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Liquefying a Market: The Transition of LNG to a Traded Commodity

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Liquefied Natural Gas ("LNG") has been an increasingly important source of fuel for over 50 years. The first major international shipment of LNG occurred from Algeria to the U.K. in 1964. By 2015, over 240 million metric tons were imported annually, with Asian countries (notably South Korea and Japan) being the major importers, and Qatar and Nigeria the largest exporters, but with Australia and the United States emerging strongly in that role. Growth was exceptional during the 1970s: liquefaction capacity grew at 380% per annum from 1964 to 1978, and the rate from 1973 to 1978 was 132% per year. Although there was a hiatus in growth in the 1980s and 1990s, it has since resumed, reaching almost 10% per year by the middle of the last decade.

Since its inception, LNG has been sold subject to long-term contracts between producers and utilities. These contracts were typically very inflexible "take or pay" type contracts indexed to oil prices, and prevented buyers from reselling gas purchased under them. The market is currently in a state of transition, moving away from these rigid contracting structures and toward a reliance on shorter-term contracts and spot transactions. In 2000, short-term transactions represented only 2% of total LNG flows. By 2015, this had increased to almost 30%, of which half were spot transactions.

This article explores the economics underlying this evolution of contracting practices, and offers a prediction of the likely future evolution. In brief, during the initial development of LNG, the salient characteristics of LNG-related assets—long-lived, highly specialized, site-specific, substantial economies of scale, sunk investment costs—meant that reliance on short-term transactions exposed buyers and sellers to what economists refer to as "small-numbers bargaining problems" and the associated transaction costs. Long-term contracts were used to mitigate these hazards. But locking early sellers and buyers into such contracts in turn meant that successive investments also created small-numbers bargaining, which required another generation of long-term contracts. The outcome, in the language of economists, has been a self-reinforcing contracting equilibrium that has exhibited considerable "hysteresis." That is to say, the practice of long-term contracting has persisted long after the initial causes for it seem to have disappeared.

Recent developments have undermined this long-standing equilibrium. Short-term shocks to LNG supply and demand, such as the Fukushima disaster and the post-Arab Spring decline in Egyptian gas production, created a need to buy gas on a short-term basis. Furthermore, prices in legacy contracts were tied to oil prices, which then disconnected from natural gas prices. And to the extent these developments undermined traditional contracting methods, they also contributed to the growth in shorter-term (including spot) trading.

There is now a very real possibility that the dominant contracting mode in LNG will shift to shorter-term and spot trading, with longer-term contracts tied to LNG spot prices (or the spot prices of gas in producing regions, notably the United States). This outcome is likely because of the virtuous cycle of market liquidity—a cycle in which increased spot trading activity increases the liquidity of the spot market, which encourages even more spot trading; and this increase in spot trading in turn reduces the need to rely on long-term contracts that are of greatest value precisely when buyers and sellers cannot rely on secondary markets for security of supply and demand.

Other commodities have made this transformation. Oil trading transitioned rapidly from long-term contracting to spot markets in the late 1970s and early 1980s. North American national gas did so after the deregulation of the early 1990s. Iron ore and coal have done so more recently. LNG is on the cusp of a similar transition.

The Economics of Contracting for LNG

Production and consumption of LNG require producers and consumers to make complementary investments. For example, producers must invest in liquefaction capacity (which super cools natural gas to transform it to liquid form that can be transported on specialized tankers); and consumers must invest in gasification facilities (which convert the liquefied fuel back to a gas suitable for transport on a pipeline). Producers and/or consumers must also invest in pipelines to transport gas to consumption locations, and often in new generating capacity capable of burning gas. Moreover, these assets tend to be subject to substantial scale economies due to high fixed costs, and these costs are largely sunk once the facility is completed. The assets also tend to be long-

lived—for instance, the Gorgon LNG facility in Australia is expected to have a productive life of 50-70 years. And, of critical importance, such assets are very "specific."

