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Emerging International Trade Issues for Fossil Fuels

André Barbé

Abstract

Recently emerging trends are reshaping world energy trade. In particular, new techniques using hydraulic fracturing have greatly increased U.S. production of crude oil, finished petroleum products, and natural gas. As a result, U.S. energy imports are falling and exports of natural gas and petroleum products are rising. This has special policy relevance for U.S. exports of liquefied natural gas and crude oil. In both cases, the consensus of the literature is that there would be large economic benefits for the United States from increased exports. Other important domestic policy issues include the imposition of stricter environmental regulation on the use of coal, the Keystone XL pipeline, and the removal of energy tax preferences. Internationally, major changes in world energy trade are occurring due to EU-Russian tensions, Mexican energy reform, international shale development, and rapidly increasing energy demand by developing countries.

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Office of Industries
U.S. International Trade Commission (USITC)
June 2015

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Introduction

World energy trade is experiencing significant structural changes. In the United States, shale oil and gas have revolutionized the energy landscape. Because of improved drilling and extraction technologies, from 2008–2014 U.S. natural gas production increased by 27 percent and crude oil production increased by 73 percent.[1] As a result, the United States now produces more natural gas and oil of all types than any country in the world.[2] Outside the United States, the changes are no less dramatic. Energy usage by developing countries is growing rapidly and developed countries are restructuring their energy demand due to disaster and geopolitics. This paper identifies the major emerging international trade issues in energy, reviews existing research on them, and identifies areas for further research.[3]

The paper begins with a discussion of the shale revolution, as it drives most trade issues related to the United States. Although U.S. conventional oil and natural gas production continues to fall, rising production from shale has more than compensated for it. As a result, projections of rising U.S. energy imports have turned into falling imports or even net exports, with benefits for U.S. oil and gas producers, consumers, and the economy as a whole. However, the shale revolution has not been without its detractors, who have raised concerns over potential environmental costs in regards to groundwater contamination and greenhouse gas emissions.

The shale revolution and the changes it has brought to the energy sector have important implications for policy. In particular, U.S. exports of both natural gas and crude oil are legally restricted and both policymakers and stakeholders are interested in learning the effect of easing these restrictions. In order for firms to export natural gas, they must apply for an export permit. This process is time consuming but feasible. On the other hand, crude oil exports are prohibited by the federal government with only a few exceptions. A number of studies have been conducted on both types of exports by consulting firms, think tanks, and government agencies. These studies have consistently shown that both types of exports would be beneficial for the U.S. economy.

In addition to oil and natural gas exports, a number of other domestic policy issues and emerging trends will impact U.S. energy producers and consumers. This paper reviews analysis of topics such as the effects of new U.S. coal regulation, the Keystone XL pipeline, and domestic energy tax reform.

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[1] Energy Information Administration (EIA), "U.S. Dry Natural Gas Production"; EIA, "U.S. Crude Oil Supply & Disposition"
[2] EIA, "International Energy Statistics."
[3] This paper's focus is on fossil fuels and especially the shale revolution. Therefore other issues, such as climate change and renewables, are not covered directly but discussed as they relate to these topics.

Although the biggest changes for U.S. fossil fuels have domestic origins, many important international pressures also exist. For example, following the 2014 Russian military intervention in Ukraine, Europe faced increased pressure to reduce its reliance on Russian energy. By contrast, Mexico is deregulating its energy sector to allow for more foreign competition. Forecasts predict that this will lead to large increases in Mexican energy production, but not large enough to keep pace with rapidly rising Mexican demand. Additionally, although the shale revolution is currently an American phenomenon, most world shale deposits exist outside the United States. With favorable geological and regulatory conditions, countries such as China, France, Poland, and Argentina could greatly increase their own oil and gas production. Whether or not this occurs will have major consequences for world energy trade, as the energy demands of developing countries are growing rapidly.

Finally, avenues for future research are considered. The discussion of research topics related to each issue occurs at the end of that issue's section and focuses on research opportunities that are novel but also policy relevant. Examples of research ideas identified in this report include evaluating the past impact of the shale revolution, forecasting the future impact of liquefied natural gas (LNG) exports, analyzing alternatives to complete repeal of crude oil export restrictions, forecasting the impact of future environmental restrictions on coal production and global emissions, estimating the changes in U.S. imports and exports due to energy tax reform, and projecting the effects of new natural gas pipelines to Mexico.

Box 1: Glossary

Conventional oil and gas: oil and natural gas resources where simply drilling into a reservoir rock releases hydrocarbons in sufficient quantities to be profitable.

Unconventional oil and gas: oil and natural gas resources where simply drilling into a reservoir rock does not release hydrocarbons in sufficient quantities to be profitable and additional techniques, such as hydraulic fracturing, are necessary. Examples of unconventionals include shale gas, coalbed methane, tight oil, and oil shale.[a]

Hydraulic fracturing: a.k.a. "fracking", is a process for creating fractures in rock in order to recover more hydrocarbons from the formation.[b] Hydraulic fracturing is commonly used in shale gas, tight gas, and tight oil.

Liquefied natural gas (LNG): natural gas that has been processed into a liquid so it can be transported via ship.

Wet gas: natural gas where natural gas liquids are present along with the primary component of natural gas, methane.

Dry gas: natural gas that does not contain natural gas liquids: only methane exists in significant quantities.

Black Shale: a.k.a. organic shale, often shortened to just "shale," is a sedimentary rock rich in organic matter which may contain hydrocarbons.[c]

Shale gas: natural gas produced from black shale formations.[d]

Tight gas: natural gas produced from very low permeability sandstone.

Crude oil: a.k.a. crude petroleum, is a naturally occurring liquid petroleum. It is called "crude" because it has not yet undergone refining to separate out its different component hydrocarbons. Most legislation uses the term "crude petroleum" to refer to this liquid while "crude oil" is the term used by the Energy Information Administration (EIA) and the latter term will be used in this document.

Oil-bearing shale: is a sedimentary rock containing oil. Hydraulic fracturing and horizontal drilling are typically used to extract this oil. Oil-bearing shale formations include the Bakken, Barnett, and Eagle Ford. The oil produced from oil-bearing shale is often colloquially referred to as "shale oil", but the International Energy Agency (IEA) recommends using the term "light tight oil" in order to avoid confusion with the "shale oil" produced from "oil shale." In addition, although the sedimentary rock in oil-bearing shale is often shale, this rock can also be tight siltstone limestone or dolomite.[e]

Tight oil: a.k.a. light tight oil, is crude oil found in rocks with very low permeability, such as shale and sandstone.[f] Tight oil is sometimes referred to as "shale oil," but this terminology is discouraged by the IEA as "shale oil" is also the name of a different substance.

Oil shale: a type of shale rich in kerogen, a precursor of oil and gas. Through a process called retorting, oil shale is heated to produce shale oil. Despite the similarity in name, "oil shale" is different from "oil-bearing shale."[g] Oil shale is currently not a major component of the shale revolution that is increasing U.S. oil and gas production.

Shale oil: This term has two different meanings. It can refer to the oil released after processing oil shale, or to the light tight oil extracted from oil-bearing shale. To avoid confusion, the IEA recommends that only the oil released after processing oil shale should be called "shale oil" and that the term "light tight oil" should be used for the crude oil extracted from oil-bearing shale.[h]

[a] IEA, "World Energy Outlook 2014," 75, 146.
[b] Colorado Oil and Gas Association, Oil Shale vs. Shale Oil.
[c] Tourtelot, "Black Shale-Its Deposition and Diagenesis."
[d] EIA, "Definitions, Sources, and Explanatory Notes."
[e] Colorado Oil and Gas Association, Oil Shale vs. Shale Oil.
[f] EIA, "Does EIA Have Data on Shale (or 'Tight Oil') Production?"
[g] Colorado Oil and Gas Association, Oil Shale vs. Shale Oil.
[h] Colorado Oil and Gas Association, Oil Shale vs. Shale Oil; IEA, "World Energy Outlook 2012," 21.

The Shale Revolution

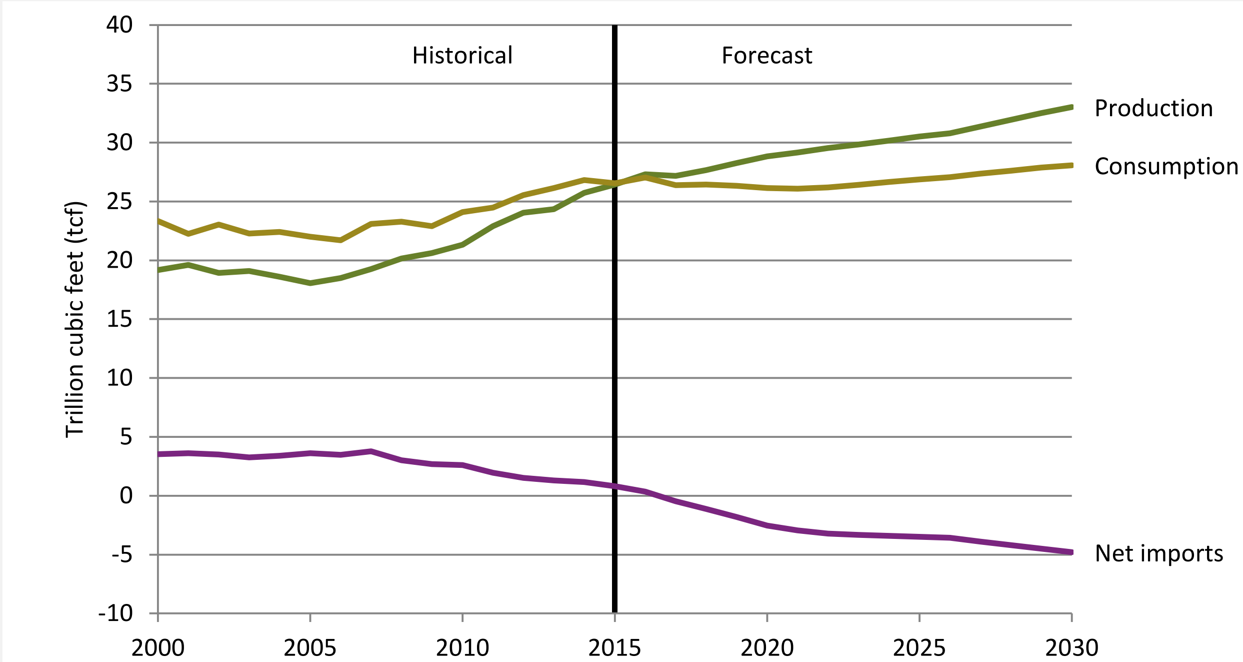
Shale deposits containing large quantities of oil and natural gas are located throughout the United States. Geologists have long known of their existence, however, the cost of extracting these resources was extremely high and thus historically little development occurred. This all changed with the development of hydraulic fracturing ("fracking") and horizontal drilling techniques that greatly reduced the costs of extracting oil and gas from shale.[4] Largely as a result of this "shale revolution," the United States is now the largest oil and gas producer in the world.[5] But because of the near total ban on crude oil exports, new production has not translated into significantly increased exports of crude. Instead, exports of downstream finished petroleum products have increased. As a result of all of these increases in U.S. fossil fuel production, estimates in the literature consistently find that the shale revolution has created millions of jobs, billions of dollars of GDP, and improved U.S. energy security. However, there is not a consensus on the environmental effects of the shale revolution. This section reviews these estimates of the current and future impacts of the shale revolution on production and trade in natural gas, crude oil, and petroleum products, discusses the overall impact of the shale revolution on the economy and the environment, and identifies some promising areas for future research.

Effects of the Shale Revolution on Natural Gas

As a result of the shale revolution, natural gas production has greatly increased, and this increased domestic energy production has led to increased domestic consumption and reduced net imports (see figure 1). The U.S. Energy Information Administration (EIA) projects that U.S. gas production will continue to grow and that the United States will soon become a net exporter of gas, notably to European and Asian markets through tanker exports of liquefied natural gas (LNG). This is in stark contrast to predictions of just a few years ago, when it was forecast that the United States would become a major importer of LNG. Lower natural gas prices have encouraged the use of natural gas for generating electricity and improved the competitiveness of industries that use natural gas and chemicals extracted alongside it as inputs in production.

[4] Shale gas extraction, hydraulic fracturing, and horizontal drilling are not new technologies. However, it was not until 2002 that Devon Energy discovered exactly how to apply all these technologies together in order to make shale gas fracturing economical (Houser and Mohan, "Fueling Up: The Economic Implications of America's Oil and Gas Boom. ") See Zhongmin Wang and Alan Krupnick, "A Retrospective Review of Shale Gas Development in the United States: What Led to the Boom?" for a review of the factors that led to the shale revolution.
[5] EIA, "International Energy Statistics."

Figure 1: U.S. natural gas trade



Source: EIA, Annual Energy Outlook 2015; EIA, "U.S. Natural Gas Consumption by End Use"; EIA, "U.S. Natural Gas Imports by Country;" EIA, "U.S. Natural Gas Exports by Country;" EIA, "U.S. Natural Gas Gross Withdrawals and Production."
Note: Data for 2015 and later years are forecasts.

