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ANALYSIS

Modeling the implications of expanded US shale gas production

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ABSTRACT

Conventional thinking just ten years ago was that the United States would become a major importer of liquefied natural gas. Yet, today the discussion has shifted to one of export potential, largely driven by the rapid development of shale gas resources. This has had dramatic implications not only for the US, but also for the rest of the world. In particular, the outlook for several gas exporting countries has been substantially altered. Namely, while the US has certainly from an energy security standpoint, Russia, Iran, Venezuela and Qatar have seen their projected fortunes reduced. Development of shale gas has effectively increased the global elasticity of supply and could substantially reduce overall dependence on exports from these critical countries.

1. Introduction

The past decade has seen rapid development of technology allowing the recovery of natural gas from shale formations. Beginning with the Barnett shale in northeast Texas, 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. In fact, Barnett shale production in 2011 has grown to over 5 billion cubic feet per day (bcfd) up from virtually nothing just ten years ago. Moreover, the techniques that have proven so successful in the Barnett shale have been successfully applied to other shale formations, including the Marcellus shale, Haynesville shale, Fayetteville shale, Eagle Ford shale, and more (see Fig. 1). Success has been so dramatic that the Barnett grew to become the largest single production play in the US by 2008, but was surpassed by the Haynesville just last year, and growth in the Marcellus has positioned it to overtake both within the next two years. In sum, shale gas production in the United States has increased from virtually nothing in 2000 to over 10 bcfd in 2010, and it is expected to reach over 50% of total U.S. natural gas production by the 2030s (see Fig. 2).

Rising shale gas supplies have significantly reduced both current and projected requirements in the US for imported liquefied natural gas (LNG). Moreover, if not disadvantaged by government policies that protect competing fuels, natural gas will likely play a very important role in the U.S. energy mix for many years(see [3]). Of course, the fact that shale gas resources are generally located in close proximity to end-use markets is both a blessing and a curse. On the one hand, the fact that shale gas resources are located near large end-use markets means that development can benefit industry, and facilitate the generation of electricity and the heating of commercial and residential establishments at a relatively low cost. In short, it offers both economic and security of supply benefits. On the other hand, being close to end-use markets raises the specter of public opposition, which can be detrimental to development opportunities. However, in most regions opposition has not severely hindered development as U.S. shale gas production is now well over a quarter of domestic production, up from less than 2% less than ten years ago.

Rising production from shale resources has implications for both domestic and international market structure as well as geopolitics. In Europe, shale gas developments in the North American gas market have, by displacement, increased the availability of LNG, which has played a key role in the ongoing renegotiation of long term oil indexed contracts. Russia has had to allow 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 is a major paradigm shift.

In Asia, shale gas developments have, again by displacement, released supplies to be shipped to Japanese buyers in the wake of the disaster at Fukushima. Absent North American shale developments, LNG spot prices would likely be even higher as global competition for supplies would be more intense. In addition, upstream developers are now investigating opportunities to develop shale resources in Europe and Asia, which could have even more significant and direct long term impacts on regional gas markets.

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Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Fig. 1. Shale basins in North America. Source: US Energy Information Administration.

In sum, while many analysts have characterized shale in North America as game-changing, it could be even more transformative in Europe and Asia. Shale developments in the United States are potentially market structure altering. The existence of viable shale gas resources is evident in other regions around the world, and shale gas potential is being actively discussed and explored in Europe, China, India, Australia, Argentina, Brazil, South Africa, and elsewhere. The sheer size of the global shale gas potential could alter geopolitical relationships and exert a powerful influence on U.S. energy and foreign policy.

Despite the apparently positive outlook that permeates the discussion above, it is important to point that sustained, rapid development of shale gas in both the U.S. and abroad is not a certainty. A stable

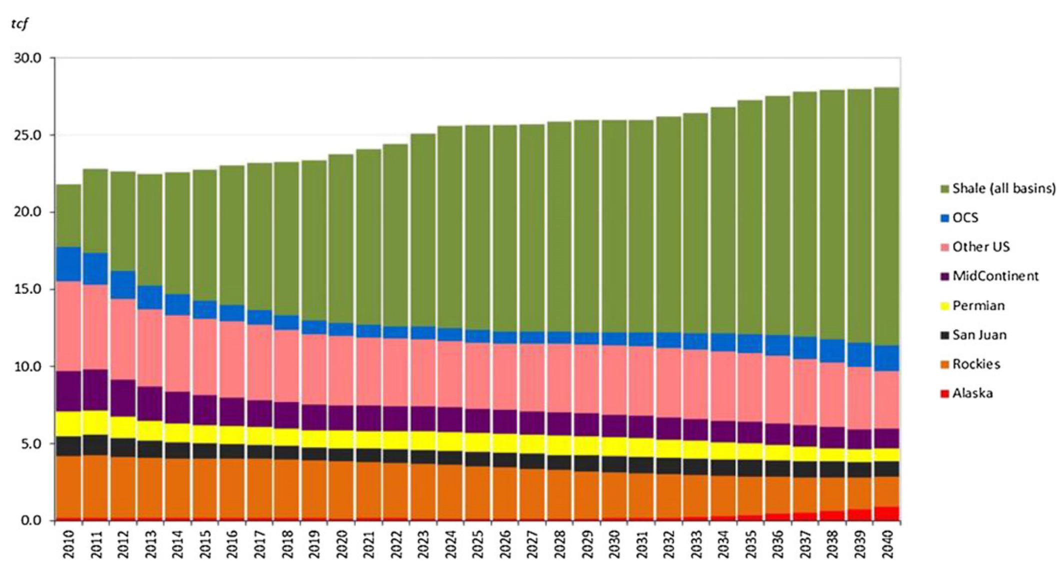

Fig. 2. Projected US natural gas production by source, 2010—2040. Source: Medlock, et al. [6].

regulatory environment is critical to achieving the potential benefits outlined above. Of prime concern are environmental issues regarding the use and potential contamination of potable water. These sorts of things must be addressed before the full benefit of shale can be realized.

