JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY
RICE UNIVERSITY

Testimony of Kenneth B Medlock III
James A Baker III and Susan G Baker Fellow in Energy and Resource Economics
James A Baker III Institute for Public Policy
Rice University

To the
Senate Committee on Energy and Natural Resources
Washington, D.C.

November 8, 2011

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. Although geologists have long known about the existence of shale formations, accessing those resources was long held to be an issue of technology and cost, and recent innovations have yielded substantial cost reductions and made shale gas production a commercial reality. In fact, shale gas production in the United States has increased from virtually nothing in 2000 to over 10 billion cubic feet per day (bcfd) in 2010, and a recent Baker Institute analysis indicates it could reach over 50 percent of domestic natural gas production by the 2030s.

Without doubt, the natural gas supply picture in North America has changed substantially, and it has had a ripple effect around the globe not only through displacement of supplies in global trade but also by fostering a growing interest in shale resource potential in other parts of the world. Thus, North American shale gas developments are having effects far beyond the North American market, and these impacts are likely to expand over time. Prior to the innovations leading to the recent increases in shale gas production, huge declines were expected in domestic production in the United States and Canada, which comprise an integrated North American market. This foretold an increasing reliance on foreign supplies at a time when natural gas was becoming more important as a source of energy.

Throughout the 1990s, natural gas producers in the Middle East and Africa, anticipating rising demand for liquefied natural gas (LNG) from the United States in particular, began investing heavily in expanding LNG export capability, concomitant with investments in regasification being made in the United States. At one point in the early 2000s there were over 47 regasification terminals with certification for construction, which was a clear signal regarding industry-wide expectations for the future of the U.S. supply. But the rapid growth in shale gas production has since turned such expectations upside down and rendered many of those investments obsolete. Import terminals for LNG are now scarcely utilized, and the prospects that the United States will become highly dependent on LNG imports in the coming years have receded, with proposals now emerging for *exports* of LNG from North America.

Rising shale gas production in the United States is also impacting markets abroad. LNG supplies whose development was anchored to the belief that the United States would be a premium market are now being diverted to European and Asian buyers. This has presented consumers in Europe with an alternative to Russian pipeline supplies, and it is exerting pressure on the status quo of indexing gas sales to a premium marker determined by the price of petroleum products. In fact, Russia has already had to accept lower prices for its natural gas and is now allowing a portion of its sales in Europe to be indexed to spot natural gas markets, or regional market hubs, rather than oil prices. This change in pricing terms signals a major paradigm shift in Europe, and could be the first signal for Asian buyers that oil-indexation may become a thing of the past. This is an important point when considering the current profit margin available to potential LNG exports, particularly when those export projects hinge on oil-indexed prices and a wide oil-gas price differential.

Certainly rising shale gas production has contributed to lower domestic natural gas prices. This, in turn, has led various interests to promote greater use of natural gas in power generation through substitution opportunities with coal, and renewal of industrial demands which had previously been fading. In addition, there has been interest in creating new demands, such as the use of natural gas in transportation particularly as the price of crude oil remains substantially higher than the price of natural gas on an energy equivalent basis. Finally, as noted above, there has been growing interest in developing LNG export capability to capture the arbitrage opportunity that currently exists with domestic natural gas prices substantially below prices in Europe and Asia.

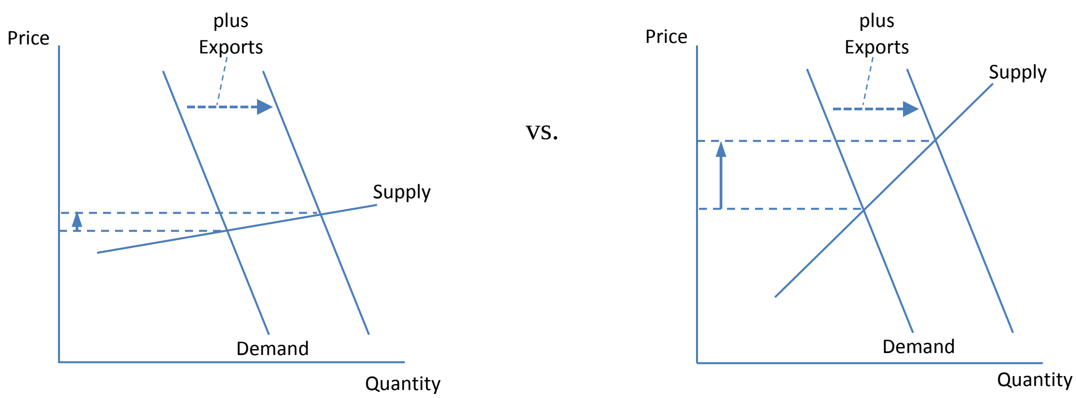
On the point of LNG exports, there are several key factors that (a) determine whether or not they occur and (b) the impact, if exports do occur, on domestic prices.  Critical factors addressed herein that determine the quantity of exports and the effect on domestic price are (i) the elasticity of domestic supply,

(ii) the elasticity of foreign supply, (iii) the exchange rate, and (iv) the cost of exports. For the purpose of this discussion, we will assume the cost of exports is not prohibitive unless otherwise stated.