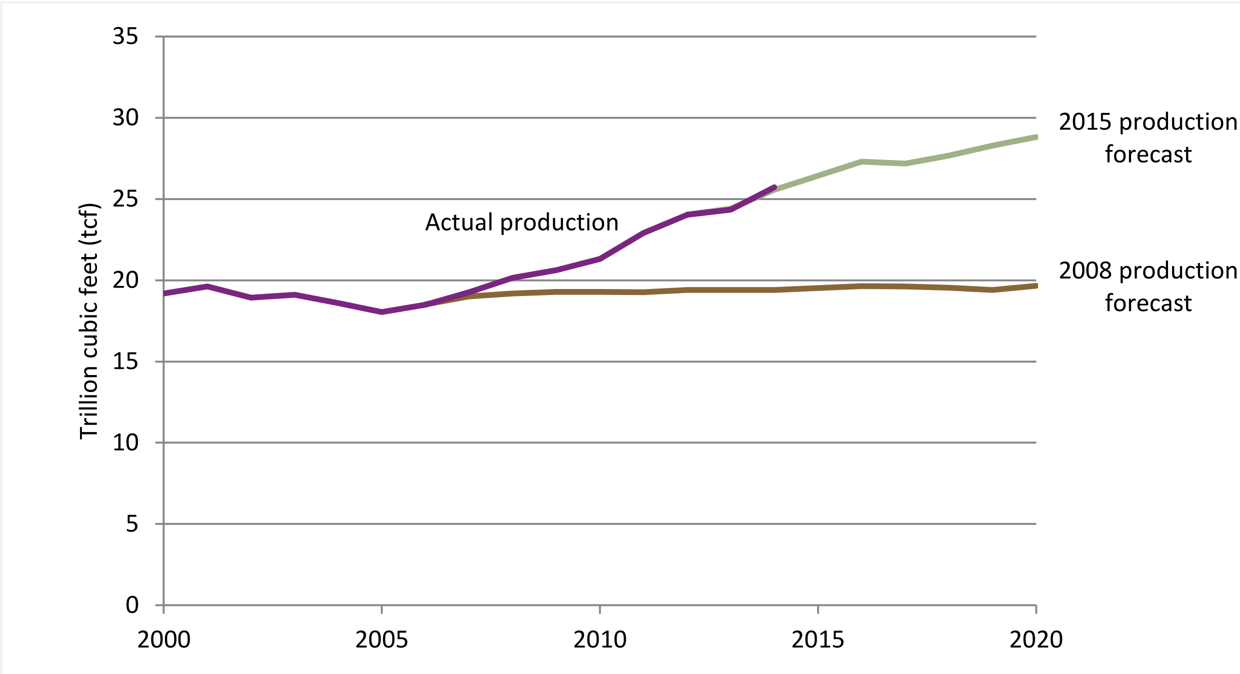
Natural Gas Production and Projected Imports

The shale revolution has transformed domestic natural gas production. Although the United States has a long history of significant natural gas production, this production was largely "conventional" and was forecast to slowly decline, forcing the United States to import natural gas from abroad. Although the United States also contained large and well-known gas deposits in unconventional shale plays, this gas was not profitable to extract. However, the combination of technologies such as hydraulic fracturing, horizontal drilling, and slickwater made the extraction of shale gas profitable. While conventional natural gas production has declined as forecast, these new gas extraction technologies focusing on shale have allowed unconventional shale gas production to greatly increase, more than making up for lost conventional production. As a result, total U.S. natural gas production has grown significantly and projected natural gas imports have turned into forecasts of natural gas exports.

To appreciate both the speed and size of the transformation caused by the shale revolution, consider forecasts made before shale and tight gas were economically recoverable. As recently as 2008, the EIA predicted that domestic gas production would fall behind growing demand and net imports would increase, primarily in the form of overseas LNG (see figure 2 and figure 3). Nor was the EIA alone in believing these forecasts. In 2008, Chenier Energy constructed a

$2 billion natural gas import terminal at the Sabine Pass River in Louisiana in order to meet these anticipated needs.[6] In total, firms increased U.S. LNG import capacity from 1 trillion cubic feet (tcf) in 2000 to over 6 tcf in 2012.[7] [8]

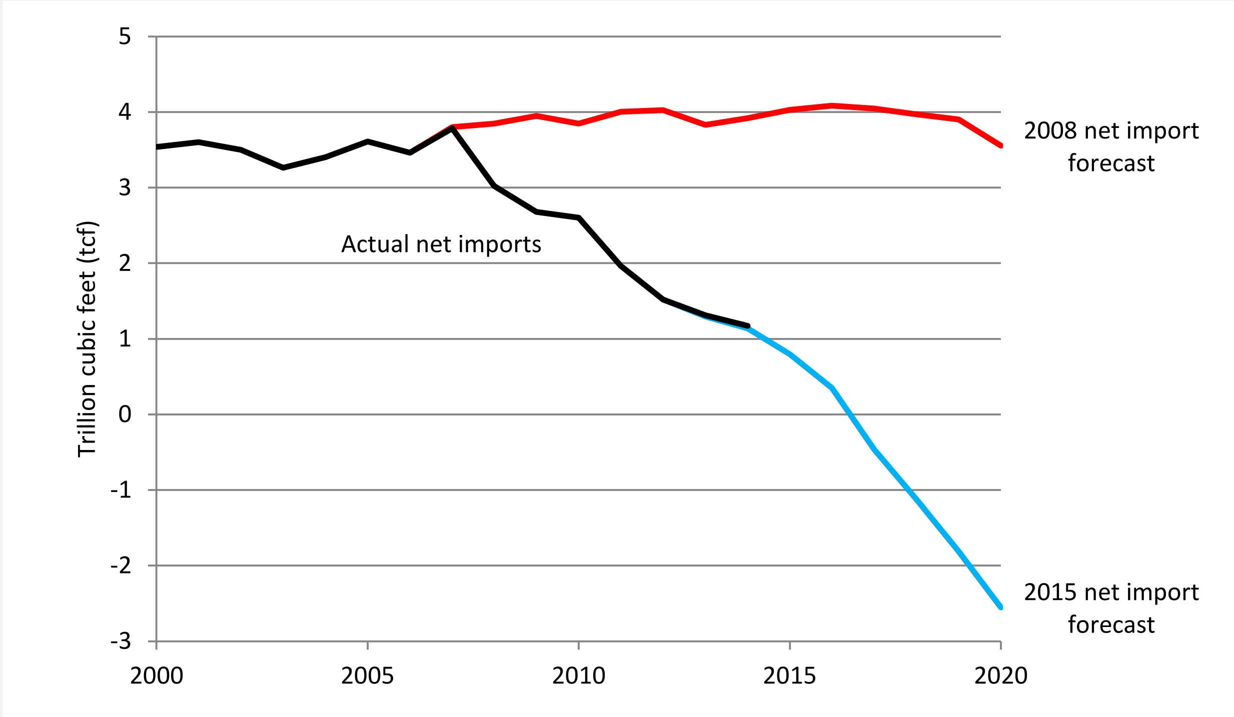
Figure 2: Projected and actual U.S. natural gas production



Source: EIA, Annual Energy Outlook 2008; EIA, Annual Energy Outlook 2015; EIA, "U.S. Natural Gas Gross Withdrawals and Production."

[6] Helman, "How Chenier Energy Got First In Line to Export America's Natural Gas."
[7] Jacoby, O'Sullivan, and Paltsev, "The Influence of Shale Gas on US Energy and Environmental Policy."
[8] The U.S. produced a total of 24.3 tcf of natural gas in 2013 (see figure 1 and figure 2).

Figure 3: Projected and actual U.S. natural gas imports

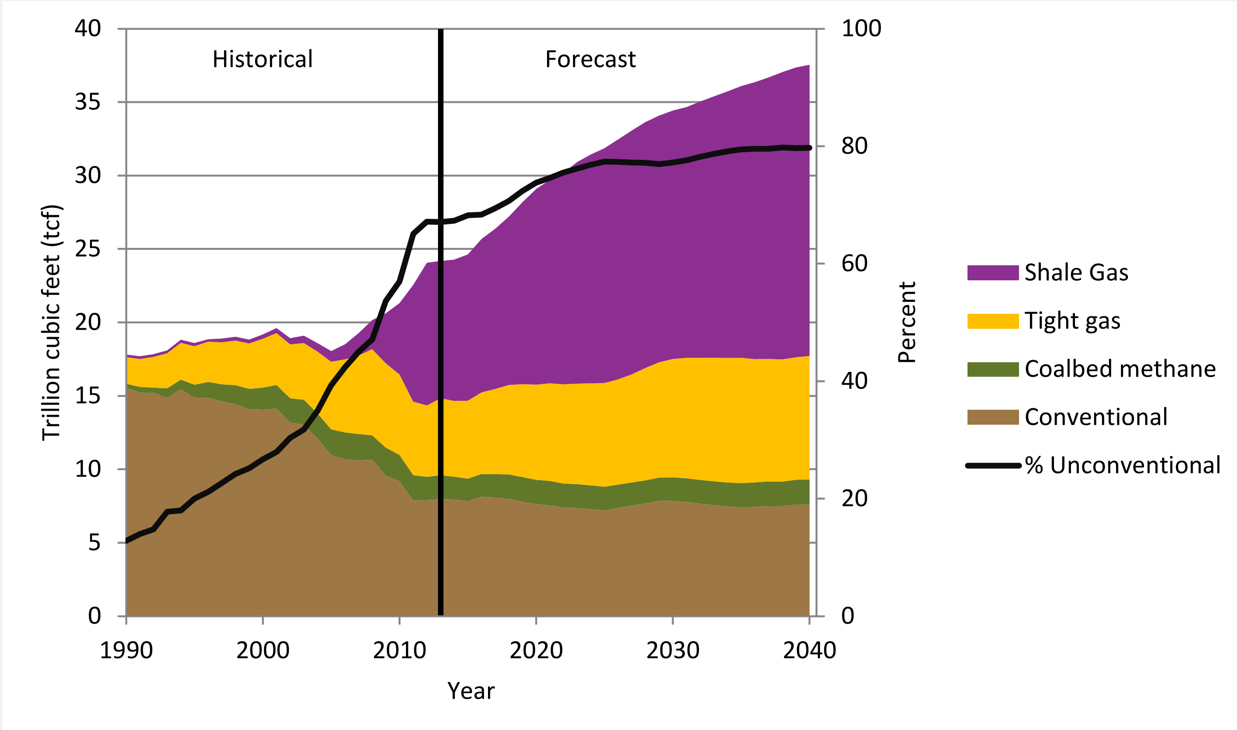


Source: EIA, Annual Energy Outlook 2008; EIA, Annual Energy Outlook 2015; EIA, "U.S. Natural Gas Imports by Country"; EIA, "U.S. Natural Gas Exports by Country."

This has all changed with the development of technology that unlocked shale and tight gas. Buoyed by increases in unconventional production, total domestic natural gas production rose by 42 percent from 2005 to 2014.[9] Proved reserves have grown even faster, increasing by 76 in the same time period.[10] And natural gas production is expected to increase by a further 13 percent between 2014 and 2020.[11] Previous forecasts were not completely wrong: by 2012 conventional gas production had fallen by 6 trillion cubic feet to 55 percent of 2000 levels (see figure 4).[12] However, the increase in shale gas has more than made up for these declines, and total gas production has gone up instead. In 2000, these unconventional sources provided less than 20 percent of U.S. natural gas production,[13] but in 2012 unconventionals provided 67 percent of gas production, and by 2040 unconventionals are predicted to reach 80 percent of production.

[9] EIA, "U.S. Natural Gas Gross Withdrawals and Production."
[10] EIA, "International Energy Statistics."
[11] Author's calculations from data in EIA, Annual Energy Outlook 2015.
[12] Author's calculations from EIA, "Market Trends: Natural Gas."
[13] Ibid.

Figure 4: U.S. natural gas production from conventional and unconventional sources



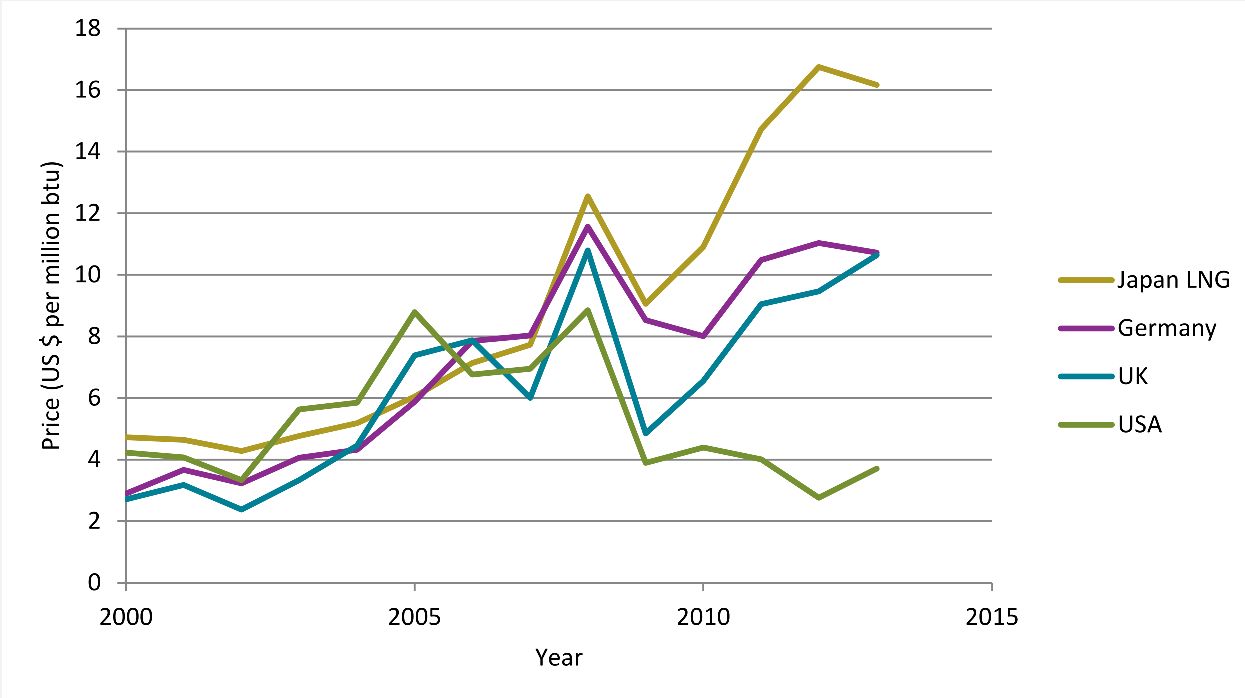
Source: EIA, "Market Trends: Natural Gas."
Notes: Data for 2013 and later years are forecasts.

