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Natural Gas Price in Asia: What to Expect and What It Means

A Research Progression from "US LNG Exports: Truth and Consequence"

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By

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Kenneth B. Medlock III, Ph.D., is the James A. Baker, III, and Susan G. Baker Fellow in Energy and Resource Economics and senior director of the Center for Energy Studies (CES) at the Baker Institute. He is also an adjunct professor and lecturer in the Department of Economics. Medlock is a principal in the development of the Rice World Gas Trade Model, which assesses the future of international natural gas trade. He also teaches courses in energy economics and supervises graduate students in the energy economics field. Medlock's research covers natural gas markets, gasoline markets, energy commodity price relationships, energy market forecasting, transportation, national oil company behavior, and the relationships between economic development, energy use, and the environment. Medlock is an active member of the International Association for Energy Economics (IAEE), and is the vice president for conferences of the United States Association for Energy Economics (USAEE). He is also a member of the American Economic Association and the Association of Environmental and Resource Economists. In 2001, Medlock won (with Ron Soligo) the IAEE Award for Best Paper of the Year in the *Energy Journal*. In 2011, he was given the USAEE's Senior Fellow Award, and in 2012 he accepted on behalf of the CES the USAEE's Adelman-Frankel Award, which is given to recognize contributions to the field. Medlock has also served as an advisor to the US Department of Energy and the California Energy Commission in their respective energy modeling efforts. He was the lead modeler of the Modeling Subgroup of the 2003 National Petroleum Council (NPC) study of long-term natural gas markets in North America, and was a contributor to the recent NPC studies *Facing the Hard Truths* (2007) and *Prudent Development of North American Resources (2011)*. Medlock received his Ph.D. in economics from Rice and held the MD Anderson Fellowship at the Baker Institute from 2000 to 2001.

Extended Abstract

A decade ago, the natural gas industry was preparing for a structurally transformative shift in the global market. Substantial capital investments were being made to facilitate the import of liquefied natural gas (LNG) to the United States from the Middle East, Africa, Russia, and other distant locations. The consensus market view at the time was that US domestic supply was in terminal decline. However, innovations involving hydraulic fracturing and horizontal drilling have led to dramatic domestic production growth from shale, which now has the US considered a possible exporter of LNG, which was virtually unthinkable just a decade ago.

Development of LNG export capability from the US is only one margin of response that is being fueled by the recent price differentials between the US and Asia that are in excess of $14/mcf. Other margins of response include: (i) the potential development of shale gas resources in China; (ii) investment in pipeline infrastructure to move supplies from Russia, Central Asia, and South Asia to Northeast Asia; and (iii) expansion of LNG supplies sourced from locations such as East Africa, the Middle East, and Australia. Asian and European consumers generally view adding US exports to their supply portfolios as desirable, particularly because they are tied to a liquid gas market and there is low risk of disruption. Meanwhile, incumbent producers in these regions view the prospect of US exports as a competitive threat that could transform the Pacific Basin market.

Constraints on the ability to meet the *unexpected* demand shock in the wake of the disaster at Fukushima resulted in the spot price of Asian LNG rising to unprecedented levels. We see similar circumstances arising in the continental North American market, when extreme cold grips certain regions and drives up local demand in excess of what existing pipeline capacity can deliver. Indeed, prices in these places can rise higher in the wake of these weather-driven demand shocks than what has been seen in Japan. But, fortunately for consumers in the US, these regional price shocks are very short-lived because the weather-related demand shocks are also short-lived, and the depth of the US market provides substantial liquidity through which price differences are quickly arbitraged.

In the Asian market, the post-Fukushima price increase has not abated quickly. This follows from the fact that Japanese nuclear capacity is not being reactivated quickly, and construction of new delivery capability to supply the country's heightened natural gas demand is plagued with long lead times. Certainly, bringing new sources of natural gas online and/or reactivation of the nuclear capacity in Japan will relax the binding deliverability constraint to the Asian market, and, all else equal, will result in a decline in the spot price of LNG in Asia back to a level that is consistent with a globally arbitraged price.

Absent greater liquidity in the Pacific Basin, sellers may be able to keep price elevated due to a lack of competition. This is where it becomes important to consider what increased trade in the global LNG market will do to the nature of pricing abroad. As the US begins to export LNG, the global market will deepen and become physically linked to the North American market, the most liquid natural gas market on the world. This should, in turn, facilitate more trade and alter the liquidity paradigm that has characterized the global LNG market heretofore. Indeed, as this happens, the nature of natural gas pricing in Asia will begin to change as well, and it could happen very quickly; after all, the rise to current price levels in Asia relative to prices elsewhere happened in only six months, a fact often forgotten in the discussion about future pricing in Asia.

Introduction

During the past decade, innovative new techniques involving the use of horizontal drilling with hydraulic fracturing have resulted in the rapid growth in production of natural gas from shale in the United States. This transformed the North American gas market and had ripple effects around the entire world. To begin, the successes in the US realized in shale gas and tight oil production have triggered tremendous interest in unlocking similar potentials in other identified shale resources around the world. While an array of above-ground factors will limit the pace of development in many places relative to what has been witnessed in the US, the interest is very strong, and investment capital is seeking to make the opportunity real.

The transformative impacts of shale development extend beyond the interest in developing such resources in places outside the US. A little over a decade ago, steady production declines were expected in the North American market. This, in turn, signaled an increasing reliance on imported supplies of liquefied natural gas (LNG). In anticipation of rising demand for LNG from the United States, developers around the world began investing in expanding LNG export capability, concomitant with investments in regasification being made in the United States. But rapid growth in shale gas production in the US has rendered many of these investments obsolete. More importantly, as discussed in Medlock, Jaffe, and Hartley (2011)[1], it forced those LNG supplies that had been developed with the US as a target market to seek new ports of destination. For a while, this displacement effect put substantial downward pressure on spot prices in both Europe and Asia. This was exacerbated by the economic malaise that afflicted global markets in the latter part of last decade. However, prices eventually rose as the disaster at Fukushima turned the global gas market around by generating a wholly unexpected demand shock. This, in turn, allowed those displaced LNG supplies to find a new home. Arguably, this effective "capacity release" from the US has helped keep prices in Asia from rising even more than they have.