An asset is specific when its value in its first best use is substantially above its value in its second best use. This tends to be true of highly specialized assets, which as noted is true of LNG facilities. A liquefaction plant, for instance, has virtually no value in any other use but producing LNG. Sunk costs and asset specificity give rise to "quasi-rents," which is the difference between the cost of building an asset, and the revenue necessary to keep it in operation once it is built. Moreover, traditional LNG assets are "site specific"—that is, tied to a specific location. In fact, it is impossible to move a liquefaction plant from one place to another.[1]

It is well known that these conditions can create contracting hazards. Consider the risks that pioneer investors in LNG would have faced if they had built LNG-related assets "on spec" in anticipation of selling or buying LNG in short-term transactions (that is, transactions with maturities far less than the economic life of the assets). Given scale economies and uncertainty about the viability of the technology, in the early days of development one (or at most two) liquefaction plants and a small number of gasification facilities would have been sufficient to satisfy demand, and the producer and buyers of LNG would thus be faced with a small numbers bargaining situation.

Building a liquefaction plant in anticipation of selling LNG to the small number of buyers would expose the producer to being low-balled by the few buyers. And because of the specificity of the liquefaction plant, the producer would have no alternative uses for the asset and could be forced to accept these low offers. Given the large sunk costs of a specialized liquefaction plant, these offers could be well below the cost of the investment, since the seller would be willing to accept any price above the operating cost. In these circumstances the seller is at risk of losing most or all of the quasi-rents in the project.

Similarly, the few buyers would face the risk that the single (or at most two) seller(s) would demand a high price, which, if rejected by the buyers, would mean that their specialized investments in gasification or pipelines would be idled. Therefore, in these circumstances, both sellers and buyers are exposed to opportunistic behavior by their counterparties.

Such a wide bargaining range leads to wasteful haggling between buyers and sellers, with the ever-present prospect that bargaining breaks down, leading to the shutdown (or underutilization) of both the buyers' and sellers' assets.[2] Given these contracting hazards, and the resulting extreme uncertainty about the revenues and costs associated with short-term dealings, producers and consumers are likely to be very reluctant to invest in—and banks equally reluctant to finance—these investments.

The investor in a liquefaction facility and potential buyers of LNG can avoid these repeated bargaining games, the rent-seeking opportunism, and the consequent uncertainty about bargaining outcomes by entering into a long-term contract before investing in the assets. A long-term contract locks in a stream of revenues for the producer and a stream of costs for the buyer, and allows them to avoid the transaction costs of recurrent bargaining to reach short-term agreements.

Thus, investment in a new technology with the characteristics of LNG-related assets is likely to occur initially only if the producer and buyers enter into long-term contracts. Even as the market grows, however, it is likely that subsequent investments will also require such contracts. Consider the second liquefaction plant. Due to economies of scale, several years of demand growth will typically be required before it is economical to invest in a third facility. During this period, the producer and buyers are in a situation very similar to the one faced by the initial producer and sellers. The first producer and buyers are locked into a contract, and hence cannot provide competition in the market for the output of the new facility. Thus, the investor in the new facility and the potential buyers of its output would be in a small-numbers bargaining situation very similar to that of the first participants in the market; and so they too will have strong incentives to enter into long-term contracts to mitigate the hazards of short-term dealings in these circumstances.

A few years later, when the market has grown enough to support a third liquefaction facility, the situation repeats itself—as it does a few years after that. Thus, long-term contracts beget long term-contracts, and the market exhibits the hysteresis in contracting practices that we noted earlier. That is to say, the combination of economic considerations with the dynamics of contracting results in a self-reinforcing contracting equilibrium that is very resistant to change.[3]

Economic considerations also affect the form of the contracts that are likely to arise. Supply and demand conditions can change dramatically, and unpredictably, over the decades-long lives of LNG assets. Deciding on a price at the inception of a contract that does not change over its life makes it likely that this price will differ dramatically from the value of LNG to buyers or the cost of producing it in the future, when supply and demand conditions can differ substantially from those envisioned when the contract is formed. Thus,

1. There are floating gasification units that can be moved between ports. Ship-based (and hence mobile) liquefaction facilities are under development.