Market structure is also very important when considering the growth opportunities for shale, and it is likely the most under appreciated factor that positively benefited growth in shale gas production in the United States. The small, independent producers are the upstream participants who drove the entrepreneurial efforts that led to the large increases shale gas production — not the large integrated majors. Arguably, the entire conversation about shale gas would not be occurring had the independent not taken the first steps into this new frontier, and they could not have done so absent the market structure that exists in the United States. As one example, in the United States natural gas market, ownership of transportation capacity rights is unbundled from pipeline ownership. Unbundling of capacity rights from facility ownership makes it possible for any producer to access markets through a competitive bid. Many of the small producers that first ventured into shale might not have been otherwise willing to do so, specifically because access to markets could have been limited. By contrast, in most other markets globally pipeline capacity is not unbundled from facility ownership meaning large incumbent monopolies can effectively present barriers to entry through control of the transportation infrastructure.

More generally, the United States has a well-developed, competitive regulatory framework governing natural gas infrastructure development, transportation services, marketing, and mineral rights. This has promoted the rapid development of shale resources, and it may not be fully or quickly replicable where government involvement in resource development and transportation is more prevalent. This could prevent market entry by large numbers of smaller producers who would be otherwise willing to test and prove concepts on a small scale. It is for this reason that U.S. energy security has benefitted from having an active sector of small, independent energy companies. Without this sector, U.S. shale gas production would likely have taken many more years to grow to its current levels. Of course this would have meant the LNG regasification terminals that were constructed in the last several years would be more greatly utilized, but it would also have yielded more market and geopolitical power to a few foreign natural gas suppliers.

2. Study detail

A recent study entitled "Shale Gas and US National Security" (see [6]) published by the Baker Institute utilizes the Rice World Gas Trade Model (RWGTM) to examine the economic and geopolitical impacts of the recent emergence of shale gas production. (Please see [4] for a more detailed description of the RWGTM. The RWGTM was developed by Kenneth B Medlock III and Peter Hartley at Rice University using the Marketbuilder software provided through a research license with Deloitte Marketpoint, Inc.) This paper presents a subset of the results from that study. In particular, we compare two scenarios, which are described as follows:

- Reference Case: The Reference Case posits that all known global shale gas resources can be developed according to their commercial viability. This scenario includes an assessment of global shale resources in the United States, Canada, Mexico, Austria, Poland, Sweden, Germany, China, and Australia (for specific information regarding cost and regional distribution see [6]).
- No Shale Case: The Reference Case is compared to a scenario in which shale gas resources are limited to the Barnett, Woodford, and Fayetteville shale plays in the United States, which is meant to represent the state of knowledge that existed prior to 2005. In addition, there are no shale gas developments outside of North America. So, this scenario is a counterfactual that demonstrates a global gas market that conforms to the expectations of the early 2000s.

Comparison of the two scenarios allows a clear delineation of the importance of shale resources to U.S. energy security, and demonstrates how shale development alters the international gas market flows.

The RWGTM is a dynamic spatial general equilibrium model in which all spatial and temporal arbitrage opportunities are eliminated. In doing so, the model proves and develops resources, constructs transportation routes and associated infrastructure, and calculates prices to equate demands and supplies while maximizing the present value of producer rents within a competitive framework. So, new capital investments in production and delivery infrastructure must earn a minimum return for development to occur. The debt—equity ratio is allowed to differ across different categories of investment, such as proving resources, developing wellhead delivery capability, constructing pipelines, and developing LNG infrastructure. By developing supplies, pipelines and LNG delivery infrastructure, the RWGTM provides a framework for examining the effects of different economic and political influences on the global natural gas market within a framework grounded in geologic data and economic theory.

Regions in the RWGTM are defined at the country and sub-country level, with extensive representation of transportation infrastructure. The extent of regional detail is largely based on data availability. Large consuming and producing countries with well-developed infrastructure, such as the United States, have extensive sub-regional detail. This is important because it allows a better understanding of the effects that intra-country capacity constraints could have on current and future gas market developments. Demand is split across 290 regions, and is modeled at the state and sub-state level for broadly defined end-use sectors the residential, commercial, industrial, and power generation sectors in the United States. Outside of the U.S., limited data availability means demand is characterized into two more broadly defined sectors — direct use and power generation — but is still regionally distinct. The regional detail tends to be greater in well-developed gas markets. For example, France is comprised of 6 regions, Germany of 7 regions, and Spain of 8 regions, to list a few. Regional detail is established to appropriately site demand sinks along transportation networks so that actual flows are reasonably simulated.