Another impact of rising shale gas production in the US has been the growing interest in exporting LNG. Certainly, the rapid production growth has contributed to lower domestic natural gas prices, which dipped below $2 per thousand cubic feet (mcf) in April 2012 and, prior to the demand pull created by the cold winter that currently grips the US, hovered in the $3 per mcf range for an extended period of time. Low prices led to greater use of natural gas in power generation through substitution opportunities with coal, a revival of industrial and petrochemical demands, and growing interest in expanding natural gas use in transportation. Low US prices relative to the prices in Europe and Asia have also triggered interest in developing LNG export capability to capture the profitable arbitrage opportunity that currently exists.

As discussed in Medlock (2012), when considering international natural gas trade, it is important to recognize that the issue is indeed *international*.[2] Thus, we must not only consider what is happening in North America; we must also consider what is happening abroad. Only then can we begin to analyze what the future may hold for natural gas pricing and trade around the world. In fact, as natural gas becomes an increasingly fungible commodity, which would be the case as the volume of global natural gas trade increases, the pricing paradigm of oil indexation will come under increasing pressure.

There are several key factors that determine the impact of LNG trade on prices in all markets, including but not limited to: (i) the relative long-run elasticity of domestic and foreign supply, (ii) the relative long-run elasticity of domestic and foreign demand, (iii) the role of short-term capacity constraints as they will be impacted by the introduction of trade, and (iv) the cost of developing and utilizing export capacity.

Identifying unexpected, transitory events is crucial to characterizing the current natural gas market. In general, unexpected changes in demand can create transitory price movements, particularly when supply cannot react quickly. We see this even in the continental North American market when extreme cold grips certain regions and drives up local demand in excess of pipeline delivery capability. But, fortunately for consumers in the US, these regional price shocks do not last very long, since weather-related demand shocks are short-lived, and the depth of the US market provides substantial liquidity through which price differences are quickly arbitraged. As we shall argue below, the strength in Asian LNG price coincides with the unexpected increase in demand that occurred in the wake of the disaster at Fukushima on March 11, 2011, and the subsequent shutdown of the entire Japanese nuclear power generation fleet. This demand shock created tightness in the LNG market that dramatically influenced the spot price of LNG in Asia. However, as new capacity emerges to deliver supplies into the Pacific basin market and/or nuclear capacity in Japan is restarted, the short-term tightness will be alleviated, which should have a countervailing effect on price.

We begin with a discussion of US LNG exports as a classic problem in international trade. This will allow us to assess the likely future of price in the Asian LNG market couched in the context of *international* trade. We then present results from the Rice World Gas Trade Model (RWGTM)[3] in order to highlight the effect of a deepening global gas market on the price of natural gas in Asia. This, of course, has implications for the attractiveness of other energy options, such as expanded use of coal, oil, and even nuclear power in the electricity generation mix in the longer term.

Asian LNG Price in a Basic Trade Paradigm

We begin, as in Medlock (2012), by considering the issue of the future of Asian gas pricing in the context of an international trade model. In Figure 1, we have a domestic and a foreign market in an autarkic equilibrium, that is, one in which there is no trade between the two markets. The supply-demand equilibrium in the domestic market yields a price below that of the supply-demand equilibrium in the foreign market. If the spread between the two prices, which would be denoted as $P^{*f} - P^{*d}$ in Figure 1, exceeds the cost of liquefaction, shipping, and regasification, it leads to an "arbitrage opportunity" that can be exploited through trade.

If the price spread between the foreign and domestic markets is large enough to cover the costs associated with trade between the two markets, then there is sufficient economic incentive for trade. In Figure 2, we see the impact on price in both markets if trade occurs such that the domestic market sees exports of x and the foreign market sees imports of m, where $x = m$. Price rises in the domestic market and falls in the foreign market. If not constrained by policy, such as quotas or tariffs, an equilibrium will be reached in which price in the two markets differs only by the cost associated with trade, indicated as τ in Figure 2.[4]

Figure 1. Domestic and Foreign Market with No Trade

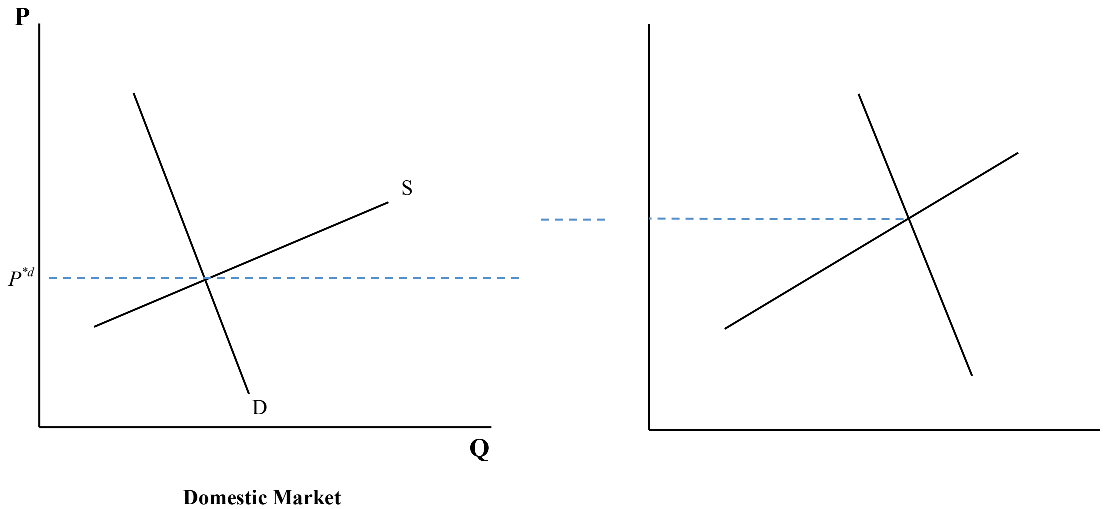
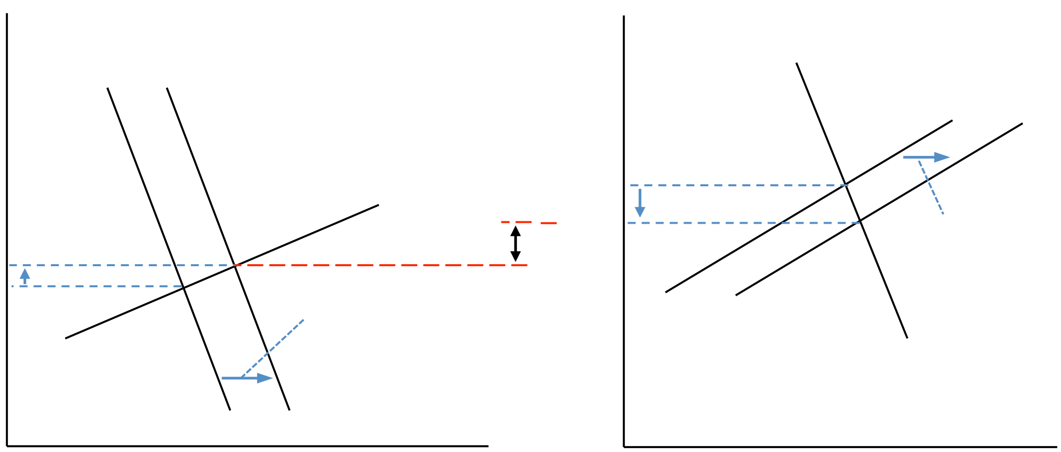