2. The first article to analyze the organizational and contracting implications of repeated short-term dealings in the output of specific assets is Benjamin Klein, Robert G. Crawford, and Armen A. Alchian, 1978 "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process," 21 *Journal of Law and Economics*, 297-326. Scott E. Masten, "Equity, Opportunism, and the Design of Contractual Relaions," 1988, 144 *Journal of Institutional and Theoretical Economics*, 180-195 presents a useful summary of the literature that followed.

3. In earlier research, I referred to the contracting dynamics that result in a long-term contracting equilibrium "contractual specificities." Stephen Craig Pirrong, 1993, "Contracting Practices in Bulk Shipping Markets: A Transactions Cost Explanation, 36 *Journal of Law and Economics*: 937-976.

long-term contracts typically require a mechanism to permit prices to adjust to reflect changing market conditions.[4]

Although long-term contracts mitigate certain difficulties and reduce transaction costs, they also have disadvantages. In particular, precisely because future supply and demand conditions may differ substantially from those anticipated at the time a contract is struck, the value of the LNG to the buyers and the cost of production to the seller may diverge substantially from the contract price. This is especially likely to be true if the price adjustment mechanism does not adequately reflect these changes in value and cost. In response to large unanticipated changes in values or costs, the buyer or the seller is likely to desire to renegotiate the contract. If these renegotiations fail to result in value-enhancing adjustments, the seller and buyer will be stuck in a contract that allocates output inefficiently. And even if ultimately successful, the renegotiation can be protracted and costly.

So how can LNG buyers and sellers escape the long-term contract equilibrium? Under some circumstances, exogenous shocks, contract maladaptations, or both, can result in a shift towards shorter-term contracting, and the development of a vibrant spot market.

Specifically, shocks that lead to demand or supply for previously uncontracted volumes on a relatively temporary basis can result in a desire by some consumers to buy only on a short-term basis. Similarly, changes in market conditions that were not anticipated at the outset of a contract can make it efficient to reduce volumes flowing from the seller to a buyer in a particular contract. In such cases, efficient renegotiation can lead to contract changes that result in a release of volumes that are then available for trading on a shorter-term basis. As will be seen, both factors have been at work in the LNG market.

Such initial shocks tend to spark a virtuous cycle of liquidity, wherein more spot trading increases the competitiveness and reduces the transaction costs of spot deals—and such reductions in transaction costs in turn induce more spot trading, which increases competitiveness and reduces transaction costs further, thereby spurring more spot trading. Further, as the spot market becomes more liquid and deep, buyers and sellers of LNG are less vulnerable to entrapment in small-numbers bargaining situations and to the opportunism of their counterparties, and so have less need for the protections of long term contracts. Moreover, as spot markets develop, prices in long-term contracts can be linked to spot prices, reducing the potential for large divergences between contract prices and gas values. In this way, a shock that leads to more spot trading can lead a market to "tip" from the long-term contracting pole to the short-term trading pole, and also cause a change in the pricing basis of longer-term deals.

This process, as I show below, is currently underway in the LNG market.

LNG Contracting and Pricing

The history of the LNG market is broadly consistent with the theory sketched above. From its inception, the LNG industry has been based on long-term contracts between suppliers and buyers. The typical contract is of 20-25 years in duration, and that has been the case since the first Algerian contracts. These contracts have been instrumental in securing the capital necessary to construct what are very expensive, and long-lived, assets.