Natural Gas Exports

The shale revolution greatly and unexpectedly increased natural gas production and, as a result, natural gas prices have fallen.[14] Average domestic wellhead price dropped from $7.97 in 2008 to $2.66 in 2012.[15] U.S. gas is now much cheaper than gas in the rest of the world (see figure 5). From 2005–2012, natural gas prices in the United States dropped 66 percent, while they increased by 35 percent in the EU.[16] This has eliminated the motivation for the United States to import gas and instead created a strong incentive for export.

[14] Hausman and Kellogg, "Welfare and Distributional Implications of Shale Gas," 16.
[15] EIA, "U.S. Natural Gas Wellhead Price."
[16] Bruijnincx and Weckhuysen, "Shale Gas Revolution: An Opportunity for the Production of Biobased Chemicals?"

Figure 5: Price of natural gas in selected countries



Source: BP, BP Statistical Review of World Energy June 2014.

The EIA forecasts that in 2017 the United States will end over two decades as a net importer of natural gas and become a net exporter.[17] These exports are forecast to increase to 2.5 trillion cubic feet of gas in 2020. The United States will be a net exporter both via pipelines and LNG, but more net exports will occur via LNG. This is consistent with the fact that natural gas prices are higher in Europe and Asia than in Canada and Mexico (and that the United States is forecast to continue to import natural gas from Canada).

Although U.S. exports are projected to be substantial compared to international LNG trade, they will still be small compared to the entire world natural gas market. The IEA projects world natural gas demand to be 139 tcf in 2020 and 175 tcf in 2035.[18] By comparison, they forecasts that U.S. LNG exports will be 1.1 tcf in 2018 and reach a peak of 3.3 tcf in 2030.[19] In addition, other gas exporting countries have also seen these export opportunities and are acting to increase their export capacity. 3.8 tcf of LNG export capacity under construction worldwide will be operational by 2018, increasing world LNG export capacity to 17 tcf.[20] [21]

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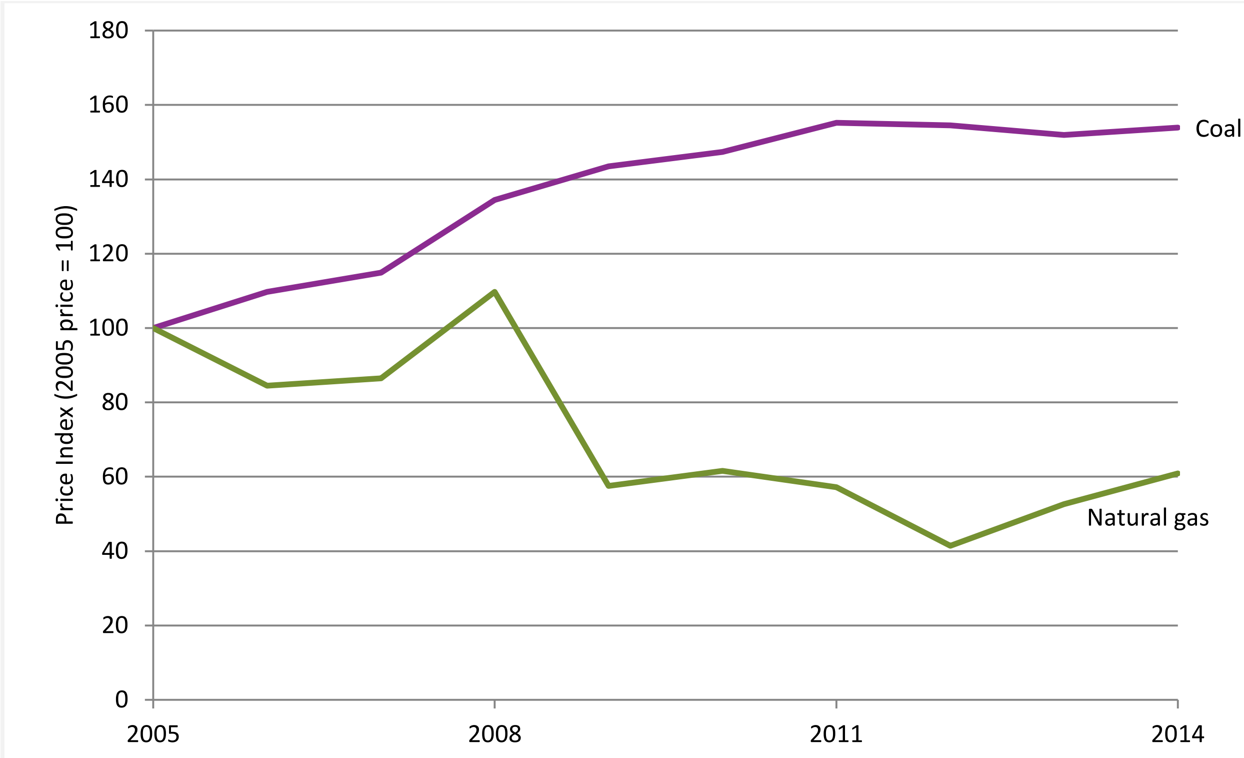
[17] EIA, Annual Energy Outlook 2015, data table 13. http://www.eia.gov/forecasts/aeo/excel/aeotab_13.xlsx.
[18] Ibid., 128. 3943 bcm is 139 tcf. 4955 bcm is 175 tcf.
[19] EIA, Annual Energy Outlook 2015, data table 13. http://www.eia.gov/forecasts/aeo/excel/aeotab_13.xlsx.
[20] International Energy Agency, “World Energy Outlook 2014,” 150. 108 bcm is equal to 3.8 tcf.
[21] Ibid., 148. 480 bcm is 17 tcf.

Natural Gas Consumption

The drop in natural gas prices caused by the shale revolution has also increased domestic consumption of natural gas, ceteris paribus. Electricity generation is the largest single use of natural gas in the United States, and the price of natural gas for electricity has fallen from $9.01 per million British Thermal Units in 2008 to $5.00 in 2014 (see figure 6). Increased natural gas use has mainly come at the expense of coal, which has seen its share of electricity generation fall from 52 percent in 2000 to 39 percent in 2014 (see figure 7). In addition, many industrial sectors (see figure 8) use dry natural gas (methane) and natural gas liquids (e.g., ethane, propane, and butane) as inputs in production.[22] Lowering these inputs' prices increases these sectors' competitiveness with the rest of the world. For example, from 2008–2013, the cost of making petrochemicals went up 20 percent in the EU but down 50 percent in the United States.[23] This affects the entire supply chain, as firms which use electricity (or these products made from natural gas) as inputs in their own production also benefit from reduced input costs and increased competitiveness.[24] Hausman and Kellogg found that the shale revolution increased manufacturing employment by around 280,000 in 2012.[25]

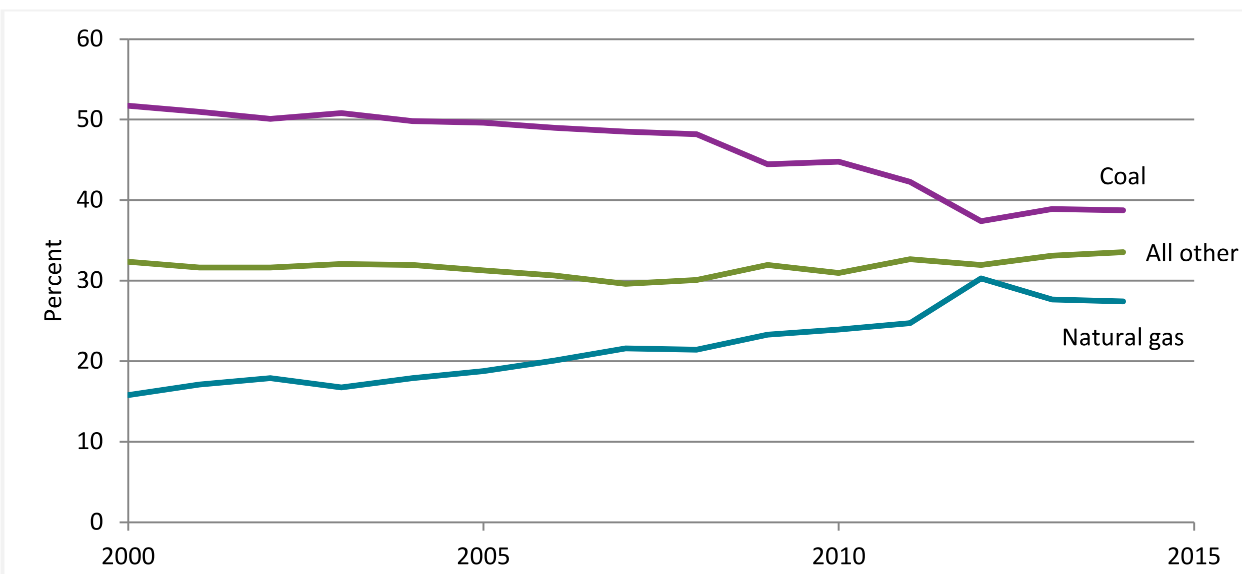
[22] EIA, What Are Natural Gas Liquids and How Are They Used?
[23] Bruijnincx and Weckhuysen, "Shale Gas Revolution: An Opportunity for the Production of Biobased Chemicals?"
[24] Note that while electricity prices are lower than they would have been had the shale revolution not occurred, other factors also influence electricity prices.
[25] Hausman and Kellogg, "Welfare and Distributional Implications of Shale Gas," 33.

Figure 6: Cost of coal and natural gas for electricity generation



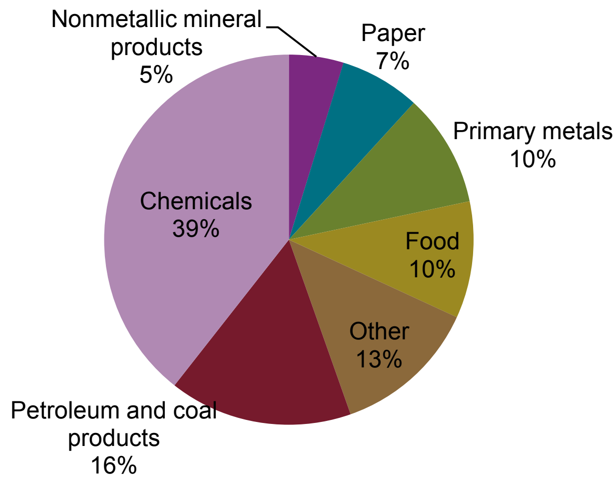
Source: EIA, "Electric Power Monthly," Table 4.1.

Figure 7: U.S. electricity generation from coal, natural gas, and all other sources



Source: EIA, "Monthly Energy Review," Table 7.2a.

Figure 8: Industrial natural gas consumption by sector, 2010



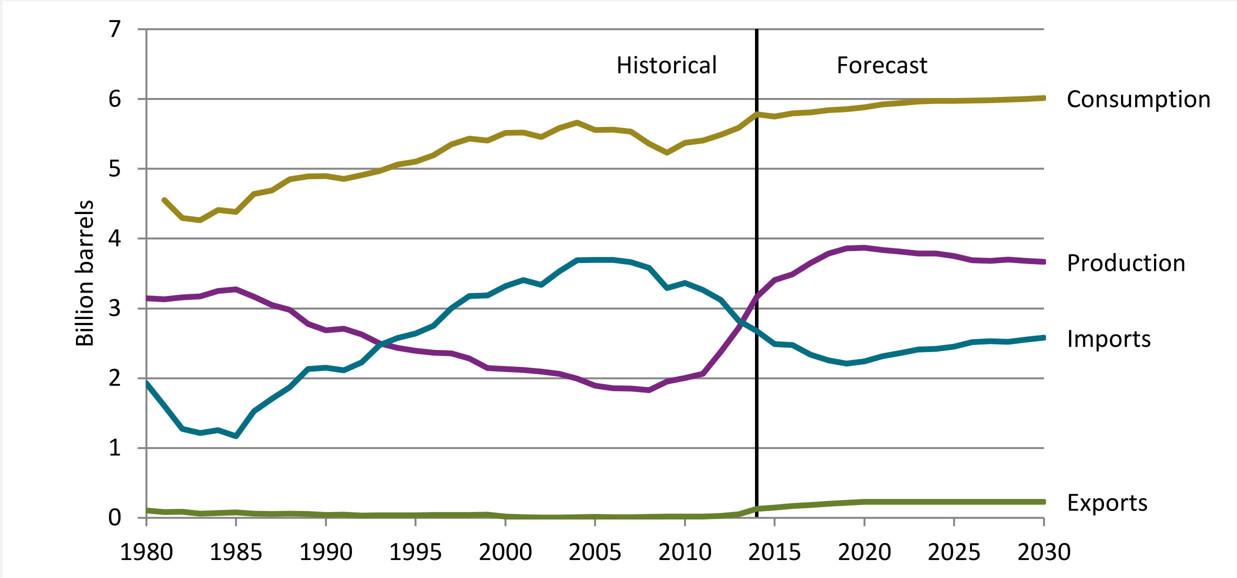
Source: EIA, "2010 Manufacturing Energy Consumption Survey," Table 1.1.
Notes: This pie chart includes only natural gas consumption by industrial sectors, not residential consumption.

