

LNG, Globalization, and Price Volatility: Understanding the Paradigm Shift

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by

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I. Introduction

Since 2000, the capacity to import liquefied natural gas (LNG) into the United States has expanded dramatically. In fact, consensus thinking within the North American natural gas industry was that sources of natural gas supply from abroad would be needed to meet a growing demand for the relatively clean-burning fossil fuel. As such, during the first decade of the 2000s many investments were made to expand LNG potential to North America, with as many as 47 terminals in the permitting phase at one point. Since 2000, 2 terminals were re-commissioned and expanded (Cove Point in Maryland and Elba Island in Georgia) and 9 others have been constructed. This has increased LNG import capacity from just over 2 billion cubic feet per day (bcfd) in 2000 to just over 17.4 bcf currently, and import capacity could reach 20 bcf by 2012.

The move to expand LNG import capabilities has not been limited to the United States. Tremendous growth in LNG import capability has also been seen in Europe. In 2000, European LNG import capacity was just over 7 bcf, but now it is over 14.5 bcf and could exceed 17 bcf by 2012. Asia already has a large LNG footprint, with Japan and South Korea being the two largest LNG consumers globally. But, the Asian footprint is set to expand, largely due to the emergence of China in the global economy.

Of course, the expanded capability to deliver LNG to multiple markets is removing the traditional paradigm – one in which the Asian, European and North American natural gas

markets were largely disconnected from one another. In fact, growth in LNG has led to a growing interconnectedness between these previously regionally disconnected markets. This has, in turn, raised energy security concerns. In particular, might the US natural gas market be more exposed to a cutoff of Russian supplies to Europe? One might think so if the event resulted in more LNG flowing to Europe as it is diverted from other destinations. This effectively transmits (by displacement) the supply reduction from Russia as supplies bound to other markets are disrupted.

Energy security refers to the notion that economic dislocations are associated with disruptions in energy supply and thus should be avoided. Diversification of supply is one means of reducing the probability and hence expected cost of a disruption to energy supply. The ability to access a diversity of energy supplies to meet demand and avoid any economic dislocation is a crucial component of any energy security argument. Specifically, diversification provides the ability to substitute between different types of energy resources, which substantially reduces the risk associated with a disruption in supply of any one type of fuel.

The concept of diversification also refers to the ability to draw upon multiple sources for a single fuel. For example, any temporary market shortage – perhaps due to a weather-driven increase in demand or disruption in supply deliverability – can be overcome if there is an easily accessible alternative source of the same fuel. This, in turn, mitigates the risk associated with uncertainty in demand or supply. Therefore, diversification of suppliers is beneficial for energy security, a fact that Europe has become all too familiar with over the past decade as tensions revolving around natural gas payments have mounted between Russia and Ukraine.

When discussing energy security we often discuss either the level of price or the volatility of price. Neither of these metrics is sufficient when linking to energy security. Rather, *unexpected* changes in the supply-demand balance (and hence price) are what generate difficulties at the macroeconomic level. Regular variation in price, provided there exists a means of mitigating risks through well-functioning forward markets, are not disruptive.

Thus, it is incorrect to argue that prices that are highly variable but in a regular manner are more problematic than prices that are very stable for a period of time then suddenly change. In fact, investment planning is much more difficult in the latter case, and it has been shown in various studies that unexpected changes in price have a much larger negative impact (see, for example, Lee et al (1995)).

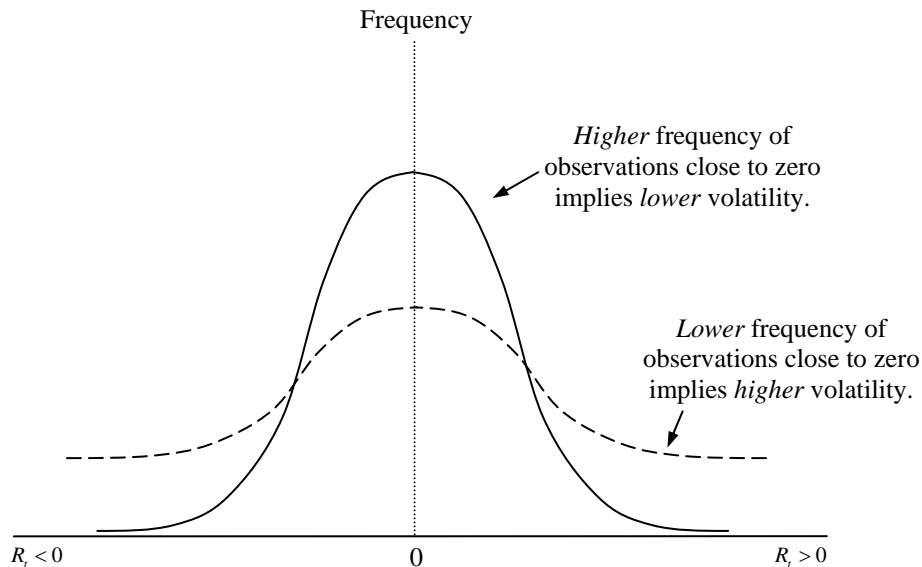
Given the preceding, the focus is often on measures of price volatility, where volatility is defined simply as the relative rate at which price moves up and down. Price volatility can be found by calculating the annualized standard deviation of the periodic (daily or weekly usually) changes in price. Typically, this is done by examining the distributional characteristics of the time series of the log return of price, defined as $R_t = \ln P_t - \ln P_{t-1}$. If price changes rapidly over short periods of time then values of R_t will be large and price is said to have high volatility. On the other hand, if price is not changing very much then R_t will be near zero and price is said to have low volatility. So, if the density function of R_t has what we call “fat tails” then it is said to exhibit a lot of volatility (see Figure 1).

If the probability density function of R_t looks more like the dashed line in Figure 1, the measure of volatility (usually the standard deviation of R_t) will typically be higher. It may also be the case that volatility occurs in clusters, and, if so, then we may have a price series that is characterized by periods of low volatility (realizations of R_t centered on zero) with periods of high volatility interspersed (realization of R_t that are substantially different than zero, either negative or positive). It is generally these periods of high volatility that are of concern, particularly when they are unexpected.¹ Moreover, it is precisely these periods which we seek to avoid, if possible, because they are associated with negative macroeconomic consequences. Increased uncertainty associated with high

¹ In these cases a time series estimation known as GARCH (generalized autoregressive conditional heteroskedasticity) is employed for analysis. *Unexpected* shocks are then defined as those price changes that move outside a particular interval (such as one standard deviation), where the interval is conditional on the estimation results.

volatility has been linked to changes in firm behavior, which translates to reduced investment, increased unemployment, and lower output (see Dixit and Pindyck (1994)).

Figure 1: Density functions of low and high volatility time series



If high volatility leads to negative outcomes, then one reaction would be to simply set price at a particular **level**. Of course, the negative consequences of such a policy intervention are well known. In particular, the information carried in price movements would be muted, which can lead to inefficient levels of investment and consumption. Usually, such situations are found to be unsustainable (a recent example is noted with regard to Iranian domestic energy policy in Brumberg et al (2008)). As a result, designing policy that addresses price volatility can be difficult at best.

The general approach to dealing with price volatility in most liberalized markets has been to establish forward markets. This allows market participants an opportunity to hedge against undesirable price movements while not masking the information carried in price signals thereby promoting efficient levels of investment. Of course, there are many who have questioned the role of futures exchanges in facilitating such a goal, especially in light of the extremely high volatility generally seen in all commodity markets in 2008.

Another approach to curb any negative influence of extreme volatility taken by governments has been to develop strategic stockpiles. This practice is common in crude oil markets. The effectiveness of this policy, however, is largely dependent on how governments use these stocks. There is much debate in the US, for example, regarding when it is appropriate to use the Strategic Petroleum Reserve (SPR). Some have argued that the high prices of 2008 could have been somewhat mitigated by releasing supplies from the SPR. Others, however, argue that the high prices were the result of market conditions, not a geopolitical intervention, so governments should remain neutral. In particular, if the oil is released to respond to a market-driven condition, then the government runs the risk of being short of supply in the case of a geopolitical disruption. Since the latter, it is argued, is the principle reason the SPR was established, market intervention is not a justified use of the SPR. In addition, if government begins to use its stocks to effectively constrain movements in market price, the development of commercial inventories could be discouraged by masking the return that could be earned otherwise.