Supplies are divided into proved reserves, growth in existing fields, and undiscovered resources for both conventional and unconventional resources across 135 regions. The assessments of technically recoverable resources are developed using peer-reviewed, scientific assessments of the properties of shales, which are used to develop technically recoverable estimates and the associated finding and development costs. The resource data derives from sources such as the *Oil and Gas Journal* (OGJ), U.S. Geological Survey (USGS), National Petroleum Council (NPC), Australian Bureau of Agriculture and Resource Economics (ABARE), and Baker Institute research on unconventional resources in North America and globally. North America finding and development (F&D) costs for non-shale resources are based on estimates developed by the NPC in its 2003 report (see [7]), and have been adjusted using data from the Bureau of Economic Analysis KLEMS database to account for changes in upstream costs since the early 2000s. These costs have been econometrically related to play-level geophysical data and applied globally to construct F&D costs for all regions of the world. In general, long-run F&D costs increase with depletion, although technological change is allowed to counteract the effect.

In the RWGTM, events in one region of the world influence all other regions because transportation links connect markets and transmit both physical commodity volumes and price signals. The costs of constructing new pipelines and LNG facilities in the RWGTM are estimated using data from previous and potential projects available from the Energy Information Administration, International Energy Agency (IEA), and various industry reports. Within the United States, Federal Energy Regulatory Commission (FERC)-filed tariff rates determine pipeline transportation costs. The costs for regions outside the United States are determined by a rate-of-return calculation. LNG regasification, liquefaction and shipping costs are based on information obtained from various industry reports.

2.1. *The shale gas resource*

The state of knowledge regarding the amount of shale gas that is economically recoverable has changed rapidly over the last 10 years. As recently as 2003, the National Petroleum Council (see [7]) estimated about 38 trillion cubic feet (tcf) of technically recoverable resources were spread across multiple basins in 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. (see [8]) 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 (see [9]) 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 (see [1]). 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, as well as 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 over magnitudes that are all substantially larger than our state of knowledge even just six years ago.

Geologists have long known about the existence of shale formations, but technical and commercial access to those resources is new. Several years prior to the emergence of shale in North America, Rogner (see [5]) estimated over 16,000 tcf of shale gas resources in-place globally with just under 4000 tcf of that total estimated to be in North America. At that time, only a very small fraction ($<$10%) of this was deemed to be technically recoverable. Developments over the last decade, however, led the IEA to recently estimate that about 40% of Rogner's estimated resource in-place will ultimately be technically recoverable. A more recent assessment of technically recoverable shale resource referenced above and done by ARI for the EIA identifies a global in-place shale resource of over 25,300 tcf — a total that does not include an assessment of FSU or Middle East shale potential. However, it should be noted that large resource in-place estimates do not necessarily imply large-scale production is forthcoming because technical innovations and cost reductions are critical to commercial viability.

Analysis done at the James A. Baker III Institute for Public Policy at Rice University indicates an estimate of U.S. technically recoverable shale resource of 637 tcf. Assuming a 12% return on investment, the "breakeven price" needed for an average "type" well in each of the identified shale plays ranges from the low \$3 to \$7. To be clear, there is a distribution that characterizes possible well performance, meaning some wells will be better than average and some will be worse. If developers are able to identify so-called "sweet spots", then prices, at least for a period of time, can be below this range. However, the general tendency of long term price will be toward the center of the distribution, meaning prices in the \$5 to \$6 range are expected.

The introduction of shale to the U.S. supply portfolio has effectively stretched the domestic supply curve. Equally important, 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. As referenced above, 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 three years, operator efficiency has dramatically improved, as witnessed by the fact that rig counts are down from 192 per 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 \$5 and \$6 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 \$6. Thus, shale has rendered domestic supply to be much more elastic.

Shale gas resources are also present in Canada, which is an integrated part of the broader North American market, and development is in fact already underway in the Horn River and Montney basins in western Canada. Shale resources in Mexico have been identified in the Burgos and Sabinas basins in northern Mexico and Tampico basin farther south, but have not to date been explored. This, along with domestic impediments to development, renders the viability of the resource in Mexico highly uncertain. Nevertheless, the RWGTM is populated with a combined U.S., Canadian and Mexican shale assessments of about 937 tcf, with 165 tcf in Canada and 135 tcf in Mexico. However, while the breakeven prices in Canada are in line with those in the US, those in Mexico are higher, which tends to shift their development to occur later in time.

Outside of North America, the RWGTM posits a technically recoverable assessment in Europe of roughly 220 tcf split between Sweden, Poland, Austria, and Germany, with the largest proportion (about 55%) in Poland, and average type-wells with a breakeven price in the \$6.00—\$7.50 per thousand cubic foot (mcf) range. In China there are an additional 230 tcf of recoverable shale resources at between \$5.50 and \$7.50, and in Australia there are 50 tcf of recoverable shale resource at between \$4.00 and \$6.00. In both China and Australia, however, transportation costs and other issues may be somewhat prohibitive. For example, the resources in western China are far from end-use markets, as are the Australian resources, particularly if they are developed with an aim to export as LNG.

To be sure, the estimates for regions outside of the United States and Canada in particular are very preliminary and full of uncertainty. Future work will incorporate a more complete assessment of the shale gas resources outside of North America as more information is made available.