LNG contracts have typically incorporated "take or pay" clauses, whereby the buyer is obligated to pay for some fraction of the contracted volume (90% is typical), regardless of whether it utilizes this entire quantity. Take-or-pay clauses thereby provide the LNG seller with guaranteed revenue from a minimum quantity of output over the life of the contract.

As noted above, long-term contracts typically require a mechanism to permit prices to adjust to reflect changing market conditions over the life of the contract, and LNG contracts are no exception. In the early stages of the LNG industry, it competed with oil as a fuel for power generation. This competition, along with the development after 1978 of a liquid and relatively transparent spot market for oil, made it natural to use oil prices to determine prices under LNG contracts (sometimes supplemented with re-opening clauses).

LNG contracts have also historically incorporated "destination clauses." These clauses specify a location where the LNG is delivered, and the buyer must take delivery at that location. This means that the buyer cannot divert a cargo to another location for resale there.

Destination clauses facilitate price discrimination, whereby a producer can sell to different buyers at different prices. Absent such a clause, a buyer with a low contract price can resell to another buyer with a higher contract price. These clauses therefore restrict resales of contracted volumes, which tends to limit the development of spot markets.

Some resales do occur in LNG markets, but through a costly and cumbersome process called "reloading." Using this process, a buyer who has contracted for volume in excess of needs can take delivery of and unload a cargo, pay for it, store it, and then reload it onto a ship for re-export to another location. In 2015, such reloads accounted for less than 2% of LNG import volumes.[5] And as this low percentage suggests, "reloading" is obviously a far more costly way of reselling LNG than merely redirecting a ship to another port.

Thus, from its outset, the LNG industry has been in the long-term contract equilibrium. Nevertheless, economic developments of the last decade are undermining this equilib-

4. Keith Crocker and Scott Masten, "Prieta ex Machina? Prices and Process in Long-Term Contracts," 1991, 34 *Journal of Law and Economics*: 69-99.

5. GIIGNL Annual Report (2016). There is some controversy over whether reloads violate destination clauses. Qatar has raised vocal objections to reloading but has not resorted to legal means to attempt to prevent reloads.

rium, and there are strong indications that the virtuous liquidity cycle is well underway.

First, in the past five years, there have been several major shocks that have led to an unexpected increase in demand for volumes on a short-term basis. These include the Fukushima disaster in 2011, which caused the shutdown of Japan's nuclear generation, the source of 30% of the country's electricity in 2010. This increased substantially the demand for LNG on a short-to-medium term basis to fuel the conventional generation that replaced the lost nuclear capacity. Furthermore, in the aftermath of the Arab Spring, Egyptian natural gas production declined substantially, by over 22%, from 2011 to 2015.[6] This reduction forced Egypt and other countries (such as Jordan) that relied on Egyptian gas to increase LNG imports to replace the lost Egyptian supplies.[7] In addition, drought in Amazonia reduced hydroelectric generation, and Brazil had to import LNG to fuel generation to replace it.

All of these shocks caused an unexpected demand for LNG supplies not previously secured by contract; and since these demands were likely to be relatively temporary, long-term volumes were not required. This spurred short-term trading, and energy trading firms such as Trafigura, Glencore, and Vitol bought and sold LNG cargoes on a spot basis to meet these demands.

Second, major changes in supply and demand as well as the structure of energy markets meant that existing long-term contracts increasingly failed to reflect prevailing fundamentals. One secular development was the divergence of oil and gas prices, which made oil price linkages in LNG contracts increasingly dysfunctional.

This divergence of prices reflects the evolution of energy markets in general in recent decades. Demand for oil and gas has become segmented, with oil becoming predominantly a transportation fuel and relatively unimportant as an input in power generation, and with LNG used primarily as a fuel in electricity generation. Moreover, whereas oil production has largely plateaued (with some exceptions in North America), gas production has increased dramatically (especially in North America). Together, these developments have led to a delinking of the price of oil and the value of gas. This delinking is strikingly evident in the regions with vibrant spot markets for gas, such as the Henry Hub in the U.S. and the National Balancing Point in the U.K. What's more, in the past several years, North American gas prices and oil prices have been *negatively* correlated. And even though European hub prices have remained (weakly) positively correlated with oil prices, there have been large divergences between the prices of oil and European hub gas on a BTU-equivalent basis.