Figure 2. Domestic and Foreign Market with Trade



In general, theory tells us that in the long run, as market participants seize arbitrage opportunities, prices will adjust to reflect the cost of arbitrage. In the short run, demand shocks and other transitory factors may present what appear to be profitable arbitrage opportunities. But these will generally be fleeting, and will not support large capital investments necessary to facilitate trade.[5]

From the Short Run to the Long Run

Framing the effect of short-run constraints on apparent trade opportunities requires a modification of Figure 2. Namely, we can capture the impact of a sudden, unexpected demand shock in the foreign market alongside a relatively abundant supply in the domestic market. This is effectively the situation we currently see between the US and Asia.

Supply abundance in the domestic market would be captured by a highly price-responsive, or elastic, domestic supply curve.[6] According to the Baker Institute study "Shale Gas and US National Security," the elasticity of supply in the United States is fairly high for prices between \$4 and \$6 per mcf.[7] Importantly, this elasticity of supply so characterized for the US is a *long-run* elasticity. We use this when considering the price impact of *expected* events, such as the opening of an LNG export terminal, because it is a more appropriate representation of supply responsiveness. Producers know the additional market "demand" in the form of exports is coming because the opening of the terminal is public knowledge. Thus, the additional demand for US-produced natural gas in the form of exports abroad should not be treated as a surprise, which is what using a short-run elasticity in this instance effectively does.

In the foreign market, we have to first recognize the impact of an unexpected demand shock, such as is the case in the wake of Fukushima. Following the tsunami, the resulting nuclear accident sparked concerns that ultimately led to the closure of all of Japan's nuclear power generating capacity and resulted in a dramatic increase in Japanese demand for LNG. This increase in demand is captured in Figure 3 with a move from *D* to *D'*. We must also recognize in the short term that there is a constraint on the ability to deliver supplies (where the constraint is represented by the vertical portion of the supply curve, *S*). It takes time to develop new supply capacity, and a sudden, *unexpected* increase in demand can result in binding short-term capacity constraints. The situation can be especially pronounced when storage capacity is lacking and/or there is an inability to physically hedge against unexpected events.

The impact of the sudden demand increase in Japan led to a large increase in the spot price of LNG in Asia. In fact, the Platts Japan/Korea Marker price, which is the benchmark daily assessment of the spot price for cargoes of LNG delivered ex-ship to Japan or Korea, increased by over $2 per mcf in the week following the incident at Fukushima and continued to climb in the following months, along with the shutdown of all of Japan's nuclear power generation plants.

Figure 3. The "Foreign" Market for Natural Gas

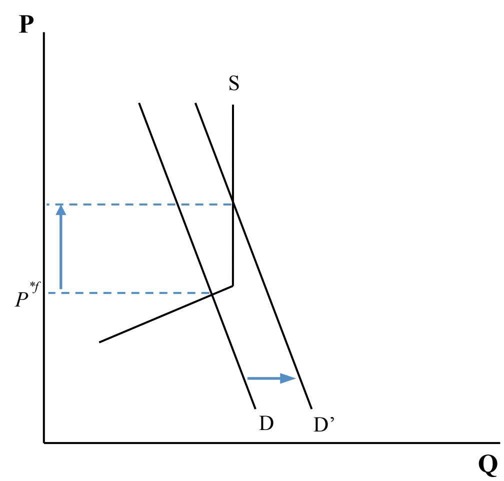
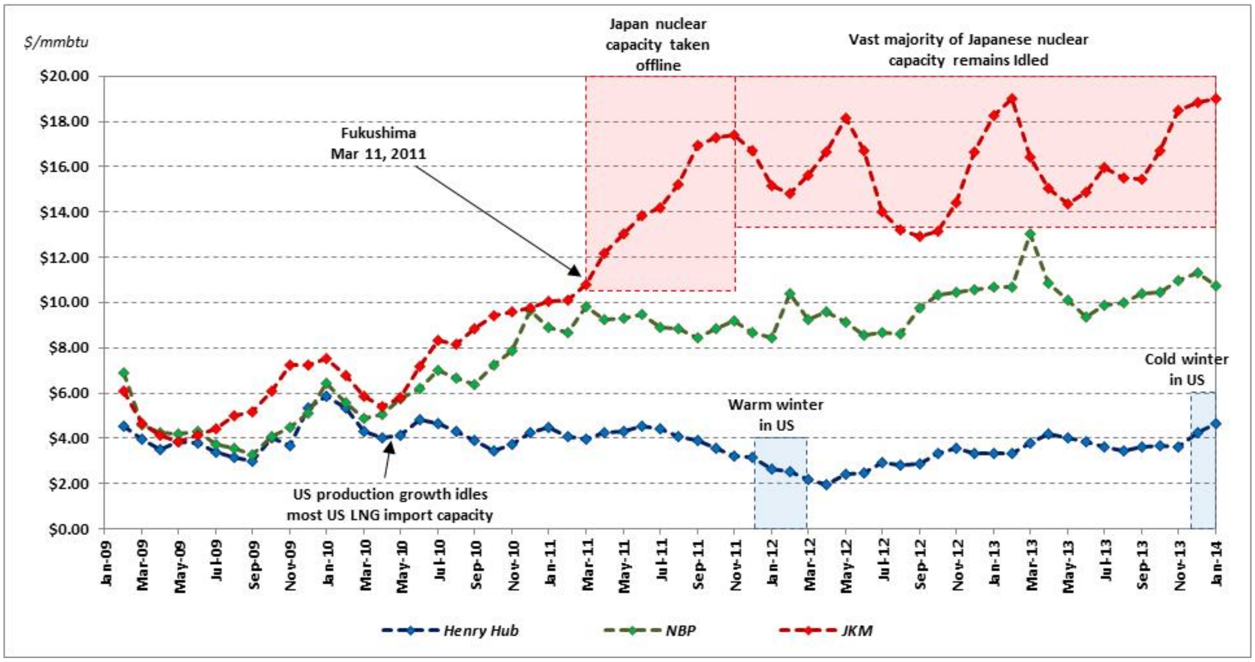