Effects of the Shale Revolution on Crude Oil

As with natural gas, U.S. oil production has dramatically increased in the past decade (see figure 9). The techniques that improved shale gas production are also applicable to light tight oil and as a result, new tight oil production is reversing historic oil production declines. Crude oil production has increased by 73 percent from a low of 1.8 billion barrels in 2008 to 3.2 billion barrels in 2014. This production growth is driven by tight oil, a type of crude oil whose production increased from zero in 1999 to 1.1 billion barrels in 2013 (see figure 10). In 2014, the United States was the world's 3rd largest producer of crude oil, behind Russia with 3.7 billion barrels per year, and Saudi Arabia with 3.6 billion. However when other petroleum liquids and refinery processing gains are included along with crude oil production, the United States now has the world's largest total oil production, with 2014 production of 5.1 billion barrels, having surpassed Saudi Arabia (with 2014 production of 4.2 billion barrels) back in 2013.[26] Combined with steady domestic demand and near zero exports, this increased production has led to a dramatic drop in U.S. crude oil imports.

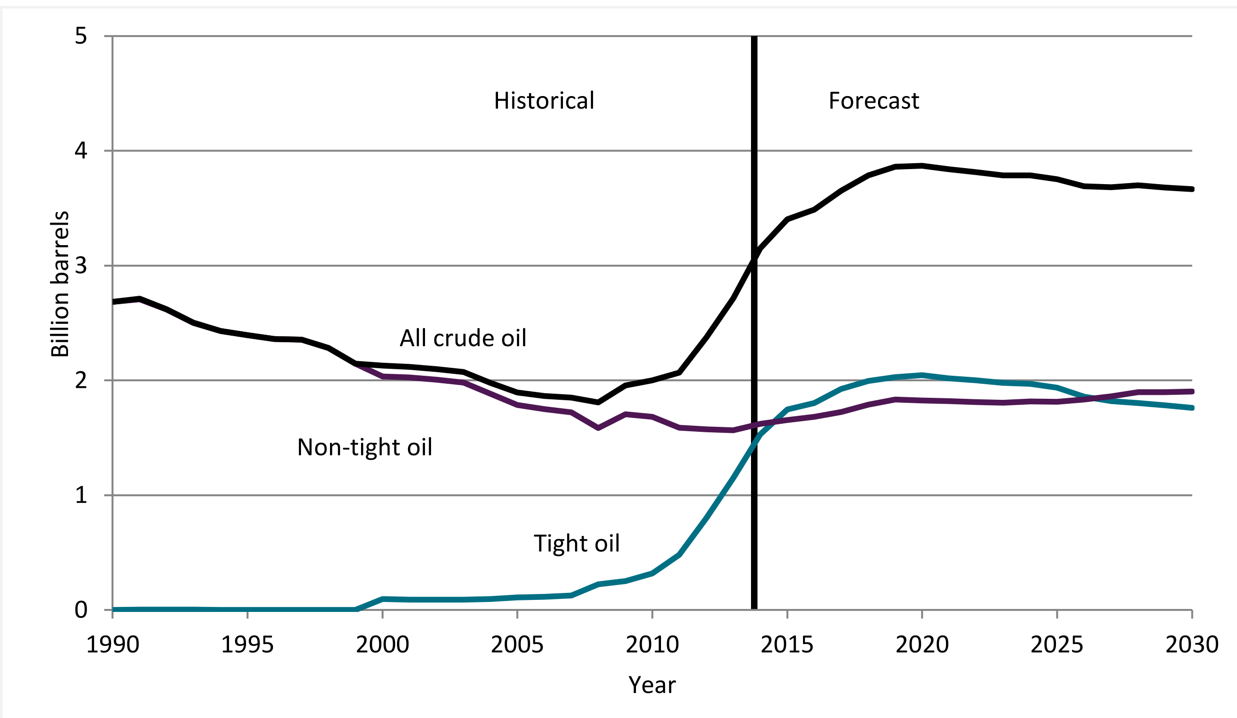
[26] EIA, "International Energy Statistics."

Figure 9: U.S. crude oil trade



Source: EIA, "U.S. Crude Oil Supply & Disposition"; EIA, Annual Energy Outlook 2015, table 11.
Notes: Data for 2015 and later years are forecasts.

Figure 10: U.S. crude oil production: Tight and non-tight oil



Source: EIA, Annual Energy Outlook 2014 Early Release, fig. 1; EIA, Annual Energy Outlook 2015, table 11.
Notes: Data for 2014 and later years are forecasts.

The shale revolution has also likely reduced oil prices, at least in the short term.[27] For example, global spare production was low in 2012 and thus oil prices at that time could have been significantly higher without the increased U.S. crude oil production from shale and other tight resources.[28] However, both supply and demand are much more elastic in the long run, reducing the sensitivity of world oil market prices to small increases in production from non-OPEC members.[29] This means that the long term impact of the shale revolution on prices should be smaller than the short term impact.

In addition to lowering price levels, the shale revolution may also have reduced price volatility. Large fixed costs and low marginal costs mean that production at existing wells is relatively unresponsive to price but the drilling of new wells is highly responsive.[30] However, traditional oil wells are slow to drill and they produce oil over a very long lifetime, so it takes a long time for changes in the rate of new well drilling to change total conventional oil output. As a result of these two effects, when there is an unexpected change in the price of crude oil, it takes a long time for increased (decreased) conventional supply to move prices back to their long run level. However, shale is the complete opposite of conventional oil in these areas. Shale oil drilling is much faster than conventional drilling and a shale well also has a much shorter lifetime.[31] As a result, shale oil production is able to increase or decrease much more quickly,[32] mitigating the impacts of price fluctuations, with the size of this mitigation depending on how much of the world's marginal oil production is in shale oil. Shale's ability to mitigate price swings may be of great importance in the future if Saudi Arabia is no longer willing to increase or decrease its oil production in order to produce the same effect.

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[27] To be clear, while prices are lower than they would be without the shale revolution, this does not necessarily imply that oil prices will fall over time or that the fall in oil prices starting in late 2014 was due to the shale revolution.

[28] EIA, Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States, 11.

[29] Ibid.

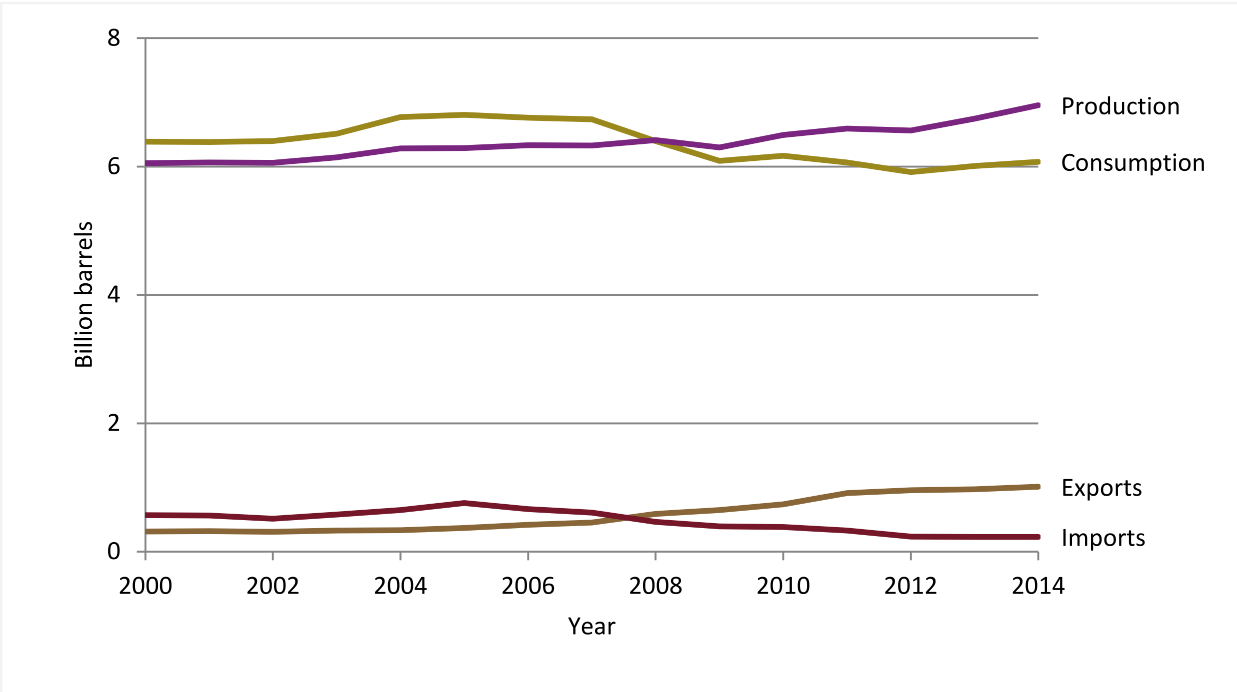
[30] Anderson, Kellogg, and Salant, Hotelling Under Pressure, 2.

[31] Maugeri, The US Shale Oil Boom: A U.S. Phenomenon, 11.

[32] Ibid.

Effects of the Shale Revolution on Finished Petroleum Products

Figure 11: U.S. finished petroleum products trade



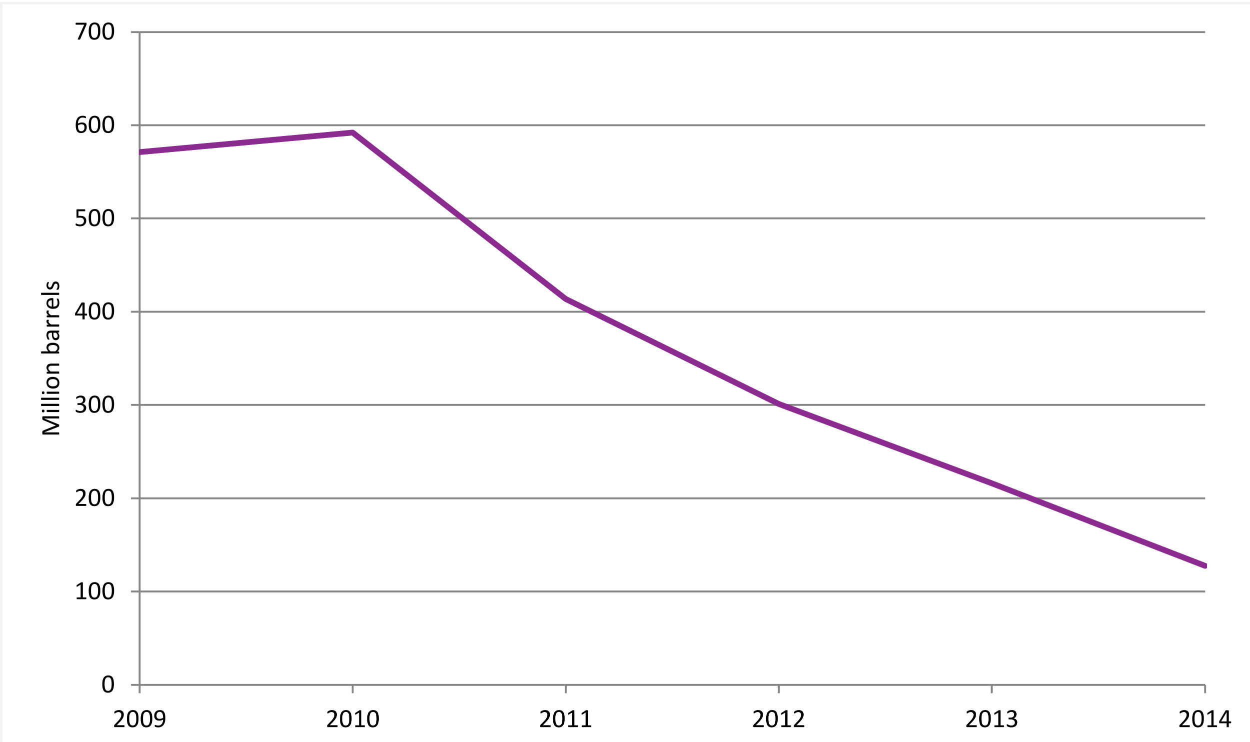
Sources: EIA, "U.S. Finished Petroleum Products Renewable Fuels and Oxygenate Plant Net Production"; EIA, "U.S. Exports of Finished Petroleum Products"; EIA, "U.S. Imports of Finished Petroleum Products"; EIA, "U.S. Refinery and Blender Net Production of Finished Petroleum Products"; EIA, "U.S. Product Supplied of Finished Petroleum Products."

The United States has long been the world's largest producer and consumer of finished petroleum products,[33] but it is now also seeing a significant increase in exports of these products (see figure 11). These exports are a consequence of increased domestic crude production interacting with a number of other factors. Although the United States is a net importer of crude oil, the new U.S. crude oil being produced because of the shale revolution is a particular type of crude (light sweet crude) that is not easily substitutable for other types. Normally, this might cause the United States to reduce imports and increase exports of this crude. However, while imports of this particular type of crude have fallen dramatically (see figure 12), total crude exports have not greatly increased. This is because, as is discussed in more detail in Section 5, the United States prohibits the export of crude oil under all but a small number of circumstances. The export of finished petroleum products, however, is not restricted. This lowers the domestic crude oil price relative to the world price, while

[33] EIA, "International Energy Statistics."

maintaining the equality of world prices for finished products. As a result, firms are incentivized to refine the oil domestically (as opposed to refining it overseas) and then export the refined products.