The questions regarding the development and appropriate use of strategic inventories is far from settled. Nevertheless, it is a well-established principle that inventories generally reduce volatility, a point which we will demonstrate below. This, in fact, is very important in understanding how increased LNG import capacity and increased connectedness among regional natural gas markets may influence price volatility in the US.

The manner in which price is determined in other markets is also important. For example, pricing that has historically been dominated by oil-indexed contracts in Europe and Asia is very different than what is observed in North America. How does this affect prices in North America? Is oil-indexation expected to persist in a truly *global* gas market? What do recent developments indicate on this front? These questions will also be explored below.

In addition to understanding the role of storage in mitigating price volatility and the manner in which globalization of gas markets may interact with traditional regional pricing schemes, the principle questions examined in this paper are:

- What are the potential impacts of North American LNG imports/exports on North American natural gas price volatility? What are the mechanisms by which LNG flows could affect price volatility? Have we observed this to date, i.e. – what do the data indicate?
- Given the relative abundance of shale gas in North America, is there any reason to believe that LNG imports will rise in the coming years? If so, is there any benefit or potential detriment to this occurring?
- In the US, how do LNG, the domestic shale gas resource, and domestic storage interact? In particular, do they contribute to price volatility or not, and are regional impacts different than what is seen at the Henry Hub?
- If there are any potential adverse impacts of globalized gas trade and increased LNG imports, are there policy options available to mitigate the adverse impacts?

The answers to the questions posed are, for the most part, left at this point to theoretical exercise, largely because developments regarding LNG and shale are both relatively recent. Analysis of time series data is simply not sufficient to glean insight because the emergence of shale and the growth in LNG imports have not been observable features of the market for a sufficiently long period of time. In essence, we are living through a structural change in the North American natural gas market that is likely to have ripple effect around the globe (see Hartley and Medlock (2010)). Such a paradigm shift inevitably leads to many questions about what the future may hold, but the data required to analyze such questions is very limited. However, there are, fortunately, theoretical models that lend themselves to addressing these types of questions. Hence, that is where we will begin. Then, we can look for corollaries in the historical data, such as regional effects of new major pipelines or other infrastructures, to test hypotheses.

This paper is organized as follows. First, we will introduce a simple model for a storable commodity. This will enable us to discuss the role of storage, the role of production

capacity, and the role of imports in price determination. Second, we will examine price data for delivery locations where large import infrastructures have been developed. Thus, we will consider the opening of the Alliance pipeline, expansion of the Northern Border Pipeline, and the recommissioning of the LNG import terminal at Cove Point, Maryland. These projects should lend themselves to analysis of what import capabilities mean for price volatility. Third, we will consider the effect of globalization of gas market, and things such as oil-indexation of LNG contracts and the role of long term contracts. Finally, we will discuss how policy may or may not play a role in mitigating any detrimental impacts of globalization of natural gas markets.

II. A Framework for Analysis: A Stock-Flow Model for understanding pricing dynamics in a market for a storable commodity

To understand the potential influence of changes in import dependence, it is important to first understand the mechanism by which price is determined in a market for a storable energy commodity. Such models have been used to explore such things as the influence of futures markets on spot prices (see Kawai (1983) and Jacks (2007) for example). In what follows, we will present the basic framework using a simple graphical representation in order to demonstrate concept.

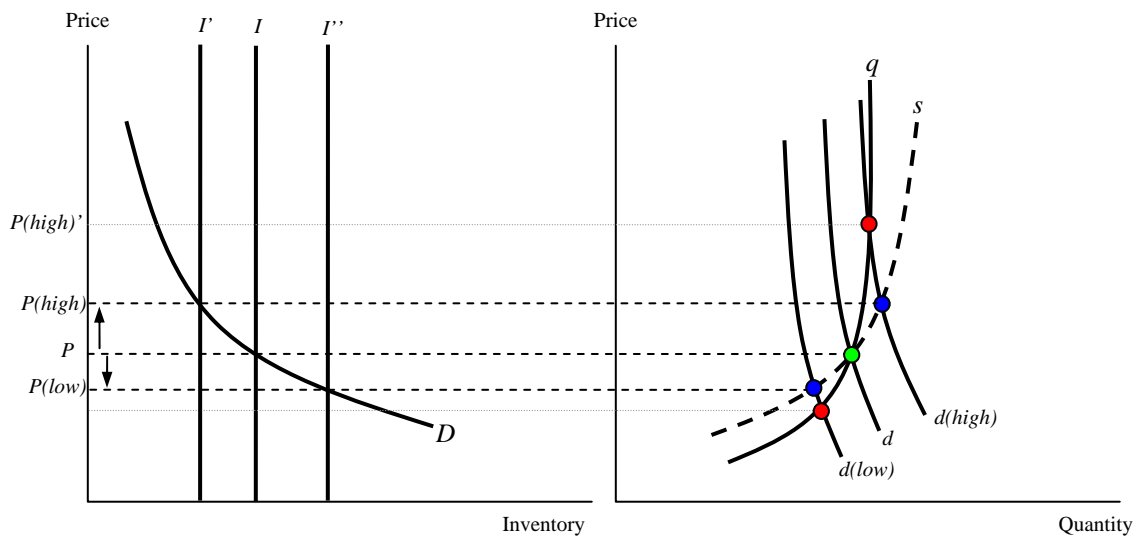
To begin, let there be two markets – an inventory (or “stock”) market and a “flow” market – in which price is simultaneously determined. The stock market represents the market in which inventories are valued against the demand for *future* supply. This provides the vehicle through which the expected future price and current price are linked. (In markets with an actively traded futures market, the “stock” market provides the link to realizations of the forward curve at any moment in time and the spot price.) So, expectations can influence price by altering the demand for inventories (or perceived value of supply in the future).

The “flow” market represents the current delivered supply and end-use demand of natural gas. Thus, it is simply the market clearing price that arises as a result of daily trade in the

physical commodity. This is the very standard partial equilibrium representation of market supply and demand that we are used to seeing when a product is not storable. Importantly, the “stock” market and “flow” market must clear at the same price.

In order to understand how this fits together, let’s consider the graphical representation of the natural gas market depicted in Figure 2. The level of inventory in the stock market is fixed at any point on time and denoted as I . The demand for inventory is given as D , and is downward sloping to reflect the notion that as the spot price, denoted as P , falls the profitability of holding inventories to be sold in some later period rises. This is the classic “but low – sell high” notion, and it holds particularly well if demand in the flow market changes on a regular basis.

Figure 2: A graphical representation of the “stock-flow” model



The demand and supply curves in the flow market are d and s , respectively. Inventories either expand or shrink depending on the position of the demand curve in the flow market relative to production, where production capability is denoted by q . To illustrate, let demand in the “flow” market change on a seasonal basis, such that in the winter the demand for natural gas increases from $d \rightarrow d(\text{high})$ but decreases to $d(\text{low})$ in shoulder

months. Thus, for a given production schedule q , there will be periods where demand is greater than production capability and periods when demand is below production capability. Absent an ability to augment production with natural gas from inventory via withdrawal, price would increase to $P(\text{high})'$. However, inventories provide an ability to augment production, and thereby dampen price volatility, when demand increases. Specifically, when price rises inventory is drawn down, so that $I \rightarrow I'$, and production in the flow market is augmented by the withdrawal from inventory. Accordingly, supply to the “flow” market is given as $s = q + \Delta I$ where q is current production and ΔI is the change in inventory. Notice, since we can use inventory to enhance production in the flow market, price only rises to $P(\text{high})$, which is much lower than $P(\text{high})'$. Importantly, if the initial level of inventory is reduced, then $s \rightarrow q$ price will begin at a higher level and generally rise to a higher level when demand increases. In the limit, if inventories are non-existent, then $s = q$ and we have much larger price swings from low to high demand periods.