Figure 4 indicates the monthly average prices of natural gas at the US Henry Hub (HH), the UK National Balancing Point (NBP), the Platts Japan/Korea Marker (JKM), and a representative crude-indexed LNG price from 2009 to the present. Following the nuclear incident at Fukushima and the subsequent shutdown of all of Japan's nuclear reactors, the JKM price ventured into unprecedented territory. In fact, as can be seen in Figure 4, JKM climbed markedly relative to both NBP and HH after Fukushima, with the spot price approaching oil-indexed parity. It is also worth noting that the standard deviation of the spread of daily prices between NBP and JKM is over two times higher post-Fukushima. Higher price and higher price volatility are both indicators of the realization of a constraint on the ability to deliver supply to the Asian market.

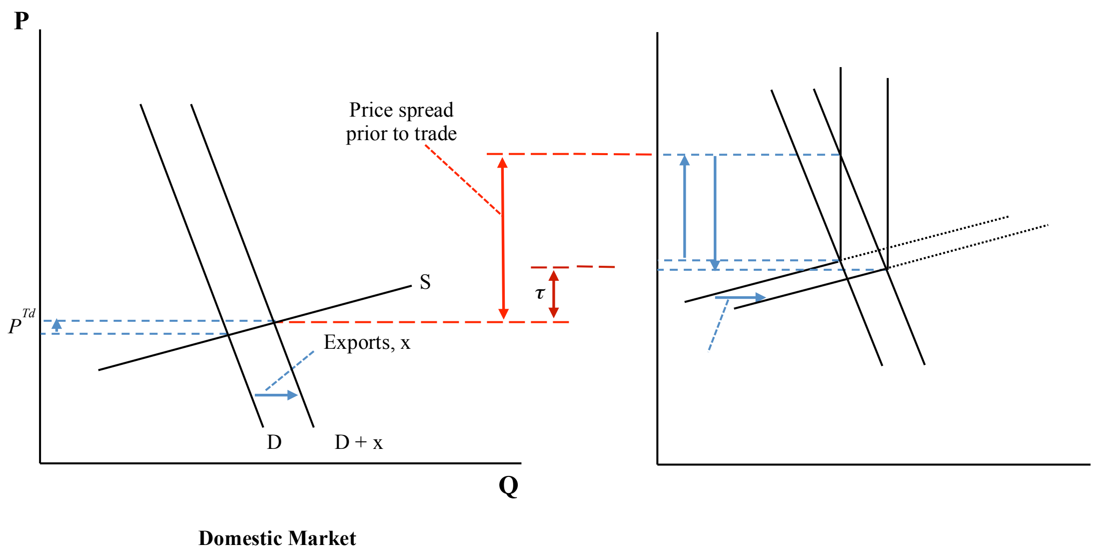
Figure 4. Global Marker Prices Annotated (Monthly, February 2009–January 2014)



Sources: Platts, US Energy Information Administration

In general, if we add supply to a supply-constrained market, the price in that market will fall precipitously, all else equal. In the case of the Asian natural gas market, supply will be added—whether in the form of LNG exports from the US or from other sources of supply via pipeline or LNG—because the current price spread is more than adequate to encourage such a response. We see in Figure 5 that the price paid by LNG importers in Asia will fall substantially when the short-term constraint on the ability to deliver supply is abated. If we take the "foreign" market in Figure 5 to represent the Asian gas market, the addition of LNG, or any other supplies for that matter, will have a large effect on Asian LNG price, even if the demand shock, Δ, is not reversed. If Japan's nuclear power generation fleet is brought back into commission, the downward movement in price would only be exacerbated. Of course, the resultant downward pressure on price in Asia will ultimately determine the amount of trade that actually occurs, but, more importantly for this exposition, any new supply will reduce price in the supply-constrained Asian market.

Figure 5. The Impact of Trade on the Asian Price



Importantly, the *relative* elasticities of supply and demand will determine the extent to which prices change in each of the traded markets. In particular, if the market abroad is short-term supply-constrained (meaning supply is inelastic) and the domestic market is supply-elastic, then the majority of the price movement that will occur when trade is introduced will be abroad. To the extent that the current price difference between Asia and the rest of the world is due to transitory factors that result in the realization of supply constraints, or short-term inelasticity, the current price differential will only persist until there is some offsetting influence. Thus, the pre-Fukushima pricing relationship between JKM and NBP can be expected to reemerge as (i) new LNG supply capability is developed, (ii) new sources of pipeline supply to Asia are developed, and (iii) Japan's nuclear reactors are restarted.