Figure 12: U.S. imports of light sweet crude oil



Source: EIA, "Imports of Light Sweet from World to Total U.S."

Macroeconomic Effects of the Shale Revolution

The improvements in industry competitiveness induced by the shale revolution have benefits for the U.S. economy as a whole. In a report for the American Chemistry Council, IHS found that unconventional oil and gas development increased U.S. GDP by $284 billion and employment by 2.1 million in 2012.[34] Other studies by Citigroup,[35] CBO,[36] McKinsey,[37] and Houser and Mohan[38] also found that the shale revolution substantially increased GDP and

[34] IHS, *America's New Energy Future,* vol. 3.
[35] Edward L. Morse et al., *ENERGY 2020: North America, the New Middle East?*
[36] Congressional Budget Office (CBO), *The Economic and Budgetary Effects of Producing Oil and Natural Gas From Shale*.
[37] Lund et al., *Game Changers: Five Opportunities for US Growth and Renewal*.
[38] Houser and Mohan, "Fueling Up: The Economic Implications of America's Oil and Gas Boom. "

employment (see table 1). Hausman and Kellogg found that the welfare benefits to the U.S. economy from the shale revolution averaged $48 billion per year from 2007–2013.[39]

Table 1: Estimates of the long-run macroeconomic effects of the shale revolution

Source	GDP Increase (billion $)[a]	Employment Increase (millions)[a]
Citigroup (2012)	370 to 624	3.6
McKinsey (2013)	380 to 690	1.0 to 1.7
IHS (2013)	533	3.9
Houser and Mohan (2014)	96 to 327	0.8 to 2.5
CBO (2014)	157[b]	0 by assumption

Source: (1) Edward L. Morse et al., ENERGY 2020: North America, the New Middle East; (2) Lund et al., Game Changers: Five Opportunities for US Growth and Renewal; (3) IHS, *America's New Energy Future,* vol. 3; (4) Houser and Mohan, "Fueling Up: The Economic Implications of America's Oil and Gas Boom."; (5) Congressional Budget Office (CBO), The Economic and Budgetary Effects of Producing Oil and Natural Gas From Shale.
Notes:

[a] Different studies use different measures of GDP and employment which are similar but not identical.

[b] CBO reports that GDP in 2040 will be 0.9 percent higher due to the Shale Revolution. In order to create a measure more comparable with other studies (which use dollar values and near term GDP), I multiply 0.9 percent by US GDP in 2014 ($17,418.9 billion according to Bureau of Economic Analysis, National Income and Product Accounts).

However, these studies are not peer-reviewed, and the peer reviewed literature on the shale revolution is much sparser. This may be a problem: Kinnaman reviewed several non-peer reviewed studies from before 2012 and he argues that the true economic impacts of shale gas extraction are likely smaller than what was found in these studies.[40] Although the studies reviewed in previous paragraph came out after Kinnaman's paper did, the criticism of not being peer-reviewed does still apply. And while the peer-reviewed literature has grown since Kinnaman's publication,[41] these studies have typically not estimated the macroeconomic effects of the shale revolution. An exception is Vipin, who found that a hypothetical 10 percent natural gas production increase would increase GDP by $23 to $100 billion and employment by 400,000 jobs. For comparison, actual natural gas production increased by 27 percent from 2008–2014 while oil production also increased by 73 percent.[42]

Other Issues in the Shale Revolution

The shale revolution has a number of important effects outside of its direct impact on oil and gas producing sectors or its indirect economic impact on the macroeconomy. For example, increased domestic fossil fuel production can lead to greater energy security by insulating the United States from supply disruptions and by reducing world oil price volatility. However, some commentators have expressed concerns about the size and permanence of the shale

[39] Hausman and Kellogg, "Welfare and Distributional Implications of Shale Gas," 25.
[40] Kinnaman, "The Economic Impact of Shale Gas Extraction: A Review of Existing Studies."
[41] Chyong and Reiner, "Economics and Politics of Shale Gas in Europe," 73.
[42] EIA, "U.S. Natural Gas Gross Withdrawals and Production"; EIA, "U.S. Crude Oil Supply & Disposition."

revolution, as well as the environmental consequences of fossil fuel extraction and consumption.

Energy Security and Price Volatility

Prior research has found that the shale revolution has had a positive impact on U.S. energy security, although not in the manner often popularly discussed. The shale revolution will not make the United States energy independent in the sense of autarky: the United States is still projected to import and export large amounts of crude oil, refined products, and natural gas.[43] And even if U.S. net oil imports became zero or negative (i.e. net exports occurred), the U.S. price of petroleum products (such as gasoline) would still be determined by the world price of those products. Moreover, although the reduction in U.S. net imports of energy products will allow the United States to significantly reduce its crude oil imports from the Persian Gulf[44] and eliminate the need for LNG imports, any reduction in production (or threats to production) in the Middle East will still affect the world price of oil, and thus U.S. prices too. However, Brown and Huntington note that "when it comes to oil security, what matters is the stability of the marginal source of world oil production, not the stability of the oil supplied to the United States."[45] Specifically, increased oil production in the non-risky United States would decrease the share of global oil production in risky locations and thus reduce world oil price volatility, benefiting all oil consumers, including the United States.[46]

Uncertainty of Supply Projections

However, despite its benefits, the short history of large scale shale extraction means that there is uncertainty about important features of shale gas plays that will determine how much oil and gas is ultimately produced. This has manifested in questions about the permanence of the production increases brought about by the shale revolution. For example, it is widely accepted that in the first few years of life, production from a shale gas well declines rapidly, much more rapidly than in a conventional well, before leveling off. Although this is often used as a stylized fact expressing the short lifespan of national shale production, production estimates of total shale resources already take this drop into account[47] and estimates, such as those from the EIA,[48] still show that the shale revolution will significantly increase U.S. production for decades to come. Other more subtle disagreements have occurred over the exact parameters which define this drop. Small changes in the values of these parameters can greatly impact national

[43] EIA, Annual Energy Outlook 2015.
[44] EIA, "Imported Liquids by Source, Reference Case."
[45] Brown and Huntington, "Assessing the U.S. Oil Security Premium."
[46] Ibid.
[47] Jacoby, O'Sullivan, and Paltsev, "The Influence of Shale Gas on US Energy and Environmental Policy," 40.
[48] EIA, Annual Energy Outlook 2015.

estimates of the expected ultimate recovery from shale resources. Unfortunately, since large scale shale gas extraction has been occurring for less than a decade, there is still legitimate disagreement over the exact values of these parameters.

In particular, a number of commentators have criticized industry and government modelers for estimating shale resources using assumptions that are too optimistic. Hughes contends that due to the scarcity of high-productivity shale plays and sweet-spots within these plays, actual shale production is likely to be below the forecasts from the EIA.[49] Other sources have also expressed doubts of the reliability of EIA estimates. Richter states that EIA assessments of total resource recovery are potentially overestimated due to extrapolation from non-representative production histories.[50] And McGlade, Speirs, and Sorrell note that the EIA uses assumptions about the expected ultimate recovery of oil and gas that are 68 percent higher than those estimated by the U.S. Geological Survey.[51] [52] But there has been pushback against these criticisms as well. For example, Maugeri notes that concentrating drilling on sweet-spots is not unique to shale.[53] "Grabbing the low hanging fruit" is something that the oil and gas industry has done throughout its history and it has led to learning how to "grasp the more difficult fruits," resulting in ultimate recovery estimates that are much larger than initially estimated.

The Environment

Although the economic effects of the shale revolution are very positive, significant environmental concerns have been raised by papers such as Osborn,[54] Jackson,[55] and Karion et al.[56] Topics of concern have included the effect of fracking on local water resources and global greenhouse gas emissions, as well as the inducement of minor earthquakes. However, other authors have defended fracking and criticized the accuracy of these environmental concerns.

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[49] Hughes, "Energy: A Reality Check on the Shale Revolution."
[50] Richter, "From Boom to Bust? A Critical Look at US Shale Gas Projections."
[51] McGlade, Speirs, and Sorrell, "Methods of Estimating Shale Gas Resources – Comparison, Evaluation and Implications."
[52] For a review of the challenges to estimating gas resources, see also Lee and Sidle, "Gas-Reserves Estimation in Resource Plays."
[53] Maugeri, *The US Shale Oil Boom: A U.S. Phenomenon*, 10.
[54] Osborn et al., "Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing."
[55] Jackson et al., "Increased Stray Gas Abundance in a Subset of Drinking Water Wells near Marcellus Shale Gas Extraction."
[56] Karion et al., "Methane Emissions Estimate from Airborne Measurements over a Western United States Natural Gas Field."

Papers by Newell and Rami,[57] Houser and Mohan,[58] Maugeri,[59] Vidic et al.,[60] Cathles et al.,[61] and Allen et al.[62] address many of the same environmental issues as the aforementioned papers but come to seemingly opposite conclusions.[63]

The effect of hydraulic fracturing on groundwater provides a good example of this disagreement. Dimock, Pennsylvania has drinking water so full of natural gas that it can be lit on fire.[64] Hydraulic fracturing has been considered a possible culprit because Dimock's drinking water comes from underground wells and the region has recently experienced rapid growth in shale gas extraction. Natural gas from natural gas wells can infiltrate groundwater through faults in the gas wells' steel casings or cement seals.[65] Although natural gas is not considered a health hazard with respect to ingestion, it can be oxidized by bacteria, leading to secondary water-quality issues, and high concentrations of it can be explosive.[66]

Papers disagree on what role hydraulic fracturing plays in such contamination. Osborn found that water wells close to natural gas wells utilizing hydraulic fracturing had statistically significantly higher concentrations of natural gas compared to water wells farther away from gas wells. However, Vidic notes that Osborn does not have baseline data for gas concentrations at these wells before drilling of the natural gas wells. It also states that the natural gas concentrations reported in Osborn are not dissimilar either from values for groundwater from areas of Pennsylvania and West Virginia prior to shale extraction or to samples in New York State, where hydraulic fracturing is currently banned. Thus it may be that Osborn detected elevated gas levels that existed prior to well drilling. Vidic supports this interpretation by citing a report by Boyer et al., which studied well chemistry in Pennsylvania both before and after the drilling of nearby Marcellus Shale gas wells. Boyer et al. found no statistically significant differences in natural gas concentrations either after drilling or related to the water well's distance from drilling.[67]

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[57] Newell and Raimi, "Implications of Shale Gas Development for Climate Change."
[58] Houser and Mohan, "Fueling Up: The Economic Implications of America's Oil and Gas Boom."
[59] Maugeri, *The US Shale Oil Boom: A U.S. Phenomenon*.
[60] Vidic et al., "Impact of Shale Gas Development on Regional Water Quality."
[61] Cathles et al., "A Commentary on 'The Greenhouse-Gas Footprint of Natural Gas in Shale Formations' by R.W. Howarth, R. Santoro, and Anthony Ingraffea."
[62] Allen et al., "Measurements of Methane Emissions at Natural Gas Production Sites in the United States."
[63] For a review of the many papers on the environmental effects of hydraulic fracturing, see Mason, Muehlenbachs, and Olmstead, "The Economics of Shale Gas Development" or Hausman and Kellogg, "Welfare and Distributional Implications of Shale Gas."
[64] Abdulaziz, "Lighting Water on Fire."
[65] Jackson et al., "Increased Stray Gas Abundance in a Subset of Drinking Water Wells near Marcellus Shale Gas Extraction"; Vidic et al., "Impact of Shale Gas Development on Regional Water Quality."
[66] Ibid.
[67] Boyer et al., "The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies."

This type of disagreement occurs not just for water resources, but for greenhouse gas emissions and earthquakes as well. This means that the literature has not reached a consensus as to what the environmental impacts of fracking are or whether fracking (and shale) has better, worse, or similar environmental impacts compared to conventional fossil fuel extraction.