Indeed, it would arguably be only slightly less efficient to put LNG on the gold standard than the oil standard. From 2009 to 2015, the correlation between the spot price of LNG delivered to Japan and South Korea (the so-called "JKM" marker) and the price of Brent crude oil was -1.4%. During the same period, the correlation between the JKM LNG price and the price of gold was -2.4%. Thus, *pace* Keynes, oil benchmarking of LNG has become a "barbarous relic" because oil-linked prices do not reflect the value of gas to purchasers, or the cost of producing it. Oil prices exhibit virtually no correlation with the LNG spot prices that reflect the commodity's true marginal value to consumers and producers.

Prices that are delinked from fundamentals send the wrong signals to producers and consumers, leading to inefficient production, consumption, and investment decisions. These inefficient decisions destroy value. Moreover, this misalignment of price and value has created tensions between buyers and sellers in oil-linked contracts; when contract prices diverge substantially from transactors' valuations, one party has a strong incentive to push for contract changes—which can lead to substantial bargaining, litigation, and transaction costs—or to attempts to escape the contract altogether. This is most evident in contract disputes between Russia and its major European customers of pipeline gas, but similar conflicts have been appearing in the LNG markets as well. Such battles destroy value, and provide an incentive for parties to renegotiate maladapted contracts to avoid such losses. Indeed, they have already led to some contract changes that have freed up some previously contracted volumes.

Third, large supplies of LNG from mega-projects are coming online precisely when demand growth in the major Asian consumption markets is slowing. In particular, large projects in Australia and the United States led in 2016 to an increase of 42 metric tons per annum of liquefaction capacity. This increase was triple the amount built in 2015, and represents a 15% increase in capacity in one year. Moreover, in 2015 140 MTPA of capacity was under construction.[8] At the same time as this large additional capacity loomed, demand growth in Asia slowed, reducing the need for contracted gas. Asian consumption declined 1.7% in 2015, with 5% declines in Japanese and Korean imports,[9] and a 1.5% drop in Chinese consumption that have been attributed to slower economic growth and cheaper prices for competing fuels.[10] Such slow growth is leading to the release of additional supplies to the

6. Brendan Meighan, Egypt's Natural Gas Crisis, Carnegie Endowment for International Peace (2016).

7. Prior to the Arab Spring, and the sabotage of pipelines in Egypt that followed, Jordan had no LNG import capacity. Due to these supply interruptions, Jordan constructed a floating import terminal.

8. GIIGNL Annual Report (2016) at 19.

9. United States Energy Information Agency, "As Japan and South Korea Import Less LNG, Other Countries Begin to Import More," (2016). Available at http://www.eia.gov/todayinenergy/detail.php?id=27652.

10. United States Energy Information Agency, "Natural Gas Weekly Update," (February 3, 2016). http://www.eia.gov/naturalgas/weekly/archive/2016/02_04/index.cfm

short-term market, and will likely lead to additional releases in the next few years as more capacity comes online.

The entry of the United States as a gas exporter is likely to have particularly important effects. Given its geographic location, the U.S. can economically serve Asia, Europe, and South America. The widening of the Panama Canal has reduced cost of shipment to Asia, making U.S. gas more competitive there. Moreover, the first U.S. exporter (Cheniere) entered into long-term contracts for its liquefaction capacity that unbundle the fuel price as follows: buyers pay 115% of the Henry Hub natural gas price plus a (contractually set) liquefaction fee. Since U.S. gas is expected to be at or near the margin in all major import markets, this pricing structure means that U.S. Henry Hub will set prices around the world. This will permit buyers and sellers to use the existing large, liquid, and deep Henry Hub-based futures and swap markets to hedge price risk—and it will also allow them to use Henry Hub prices as a benchmark in long-term contracts.