One final but important point regarding the effects of increased trade pertains to market liquidity. As the Asian gas market deepens with new sources of supply being introduced, an ability to arbitrage regional price differentials will push prices into relative ranges defined by transportation costs. It is the lack of capability to arbitrage current regional price differences, or lack of physical liquidity, that allows regional prices to drift apart dramatically. If the US develops export capability, an additional arbitrage mechanism will be introduced, and all else equal, this will force a shift in the relative prices of gas in markets around the world to long-run equilibrium differentials that are defined by transportation costs and currency values.[8] This will impact more than just the trade at the margin, or spot price. As discussed in Hartley (2014),[9] greater liquidity will also reduce the willingness of consumers to pay prices above marginal cost for supplies. This will, in turn, have direct implications for oil indexation as a pricing paradigm in the Asian market.

Implications for Market Liquidity and the Pricing Paradigm

When a profitable arbitrage opportunity exists, excessive rents can only persist in the long run if suppliers—regardless of location—are willing to forego the fixed costs associated with expansion to capitalize on the opportunity. With regard to the Asian LNG price, this means the current differentials can only persist if US producers are willing to forego future LNG export capacity expansion in the face of large rents, or if they are prevented through policy action from doing so. It would also be necessary that all other supplies—East African LNG, Russian pipeline gas, etc.—either also be prevented from delivering supply to Asia, or be more costly to deliver to Asian consumers than US supply. In the latter case, the current price in Asia could be viewed as accurately reflecting the marginal cost of non-US resources delivered to Asia. Moreover, in this case, only US suppliers could realize rents by serving the Asian market.

It is highly unlikely that such a specific set of restrictive conditions exists. Given the current push to develop LNG export terminals in the US, it is evident that developers will seek to capture profits associated with LNG exports to Asia in spite of the high upfront costs. Moreover, the quantity and cost of supply around the world indicate that there is a large amount of natural gas that could be delivered to Asia at well below the current price. This is particularly true in regions with high quantities of associated liquids—such as in currently producing areas in the Middle East and North and West Africa—and is likely true in regions with newly identified resources that are not currently exporting LNG or pipeline supplies to Asia—such as East Africa, South America, and Russia. Already, developers in those regions are directing development activities toward serving Asian demand. To varying extents, there are policies and institutional factors that may inhibit development in some regions, but these are not universal; thus, a supply response to the current high price environment can be reasonably expected.

Given the nature of the supply constraint in Asia, one should expect the emergence of multiple competing opportunities to provide natural gas supplies to Asia. Examples could include development of shale resources in China; pipeline options from Russia, Central Asia, and South Asia; and LNG supplies from Australia, East Africa, the Middle East, and North America. As detailed above, the current arbitrage opportunity is being aided by short-run *inelasticity* of supply to Asia, but this cannot be expected to persist in the long run because of the number of different potential supply options.

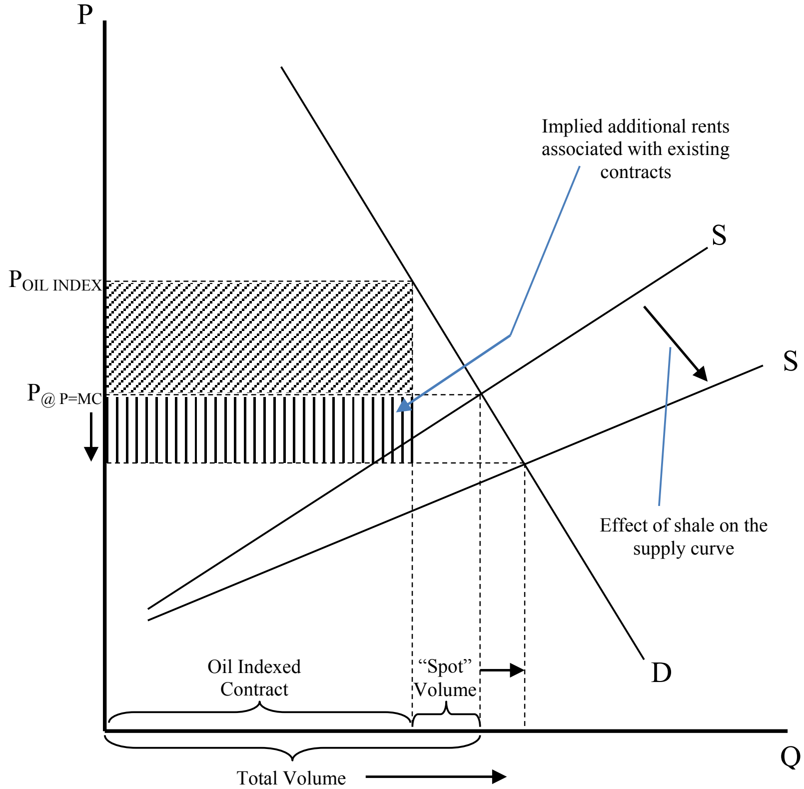
Analysis at the Baker Institute indicates that Asian natural gas prices will likely soften relative to their current levels. This reflects:

- Longer-term shale developments in places such as China and Australia will become commercially attractive in price environments in excess of $10 per mcf. Indeed, wide-scale success in shale development in China could be as transformative to the global gas market as the successes in North America have been over the past decade.
- The development of pipeline supplies from Russia, Central Asia, and South Asia to China will displace the need for LNG into China, all else equal. This frees up those LNG supplies for consumers in Korea and Japan. Thus, pipeline supplies serve as another point of competition for LNG longer term, particularly in developing continental markets.
- Furthermore, if the Japanese nuclear situation reverses and we see the reactivation of the nuclear power generation fleet across the country, the currently constrained market equilibrium will be alleviated just as if new supplies are brought to bear. Arguably, the current price of natural gas delivered to Japan is a catalyst in this direction. If the nuclear generation fleet is reactivated, it will serve to accelerate the pace at which prices adjust downward, particularly if the demand for LNG falls just as new supplies are made available. In essence, the market would be forced into an excess capacity situation and price would be driven down as competition for customers would be intensified.