By analogy, when demand falls toward $d(\text{low})$ we see that price will decline. This will encourage injections into inventory thus taking production out of the flow market. As a result, price does not decline as much as it would if there was no storage capability. In general, storage acts to buffer price movements in response to stimuli to demand and supply.

Importantly, the size of the change in inventory is positively related to the initial level of inventory and storage capacity. So, as storage capacity increases, the possible size of injections and withdrawals rise, thereby flattening the supply curve in the flow market. However, this does not necessarily mean a larger storage capacity is desirable. In particular, a flatter supply curve will render seasonal movements in price smaller. This, in turn, would at some point render storage capacity commercially unviable.²

² This follows because the incentive to store is related to the profitability of buying in a low demand period and selling in a high demand period. As prices in the two periods move closer to one another, the incentive to inject into storage is diminished. This results in lower utilization of storage capacity (when capacity is

An important aspect of the stock-flow model pertains to expectations. In particular, the position of the curve depicting demand for inventories, D , in the stock market is largely dependent upon expectations about future market conditions. For example, if there is concern that supplies in the next few months might become scarce, perhaps due to an active hurricane season or a colder than normal winter, then demand for inventories will increase. This will tend to drive price up today. To the extent this happens, it should create an excess supply condition in the flow market, thereby resulting in injections to storage which keeps price from rising wildly. However, if adequate injections to storage do not occur, perhaps due to extreme market tightness, then price will continue to rise until inventories can be filled. Note this also means that the futures curve moves into steeper contango, hence the link between inventories, the futures market and spot price. In particular, to the extent that the spread between current spot price and the price on the forward curve is what determines storage injection and withdrawal, then the demand for inventories curve, D , will be a function of the shape of the forward curve.

III. LNG Imports and Natural Gas Price Volatility

Building on the model presented in the previous section, let's consider the effect of greater import capacity. This will tend to render our problem a bit more complicated, but tractable nonetheless. Import capacity modifies the supply curve in the flow market in much the same manner as changes in inventory, so that we have $s = q + \Delta I + m$, where m denotes the quantity of imports.³ In addition, we assume imports generally increase as domestic price rises as long as, of course, the foreign price is not also rising. In the case of rising foreign prices, imports will not increase. In the limit, we are left with $m = 0$ such that $s = q + \Delta I$, which is just the result from the simpler model presented above.

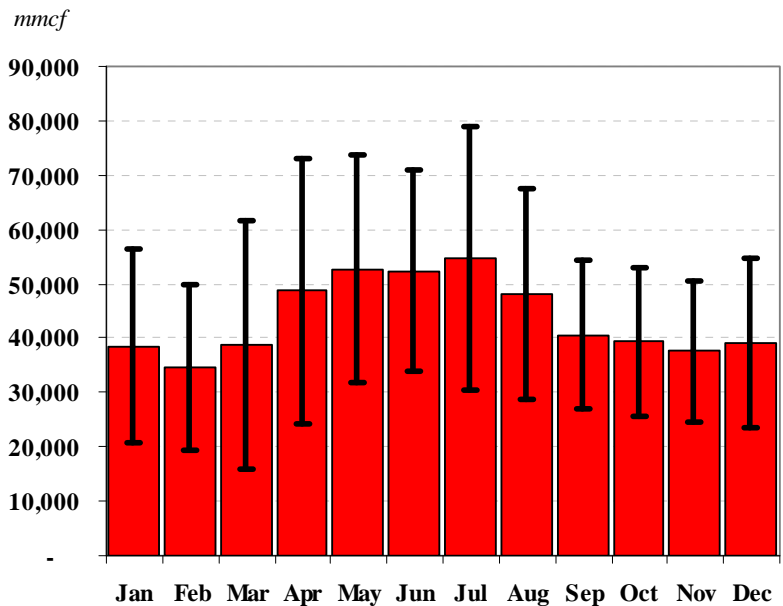
sufficiently large), which in turn renders that capacity unprofitable. This point is, in fact, often raised with regard to government stockpiles being a disincentive for commercial stocks.

³ Note that we could more directly link to import capacity by allowing $m = u \cdot M$ where M denotes import capacity and u denotes capacity utilization, but this complication is only necessary if we want to make distinction between capacity and utilization.

Given the sensitivity of imports to the relative price in the domestic and foreign markets, we can have situations in which imports are positive *and* there are, at the same time, injections to inventory. This is a possible outcome, in particular, when domestic storage capacity is vary large, and foreign storage capacity is not. In particular, the oversupply condition in the flow market *abroad* should divert supplies to the domestic market because adequate storage capacity will tend keep price from falling as far domestically in low demand periods. Thus, given storage capacity in the US relative to Europe and Asia, it is reasonable to expect LNG cargoes to flow to the US market in low demand periods, especially because low demand periods are coincident in the Northern Hemisphere.

In high demand periods, however, low storage capacity in the foreign market will mean upward pressure on price in the foreign market is greater. This will tend to reduce imports to the domestic market, meaning price will tend to be mitigated by storage withdrawals rather than imports. Thus, it is reasonable to expect LNG flows to the US in high demand (winter) periods to be reduced, as it will be directed to meet higher loads in Europe and Asia where storage capacity is relatively limited.

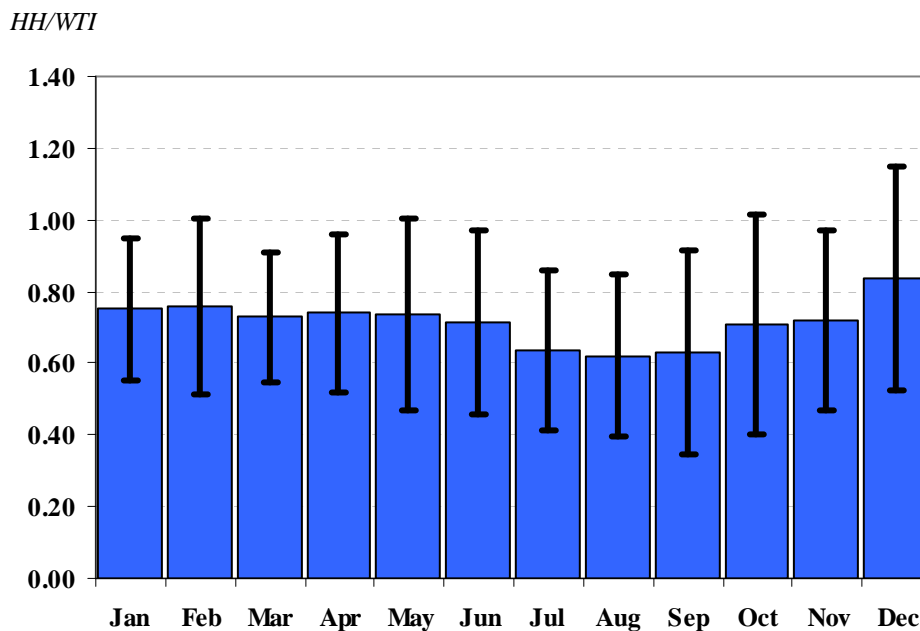
Figure 3: Average Monthly LNG imports to the US (1/2002-2/2010)



Data Source: US Energy Information Administration, Author's Calculations

Figure 3 depicts the average of LNG imports to the US by month since January 2002. A clear pattern is evident – one in which summer month LNG imports exceed winter month LNG imports. This is consistent with behavior as predicted by the stock-flow model. Also graphed in Figure 3 are the standard deviations by month of LNG imports. Again, a pattern is evident. One obvious question to ask is whether or not the seasonal movements in LNG imports have contributed to price volatility.