*The Domestic Supply Picture*

With regard to point one above, a comparison of the two diagrams below illustrates very simply the effect of the elasticity of domestic supply on the impact of increased exports on domestic price. In particular, if domestic supply is highly elastic as in the first diagram, meaning production can be profitably increased with only small changes in price, then exports, which are shown here as an increase in demand for domestic resources, will not raise price by much. This contrasts to the case in the second diagram where supply is not very elastic. In this case, the same export quantity will raise price by a substantial amount.

**Elasticity of Domestic Supply and the Impact of Exports on Price**




While this is an admittedly simple way to examine the posed problem, it can yield some powerful insights. We still need to understand the effects of the elasticity of foreign-sourced supply as well as the exchange rate, but these issues will largely determine the quantity of exports if allowed to increase unconstrained. However, we are still left with the task of understanding how elastic the domestic supply of natural gas is. To do so, we must first understand the magnitude of the technically recoverable domestic resource base, something which has changed rapidly over the last decade.

As recently as 2003, the National Petroleum Council[1] estimated about 38 trillion cubic feet (tcf) of technically recoverable resources were spread across multiple basins in the North America. In 2005, the Energy Information Administration (EIA) used a mean estimate of 140 tcf in its Annual Energy Outlook for technically recoverable shale gas resources. In 2008, Navigant Consulting, Inc.[2] estimated a mean of 280 tcf of technically recoverable resources from reviewable geologic literature, but a survey of producers indicated up to 840 tcf. In 2009, the Potential Gas Committee[3] put its mean estimate at just over 680 tcf. In 2011, Advanced Resources International reported an estimate of about 1,930 tcf of technically recoverable resource for North America, with over 860 tcf in U.S. gas shales alone.[4] Although the assessments listed above are from independent sources, the estimates are increasing over time, which is a pattern that is largely coincident with more drilling activity and technological advances, which is an indication of the learning-by-doing that is still occurring. While there remains disagreement about the exact size of the shale resource base, the disagreement is about magnitudes which are all substantially larger than our state of knowledge even just six years ago.

The introduction of shale to the US supply portfolio has effectively stretched the domestic supply curve. Equally importantly, however, is the cost of recovery as cost determines how much of the resource is commercially recoverable at a particular price. To understand this, most analysts examine data involving the costs from acreage acquisition to well completion and the production profile and estimated recoverability of each well. This enables a cost ranking of wells and the construction of a distribution of "type" wells. Usually, these analyses indicate a great degree of heterogeneity among wells drilled in a single shale play, with some wells profitable at relatively low prices and others at much higher prices, meaning some wells drilled are indeed uneconomic. However, the producer's decision to develop is based on a portfolio of wells, and even uneconomic wells can inform future development decisions in that they reveal information about the acreage being developed. In fact, it is this latter point that can bear long term returns, as witnessed in the Barnett shale today.

The Barnett shale, the most mature of the shale plays and where the venture into shale began in earnest less about a decade ago, is a good barometer for the "learning-by-doing" that occurs as shale wells are drilled. In the Barnett to date, over 12,000 horizontal wells have been drilled. In the last 3 years, operator efficiency has dramatically improved, as witnessed by the fact that rig counts are down from 192 per

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[1] NPC, *Balancing Natural Gas Policy: Fueling the Demands of a Growing Economy*, September 2003.
[2] Navigant Consulting, *North American Natural Gas Supply Assessment*, July 4, 2008.
[3] The Potential Gas Committee, *Potential Gas Committee Biennial Assessment*, June 18, 2009.
[4] *World Gas Shale Resources: An Assessment of 14 Regions outside the United States*, a report prepared by Advanced Resources International for the United States Energy Information Administration, April 2011.

week in September 2008 to 64 per week in September 2011, but production was higher. Much of this owes to operators finding the so-called "sweet spots" in the shale and understanding better an optimal drilling strategy. Moreover, there are ongoing innovations that will challenge our understanding of both cost and recoverability as drilling is being reduced from 80 acre spacing to 40 acres, with some operators now testing 20 acre spacing. In all, as operators develop shale they learn about the resource and apply those lessons to reduce costs. In the upstream in general, this is nothing new, and it tends to make supply more elastic.

Bringing it all together, many estimates indicate there is a very large quantity of shale resource that is economically recoverable at between five and six dollars per thousand cubic feet. The Baker Institute, for example, estimates that up to 350 trillion cubic feet of shale gas is commercially viable in North America at prices up to six dollars. So, using this as a benchmark, we can say that the domestic supply curve has effectively been stretched horizontally with the commercialization of shale. In other words, it is as if we have moved from a world that more closely resembled the supply curve in the second diagram above, to one which more closely resembles the supply curve in the first diagram, i.e. – shale has rendered domestic supply to be much more elastic.

An important factor that could limit the amount of shale gas that could be developed at particular prices pertains to regulation. Specifically, regulations that inhibit development will effectively render domestic supply to be more inelastic. Thus, if concerns exist that exports will raise price domestically, then it is important to juxtapose any potential set of regulations that could limit domestic production in certain regions against the regulatory approval of export projects.