All of these factors support the thesis that growth in trade in the Asian market will foster market deepening and increased liquidity. As demonstrated in Hartley (2013), this will, in turn, support a movement away from the traditional pricing paradigm of long-term oil-linked contracts. This follows because growth in market liquidity reduces the risk of being able to secure supplies. As long as oil price remains above the price of various new natural gas supply options, the willingness to pay above marginal cost due to security-of-supply concerns is diminished (see Figure 6). In fact, Brito and Hartley (2007)[10] show that as physical liquidity increases, the ability of any single supplier to set a price above marginal cost is diminished. This, all else equal, will mean oil indexation is likely to lose its prominence. Importantly, there is no guarantee that movement away from oil indexation will result in natural gas prices falling longer term relative to crude oil; rather, a lack of oil indexation should only mean that gas will be priced according to its marginal cost. It should be noted that *contract* prices can be substantially different from *spot* prices. As indicated in Figure 6, in this case, one can think of contracted supplies as being inframarginal and the result of price discrimination.

In general, for a firm to be able to price discriminate, (1) it must be able to distinguish consumers and prevent resale, and (2) its consumers must have identifiable and different elasticities of demand. An increased ability to trade (i.e., increased physical liquidity) violates condition (1). This is more likely to happen as the supply curve in Figure 6 becomes more elastic (flatter). It is also prone to happen in a liberalized market where trading is unfettered because price signals communicate arbitrage opportunities that can be captured. This promotes entry and, to the extent that hubs develop, financial liquidity. Once that occurs, the means to use capital markets to underwrite physical transactions increases and liquidity grows, thus making it difficult to price discriminate. As liquidity increases along with the long-term elasticity of supply, the rents associated with inframarginal contracts also increase, which in turn triggers calls for renegotiations of terms between producers and consumers.

Figure 6. The Supply Curve Effect of More Elastic Supply and Implications for Price



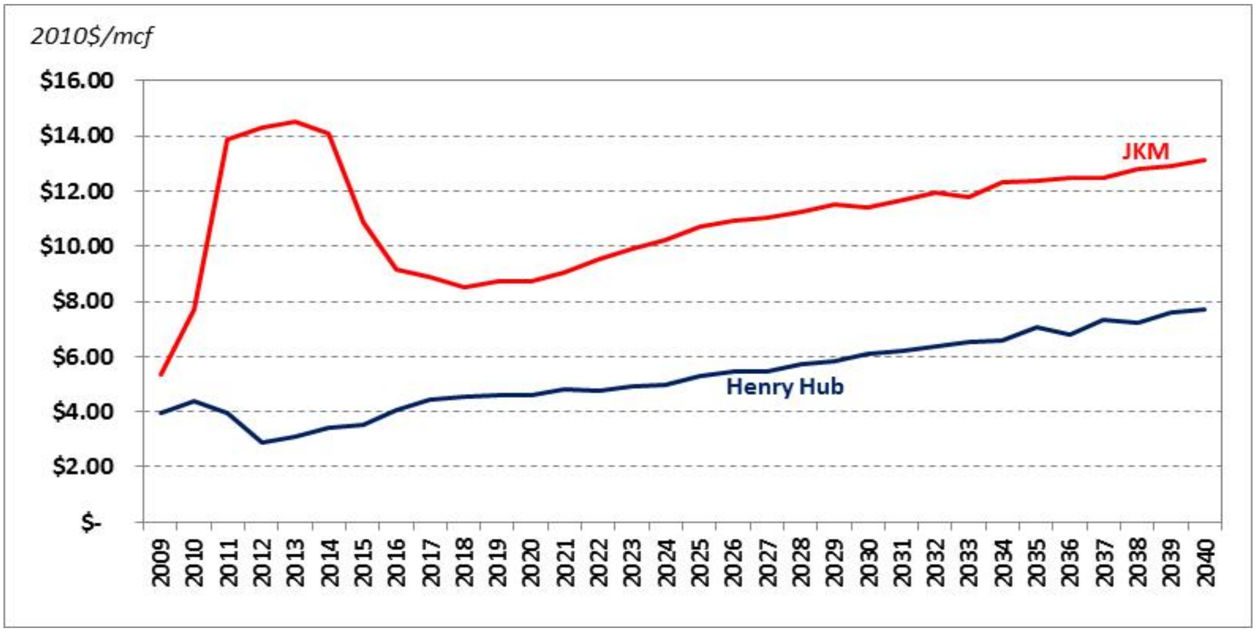
Relatively high prices in Asia have already encouraged producers to begin investigating the opportunity for profitable shale development in those markets. The initial forays into shale in Asia and other regions have proven to be more costly than what has been experienced in the US. Much of this is due to the lack of a well-developed upstream service sector, which means there is limited availability of equipment and personnel. However, as those sectors develop, encouraged by sustained demand pull from increasing upstream activity, the current high costs should prove transitory. Accordingly, the prospects for longer-term shale development in places such as China, Australia, and Argentina—the latter two of which could serve the Pacific basin via LNG—look promising. In fact, a recent Baker Institute analysis revealed that shale gas developments in China could be equally as game-changing over the next couple of decades as shale gas developments in North America have been in the last decade.[11]