3. Economic and geopolitical impacts

Prior to the mid-2000s and the innovations that led to the recent growth in shale gas production, huge production declines were

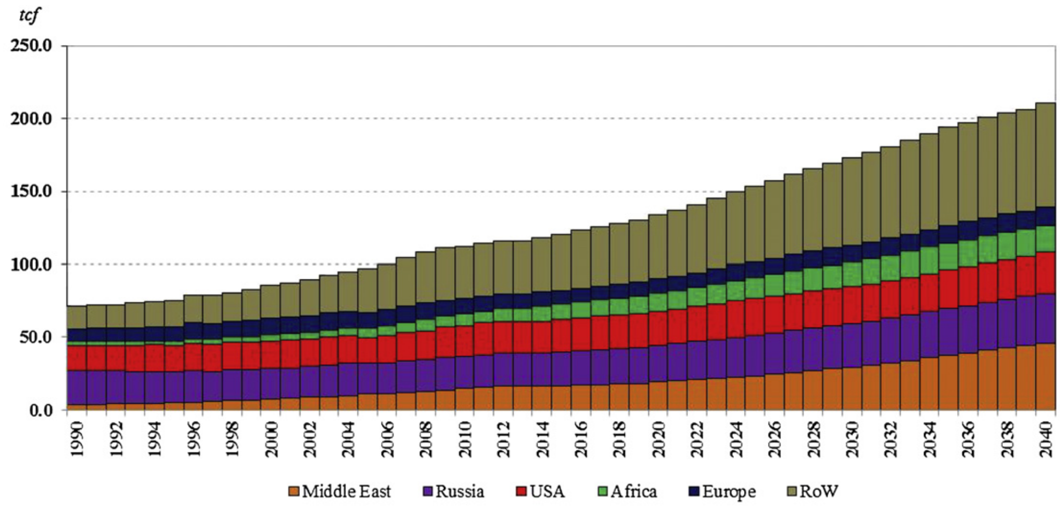

Fig. 3. World supply by region, 1990–2040 (Reference Case). Source: Medlock, et al. [6].

expected in the United States, Canada, and the North Sea. This, in turn, meant an increasing reliance on foreign-sourced supplies. In addition, prior to the revelations about shale, Russia and Iran accounted for more than half of the world's known gas resources, which put these countries in a unique position to leverage the apparent pending increase in global reliance on their resources.

If shale had not emerged, Russia and Iran would have been dominant forces in the global market (see Figs. 3 and 4). In the Reference Case, as can be seen in Fig. 3, world dependence on Middle East natural gas remains below 20% until the late 2030s. However, as indicated in Fig. 4, when shale gas output is constrained global reliance on the Middle East rises to about 27% by 2040. The implication is that the Middle East country that is disadvantaged the most as a result of rising shale gas production is Iran. Russia is also significantly impacted by shale gas production, as seen in Fig. 4. In sum, when shale gas is constrained, increased production from Russia and the Middle East, along with reduction in demand that are rationed by higher overall prices (not pictured), is needed to maintain the supply–demand balance.

Under the Reference Case where shale is developed unfettered, LNG exports originate from a wide diversity of sources instead of being concentrated in any one geographical region, and no single supplier gains significant market leverage (see Fig. 5). Qatar remains the largest LNG exporter while Australia emerges as a close second. Eventually, Nigeria, Iran, and Venezuela each grow to positions of prominence, collectively accounting for about 26% of global LNG exports by 2040.

However, the insights of what shale has meant for global gas market structure are not fully understood until we compare the Reference Case to the No Shale Case. To wit, the rise of Iran and Venezuela in global gas markets is substantially different when shale is not allowed (see Fig. 6). In fact, without shale we see a greater concentration of supplies in future years. Fig. 6 indicates the change in LNG exports when shale is not allowed relative to the Reference Case. Qatari exports are larger in this case, but so are Iran and Venezuela. Thus, the absence of shale reveals a world that is far more dependent on Iranian and Venezuelan LNG supplies to meet demand. Since natural gas is expected to become a pivotal fuel in meeting growing energy demands and environmental objectives, the emergence of these two countries as crucial suppliers runs counter to U.S. interests against the existing backdrop of U.S.–Iranian and U.S.–Venezuelan relations. Shale gas not only has spatial impacts on the global gas market, but also temporal impacts, as seen by the fact that the emergence of shale gas greatly reduces the chance of any individual or group of producers gaining substantial market share.