Fourth, regulatory changes are likely to expedite this process. Japanese antitrust authorities are investigating whether destination clauses violate fair trade laws, and have told LNG sellers that they will stop investigating them if they remove the clauses from their contracts. The affected contracts represent 70% of contracted sales to Japan, which is the largest buyer of LNG in the world. Eliminating destination clauses would free volumes for spot trading by allowing Japanese buyers to sell unneeded contracted LNG on a short-term basis to other destinations.

Indeed, the Japanese regulator's actions are likely driven by the fact that Japan's contracted purchases for 2017-2023 exceed expected consumption by as much as 20%. Allowing Japanese utilities to resell excess volumes would reduce the burden of these contracts—and at the same time boost spot LNG trading, contributing to market liquidity

These developments are already leading to a pronounced shortening of contract durations on LNG. Whereas short-term contracts (defined as maturities of four years or fewer) represented 2% of imports in 2000, this share had increased to 20% by 2010; and by 2015 it had reached almost 30%. In 2015, 15% of world LNG imports were purchased on a spot basis (defined as contracts with fewer than 90 days between fixing and delivery).[11]

Although only a handful of spot cargoes trade each day, a critical mass of spot trading is developing. Once this happens, the market is likely to "tip" rapidly to spot trading and spot-based pricing mechanisms, even in long-term contracts. Again, the ability to tap into the liquidity of the U.S. natural gas market, and to use U.S. prices as a benchmark due to the emergence of the U.S. as an LNG exporter will expedite this process.

The shift in contracting practices that has already occurred is having other effects that contribute to the virtuous cycle. Most notably, poor creditworthiness prevents some countries (such as Pakistan) from buying on a long-term contract basis. Legal enforceability issues (notably, the practice of "price majeure") make sellers unwilling to deal on a long-term basis with some buyers. The development of a shorter-term market permits these buyers to enter the LNG market (as Pakistan, for example, has done in the past year). These parties perforce trade on a short-term basis, and their purchases are contributing to a more vibrant spot market, which will reinforce the virtuous liquidity cycle.

Implications for Long-Term Contracts

Long-term contracting is unlikely to disappear completely, mainly because some developers may not be able to finance projects without contracted demand. However, the development of liquid short-term markets will likely transform the nature of these long-term contracts. Most notably, liquid and transparent spot LNG pricing makes possible the linking of contract prices to LNG prices rather than oil prices. Ironically, this reduces the cost of long-term contracting because it reduces the potential divergences between contract prices and the values of gas.

Furthermore, a liquid spot market facilitates the development of longer-dated hedging instruments, which in turn permits the unbundling of fuel prices from liquefaction charges. Such unbundling would tend to favor the increased use of long-term contracts in which buyers obtain liquefaction services on a long-term, fixed-price basis and purchase gas at prices indexed to spot prices.

Historical Antecedents

In sum, the LNG market is on the cusp of transitioning from one dominant contracting mode to another. There are historical precedents for such a transition.

Three particularly apposite examples are natural gas in the United States in the 1990s, the oil market in the late 1970s and early 1980s, and the iron ore market in recent years. Although the specific details differ, these examples have several common features, including most notably a misalignment of contract prices and commodity values, a diversity of supply and demand sources, and volatile fundamental market conditions. Each of these features made rigid long-term contract pricing mechanisms ill-suited for prevailing market conditions. These conditions exist in LNG today, and are likely to persist into the future, thereby setting the stage for a shift in pricing mechanisms similar to what has occurred with these other commodities.