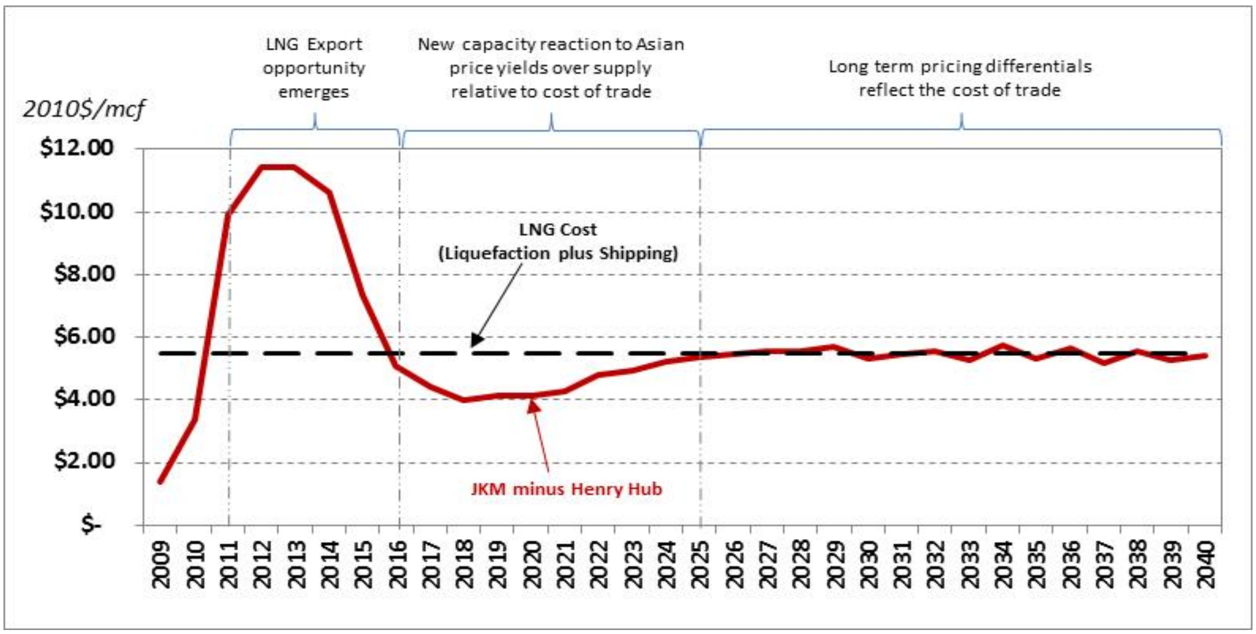
Altogether, the evidence is substantial that the long-run supply curve outside of North America is much more elastic than the current market indicates, and development of these supplies will put downward pressure on Asian natural gas price. Of course, geopolitical and regulatory uncertainties and constraints could overwhelm commercial considerations, but even if these "above-ground" constraints do exist, they would have to be substantial, widespread, and persistent given the number of competing supply opportunities that exist in the longer term.

The Long-Term Price in Asia

According to analysis using the Rice World Gas Trade Model (RWGTM), the differences between the JKM price and Henry Hub will contract as new supplies are introduced into Asia. Figure 7 indicates the long-term prices at JKM and Henry Hub, as well as the price spread juxtaposed against the cost of trade between the two markets.

Figure 7. Long-Term Projection of Prices and Spreads in Asia and the US





Source: RWGTM v.Feb2014, Medlock

We see in Figure 7 that on an annual basis, the current price differential is eliminated when new LNG supplies come to market from the US and Australia. Exacerbating matters in this exercise is the assumption of the slow reactivation of the Japanese nuclear fleet from 2015 through 2019. Importantly, however, the majority of the spot price movement is the result of new supplies being brought to bear, as the price impact is most dramatic between 2014 and 2017. Shale development in this case does not materialize in China in a meaningful manner until the mid- to late-2020s. Hence, domestic supply options are not driving the compression of the price spread between Asia and the US. In addition, while Russian pipeline supplies are ultimately developed to serve Chinese demands, they do not matriculate into service until after 2018. Thus, the only real, meaningful impetus for the compression of the Asian premium is the relaxation of the constraint to serve the Asian market with the emergence of LNG supplies. In the long term, US LNG exports approach 5.5 billion cubic feet per day, and the price spread between the US and Asia settles in at roughly the cost of trade, covering liquefaction and shipping.

There are, of course, numerous assumptions that are contained in any model simulation—such as assumptions about economic growth in different countries that translate into demand outlooks—but the results presented herein are robust to a number of differing scenarios.[12] In fact, in the results presented herein, the model indicates significant market deepening as LNG trade roughly doubles over the next decade and continental supply sources to Asia also begin to emerge via pipeline from Russia and shale development in China. Altogether, this translates into greater market liquidity and will foster the emergence of trading hubs in Asia,[13] which will in turn promote financial liquidity and begin to transform the manner in which prices are formed in Asian natural gas trading.

Concluding Remarks

The global gas market is in a period of transition that has been prompted by the emergence of shale in North America. In fact, the emergence of shale in the US turned the LNG market upside-down in a matter of a decade, as the consensus view that the US would be a major LNG importer transformed into one of the US becoming an LNG exporter. This has occurred against a backdrop in the global gas market in which the spot prices of natural gas delivered in Europe, Asia, and the US diverge dramatically from long-standing historical relationships.

The wake of the disaster at Fukushima triggered an unexpected rise in demand for waterborne LNG supplies. Constraints on the ability to meet the unexpected demand shock resulted in the spot price of Asian LNG rising to unprecedented levels relative to other global spot price markers. This phenomenon is not unprecedented, as we have seen similar circumstances in the continental North American market, when extreme cold grips certain regions and drives up local demand in excess of what existing pipeline capacity can deliver. For example, an extreme cold weather event in the Northeast has been known to trigger the daily price in Boston (at Algonquin City Gate and TGP Zone 6) to jump more than $70 per mcf above the price at Henry Hub because pipeline capacity is not sufficient to meet the sudden surge in heating demand. This is often referred to as a "basis blowout." Fortunately for consumers in the affected regions, these price shocks are short-lived and subside when the cold weather event passes. Moreover, the depth of the US market provides substantial liquidity through which price differences are quickly arbitraged as the supply constraint is relaxed.

Unfortunately for Asian consumers, the Asian market price will not come back down until something is done to alleviate the constraints on deliverability, such as a demand reduction or the introduction of new supplies. Such an adjustment will take time to materialize because Japanese nuclear capacity is not being reactivated quickly, and construction of new LNG capacity is plagued with long lead times. However, as new supplies come online and/or nuclear capacity in Japan is brought back up, we should see a return in the Asian LNG spot price to a level that is consistent with a globally arbitraged price. Indeed, the current high price in Asia is causing most prospective LNG developers around the world to hone their focus on being able to deliver to the Asian market.