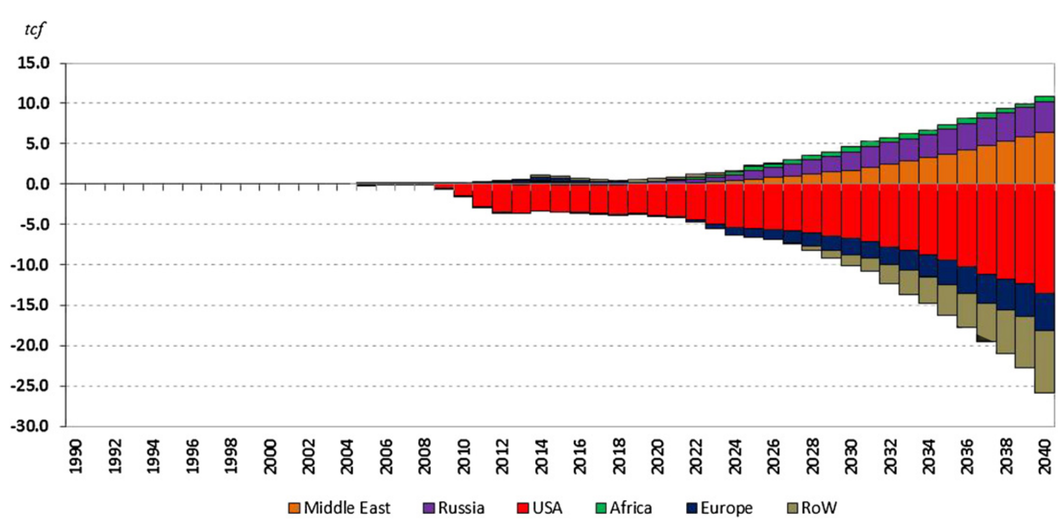

Fig. 4. World supply by region, 1990–2040 (Scenario 2 Delta to Reference Case). Source: Medlock, et al. [6].

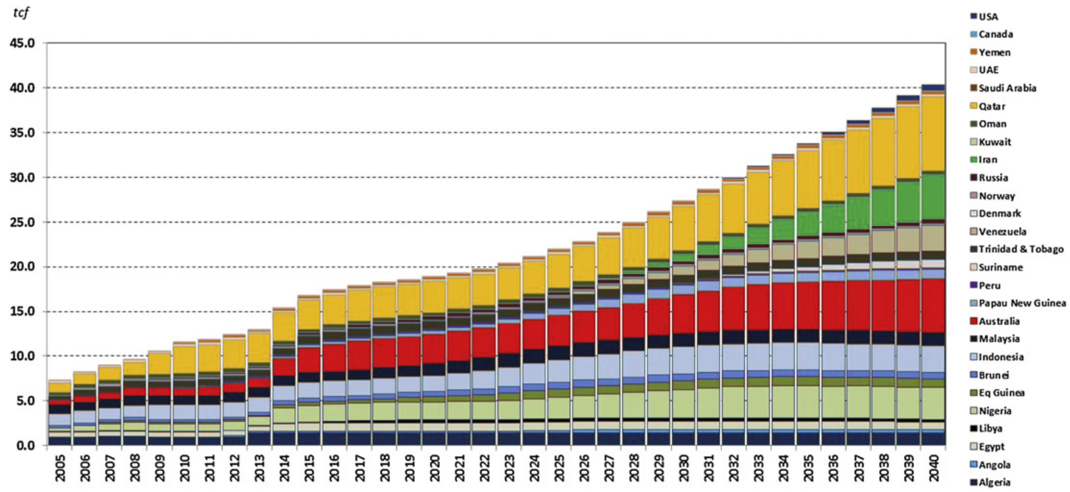

Fig. 5. Reference Case LNG exports (by country) to 2040. Source: Medlock, et al. [6].

The reinvigoration of U.S. domestic production due to the emergence of shale renders the United States to be less reliant on LNG (see Figs. 7 and 8). In fact, this is the principle driver of lower overall LNG exports globally. Nevertheless, even in the Reference Case, global LNG trade is projected to continue to grow, largely due to demand growth in Asia. So, the potential for shale gas development to occur in Asia is a point that must be closely watched.

Under the Reference Case, low capacity utilization remains a feature of U.S. regasification capacity through the 2020s (see Fig. 7). By contrast, LNG imports to the United States would be substantially higher under the case with no shale (see Fig. 8). In fact, absent shale, by the 2020s imported LNG represents a major component of the U.S. natural gas supply, with higher prices and lower demand. This would have resulted in greater reliance not only on LNG, but on supplies from historically volatile regions.

The No Shale Case reveals an outcome in line with the majority of industry expectations just a decade ago — one of inexorable domestic production declines, rising import dependence, and higher natural gas prices. So, for the United States, the economic and geopolitical impacts of rising domestic shale gas production are dramatic. The projections of North American shale gas production illustrated in Fig. 9, particularly when combined with the trends seen in Figs. 1 and 10, reveal the implications that shale will have on the domestic supply—demand balance.

The U.S. economy already faces challenges from the high costs of importing foreign oil. Large trade deficits driven by oil imports and the threat of oil supply disruptions driven by unrest in producing regions remain a risk factor to overall macroeconomic stability. Against that backdrop, the idea of further increasing U.S. exposure to international events through an increase in imports of LNG is not a desirable outcome. Thus, rising domestic production of natural gas, rather than rising imports, improves the energy security outlook for the U.S.

As seen in Fig. 11 below, the price of natural gas is $1.50 lower by the 2030s, and it is sourced domestically, when shale developments occur unfettered. The availability of cheaper, ample domestic natural gas supplies could also give the United States greater flexibility to forge policies to diversify its transportation sector away from overwhelming reliance on oil-based fuels. For example, since the United States uses barely any oil to generate electricity, ample natural gas for electricity generation means a shift to electrified vehicles would lessen our dependence on imported oil at a lower cost than might otherwise have been possible.