Figure 4: Average Monthly Henry Hub normalized on WTI (1/2002-2/2010)

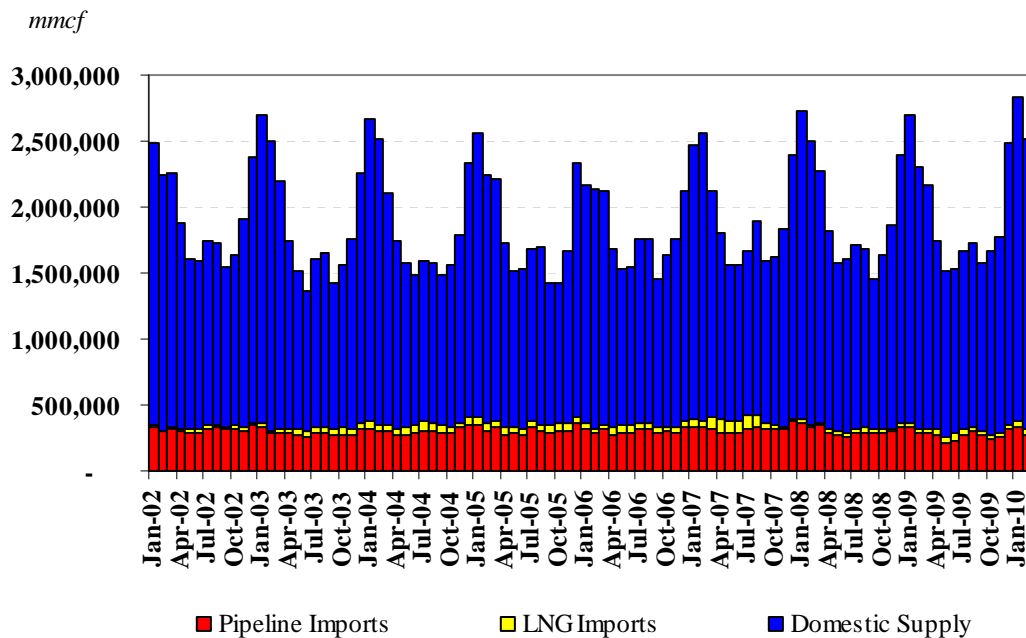


Data Source: US Energy Information Administration, Author's Calculations

Figure 4 graphs the average monthly price at Henry Hub divided by WTI (in \$/mmbtu) for the period January 2002 through February 2010 along with the monthly standard deviation. Normalizing on WTI is done to control for any movements in world oil price that drive changes in natural gas price (see Hartley, Medlock and Rosthal (2008)). The lowest average monthly natural gas prices, once normalizing for the price of oil, occurs in July and August, which also happen to coincide with higher LNG imports. Moreover, the standard deviations of the monthly prices are relatively low in July and August, which indicates that higher LNG imports are correlated with lower variation in price. It is

important to point out here that this is simply a *correlation*, so the nature of *causal* influences cannot be discerned. Nevertheless, the evidence is at least consistent with the stock-flow theoretical framework. Namely, higher imports tend to dampen volatility because they flatten the domestic supply curve, particularly when imports increase in a traditionally low demand period.

Figure 5: The Relative Scale of LNG Imports (1/2002-2/2010)



Data Source: US Energy Information Administration, Author's Calculations

Despite the preceding discussion, it is important to maintain perspective in the historical record. In particular, the quantity of LNG imports in any given month is still very small relative to pipeline imports from Canada, and even smaller when compared to monthly demand, variation in which is driven largely by weather. Figure 5 – which indicates total monthly demand (the height of each bar in the graph) and the manner in which it is met via LNG imports, pipeline imports and domestic production plus net withdrawals from storage (other) – summarizes this point. Specifically, monthly LNG imports from January 2002 to February 2010 have averaged 12.6% of all US imports (pipeline plus LNG), with a maximum of 25.5% and a minimum of 2.3%. In addition, monthly LNG imports have averaged 2.4% of total demand, with a maximum of 6.3% and a minimum

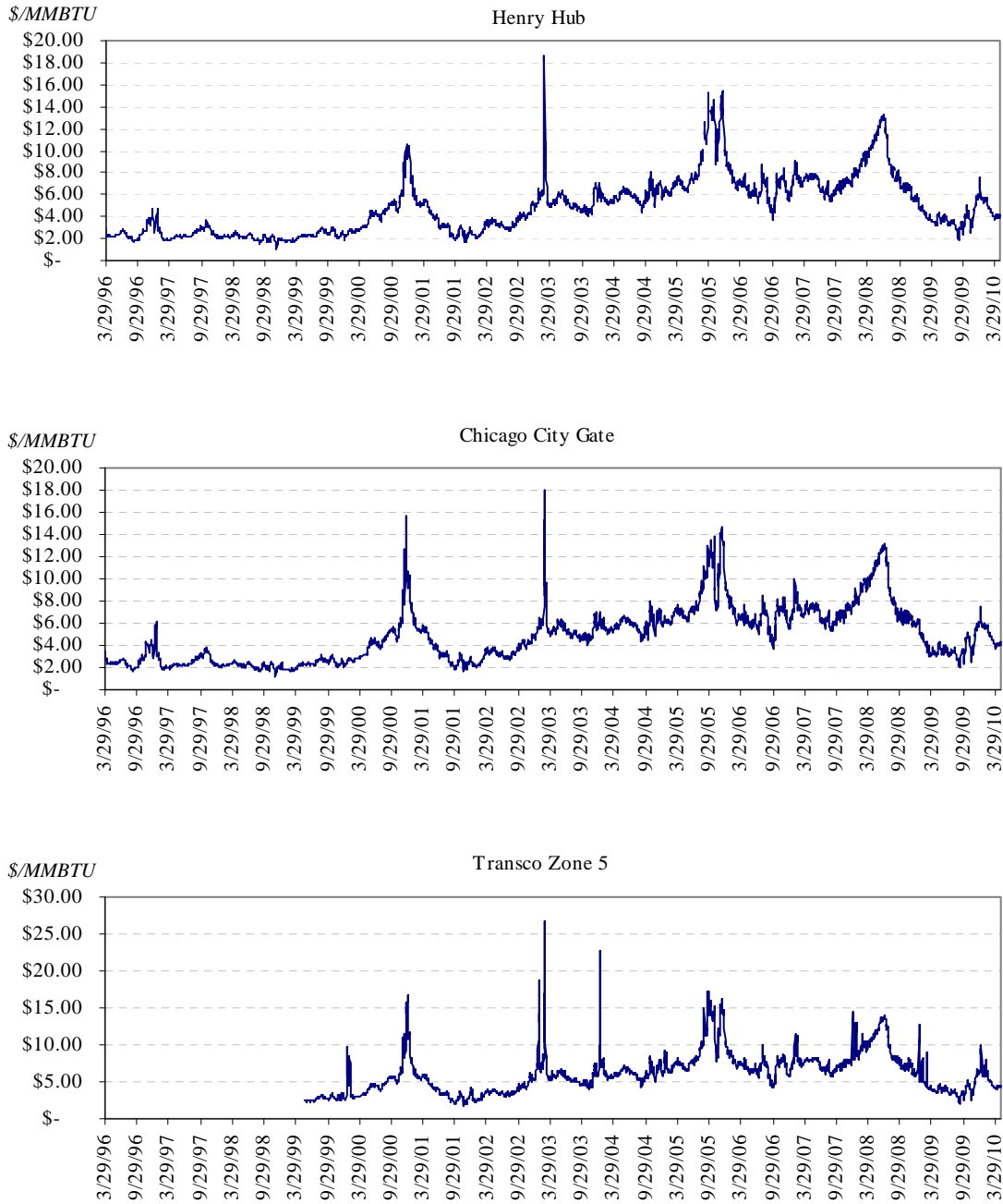
of 0.3%. Also of note is the fact that the maximum quantities of LNG imports relative to total imports and total demand occurred in the summer of 2007, which was a relatively low demand period. In sum, it is more likely that monthly changes in demand and the ability of storage to meet demand variation are much more important than LNG imports in the historical context with regard to observed volatility in price. Notwithstanding the relative elasticities of demand and supply, in the context of the stock flow model this indicates that the influence of changes in inventory, ΔI , far outweighs the influence of imports, m , particularly the small portion of total imports that consist of LNG.