The transition from long-term contracts to market-based mechanisms occurred rapidly in the U.S. natural gas market

11. GIIGNL Annual Report (2016) at 19.

after the market was deregulated in the early 1990s. The natural gas market in the U.S. was highly regulated, with wellhead price controls. The energy price shocks of the 1970s led to changes in the price control regime that resulted in a Byzantine pricing system, with the price of gas varying widely depending on the vintage of the producing well. Moreover, to secure supplies gas consumers entered into long-term contracts with pipelines, which in turn purchased gas from producers under long-term take-or-pay contracts. Declines in gas values in the mid-1980s attributable to the collapse in the price of oil caused a severe misalignment between these values and contract prices, which imposed substantial burdens on buyers and resulted in a surge in costly litigation. In response, U.S. government regulators implemented a series of changes, culminating in Order No. 636 (by the Federal Energy Regulatory Commission), which unbundled the sale and transportation of gas. Pipelines became purely common carrier transporters of gas rather than marketers.

Largely in response to these developments, spot and term markets for physical gas developed in which consumers, producers, and trader-intermediaries bought and sold gas to match supply and demand. Producers became confident that there would always be a ready market for their gas, and consumers became confident that producers would be able to meet their needs, even in the face of extreme weather shocks. Markets provided security of demand and supply during a tumultuous period in which prices rose and fell dramatically due to dramatic changes in the supply-demand balance—a period in which prices were in the $2 range in the 1990s, and then spiked to about $14 in the mid-2000s when demand outstripped supply, before plunging to below $2 in 2012 as shale gas supplies surged.

This process worked well in part because there was a diverse set of suppliers and demanders, which permitted the creation of a deep, liquid, and flexible spot market. Moreover, as the market was deregulated, specialized trading firms entered to help consumers tap multiple sources of supply, and give producers access to large numbers of customers.

What's more, derivatives markets—also known as "paper markets"—for futures, options, and swaps developed in parallel to the spot and term physical markets. These paper markets permitted producers and consumers to manage their price risks independently of the process of buying or selling physical gas. This unbundling of the movement of methane from the management of price risks facilitated the ability of capital and banking markets to finance a drilling boom in the United States.

A similarly rapid evolution occurred in the oil market starting in the late-1970s. The 1960s and 1970s had seen an evolution of the oil market from "posted prices" set by the "Seven Sister" oil companies to one in which governments sold to oil companies (including independents) at "official selling prices" under long-term contracts. Due to the substantial fundamental volatility during this period, the value of oil in the (relatively limited) open market exceeded contract prices. This price disparity induced suppliers (notably the OPEC countries with the exception of Saudi Arabia) to abandon long-term contracts, and to market their oil almost exclusively through spot and short-term contracts at negotiated prices. Soon the entire market tipped from one in which spot transactions were the exception to one in which they were the rule.

As in the U.S. natural gas market, buyers found that the spot market offered security of supply, and sellers found that it provided security of demand. Indeed, whereas prior to the development of the spot market the upstream and downstream oil sectors were tightly integrated because of the inability of refiners to obtain crude through market channels, the development of the spot market made it possible for refiners to supply their operations from a diverse set of producers. This reduced the benefits of vertical integration that tied a refinery to a particular upstream supply source; and as a consequence, the oil industry became less integrated in the spot market era. These changes in oil markets provide a striking illustration of how the development of liquid physical markets can provide security of supply that renders unnecessary contractual and organizational measures intended to guarantee access to vital inputs.

As in the U.S. gas market, the existence of diverse sets of producers and consumers of oil created a degree of competition that created this security. No buyer (or seller) was tied to a small set of sellers (or buyers); each could draw on a relatively large set of firms and countries competing for their business. Further, trading firms entered the oil market and provided the service of enabling buyers and sellers to access efficiently a broad array of suppliers and customers, respectively. And, again, deep, liquid, and competitive derivatives markets grew in parallel with the physical spot markets, making possible the management of price risks independently from the process of buying and selling physical oil.