4. Other potential economic implications

Brito and Hartley (see [2]) show that growth in liquidity limits the ability of a single supplier to price above marginal cost. Increasingly abundant natural gas supplies, prompted by the dramatic growth in

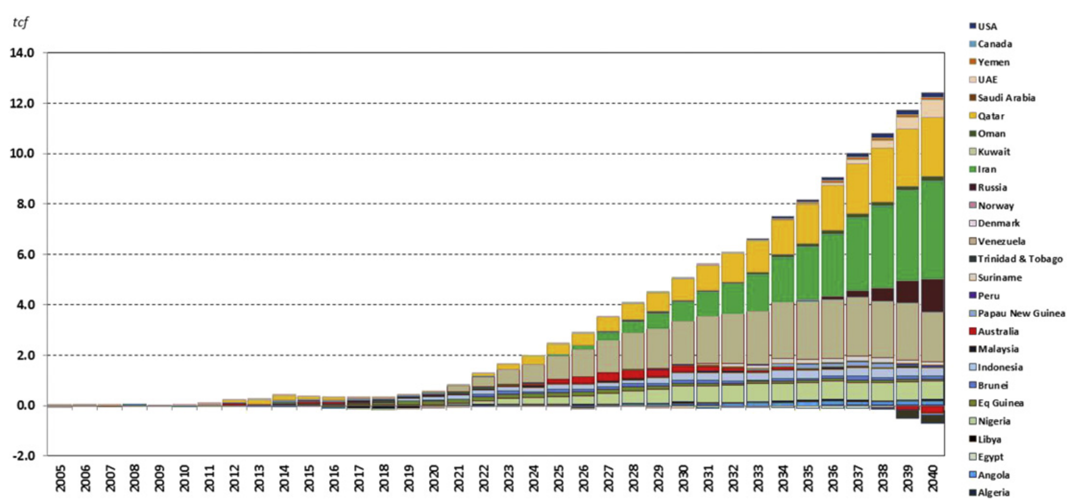

Fig. 6. LNG Exports (No Shale Case Delta to Reference Case). Source: Medlock, et al. [6].

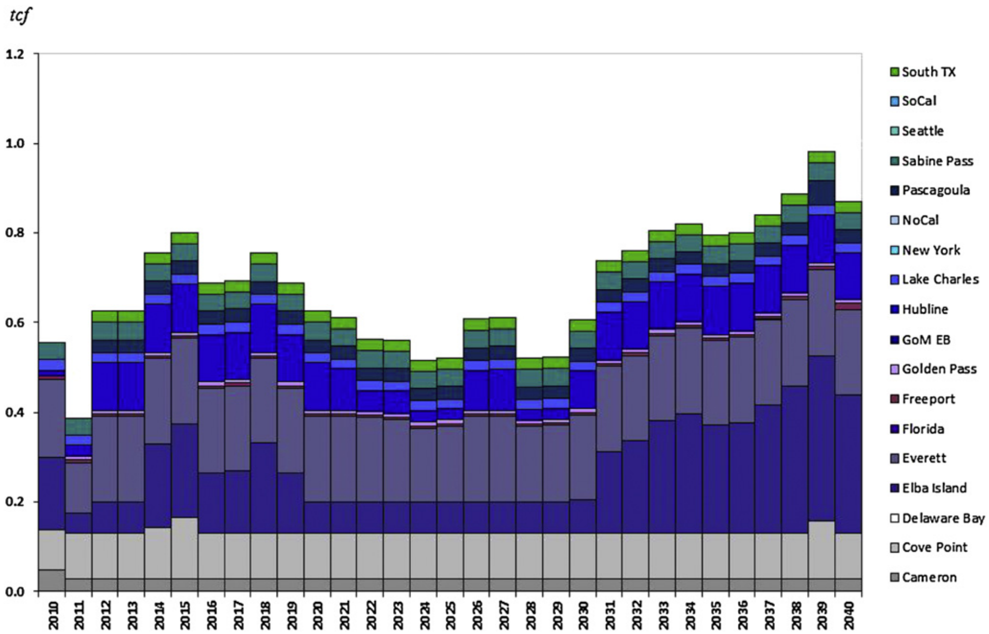

Fig. 7. Reference Case US LNG imports, 2010—2040. Source: Medlock, et al. [6].

shale, increases the competition for market share among producers. In turn, this will influence pricing of existing and future supplies. In general, as the natural gas supply curve becomes more elastic it will become increasingly difficult to price natural gas above marginal cost, which means the paradigm of oil indexation is likely to lose some of its prominence.

Oil indexation, in the absence of storage and liquidity, provides an element of price certainty. But, oil indexation can be thought of as a form of price discrimination. In order for a producer to sell natural gas at an oil indexed price, (i) it must be able to distinguish consumers and prevent resale, and (ii) it must face consumers with different demand elasticities. Although historically both of these conditions have been met in Europe and Asia, an increased ability to trade between market participants, which would occur as supply becomes more elastic, leads to a violation of condition (i).

Importantly, the ability to price discriminate will also be diminished in a liberalized market where trading of transportation capacity rights is allowed, insomuch as the arbitrage allows price signals to clearly transmit. This promotes market entry and, to the extent that trading hubs develop, financial liquidity. Then, the means to use capital markets to underwrite physical transactions increases and liquidity grows, thus making it increasingly difficult to price discriminate.