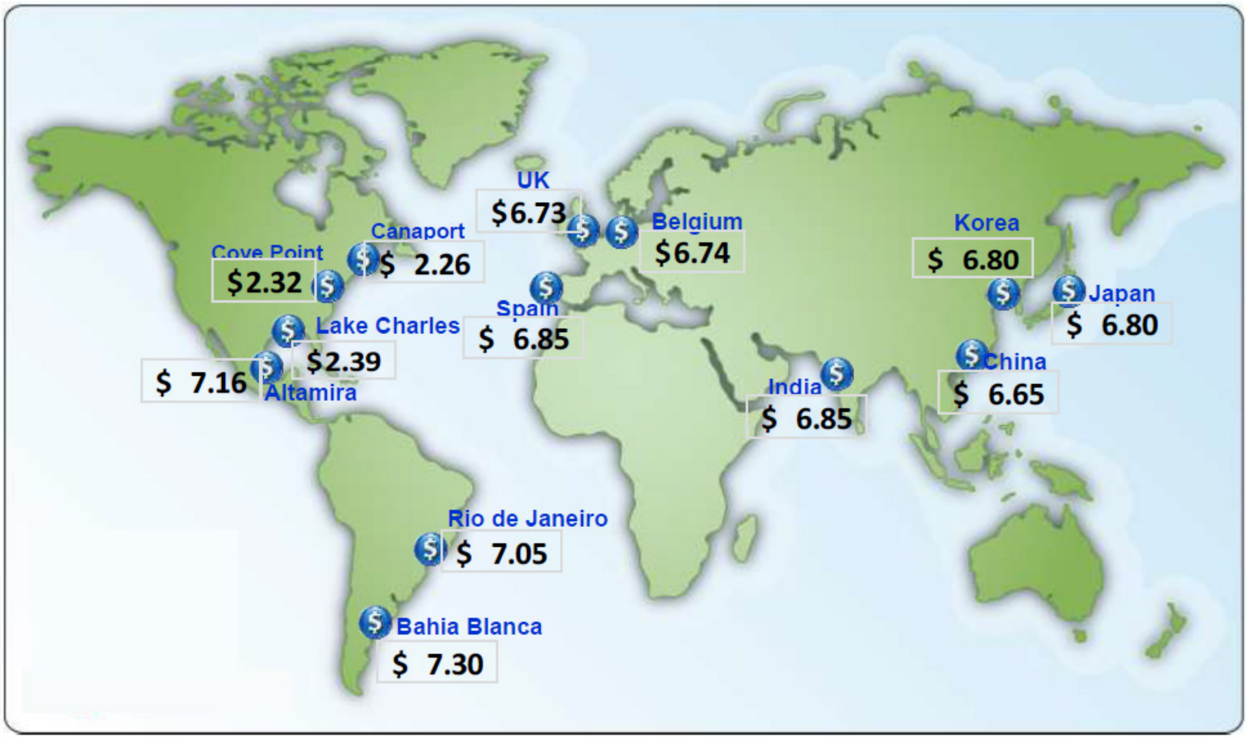
Areas for Future Research on the Shale Revolution

The shale revolution has transformed the energy landscape, both within the United States and internationally. As a result of its broad implications, there are many different issues relating to the shale revolution which could be profitably researched. For example, while many papers have found that the shale revolution has economic benefits, Kinnaman has raised a number of methodological concerns with these papers that cast doubt over their results. A paper that reevaluated these estimates in a computable general equilibrium model, while taking Kinnaman's criticisms into account, could rigorously confirm or deny the conventional wisdom on the shale revolution's effects. Alternatively, an econometric model could be used to estimate cost functions for manufacturing or other industries. This would allow the researcher to calculate how production and prices would have looked without the natural gas price drop caused by the shale revolution. Another avenue is to examine the international effects of the shale revolution: if the United States is importing less oil and natural gas, where did those resources go instead? A paper could examine what international trade flows would be like if the shale revolution had never happened.

Liquefied Natural Gas Exports

Because of increased U.S. natural gas production and rising foreign natural gas prices, natural gas prices in Europe and Asia are now almost triple prices in the United States (see figure 13). These prices incentivize the export of natural gas from the United States. Several studies have found that such exports would benefit the United States economically. However, competing environmental benefits and concerns mean that it is not clear if the environmental effects of exports are net positive or net negative. This section will review these issues for LNG exports, starting with current policy before moving to discuss the projected impact of exports on the U.S. economy and environment, as well as impacts in foreign countries.

Figure 13: World LNG prices in April 2015



Source: Federal Energy Regulatory Commission, "World LNG Estimated April 2015 Landed Prices."

Background of LNG Exports

Fundamentally, LNG is just a method for transporting natural gas, with the other major method being pipelines. Pipelines are the most common and least costly method for transporting natural gas in most cases, but the construction of undersea gas pipelines to reach high price European and Asian markets is not economical with current technology. When pipelines are not available, liquefaction can be used instead. In this method, natural gas is cooled into a liquid at liquefaction facilities located at ports and then loaded onto specialized tanker ships. The LNG is then turned back into a gas at a regasification facility at the destination port.

Although it avoids the need for pipeline connections between continents, LNG has problems of its own. For one, it is expensive. Medlock estimates that for a firm exporting LNG to Japan during 2011–2020, acquiring natural gas at a U.S. Gulf Coast export terminal would only be 44 percent of total costs, while liquefying and transporting that gas to Japan would make up the remaining 56 percent of costs.[68] In addition, U.S. exports of natural gas also face a number of regulatory hurdles. Firms that wished to export natural gas would need to consider regulations from the Office of Fossil Energy, the Federal Energy Regulatory Commission (FERC), United

[68] Author's calculations from Medlock, *U.S. LNG Exports: Truth and Consequence*, 30.

States Coast Guard, the Pipeline and Hazardous Materials Safety Administration, the Clean Air Act, the Coastal Zone Management Act, and the Clean Water Act, among others.[69] Any parties opposed to export can use these regulatory approval requirements to slow or block the siting of facilities and thus inhibit export.[70] However, regulations do not appear to be so stringent as to completely prevent exports. As of April 14, 2015 export terminals at Sabine, LA, Hackberry, LA, Freeport, TX, Corpus Christi, TX, and Cove Point, MD have been approved by FERC and are under construction.[71]

Current policy could still be changed in a number of ways in order to reduce the regulatory burden of exports further. For example, export authorization would be easier for firms to acquire if the United States signed a free trade agreement[72] with the EU or passed legislation to permit LNG exports to specific countries, such as NATO allies. However, even in the absence of any direct exports, indirect exports could occur via Canada. This could occur either by U.S. firms directly contracting with Canadian LNG export terminals or by Canada exporting more Canadian produced gas to Asia or Europe by decreasing their net exports to the United States.[73]

The Impact of LNG Exports

Prior quantitative research has found that LNG exports would have, on net, positive economic benefits for the United States. According to this literature, exports would increase domestic natural gas prices and reduce domestic natural gas consumption somewhat, but most of the exports would actually come from increased natural gas extraction. This would lead to net economic benefits for the United States as GDP and employment increase. And while exports would increase domestic greenhouse gas (GHG) emissions, their effect on world GHG emissions is ambiguous. But in either case, exports would reduce Europe's dependence on Russian gas.

[69] See Ratner et al., *US Natural Gas Exports: New Opportunities, Uncertain Outcomes* for a detailed discussion of the relevant regulation.

[70] Krupnick and Kopp, *Attaining Sustainable Development of Oil and Gas in North America: A Review of the Environmental Regulatory Landscape*, 13.

[71] Federal Energy Regulatory Commission, "North American LNG Import/ Export Terminals Approved."

[72] Department of Energy approval for exports requires that they be "consistent with the public interest." Exports to free trade agreement countries are automatically deemed consistent with the public interest. See 15 U.S.C.§717b(c). Regulations implementing this section of the NGA were promulgated under 18 C.F.R. Part 153, "Applications for Authorization to Construct, Operate, or Modify Facilities Used for the Export or Import of Natural Gas." Canada, Mexico, and the Republic of Korea (South Korea) are the only major natural gas importers with which the United States has a free trade agreement.

[73] Berzins, *European Views On American Natural Gas Exports*, 8.

Macroeconomics

First, in regards to macroeconomic effects, a number of studies have examined the impact of LNG exports on the U.S. economy (see table 2).[74] They have found that LNG exports would be a net benefit to the economy[75] and that these benefits increase as more natural gas is exported.[76] [77] U.S. natural gas prices are projected to rise by a few percent, stimulating new production which would provide 61 percent to 84 percent of the LNG for export.[78] Most of the rest of the exported natural gas would come from reduced domestic gas usage due to the higher prices, with only a minor contribution from increased imports from Canada.[79]

Table 2: Estimated effects of increased LNG exports

Study	Domestic natural gas price increase (percent)	Annual GDP increase (billion $)	Employment increase (thousands)
Deloitte (2011)	1.7	Not Estimated	Not Estimated
Navigant (2012)	3.0 to 6.7	Not Estimated	Not Estimated
ICF (2013)	12.5	25.4 to 37.2	113 to 230
NERA (2014)	5.4	3.5	45 short term, 0 long term
EIA (2014)	4	8.7 to 29.6	0

Sources: (1) Report for Cheniere Energy by Deloitte: Tom Choi et al., Made in America: The Economic Impact of LNG Exports from the United States; (2) Report for Jordan Cove Energy Project by Navigant Consulting, Jordan Cove LNG Export Project Market Analysis Study; (3) Report for the American Petroleum Institute by ICF International, U.S. LNG Exports: Impacts on Energy Markets and the Economy; (4) Report for Cheniere Energy by NERA, Updated Macroeconomic Impacts of LNG Exports from the United States; (5) EIA, Effect of Increased Levels of Liquefied Natural Gas Exports on U.S. Energy Markets.
Notes: These studies contained many different scenarios with different assumptions and thus different estimated effects. The results presented here are for the "median" scenario with the most typical or middle-of-the-road assumptions. For example, the NERA results refer to the yearly average effects of exports in the reference case with no export restraints or other shocks. Additionally, EIA and NERA report the effect on GDP in percentage terms. In order to create a measure more comparable with other studies (which use dollar values), I multiply the percent change by US GDP in 2014 ($17,418.9 billion according to Bureau of Economic Analysis, National Income and Product Accounts).

Individual Sectors

Although U.S. LNG exports would raise domestic natural gas prices, exports would not have a large negative impact on natural gas consuming industries. NERA finds that even with unlimited LNG exports, the chemicals sectors that use natural gas as a feedstock would still have annual growth rates of at least 2 percent.[80] There are two main reasons why exports would not have a

[74] Hausman and Kellogg, "Welfare and Distributional Implications of Shale Gas" examines this topic using a different methodology than those mentioned in Table 2 but gets the same sign for the effects on the economy and gas prices.
[75] NERA, *Updated Macroeconomic Impacts of LNG Exports from the United States*; EIA, *Effect of Increased Levels of Liquefied Natural Gas Exports on U.S. Energy Markets*; Levi, *A Strategy for U.S. Natural Gas Exports*.
[76] NERA, *Updated Macroeconomic Impacts of LNG Exports from the United States*, 7.
[77] EIA, *Effect of Increased Levels of Liquefied Natural Gas Exports on U.S. Energy Markets*, 13.
[78] Ibid., 12.
[79] Ibid.
[80] NERA, *Updated Macroeconomic Impacts of LNG Exports from the United States*, 14.

significant negative impact on affected industries. First, the domestic price increase that exports will cause is likely to be small (see table 2), especially when compared with the pre-existing global natural gas price differentials that benefit U.S. manufacturing (see figure 5). And second, exports would have other indirect benefits for natural gas consuming sectors. More natural gas exports mean more natural gas production, which also increases the production of ethane and other natural gas liquids that are extracted from the ground along with the natural gas. Industries which use these other chemicals as inputs would therefore benefit from increased natural gas production for export.[81]

The Environment

Despite its economic benefits, some commentators have expressed opposition to LNG exports for environmental considerations related to either the local environmental effects of fracking itself or greenhouse gas emissions in general. Taking fracking first, previous studies have indicated that LNG exports will primarily come from increased production and thus exports will likely increase fracking. The Environment section on page 21 of this working paper discusses the literature on the local environmental impacts of fracking and describes how there is not a consensus. However, even if there were large negative local environmental externalities to fracking, export controls would not be the least costly method of pollution abatement. Any economically efficient (least-costly) regulation of fracking would need to apply to all gas production and thus would not differentiate between fracking for natural gas for export or for domestic consumption.

In regards to climate change, previous research has not reached a consensus on the impact of LNG exports on GHG emissions. The problem is that LNG exports would have a number of effects that act in opposite directions and their relative magnitudes are unclear. Domestically, exports would reduce the usage of natural gas, which would reduce emissions, but increase natural gas extraction and the use of alternative fuels, which would increase emissions. EIA finds that exporting LNG would increase domestic coal usage and thus increase domestic emissions, as coal is more emission intensive than natural gas.[82] However, the effect on foreign emissions could be exactly the opposite: greater natural gas supply would encourage greater total energy use but replace some coal with natural gas. If exported U.S. natural gas displaced coal used in foreign markets, Levi estimates that LNG exports would actually reduce global emissions, despite a domestic emissions increase.[83]

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[81] Ibid.
[82] EIA, *Effect of Increased Levels of Liquefied Natural Gas Exports on U.S. Energy Markets*, 20.
[83] Levi, *A Strategy for U.S. Natural Gas Exports*, 17.

Foreign Countries

In addition to domestic concerns, U.S. natural gas exports will impact countries that import gas from the United States, as well as the natural gas producers whose gas will be displaced by U.S. exports. U.S. LNG exports would make gas importing countries less dependent on current gas exporters and reduce their market power.[84] The two main areas where this could occur are Europe and Asia.

The European Commission is looking to diversify its energy supplies away from Russia as part of its Energy Union Package of proposals.[85] Although Europeans already import most of their natural gas, the EIA predicts OECD Europe's natural gas imports will grow by a further 50 percent between 2011 and 2030.[86] Notably, Russia provided 27 percent of the EU's natural gas in 2013. However, Russian dependency varies by country and many Eastern European countries get all or almost all of their gas from Russia (see table 3).

Table 3: Russian gas imports as a percentage of total inland sales in European markets, 2013

Country	Percent	Country	Percent	Country	Percent
Slovakia	107	Turkey	57	Sweden	0
Lithuania	100	Poland	57	Pain	0
Latvia	100	Germany	46	Malta	0
Estonia	100	Italy	34	Switzerland	0
Finland	100	EU-28 Average	27	Croatia	0
Bulgaria	97	Luxembourg	25	United Kingdom	0
Hungary	83	France	18	Cyprus	0
Slovenia	72	Romania	15	Ireland	0
Greece	66	Netherlands	5	Denmark	0
Czech Republic	63	Belgium	1		
Austria	62	Portugal	0		

Source: Author's calculations from Eurogas, Statistical Report 2014, 5–6.
Notes: Russian Natural Gas Supply to Slovakia exceeds 100 percent because all natural gas for Slovakia comes from Russia but Slovakian "Other sources of natural gas" are negative.