IV. Regional Microcosms of Increased Import Dependence

Despite the relative unimportance of LNG imports in the historical context, it goes without saying that the future may be very different. In particular, if the LNG import share of total demand were to increase, we could see stronger influence of LNG imports on market price. So, it can be valuable to examine microcosms of this where available. Fortunately, we can test whether or not there have been discernible effects on regional prices of particular events – the opening of the Alliance pipeline and Northern Border pipeline and the effect of each on the Chicago gas market, and the regional impact of reopening the LNG import terminal at Cove Point, Maryland.

Figures 6 through 9 indicate the prices and log returns of daily prices at the Henry Hub, the Chicago City Gate, and the price at Transco Zone 5, respectively. Also indicated in selected figures are the points in time when both the Alliance pipeline and the Northern Border Pipeline began deliveries to the Chicago market area (with respect to price at Chicago City Gate), and the period when Cove Point LNG terminal was reactivated (with respect to price at Transco Zone 5). The Henry Hub price is included as a point of reference.

**Figure 6: Daily Price at Henry Hub, Chicago City Gate, and Transco Zone 5
(3/1996-4/2010)**



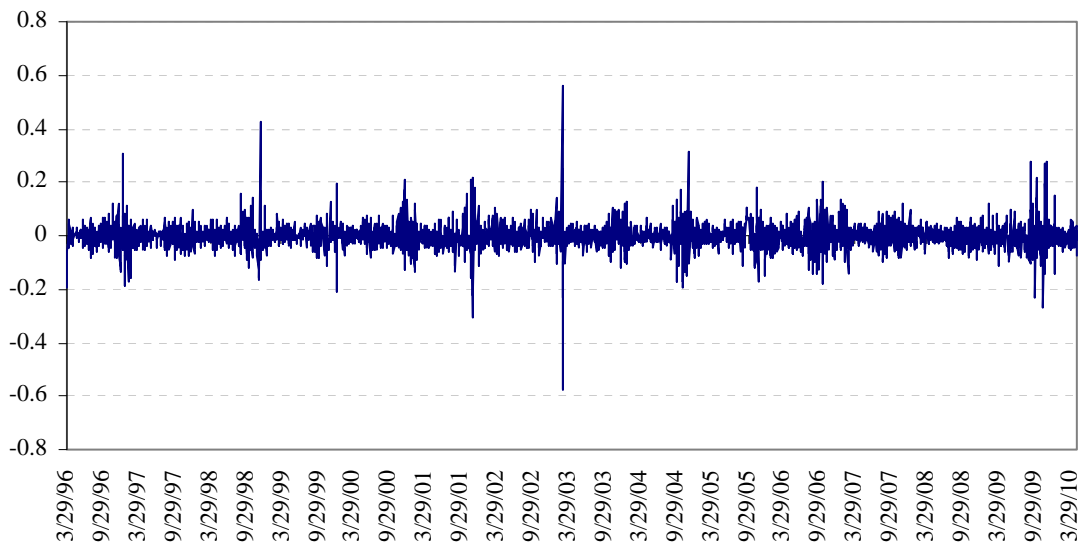
Data Source: Platts

Focusing first on Henry Hub price, with the exception of the middle of 2005 and 2008, price increases tend to occur during winter months when demand rises. In fact, the

extreme price movements observed in the winters of 2000-2001 and 2002-2003 occurred during extreme cold periods. The price increases in middle of 2005 are related to the extremely active hurricane season which resulted in substantial reduction of production in the Gulf Coast region. The price increase of 2008 coincides with the general spike in commodity prices, when oil prices peaked at over \$147 per barrel. With the exception of the price increase in 2008, the periods of major volatility tend to be associated with constraints that arise due to rapid increases in seasonal demands or sudden disruptions in supply.

We can see the influence of these strong upward movements in price in the log returns of Henry Hub (see Figure 7). There is an almost regular increase in volatility during winter months, a fact motivated by increased demand. The extreme departures from zero identify those periods where price volatility was rather high.

Figure 7: Log Returns of Daily Henry Hub Price (3/1996-4/2010)



Data Source: Platt's, Author's Calculations

Table 1 indicates the annualized volatility at Henry Hub, Chicago City Gate, and Transco Zone 5 for selected time periods. The reference time periods are chosen around Northern Border expansion in November 1998, the commencement of flows on the Alliance

pipeline in December 2000, and the re-commissioning of Cove Point in June 2003. The annualized volatility at each location is indicated before and after each of these infrastructure developments.

Regarding the Chicago City Gate, we can see in Table 1 that the annualized volatility increases after both the Northern Border expansion and the Alliance in-service date. However, the observed volatility is highly correlated with volatility at the Henry Hub (the log returns have a correlation of 0.865). In fact, we see that the annualized volatility increases at the Henry Hub as well.

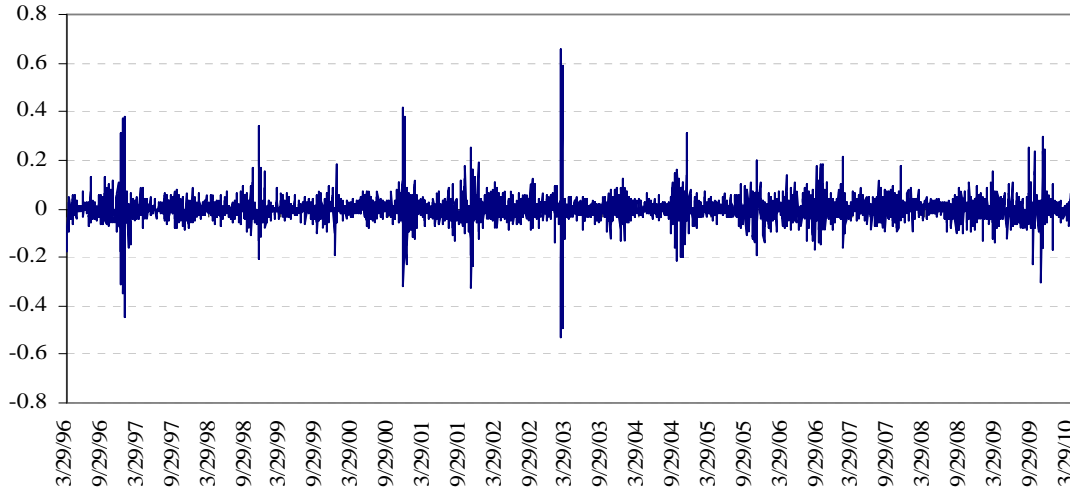
Table 1: Annualized Volatility of Regional Natural Gas Prices for Select Periods

	Henry Hub	Chicago	Transco Zone 5
<i>entire sample</i>	0.0482	0.0547	0.0825
<i>pre-Nov 1998</i>	0.0412	0.0531	---
<i>post-Nov 1998</i>	0.0497	0.0550	---
<i>pre-Dec 2000</i>	0.0415	0.0481	---
<i>post-Dec 2000</i>	0.0513	0.0577	---
<i>pre-Jun 2003</i>	0.0503	0.0592	0.0895
<i>post-Jun 2003</i>	0.0460	0.0495	0.0781

Data Source: Platts, Author's Calculations

Figure 8a depicts the log returns of the Chicago City Gate price for the entire sample, and Figure 8b depicts the log returns for the sample in the month preceding and month following the event of interest. There is a period of extreme volatility that roughly coincides with the opening of Alliance (mid-December 2000). However, a sharp increase in volatility also occurs at the Henry Hub and Transco Zone 5 locations (see Figures 7 and 9a). Given that the increase occurs in multiple locations that are not all directly connected it is difficult to argue that the opening of Alliance is the cause. Rather, an increase in cold weather coupled with below normal storage levels is the more likely culprit, as this would have a much broader market impact.