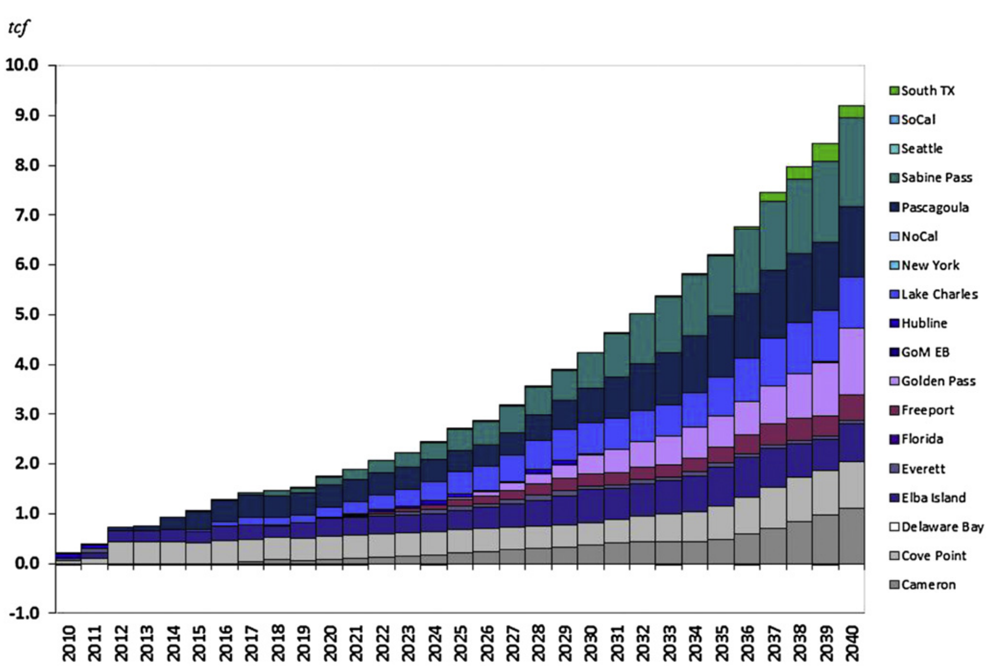

Fig. 8. U.S. LNG imports (No Shale Delta to Reference Case). Source: Medlock, et al. [6].

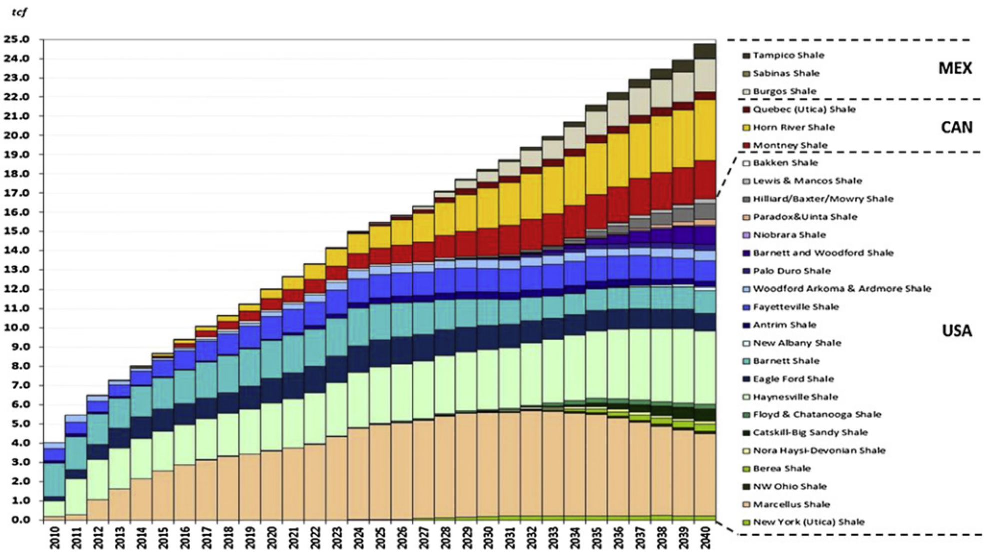

Fig. 9. North American Shale Gas production. Source: Medlock, et al. [6].

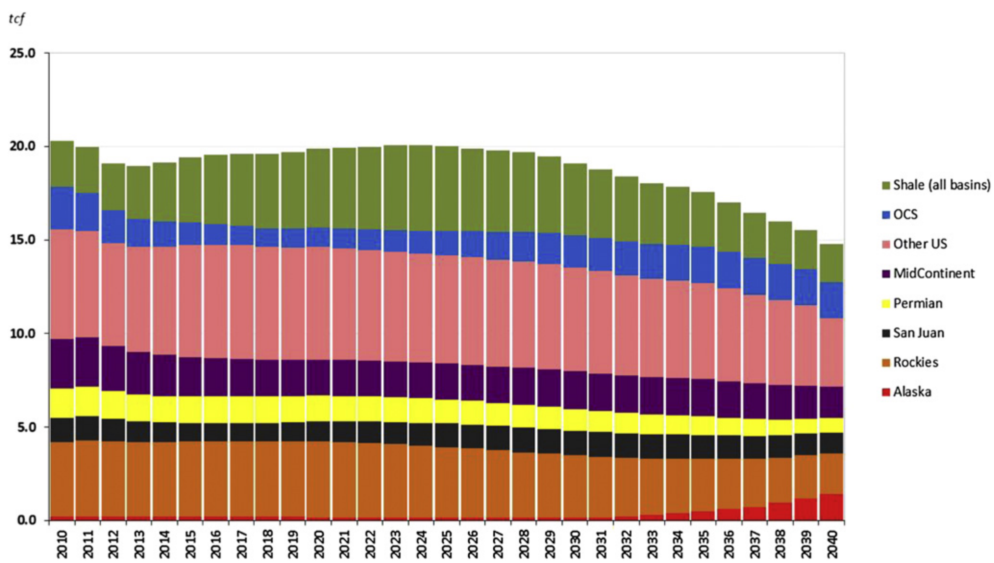

Fig. 10. No Shale Case U.S. Natural Gas production, 2010—2040. Source: Medlock, et al. [6].