U.S. exports could play an important role in accomplishing the European Commission's objectives. U.S. shale gas production has already caused Russia to accept lower prices for its natural gas.[87] Furthermore, because of shale gas, Russia's market share in natural gas for Europe (outside of former Soviet Union countries) is projected to decline from 27 percent in 2009 to 13 percent by 2040.[88] However, while U.S. LNG exports would reduce Russia's market

[84] Ebinger, Massy, and Avasarala, Liquid Markets: Assessing the Case for U.S. Exports of Liquefied Natural Gas, 43.
[85] Stratfor, "The European Commission Unveils Its Energy Union Plan."
[86] EIA, "World Net Trade in Natural Gas by Region, 2010–2040, Reference case."
[87] Medlock, U.S. LNG Exports: Truth and Consequence, 11; Bordoff and Houser, American Gas to the Rescue? The Impact of US LNG Exports on European Security and Russian Foreign Policy, 3.
[88] Medlock, Jaffe, and Hartley. Shale Gas and U.S. National Security.

power in Europe, it would not eliminate it: Russia will still remain the dominant gas supplier to Europe for the foreseeable future.[89]

Despite natural gas' importance in Europe, natural gas, and especially LNG, may be even more important to Asia. Japan alone imports more LNG than all of Europe combined,[90] and it pays some of the world's highest prices for natural gas. [91] Moreover, Asian LNG demand is predicted to dramatically increase over the coming years, fueled by increased Chinese consumption and imports (see table 4 and table 5). Although Chinese gas imports in 2010 were only one seventh of Japanese imports, Chinese imports are forecast to exceed Japanese imports by 2020 and be approximately double the level of Japanese imports by 2035.

Table 4: Historical and projected Asian natural gas consumption (tcf)

Year	2012	2020	2035
Japan	4.5	3.5	3.6
China	5.2	10.4	19.2

Source: IEA, "World Energy Outlook 2014," 139.

Table 5: Historical and projected Asian natural gas imports (tcf)

Year	2010	2020	2035
Japan	3.5	4.0	4.3
China	0.5	4.6	8.0

Source: IEA, "World Energy Outlook 2012," 147.

Areas for Future Research on LNG Exports

There are opportunities for research on LNG exports, but they are limited by what has been done already. Because LNG exports are a topic of great policy interest, many studies have already been conducted in order to estimate their economic impact. Therefore, additional analysis of future LNG exports would add little to the discussion of the issue unless it incorporated some unique wrinkle omitted by previous work. Fortunately, several such wrinkles exist.

For example, the crux of opposition to natural gas exports is fear of negative environmental impacts from fossil fuels in general (via climate change) and also hydraulic fracturing in particular. Although previous studies have examined the economic impacts of LNG exports and uniformly shown them to be positive, the modeling of the environmental effects is much less robust. In particular, previous studies have not modeled how LNG exports will change the fuel mix of the importing countries, but this factor would determine whether LNG exports had

[89] Bordoff and Houser, American Gas to the Rescue? The Impact of US LNG Exports on European Security and Russian Foreign Policy.
[90] GTIS, "Global Trade Atlas," Import Statistics for Commodity 271111.
[91] See figure 14.

positive or negative impact on world GHG emissions.[92] In addition, none of these studies estimating the economic effects of LNG exports have included the environmental costs of hydraulic fracturing itself. Even very rough modeling of these issues could provide upper and lower bounds on the environmental effects and thus would produce a much more convincing estimate of the overall impact of LNG exports.

Another interesting research topic is the regional incidence of LNG exports. Natural gas producing regions of the United States may benefit from exporting more gas at higher prices but gas consuming regions might be similarly hurt by the higher prices. Similar to work done by ICF on hydraulic fracturing,[93] regional analysis of LNG exports could illustrate which regions are winners or losers, an import consideration for Congressional representatives. It may be useful to focus such an analysis on the Northeast United States which, due to a lack of pipelines, has higher natural gas prices than the rest of the United States.[94] A natural policy experiment would be to consider the impact of building new pipeline capacity to "export" natural gas to the Northeast, instead of exporting LNG internationally.

Crude Oil Export Restrictions

The United States federal government restricts the export of U.S. crude oil. Under current law, export is prohibited unless the oil meets one of a small number of exceptions.[95] This policy was

[92] Levi, *A Strategy for U.S. Natural Gas Exports*.
[93] ICF International, *Tech Effect: How Innovation in Oil and Gas Exploration Is Spurring the U.S. Economy*, 63–64.
[94] Philips, "Northeast's Record Natural Gas Prices Due to Pipeline Dearth."
[95] There are a number of enumerated exemptions under which exports are allowed and applications which do not fall under these exceptions can still be approved on a "case by case basis" (Brown et al., *US Crude Oil Export Policy: Background and Considerations*.). In 2014, exports equaled 4.0 percent of domestic crude production (Author's calculations from data in EIA, U.S. Crude Oil Supply & Disposition). 94 percent of these exports went to Canada (EIA, Exports by Destination).

implemented in 1975 in the aftermath of the Arab Oil Embargo.[96] [97] [98] At the time there were price controls on oil in the U.S., and it was feared that these price controls might cause U.S. oil to be exported in search of higher foreign prices.[99] However, the price controls were eliminated in 1981 and thus, until recently, the exports that this policy prohibited would likely have been relatively small.[100] However, the shale revolution changed the situation by greatly increasing U.S. crude oil production and, because exports were banned, reducing the price of crude oil in the U.S. below that of the world market. By contrast, export of refined petroleum products made from domestic crude is not banned, allowing refiners to buy crude at a discount and then sell the products they create at world prices. As a result, some policymakers are now arguing that the crude oil export restrictions should be lifted.[101]

A number of studies have been conducted to inform decision makers on the impact of removing export restrictions on crude. As with most economic policies, there are winners and losers, but there is consensus that the economic effects would be net positive for the United States. However, perhaps surprisingly, gasoline consumers would be among the winners: U.S. crude exports are predicted to increase refinery efficiency and thus reduce U.S. gasoline prices. This would also have the side effect of improving U.S. energy security. And although there would likely be environmental costs from increased GHG emissions, these are estimated to be small compared to the economic benefits.

Problems with the Current Situation

For many decades, the prohibition on the export of almost all crude oil was not an issue. The United States was a net importer of oil from the rest of the world and domestically extracted oil could be easily transported to refineries that could efficiently convert them into petroleum products.[102] However, this changed with the shale revolution (see page 5). Hydraulic fracturing and other technologies that enabled the economic recovery of shale gas have also opened up tight oil.[103] As a result, tight oil production increased from less than 0.1 billion barrels in 2000,

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[96] For more information on the regulations forbidding crude oil exports, see Brown et al., *US Crude Oil Export Policy: Background and Considerations*.
[97] Although the EPCA is the primary policy banning crude oil exports, a number of other policies also restrict crude oil exports in some manner. These include the Export Administration Act, Minerals Leasing Act of 1920, the Outer Continental Shelf Lands Act, and the Naval Petroleum Reserves Production Act (Ebinger and Greenley, *Changing Markets: Economic Opportunities from Lifting the U.S. Ban on Crude Oil Exports*, 12.).
[98] For a thorough review of the origin of crude oil export restrictions including events preceding the 1973 Arab Oil Embargo, see Bordoff and Houser, *Navigating the US Oil Export Debate*.
[99] Cutler, *The Trans-Pacific Partnership as a Pathway for U.S. Energy Exports to Japan*.
[100] Ibid.
[101] Gardner, "Congressman to Introduce Bill to Lift U.S. Oil Export Ban."
[102] Brown et al., *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*.
[103] Ibid.

up to 0.8 billion in 2012, and the EIA projects that tight oil production will continue to increase up to a peak of 1.75 billion barrels in 2021 (see figure 10).

Unfortunately, the location and composition of this new oil created a number of problems. This new oil production occurred primarily in the Permian and Eagle Ford plays of Texas and the Bakken play of North Dakota, in the Midwest United States. However, the Midwest contains less than a quarter of U.S. refining capacity.[104] In addition, the existing oil transportation infrastructure (i.e. pipelines) was insufficient to transport all this oil out of the Midwest and to the Gulf Coast refineries. As a result, crude oil supplies became bottlenecked in the Midwest.[105] [106] Higher cost rail transportation has been used as an alternative and as a result, monthly shipments of crude by rail have surged from 0.6 million barrels in January 2010 to 33.7 million barrels in January 2015.[107]

This situation was exacerbated by the specialization of U.S. refineries. There are different types of crude oil and any particular refinery is not equally effective at processing all types, but is designed to use a specific crude oil blend.[108] Prior to the advent of the shale revolution and tight oil, U.S. refiners invested in equipment to process heavy crudes from Canada and Latin America,[109] while foreign refineries were better suited to process light crudes.[110] However, the boom in U.S. oil production is in light tight oil (see figure 14). This created a mismatch between the types of oil that U.S. refineries were optimized for consuming and what domestic producers

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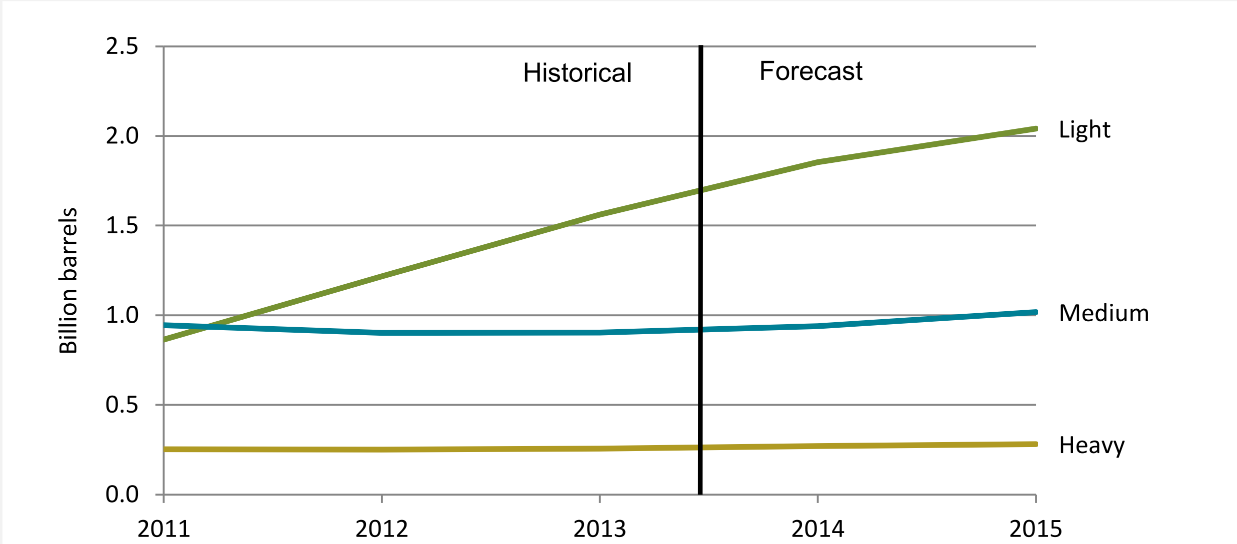
104 Bordoff and Houser, *Navigating the US Oil Export Debate*, 20.
105 Brown et al., *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*, 2.
106 Maugeri, "Oil: The next Revolution," 57 also cites the Jones Act as a contributing factor to transportation problems. The Jones Act mandates that waterborne shipping between U.S. ports be done by ships built in the United States, flying the U.S. flag, and manned primarily by Americans. As a result, it is expensive to move oil from one American port to another. For more information about the effect of the Jones Act on oil transportation, see Frittelli, *Shipping U.S. Crude Oil by Water: Vessel Flag Requirements and Safety Issues*.
107 EIA, Total Crude Oil by Rail.
108 Brown et al., *US Crude Oil Export Policy: Background and Considerations*, 13.
109 Ibid., 4.
110 Brown et al., *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*, 1.

Figure 14: U.S. crude oil production by API gravity



Source: EIA, U.S. Crude Oil Production Forecast-Analysis of Crude Types.
Note: Data for 2014 and later years are forecasts. In this graph, crude oil is defined as light if it has an American Petroleum Institute (API) gravity greater than 35, heavy if it has a gravity less than 27, and medium if it has a gravity between 27 and 35.

were actually extracting from the ground. While domestic refineries can use the domestically produced tight light oil, foreign refineries have a comparative advantage in processing this type of crude oil.