The eventual emergence of new suppliers in the global gas market makes it paramount to consider what the increased trade in LNG will do to the nature of pricing. As the US becomes an LNG exporter, the effects on global markets could be profound. The global gas market will deepen and become physically linked to the most liquid continental natural gas market in the world. This should in turn promote greater trade and ultimately alter the liquidity paradigm that has dominated the Asia-Pacific market, which will in turn alter the manner in which natural gas is priced in Asia. Moreover, when this happens, it will likely do so quickly; after all, the rise to current price levels in Asia relative to prices elsewhere happened in only six months, a fact often forgotten in the discussion about future pricing in Asia.

Even if, ex post, the compression of the JKM-Henry Hub price differential renders US LNG liquefaction investments less profitable than forecasts suggest, the establishment of a link from US supplies to foreign markets will have potentially dramatic implications. A direct link between the US and abroad will only serve to accelerate international market liquidity, thereby lowering liquidity risk. This could, all else equal, alter the financing risk of LNG projects and lower the importance of oil-linked bilateral relationships. In any case, as the story continues to unfold, the international gas market will evolve into something dramatically different from what it is today.

Finally, the spot price in Asia will remain relatively high until there is investment in new gas delivery capability or nuclear capacity in Japan is reactivated. When new supply is added or demand is reduced, thereby alleviating the deliverability constraint, price in Asia will fall very quickly. The transition will occur more quickly as market liquidity deepens once new supplies emerge. This is reflective of the manner in which constraints affect markets. As expounded above, global supply today is highly inelastic, meaning any movement in demand or additional supply will have substantial ramifications for price. The simulations in the RWGTM indicate the near-term constraints contributing to short-term price pressures will likely be alleviated in the next couple of years, thus yielding significant downward pressure on price. In the longer term, price should settle at a level reflective of the marginal cost of supplies delivered into Asia, averaging $10 to $12 per mcf for the next couple of decades. This brings up a final important point: there will not be a "single price" for gas. Rather, there will remain regional price differences reflective of transportation costs, which is indeed a long-standing characteristic of the very liquid and efficient US natural gas market.

Notes

1. See Kenneth B. Medlock III, Amy Myers Jaffe, and Peter R. Hartley, "Shale Gas and US National Security," Baker Institute Policy Report 49, October 2011, available online at http://www.bakerinstitute.org/news/shale-gas-and-us-national-security.

2. See Kenneth B. Medlock III, "US LNG Exports: Truth and Consequence," James A. Baker III Institute for Public Policy, August 10, 2012, available online at http://bakerinstitute.org/research/us-lng-exports-truth-and-consequence/.

3. The Rice World Gas Trade Model is developed on the MarketBuilder software platform from Deloitte MarketPoint. It is available to the Baker Institute through an academic license agreement. All model characterizations of infrastructure as well as all data inputs for demand, supply, and infrastructure and development costs have been independently developed by Kenneth B. Medlock III and Peter Hartley at the Baker Institute Center for Energy Studies.

4. Henceforth, we refer to the sum of liquefaction and shipping simply as "transport costs" or the cost of trade.

5. As an illustrative microcosm of the principles of trade theory in practice, we can consider what occurs in the US domestic natural gas market. Arbitrage opportunities occasionally present themselves as large differences in regional prices. If pipeline capacity is sufficient between the two regions, marketers will quickly eliminate the pricing difference through trade by scheduling shipments across the pipeline. If pipeline capacity is not sufficient, pipeline developers will evaluate the opportunity to add capacity. In particular, if the regional price differences are due to short-term factors, capacity will not generally be added. But if the regional price differences are due to more structural elements, then capacity will generally be added. In either case, the responsiveness of price to trade in both regional markets is a critical determinant to the capacity investment decision.

6. Note that we do not focus on the elasticities of demand, because in both the domestic and foreign markets, demand is being driven by growth in power generation requirements. Given the lack of technological differences, the availability of competing fuels, and the fact that demand for natural gas is relatively own-price inelastic in all major end-use markets—generally varying between 0.15 and 0.3 according to Baker Institute analysis—we focus instead here on the relative elasticities of supply. In fact, allowing for variable elasticities of demand will tend to reinforce the results herein.

7. Indeed, that study indicates the price elasticity of supply, post-shale, has risen over fivefold, from 0.29 to 1.52. "Shale Gas and US National Security" was sponsored by the Office of International Policy and Affairs of the US Department of Energy. The study was released in June 2011, and is available online at http://www.bakerinstitute.org/news/shale-gas-and-us-national-security.

8. Although not explored in this exposition, currency values are important to determining price differentials because natural gas is not delivered to end-users in a common currency denomination. See Medlock, "US LNG Exports: Truth and Consequence," for more on this issue.

9. See Peter Hartley, "The Future of Long-Term LNG Contracts," James A. Baker III Institute for Public Policy, October 31, 2013, available online at http://bakerinstitute.org/research/future-long-term-lng-contracts/.

10. Peter Hartley and Dagobert Brito, "Expectations and the Evolving World Gas Market," *Energy Journal* 28, no. 1 (2007): 1-24.

11. The Baker Institute paper "Quantitative Analysis of Scenarios for Chinese Domestic Unconventional Natural Gas Resources and Their Role in Global LNG Markets" by Kenneth B. Medlock III and Peter Hartley revealed that shale gas development in China could be as game-changing in the coming years as shale gas developments in North America have been in the last decade. The study is available online at http://bakerinstitute.org/research/quantitative-analysis-of-scenarios-for-chinese-domestic-unconventional-natural-gas-resources-and-the/.

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12. This is detailed in the Geopolitics of Gas study done jointly by Rice University's Baker Institute and Harvard's Kennedy School. The study papers are available online at http://bakerinstitute.org/research/geopolitics-natural-gas/.

13. Indeed, the RWGTM simulations indicate the possible emergence of a notional hub in Shanghai, with a physical presence for hub services emerging at Xian in the Southern Ordos Basin. This is facilitated by multiple sources of gas moving through the area longer term from Russia, Central Asia, and domestic sources. A connection to the coast provides a touch point for competition between these supply sources and waterborne LNG, which only serves to enhance liquidity in the region.