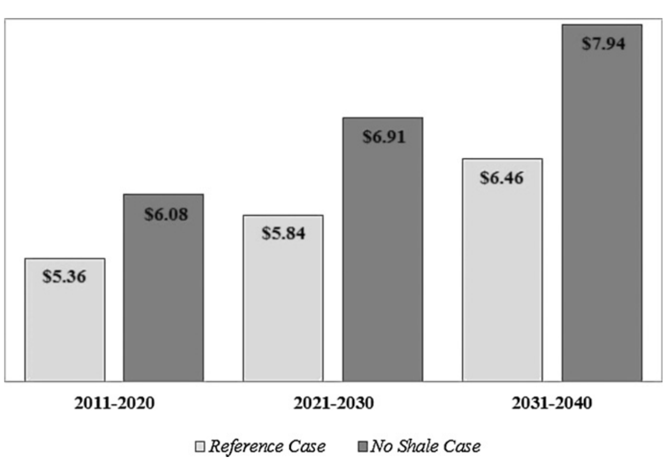

Fig. 11. Henry Hub Price in Two Cases, 2010—2040 (Decadal Averages). Source: Medlock, et al. [6].

As a matter of clarification, it is also important to note that oil indexation does not preclude spot transactions, but market structures that do not easily allow resale can severely limit them. In fact, it is possible to have both oil indexed deliveries and spot deliveries in a single market.

The ability to price discriminate appears to already be diminishing in Europe. In the past couple of years, particularly with the emergence of vibrant trade at continental market hubs, there has been an increasing propensity to index at least a portion of gas sales to spot prices. If shale resources are proven to be commercially viable in Europe and Asia, this will likely accelerate leading to much more intense competition.

5. Concluding remarks and future research

In the United States, full development of commercial shale gas resources will limit LNG imports, thus reducing negative energy-related pressures to the U.S. trade deficit. The cost to average Americans of reducing greenhouse gas emissions and meeting other environmental goals will also be lower than in the alternative case. Moreover, greater shale gas production creates greater competition in global markets, and keeps *longer term* natural gas prices from rising substantially. Increased competition also reduces the possibility of a viable natural gas producer cartel forming. So, the potential benefits of rising shale gas production extend well beyond lower prices and higher domestic production in the U.S. As argued by Medlock, Jaffe and Hartley (see [6]), the economic and geopolitical repercussions of expanded shale gas production extend to Europe and Asia.

Future research will expand on the broader international economic and energy security benefits noted by Medlock, Jaffe and Hartley (see [6]) that would accrue directly to Europe and Asia, which may also provide a buttress for U.S. foreign policy goals. In particular, the analysis indicates that Europe's dependence on Russian gas will decline if the upstream successes in shale plays in North America translate abroad. In particular, European buyers gain alternatives to Russian supplies, which reducing Moscow's leverage in the balance of power between Russia and the EU. More generally, a more energy independent Europe would be better positioned to join with the United States in global matters that might not have the full support of Russia.

Future research will also focus in more detail on the implication of rising U.S. shale gas supplies for Iran and other Middle East countries. As noted in Medlock, Jaffe and Hartley (see [6]) current global gas market developments render need for Iranian natural gas to be minimal for an extended period. Since shale gas effectively delays the need for Iranian gas, the development of pipelines to India and/or Pakistan is less urgent, which could serve to limit a possible point of contention between India and the U.S.

Future work will also attempt to reduce the uncertainty around data for shale plays outside North America. A dearth of commercial activity in shale plays outside of the United States and Canada renders assessments in those regions highly uncertain. However, in-depth studies are currently underway to fully assess shale resource potential in Europe, Asia, and Australia. The ARI study (see [1]) provides a preliminary look at the technically recoverable resource in many of these areas, but information on cost so that commercial viability can be gauged is still lacking.

Natural gas stands to play a positive role in the global energy mix, making it easier to shift away from more polluting, higher carbon-intensity fuels and increasing the near-term options to improve energy security and handle the challenge of climate change. The ample geologic endowment of shale gas in North America and potentially elsewhere around the globe means that natural gas prices will likely remain affordable and that the high level of supply insecurity currently facing world oil supplies could be eased by a shift to greater use of natural gas without fear of increasing the power of large natural gas resource holders such as Russia, Iran, and Venezuela.

To tap this benefit domestically, it will be essential for the United States to promote a stable investment climate with regulatory certainty. In particular, the United States will need adopt policies that ensure shale gas exploitation can proceed steadily and predictably with sound environmental oversight that requires transparency by operators. This is the only way to ensure that shale gas can positively contribute to greater diversification of global energy supplies.

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