Figure 8a: Log Returns of Daily Chicago City Gate Price (3/1996-4/2010)

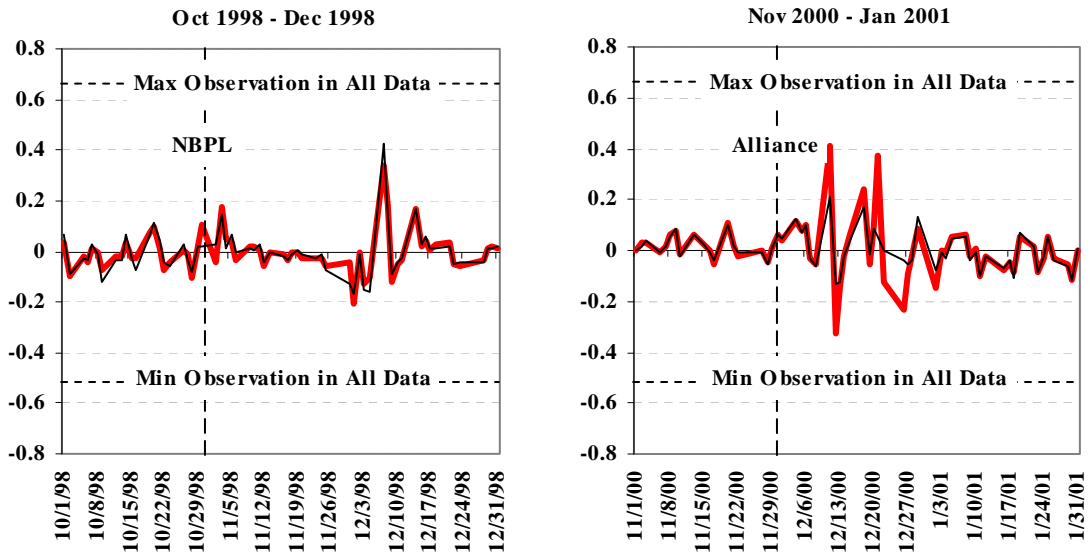


Data Source: Platt's, Author's Calculations

Figure 8b: Log Returns for select periods at Henry Hub and Chicago City Gate

Note: The thin black line is the Henry Hub data and the thick red line is the Chicago City Gate data.

The date of infrastructure opening is indicated by the name of the facility.



Data Source: Platt's, Author's Calculations

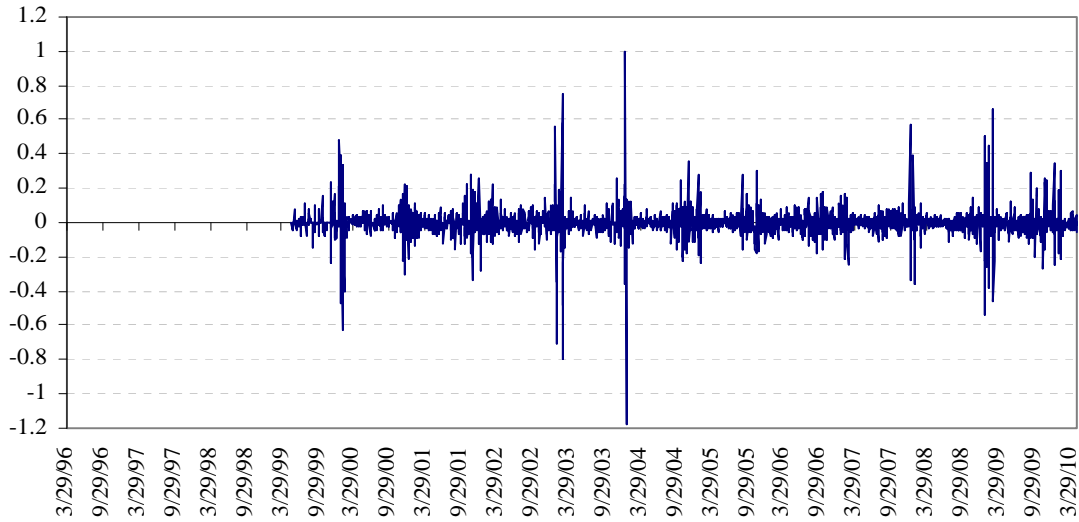
Deliveries to the Chicago area from the Northern Border Pipeline via the Natural Gas Pipeline Company system began in 1992, which predates the available daily data.⁴ However, the expansion in November 1998 increased deliverability by almost 700 mmcf per day. Volatility does increase in December 1998, but this is highly correlated with an increase in volatility at the Henry Hub, indicating it – just as with Alliance – is in response to some macro stimulus, such as weather and/or inventory levels, instead of being related to the Northern Border pipeline expansion.

With regard to price at Transco Zone 5, the time series is shorter since data are not available prior to May 1999. But, for the available data, there is a reasonably strong correlation (0.63) between the log returns of the price at Henry Hub and the log returns at Transco Zone 5, albeit not as strong as that between Chicago and Henry Hub. One primary factor for the lower correlation is the fact that the volatility at Transco Zone 5 is generally much higher than at Henry Hub (see Table 1). This is an artifact of the differences in seasonal price movements at the two locations.

We are interested specifically in the impact of re-commissioning Cove Point LNG in the summer of 2003. As the facility was being reintroduced to service, there was concern expressed by marketers that pipeline take-away capacity would not be sufficient to handle the additional supplies of natural gas that were thought to be forthcoming. This was not an issue. In fact, volatility has declined substantially since June 2003. While this has also happened at Henry Hub and Chicago, the decline in volatility is much larger at Transco Zone 5. In the winter of 2003-2004 do we see an uptick in price volatility with a very sharp increase in price to over \$22 per mmbtu on January 14, 2004. However, this was a very short lived phenomenon related to extreme cold temperatures that drove an increase in demand and stressed available pipeline delivery capacity to Middle Atlantic markets.

⁴ The pipeline was delivering to Ventura in Iowa for many years prior to 1992.

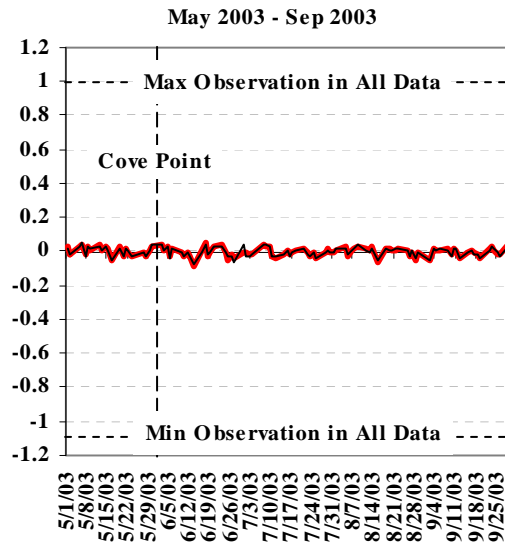
Figure 9a: Log Returns of Daily Transco Zone 5 Price (3/1996-4/2010)



Data Source: Platt's, Author's Calculations

Figure 9b: Log Returns for select a period at Henry Hub and Transco Zone 5

Note: The thin black line is the Henry Hub data and the thick red line is the Transco Zone 5 data. The date of infrastructure opening is indicated by the name of the facility.



Data Source: Platt's, Author's Calculations

It is apparent from the data, even in this relatively non-technical exploration, that there are not any significant impacts from the opening of these major regional import facilities. In fact, none of the cases show a substantial *increase* in volatility that can be related to the commencement of operations of the specific import infrastructure. Rather, annualized volatility at Chicago following the Alliance in-service and at Transco Zone 5 following the re-commissioning of Cove Point LNG actually declined *relative* to overall market volatility (as measured at Henry Hub). In addition, it is apparent that volatility is more closely related to broad market stimuli – as indicated by the high correlation of the price volatility at Chicago and Transco Zone 5 with price volatility at Henry Hub – and demand-driven pipeline capacity constraints – as indicated by generally higher winter volatilities in the Chicago and Transco market areas.