In relation to European and Asian markets, the United States has a well-developed, competitive regulatory framework governing natural gas infrastructure development, transportation services, marketing, and mineral rights ownership and acreage acquisition. This regulatory environment has promoted the rapid development of shale resources, and it may not be fully or quickly replicable in other markets around the globe where state involvement in resource development and transportation is more prevalent. For example, investor access to shale resources is likely to be more heavily controlled in most Asian and European countries, where land ownership is generally distinct from the ownership of mineral rights. This will in general render US supply to be more elastic, particularly in the context of shale gas, than foreign supply. However, it is difficult to argue that foreign supply is inelastic when one considers the vast quantities of resources available in Russia, Australia, the Middle East and North Africa. Thus, we are left with a situation in which both domestic and international supplies are relatively elastic, albeit they are so at different marginal costs.

*International Factors*

Perhaps the most voiced concern regarding export of LNG from the US is one which posits the domestic natural gas price will rise to international parity. To understand whether or not this will indeed occur, one must first understand under what circumstances it could occur. First, it must be true that export capacity be sufficient to fully arbitrage the difference between domestic and international gas prices. In other words, there can be no constraint on export capacity. If export capacity is constrained, then, all else unchanged, the international price will remain substantially above the domestic price, but of course, this would provide incentive for investments in export capacity.

Second, if we pose no constraints on export capacity, the change in the domestic price will depend on the shape of the international supply curve, as well as the exchange rate, assuming of course that cost is not an impediment. In general, if foreign supply is inelastic, then the price in the foreign market should be lowered as foreign suppliers are driven out of the market by lower cost supplies from US exporters. If domestic supply is very elastic, then the domestic price will not change much, but the foreign price would. In fact, if this were the case, the long run price in overseas markets would simply be the domestic price plus the cost of exports. In other words, most of the price action would occur in overseas markets.

If, however, domestic supply is relatively inelastic, then price would be driven up domestically at the same time price is driven down in the foreign market. But, this dynamic would limit the quantity of exports as profitability would quickly become challenged. In either case involving inelastic foreign supply, the domestic price will not simply increase to the current foreign price. Instead, it will rise to something below it, but the degree to which domestic price increases will depend on domestic supply elasticity.

Assuming domestic exports are profitable, if foreign supply is very elastic, then exports would increase until either almost all foreign supply is displaced (if domestic supply is very elastic) or until the domestic price is driven up to the point where exports are no longer profitable (if domestic supply is very inelastic). Again, the domestic price impact is largely determined by domestic supply elasticity, but now the price impact could be one in which the domestic price rises while the foreign price is relatively unchanged. This would only occur, however if domestic supply is inelastic *and* foreign supply is elastic.

Another point worth noting, as done is a recent Baker Institute working paper, is the effect that the exchange rate has on the commercial feasibility of exports. In the US, natural gas is traded in dollars per million British thermal units ($/mmbtu). In the UK, for example, natural gas is traded in pence per therm (p/therm). In order to assess the arbitrage opportunity that exists through exporting natural gas from the US to the UK, we must multiply the UK price by a heating conversion, which is constant, and the exchange rate. Thus, if the US dollar is relatively weak, then the arbitrage opportunity expands. However, this type of opportunity arises due to nominal exchange rate movements, and investments made on this basis will be subject to substantial risk based solely on exchange rate movements.

To put the exchange rate risk into the context discussed above, one only need understand that movements in the exchange rate would effectively shift the foreign supply curve (when denominated in $/mmbtu) up and down, so long as we are measuring things in nominal terms. Hence, a stronger dollar would effectively lower the foreign supply curve and limit the commercial feasibility of exports. Thus, any investment in export capacity made today that does not account for this could run a serious risk of being "upside down" in the future.

*Concluding Remarks*

To summarize, the effect of US LNG exports on the price of natural gas in the US depends on a number of factors. In general, LNG exports, if allowed to increase to the point where all arbitrage opportunities are allowed, would both increase the domestic price and decrease the foreign price. However, the degree to which each price moves will depend on the relative elasticity of supply in each market. Research done at the Baker Institute indicates that the long run elasticity of supply is relatively high both domestically and internationally. This means that capacity constraints on the ability to trade between markets heavily influence regional price differences. Furthermore, such constraints represent real opportunities that may signal real investment opportunities in developing export capacity.

Highly elastic supply curves both domestically and internationally suggest that prices in the US if exports are allowed will not likely increase much, particularly not given the combined capacity of the current slate of LNG export projects. Nevertheless, an assumption that all exports will be valued at an oil-indexed premium in all future years may be a strong one. By adding low cost supply to a market, the effective supply curve becomes more elastic, which will tend to reduce the ability for producers to price their supplies above marginal cost.

Finally, movements in the exchange rate contribute to nominal price differences, although these differences should not generally signal investment opportunities. Specifically, exchange rate motivated arbitrage opportunities are likely to be transitory.