A more current case provides a final example. Historically, iron ore was sold under contracts between miners and steelmakers, and prices were determined annually in a typically protracted and painstaking negotiating process. Very little ore was sold on a spot basis. However, extreme market fluctuations in the 2007-2010 period put this structure under extreme stress. First, a boom in demand originating primarily in China caused the value of ore (as indicated by the few spot trades) to rise substantially above the contract prices, and miners looked for ways to sell at the higher spot prices. Then, the Great Financial Crisis that began in late 2008 caused the value of ore to plunge below contract prices—and several steelmakers defaulted on their contracts. In response to these conditions, miners and Japanese steel firms pushed for a fundamental change in the pricing mechanism for ore, and, after some resistance, Chinese firms went

along. A larger fraction of ore was sold spot, but importantly, contracts between steel firms and miners began to use spot prices to determine the prices in their supply contracts. In a period of a few years, the business switched from negotiated prices to spot-based pricing.

As in U.S. natural gas and oil, trading firms are helping to secure supply and demand by allowing buyers and sellers to access a broad array of producers and customers. Again in parallel with the process that occurred in the other markets, derivatives markets in iron ore are growing rapidly; open interest in cleared iron ore swaps has increased more than ten-fold in the last four years, during which time the market has tipped to spot-based pricing.

These experiences in U.S. natural gas, crude oil, and iron ore demonstrate that expensive, durable investments in specialized capital are completely compatible with spot market pricing complemented by market risk-transfer mechanisms. In essence, liquid markets create security of supply and security of demand, reducing the need for contractual protections against opportunistic behavior in the trade of commodities produced by specialized, long-lived assets. It is likely that the LNG industry will undergo a similar evolution; and due to the non-linear nature of liquidity, this evolution will be of the "punctuated equilibrium" variety, with a rapid transition away from oil-based pricing.

Conclusion

The LNG industry has experienced remarkable growth and development in the half-century since the first LNG tanker—the *Methane Princess*—set off on the first of its more than 500 voyages. The future holds the prospect of continued growth in the volume and diversification of supply sources. These developments will be a continuation of a process that has been ongoing since the industry began.

Economic theory developed in the roughly 40 years since the mid-1970s demonstrates that contracting modes adapt to facilitate efficient exchange, and that the efficient contracting mode depends on technological, market, and regulatory factors. When important characteristics of the technology of production—for example, the use of highly specialized assets—implies that reliance on short-term dealings would typically result in repeated small-numbers bargaining situations, it is efficient to use long-term contracts (or vertical integration) to organize and govern exchange. Conversely when technological and market conditions allow considerable competition between buyers and sellers after investments have been made, it is efficient to rely on shorter-term (and spot) markets for exchange.

The history of the LNG industry supports these theoretical predictions, and provides a compelling illustration of the transition from one contracting mode to another. For most of its history, the specialization and scale of LNG assets have caused a reliance on long-term contracts. In recent years, however, market and regulatory shocks have caused growth in short-term and spot contracting. This has commenced a virtuous cycle of market liquidity. As buyers and sellers realize that they can obtain or dispose of LNG in an active trading market, they need less protection against the opportunism of their trading partners that long-term contracts provide. This results in more spot market liquidity, which encourages even more such trading.

This process is currently ongoing and well advanced in LNG. Considering the self-reinforcing nature of the process, it is likely that the process will continue, and that within the foreseeable future the LNG market will look nothing like it did even a decade ago. Instead of relying almost exclusively on long-term contracts linked to oil, buyers and sellers will rely on shorter-term contracts, and the longer-term contracts that do exist will be linked to spot LNG prices. LNG will become a traded product much like oil. The beneficiaries of this transition will not be just commodity traders. Consumers and producers will benefit from more flexible pricing that accurately reflects rapidly changing supply and demand fundamentals. And such pricing will in turn facilitate the efficient flow of LNG, which will then encourage the development of financial derivatives that make possible the efficient transfer of risk.

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