V. Globalization and the Role of Oil-Indexation

Admittedly, the three examples discussed in the previous section do not comprise a *complete* list. Nevertheless, from the examples considered there is no apparent influence on price volatility from the opening of a major import facility. This, in fact, follows if local demand and/or additional transportation infrastructure is developed (or already adequate) so that the import supply does not create any infrastructure constraints. In such a case, the price is transmitted away from the local point, thereby diminishing the local area impact of the new imported supply. This can occur because the North American pipeline grid is sufficiently flexible and the market sufficiently liquid that the capability to redirect supplies through displacement is very high. Thus, understanding the degree of physical liquidity is very important to understanding the manner in which new sources of supply will impact a market.

Globalization of natural gas markets will certainly lead to a situation where events in one region of the world will influence outcomes in other regions (see Hartley and Medlock (2006)). However, the interconnectedness of the global market also provides additional avenues for mitigating singular disruptions. Of course, if globalization of gas markets leads to greater dependence on supplies from regions with a history of volatility, then the

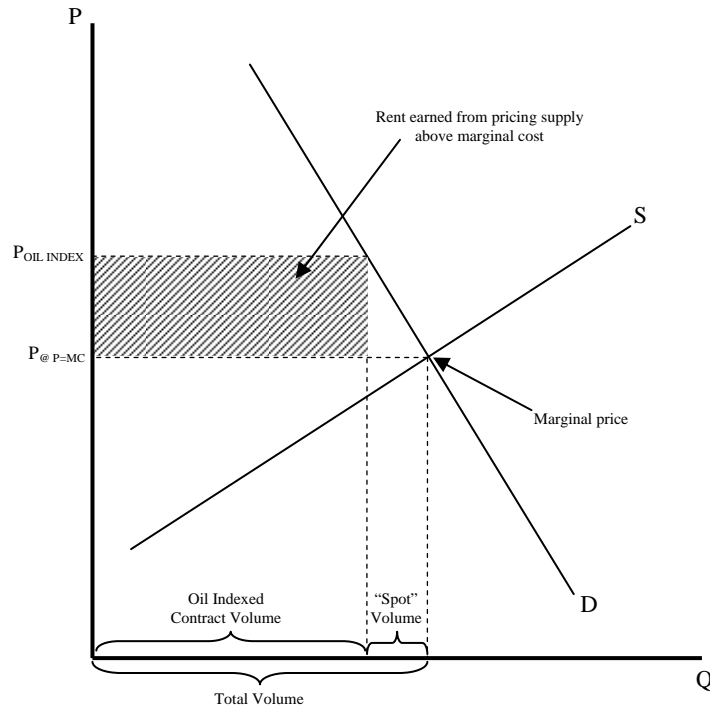
likelihood of supply disruptions on a global scale may increase. This, in turn, could make storage capabilities much more important if large movements in price are undesirable.

Oil indexation of gas prices in markets outside North America can also play an important role if LNG takes a larger share of the North American market. For example, in a perfectly rigid oil-gas price relationship, the price of natural gas would move lockstep with the price of crude oil products in international markets. As long as the price of natural gas in North America remains below this price, then imports will be at a minimum. However, if North American demand increases beyond indigenous supply capabilities, then price would have to rise to reflect international oil-indexation practice plus transportation costs in order to attract LNG. In this case, all markets would be explicitly or implicitly linked to the price of oil, which means that all factors influencing crude oil price would matriculate into the natural gas price. This, would, of course, render natural gas price volatility to be very closely related to crude oil price volatility.

The preceding result relies critically on two major assumptions. The first is that the relationship between natural gas and crude oil is “perfectly rigid” in European and Asian markets. The second is that growth in the LNG market does not trigger changes to market structure. This latter point is certainly worth exploring in light of the developments of the last decade in international gas markets.

One particular aspect of natural gas markets that we are beginning to see change concerns the nature of natural gas pricing. In Europe and Asia, LNG volumes have traditionally been nominated using oil-indexed terms. To be sure, oil-indexation is a form of price discrimination. In the presence of price discrimination, a certain quantity of demand is supplied at a price above marginal cost. In Figure 10, the oil indexed volume accounts for roughly 80% of delivered volumes. If the demand curve is more inelastic, then this share can be much higher, and if demand is more elastic, the share will generally be lower.

Figure 10: Price Discrimination and Oil Indexation



Two basic conditions are required for price discrimination:

1. The seller must be able to distinguish consumers and prevent resale.
2. Different consumer groups must have different elasticities of demand.

Both of these conditions have been historically met in Europe and Asia, but not in North America. In general, as the ability to trade between suppliers and consumers (physical liquidity) grows condition (1) will be violated. This will generally happen in a liberalized market and could occur as LNG trade continues to grow. A violation of condition (1) is sufficient to inhibit the ability to price above marginal cost, unless of course there is a single dominant supplier or a cartel. If there is a dominant supplier or cartel, then oil indexation is not the likely outcome, rather it will be some other price above marginal cost that reflects monopoly rents.

A clear indication that price discrimination is occurring can be seen in historical European market pricing. For example, the lack of pricing that reflects transport

differentials between, for example, Turkey and Germany, is an indication that suppliers are exerting market power in order to set prices above marginal cost in both markets. Note that this does not reflect the true marginal cost of gas in either market.

The European market has historically been characterized as a market with a single large supplier and large consumers that could be distinguished from each other due to a lack of arbitrage capability. This has been changing fairly rapidly however, for several reasons, such as: (a) a significant increase in LNG import capacity, (b) an increase in pipeline supply options from North African countries and potentially Central Asia and the Middle East (note that credible competitive threats also matter), and (c) an increase in demand by multiple countries due to an expansion of gas demand for power generation.

Thus, the ability for oil indexation to persist is becoming compromised. Note this does not mean oil-indexed contracts will disappear. It simply means suppliers will have to find buyers willing to pay above marginal cost, which will be increasingly difficult due to the greater number of supply options. In fact, as the number of supply options increases the ability for suppliers to price above marginal cost (or exert market power) will be diminished (see Brito and Hartley (2007)). Moreover, if the European market is liberalized, the ability to resale lower cost gas when it is not needed should decrease the volumes of gas that are sold at oil-indexed prices. In fact, we have already seen this occurring in the renegotiation of contracts from Russia and Norway. Specifically, in each case a portion of gas sales is now to be indexed to the spot market, which is an unprecedented development. The move is seen by many as necessary to maintain market share in an environment where spot sales have been increasing for over a decade and global supplies are more than adequate to meet demand. The development of shale gas in North America, the increase in global LNG exports and the global reduction in demand following the recession are the primary culprits for this.

In Asia, a lack of indigenous supplies renders physical liquidity lower. This could mean a differential could emerge that reflects a higher price in Asian markets than in others. Also, as long as the Japanese market and the Chinese market remain physically distinct

and the elasticity of demand is different across the two countries, then the existence of different prices in these two markets is more likely. Nevertheless, even in Asia, an increase in the number of supply options will lessen the ability of oil-indexed contracts to persist in historical ratios.

In general, as the market continues to grow, increased flexibility provided by greater physical liquidity should mean that globalization will bring positive benefits. However, these benefits could diminish if a concentration of supplies in a few countries emerges in the future. Specifically, if the market evolves to one in which consuming countries are heavily dependent on a few large producers who are not necessarily stable (such as Iran, Russia, and Venezuela), then globalization could bring with it a new leverage structure in which gas is used to manipulate political outcomes. The idea is not far-fetched, having just witnessed a deal between Russia and Ukraine in which Russian naval presence in the Ukrainian Black Sea was extended was exchanged for a lower price of natural gas to Ukraine.

VI. A Comment on the Impact of Shale Gas

Perhaps the most intriguing development in global energy markets in the last decade or so is the emergence of shale gas. The application of innovative new techniques involving the use of horizontal drilling with hydraulic fracturing has resulted in the rapid growth in production of natural gas from shale. Moreover, the production potential that has been identified since the emergence of the Barnett shale in Northeast Texas – which is now the largest single producing natural gas play in North America – has dramatically altered expectations for global LNG trade. Fewer than 10 years ago, most predictions were for a dramatic increase in LNG imports to North America and Europe, but shale production in North America has turned this thinking upside down. Today, growth opportunities for LNG developers are seen in primarily in Asia.

