February 2014 (Winner of Best Poster Award).

"Modeling Singapore's Electricity Demand: The Impact of Temperature, Price and GDP." Australian Agricultural and Resource Economics Society Conference, Port Macquarie, February 2014

"Comparing Energy Efficiency Across Countries and Over Time: A Decomposition Approach," 36th Annual IAEE International Conference, Daegu, Korea, June 2013.

PROFESSIONAL ACTIVITIES

Referee for *Applied Energy*.
Member of the International Association for Energy Economics.
Member of the Australian Agricultural and Resource Economics Society.

PERSONAL

Citizenship: Bangladeshi
Languages: Bengali (native), English (fluent)
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December 14, 2017

Dear Ms. Elisa Pepe,

I am very pleased to write this recommendation letter for Nahim Bin Zahur, a 4th-year PhD student at the Department of Economics in Cornell University. Nahim is one of the best students in his cohort – maybe the best in the past five years from Cornell -- and I think he will benefit greatly from the NBER Pre-Doctoral Fellowship in Energy Economics.

I first met Nahim when he took the graduate Industrial Organization class that I taught two years ago. It was a rather demanding and intensive class with weekly quizzes, three long problem sets, one research proposal, and two exams. I covered a large number of papers (including recent job market papers) and a lot of analytically demanding material. He was very comfortable with highly technical material and at the same time had very good empirical intuition. He was the only student in his class who finished all three lengthy problem sets, including a problem set on a dynamic model that is an extension of Besanko and Doraszelski (2004). He received a well-deserved A+ (a grade that I use rarely) for his performance. Perhaps not surprisingly, Nahim had the best PhD qualifying exam scores among all of our PhD students for the past five years, with distinction in both Micro and Macro (which is extremely rare, since only a few students get distinction in either subject). He is very diligent, sets very high standards for himself, and excels at everything he does.

Nahim is interested in Energy and Environmental Economics as well as Industrial Organization, and is very knowledgeable across a broad range of topics. His PhD thesis studies the contract design of the global liquefied natural gas (LNG) industry, where buyers and sellers are gradually switching away from long-term contractual arrangements to buying in the spot market. Professor Jean-François Houde, Professor Shanjun Li and I are supervising his thesis. The model he has developed illustrates an important trade-off faced by firms in this industry. Long-term contracts facilitate efficient levels of long-term investment by sellers in the presence of a hold-up problem, but these contracts tie buyers and sellers into trading arrangements that can be inefficient in the short-run. As the number of firms grows over time, it could be socially optimal for the industry to switch from long-term contracts to spot trade. However, such a transition is difficult because no individual firm has an incentive to make the switch unilaterally: the benefits from switching to the spot market is significant only when it has many buyers and sellers (a thick market); for this to happen many firms need to simultaneously make the switch to spot trading. As a result, the industry might remain in an inferior equilibrium where firms are stuck with long-term contracts. The issues that Nahim is studying – specificity of investment, hold-up problems, and welfare impacts of contracts - are interesting for both

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energy economics and industrial organization, where there has been a lot of interest in recent years on understanding vertical relations and firm bargaining.

Nahim has collected rich data on contracts, investments, prices and trading flows from various industry sources. In a preliminary analysis, he shows evidence of significant short-run misallocation in the LNG industry, with the market unable to react quickly in response to demand disruptions due to rigidities introduced by long-term contracts. Over the course of the next year, he will estimate a full structural model of investment, contracts and trade in the LNG industry. I think this project has a lot of potential, and will contribute to our understanding of how spot markets can develop in industries governed by bilateral contracts. The project is also relevant to our understanding of whether scarce energy resources are efficiently allocated, an important policy issue that has not received adequate attention (a recent paper is Asker, Collard-Wexler, and De Loecker (2017) that studies production misallocation in the global oil market).

Nahim recently finished a paper (joint with me, Prof Shanjun Li, and Deyu Rao, a PhD student at Dyson) that examines how air pollution, and in particular PM2.5, affects health consumption in China. Our identification strategy relies on the fact that changes in wind direction and speed influence how much PM2.5 a city imports from faraway regions and exogenously change local pollution levels. Using daily data from 2013 to 2015 across all major cities in China, we find that when PM2.5 increases by 10 μg/m3 (PM2.5 index above 100 is considered unhealthy), health consumption increases by about 2.3% in the long-run. This is a much bigger impact than those reported using U.S. data. Much of the existing literature focuses on the effect of PM2.5 on mortality or emergency room visits, but ours is one of the first that analyzes the impact on total health expenditure in a developing country. Our estimates imply that if China were to reduce pollution levels sufficiently to comply with WHO standards, its annual health cost savings alone would amount to $44 billion or 0.4% of its GDP. Some of our results use complex econometrics tools (e.g., the use of the Almon Technique combined with splines to estimate the causal effect of serially correlated regressors). Nahim is very comfortable with technically challenging material and did a superb job throughout our project.

Nahim's third project combines high-frequency level (hourly and daily) Chinese bank-card spending data with congestion data in Beijing to examine how consumers adjust their spending in response to congestion. This is one of the first studies that examine the impact of congestion on economic activities. Nahim finds that an increase in average travel time by 15% leads to a 3.7% reduction in consumption spending, and that ignoring this channel significantly underestimates the social cost of congestion. He presented this paper at the Association of Environmental and Resource Economists (AERE) conference this past June and the paper was very well received.

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Department of Economics

Nahim and I have a paper that analyzes the impact of Chinese industrial policies, using the shipbuilding industry as an example. There is currently a lot of intellectual debate in China about the effectiveness of industrial policies, but few of the arguments proposed are based on empirical findings. This project, joint with Myrto Kaloupstidi from Harvard, will be one of the first empirical studies that fill this hole in the literature. Our analysis features the policy impact on firm entry and investment, which requires a rather complex dynamic model. The preliminary results suggest that both entry subsidy and investment subsidy are important in explaining the drastic expansion of China's shipbuilding industry in the first decade of 2000s, but such policies attract low-quality firms and entail substantial social cost.

Nahim has real intellectual firepower: his theoretical skills are first rate, his ability to execute empirical analysis is superb, and his econometrics skills are top notch. I am very excited about Nahim's potential and I anticipate that he will have a polished, first rate paper on the LNG industry by the time he completes the fellowship. Without reservation, I give Nahim Zahur my highest recommendation. If you have any questions, please do not hesitate to contact me.



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