To understand the shear speed with which shale potential has emerged, we need only look at assessments of recoverable resource over the past several years. As recently as

2005, the Energy Information Administration was using an estimate of 140 tcf in its forecasting efforts. In 2008, Navigant Consulting, Inc. estimated a range of between 380 tcf and 900 tcf of technically recoverable resource, which puts the median at about 640 tcf. In 2009, the Potential Gas Committee put its estimate at just over 680 tcf, and in 2010 Advanced Resources International reported an estimate of over 1000 tcf. Note that although each assessment is from an independent source, the estimates are increasing over time.

The emergence of shale gas has significant implications for global gas trade, and it has already resulted in a paradigm shift with regard to LNG trade. It is resulting in North America remaining largely independent of LNG. However, the growth of shale in North America is also yielding liquidity benefits abroad. Specifically, tremendous growth in the resource has made the global supply curve more elastic (or flatter). This has rendered international gas prices lower and less volatile. Prices are lower because supply is relatively abundant. Volatility is lower because a flat supply curve means no production constraint is present, and, generally, constraints are necessary for volatility to arise.

Shale production growth may also provide a secondary benefit. The ability to adjust drilling activities and production may provide a virtual storage service. In particular, as developers are able to stimulate production through hydraulic fracturing such that high flows are timed to coincide with seasonal increases in demand, then the shale reservoir becomes a *de facto* form of storage, or a “just-in-time” source of production. To the extent this eventuates, it should dampen the price volatility associated with temporary market tightness that results due to seasonal increases in demand, which follows from the discussion of the stock-flow model in section II above.

VII. Concluding Remarks and Policy Discussion

The risk of exposure to international market fluctuations is likely to grow if North American LNG import dependence increases. This follows from the fact that more LNG into North America renders it more connected to markets abroad. However, the

emergence of shale gas has called into question whether or not the North American market could effectively disconnect from the global arena for an extended period. While this is beyond the scope of this paper, recent analysis by Hartley and Medlock (2010) indicates that LNG imports will not substantially increase to North America until the 2030s, absent some policy that results in limiting supply. Currently, the relatively small share of LNG in the North American market has resulted in price volatility being largely determined by changes in demand that are a function of seasonal weather patterns. Moreover, there is no evidence in the historical data examined herein that increased imports adversely effect price volatility.

Nevertheless, there is concern that globalization of natural gas markets through increased trade in LNG could bring increased uncertainties. Certainly, the specter of a supply cut-off or the use of gas supplies to manipulate political outcomes is a concern to governments everywhere. To the extent that global supplies become concentrated in the hands of a few large producers, this risk is heightened. So, what steps can be taken to prevent such an outcome?

First, promotion of the development of many different sources of supply is important. As indicated in Hartley and Medlock (2010), shale gas developments are changing the global dynamics of gas trade. In fact, the success of shale developments in North America alone has resulted in a paradigm shift with regard to the manner in which stakeholders are thinking about supplying the North American market. A decade ago the story was about increased LNG imports. Today, the story has shifted to one of domestic production. This has left more LNG available to European consumers by effectively flattening the global supply curve for natural gas.

A key vehicle to achieving diversity in supply sources and overall market flexibility brings us to a second point. Namely, liberalization of gas markets should be promoted. As a matter of policy, promoting flexibility within markets is an important step to ensuring secure delivery of energy supplies. This runs counter to the arguments of many large consumers and large producers who support the use of bilateral long-term contracts

to promote energy security. However, such arrangements allow for substantial dislocations if circumstances emerge that disrupt delivery, particularly when there is no accessible alternative source of supply. Competitive, liberalized markets operating through well-functioning, transparent exchanges allow the risk associated with dealing with any single counterparty to be mitigated. They do so by letting consumers and producers rapidly find new trading partners if there is a problem with an existing agreement. Such markets also allow any arbitrage opportunities that may arise to be quickly eliminated. This is, in fact, a general benefit of market liquidity. Moreover, large numbers of market participants are encouraged when there are ample opportunities for each to gain by inclusion. By contrast, a market that is limited to bilateral contracts that exclude opportunity for additional participants does not provide the benefits that liquidity brings.

In general, the natural gas market in Europe has been dominated by long term contractual relationships that allowed a national operator to control the distribution of gas from producer to consumer and allowed little, if any, room for competitive threat from an third party supplier. Incumbent suppliers, such as Russia, stood to benefit from this arrangement because by locking up markets long term they faced little competitive threat to building a position of dominance within the European market. On the one hand, this arrangement is desirable from the standpoint that it brings the benefits of certainty, and therefore may facilitate relatively easier expansion of long haul facilities such as pipelines. On the other hand, the lack of competition associated with the structure of the market tends to raise the average price paid for natural gas.

Liberalization in natural gas markets usually means that capacity rights and transportation services are marketed separately (often called ‘unbundling’ of transportation services). A chief benefit of this arrangement is that it should stimulate production at the margin by removing any constraints for potential producers to access a market, i.e. – it provides physical liquidity. This, in fact, has occurred very successfully in North America, with most recent evidence in the recent expansion of shale gas production in the US, which arguably would not have occurred at its current pace had the market not been liberalized.

The ability to secure capacity rights on pipelines and trade natural gas at various liquid 'hubs' has allowed producers to receive a guarantee of competitive pricing. By effectively removing volume risk, liberalization has facilitated the timely expansion of domestic supplies, in many cases from small producers, needed to meet demand growth. Moreover, this has occurred without the use of long term contracts.

Liberalization of the natural gas market has also provided many benefits associated with energy security. Market participants can buy and sell rights to transportation and storage capacity and nominate gas from multiple sources. The ability to trade pipeline capacity effectively guarantees that the consumer who places the highest value on natural gas at any particular point in time will receive it. The ability to nominate supplies from multiple sources provides a diversification benefit. In particular, it prevents any one party from extracting exorbitant rents by allowing demands to be met in multiple ways.

Finally, liberalization has also yielded benefits in the North American natural gas storage market. In general, the ability to trade storage capacity allows one to move commodity temporally, which can mitigate the effects of short term price pressures created by unexpected and sudden increases in demand or reductions in supply. More specifically, the adoption of market-based pricing for storage services, as opposed to pricing based on a regulated rate of return, has led to an increase in the amount of investment in both storage capacity and the ability to cycle storage more quickly. The former allows a greater amount of supply to be sold forward or held for times of excess demand. The latter allows storage to be withdrawn and re-filled more quickly, thus allowing greater ability to meet near term variations in demand without compromising the ability to do so in the future.

Importantly, promoting liberalization is counterintuitive to many. In particular, if we are concerned primarily with the delivery of supply, then locking those volumes up in long term contractual arrangements may seem to be the correct thing to do. However, history with the North American market has taught us this is not a correct thesis. Moreover, for European consumers, long term contracts with Russia yielded no benefit during the

Russia-Ukraine pricing disputes in the winters of 2005-2006 and 2008-2009. In fact, a liberalized market may have facilitated a better reaction to the cut-off of supplies precisely because it would have allowed for a greater number of supply options.

One last comment pertains to the development of strategic stocks. In particular, such a move could have negative unintended consequences. As discussed above, a government inventory discourages the development and use of commercial inventories. This puts the responsibility of responding to regular changes in price induced by changes in demand on the government rather than in the market. In addition, market participants could be exposed to an additional source of uncertainty – namely, when and how will the government use its inventories. While this can be specified in legal doctrine, in practice strategic stocks are designed to be used for unforeseen emergency situations. But, defining “unforeseen emergency situations” can be difficult, especially since by supposition, they are unforeseen. This typically leaves latitude in the response mechanism, which can differ across administrations, and would invariably inject uncertainty – and volatility – into the market.

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