As result of these refinery and transportation problems (and the export restriction), domestic and foreign crude oil prices diverged. Figure 15 shows benchmark crude oil prices for Oklahoma in the Midwest, the U.S. Gulf Coast, and Europe. The prices moved in locked step until 2011 but then separated. The difference between Oklahoma and Gulf Coast prices illustrates the effect of transportation problems and the difference between Gulf Coast and European prices shows the effect of the refinery mismatch problem. As a result of these issues, crude oil prices have been up to $30 per barrel lower in the United States than in the rest of the world,[111] but the gap narrowed in 2014 to an average of $8 per barrel.[112] Improvements in transportation between Oklahoma and the Gulf Coast have reduced that source of that price gap, but the refinery specialization problem remains.[113]

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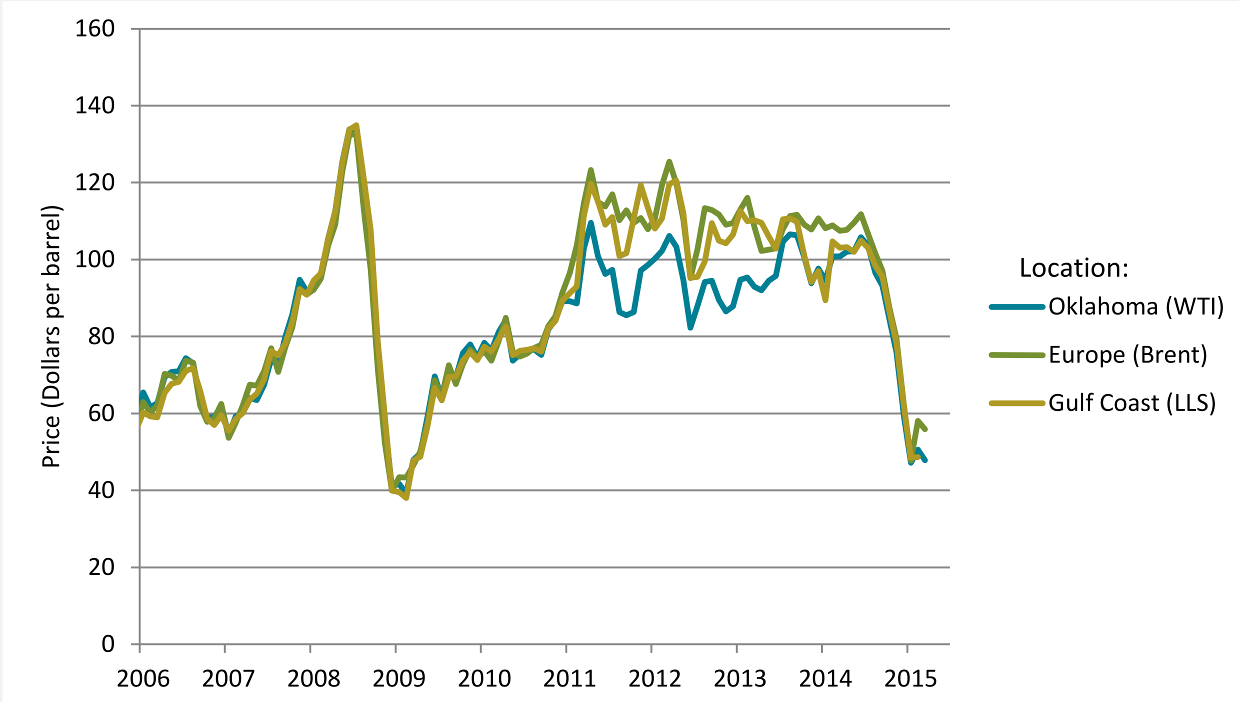
[111] Ebinger and Greenley, *Changing Markets: Economic Opportunities from Lifting the U.S. Ban on Crude Oil Exports*, 3.
[112] Government Accountability Office, *Changing Crude Oil Markets: Allowing Exports Could Reduce Consumer Fuel Prices, and the Size of the Strategic Reserves Should Be Reexamined*.
[113] Bordoff and Houser, *Navigating the US Oil Export Debate*, 21.

Figure 15: Crude oil prices in different locations

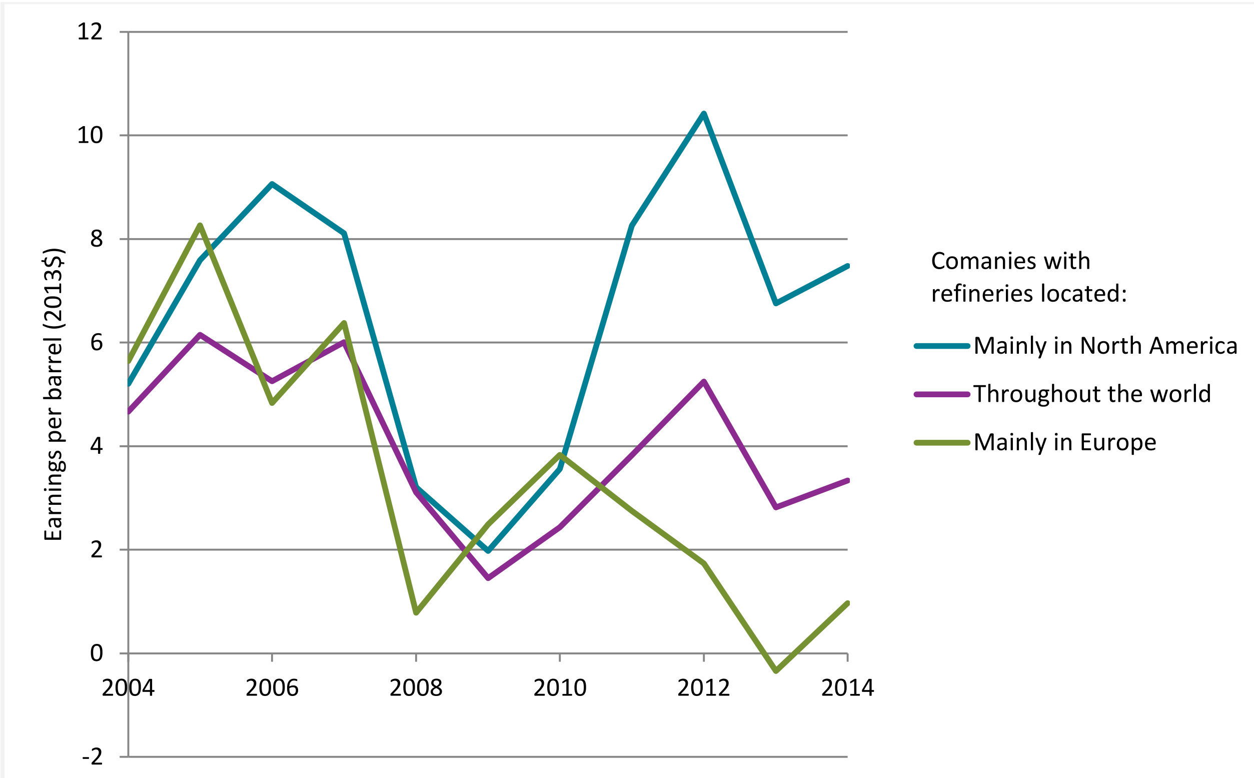


Source: EIA, "Cushing, OK WTI Spot Price FOB"; EIA, "Light Louisiana Sweet First Purchase Price"; EIA, "Europe Brent Spot Price FOB."

Researchers have found that the export restrictions and the price divergence that it allowed have benefited U.S. refiners.[114] This is because U.S. refiners can buy crude oil at a discount relative to the world price, but then sell refined products at the world price. This encourages firms to refine crude oil into final products in the United States and then export those products to the rest of the world. As a result, refineries in North America are now achieving much higher profits per barrel than their foreign counterparts (see figure 16). Higher expected profitability encourages additional investment in new refining capacity more suited for light tight oil, which would eliminate the price differential. However, investment takes time and may be constrained by factors such as uncertainty over whether the U.S. government will eventually eliminate export restrictions and also the existence of permitting and regulatory barriers to expanding refining capacity.[115]

[114] Plante, *Crude Oil Export Ban Benefits Some … but Not All*; Bordoff and Houser, *Navigating the US Oil Export Debate*, 4; Brown et al., *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*.
[115] Bordoff and Houser, *Navigating the US Oil Export Debate*, 25.

Figure 16: Refining company earnings per barrel processed, by region



Source: Barron, Lower Crude Feedstock Costs Contribute to North American Refinery Profitability.
Notes: 2014 includes data only for the first quarter of 2014.

The Impact of Liberalizing Crude Oil Export Policy

Prior research has concluded that removing the restrictions on exporting U.S. crude oil would have a number of effects. The macroeconomic effects of allowing exports would be positive, increasing GDP and employment. Surprisingly, although exports would increase crude oil prices in the United States, domestic gasoline prices would fall. Crude oil exports would also increase U.S. oil production and improve U.S. energy security. However, allowing exports might increase U.S. GHG emissions.

A number of studies have analyzed the macroeconomic effects of lifting the prohibitions on crude oil exports and, in general, have found the macroeconomic effects of eliminating the restrictions would be positive (see table 6).[116] Unrestricted crude exports would increase U.S. gross domestic product (GDP), employment, household welfare, and balance of trade. Although

[116] For a review of these studies, see Brown et al., *US Crude Oil Export Policy: Background and Considerations*; Government Accountability Office, *Changing Crude Oil Markets: Allowing Exports Could Reduce Consumer Fuel Prices, and the Size of the Strategic Reserves Should Be Reexamined*; Bordoff and Houser, *Navigating the US Oil Export Debate*. Bordoff and Houser also critique the studies they review, suggesting that although these studies correctly estimate the signs of the various effects of free trade, the effects' magnitudes may be inflated.

results vary across different studies, the GDP impact is consistently estimated to be in the billions of dollars and the employment increase in the hundreds of thousands of jobs.

Table 6: Macroeconomic effects of lifting crude oil export restrictions

	ICF	IHS	NERA	Aspen Institute
Annual U.S. GDP increase (billion $)	14.8 to 27.1	86	4.0 to 66	83 to 126
Annual U.S. employment increase (thousands)	118 to 220	394	200 to 350	282 to 434
U.S. welfare increase (percent)	Not estimated	Not estimated	0.14 to 0.40	Not estimated
Annual reduction in trade deficit (billion $)	22.3	Not estimated	Not estimated	Not estimated

Sources: (1) Report for the American Petroleum Institute by ICF International and EnSys Energy, The Impacts of U.S. Crude Oil Exports on Domestic Crude Production, GDP, Employment, Trade, and Consumer Costs; (2) Report for Baker Hughes by IHS, US Crude Oil Export Decision: Assessing the Impact of the Export Ban and Free Trade on the US Economy; (3) Report for the Brookings Institution by Baron et al., Economic Benefits of Lifting the Crude Oil Export Ban; (4) Report for the American Petroleum Institute by the Aspen Institute, Duesterberg, Norman, and Werling, Lifting the Crude Oil Export Ban: The Impact on U.S. Manufacturing.
Notes: Different studies use slightly different conventions for presenting results (i.e. whether to deflate dollar values and the basis year to use).

In addition, the literature has consistently found that allowing crude oil exports would actually reduce the price of gasoline in the United States.[117] This counterintuitive result would occur because there is currently a mismatch between the light oil being produced by the United States and U.S. refineries optimized for heavy crude. Due to the export restrictions, this domestic light crude must go to U.S. refineries. However, foreign refineries are more specialized in light crude, while U.S. refineries are better suited to process heavy crude. The key insight is that gasoline prices are set in an international market: they are not determined just by U.S. refineries, but by the world price of crude oil and refinery production efficiency.[118] Lifting the ban would improve the efficiency of the global refinery operations by better matching different types of crude to the refineries that best refine them.[119] This lowers the margin between the prices for final petroleum products and that of the crude oil input, increasing both the world supply of petroleum products and world demand for crude oil.[120] As a result, the United States would see lower gasoline prices but higher gasoline production, crude oil production, and crude prices.

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[117] Brown et al., *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*; ICF International and EnSys Energy, *The Impacts of U.S. Crude Oil Exports on Domestic Crude Production, GDP, Employment, Trade, and Consumer Costs*; IHS, *US Crude Oil Export Decision: Assessing the Impact of the Export Ban and Free Trade on the US Economy*; Baron et al., *Economic Benefits of Lifting the Crude Oil Export Ban*; Bordoff and Houser, *Navigating the US Oil Export Debate*, 4.
[118] Ebinger and Greenley, *Changing Markets: Economic Opportunities from Lifting the U.S. Ban on Crude Oil Exports*, 27.
[119] Brown et al., *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*.
[120] Ibid., 6.

The size of the gasoline price drop that export liberalization would cause has been examined in a number of papers. In a report for the Brookings Institute, NERA estimated that fully liberalizing crude exports would reduce U.S. gasoline prices by 9 to 12 cents in 2015 and that the more the United States exports, the more prices would fall.[121] Other studies agree that gasoline prices would fall but the estimated size of the decline ranges from 1.5 to 12 cents per gallon (see table 7).

Table 7: Effects on price and quantity of crude oil and consumer fuels (gasoline) of lifting crude export restrictions

	ICF	**IHS**	**NERA**	**Aspen Institute**	**RFF**
U.S. crude oil price Increases ($ per barrel)	2.4 to 4.2	7.9	1.7	9.9 to 11.0	6.7
U.S. consumer fuel (gasoline) price decrease (cents per gallon)	1.5 to 2.4	8 to 12	3	7.3 to 8.5	1.8 to 4.6
U.S. crude oil production increase (million barrels per year)	40 to 183	440	550 to 730	103 to 159	31

Sources: (1) Report for the American Petroleum Institute by ICF International and EnSys Energy, The Impacts of U.S. Crude Oil Exports on Domestic Crude Production, GDP, Employment, Trade, and Consumer Costs; (2) Report for Baker Hughes by IHS, US Crude Oil Export Decision: Assessing the Impact of the Export Ban and Free Trade on the US Economy; (3) Report for the Brookings Institution by Baron et al., Economic Benefits of Lifting the Crude Oil Export Ban; (4) Report for the American Petroleum Institute by the Aspen Institute, Duesterberg, Norman, and Werling, Lifting the Crude Oil Export Ban: The Impact on U.S. Manufacturing; (5) Brown et al., Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States.
Notes: RFF crude production increases only include Canada and the Midwestern United States.

Although removing the crude oil export ban would aid the United States as a whole, research has found that refineries would lose out.[122] As noted earlier, U.S.-based refineries benefit from the ban because they can buy crude oil at a discount relative to world prices and then sell refined products at world prices. Eliminating the crude oil export ban would eliminate these economic rents.

The literature has consistently argued that crude oil exports would improve U.S. energy security. "Energy security" includes issues for energy resources such as their availability (Are supplies on the market?), accessibility (Can you get to them?), and affordability (Can you get them at competitive prices?).[123] Bordoff and Houser contrast energy security with "energy independence" and argue that, judged on these criteria, energy interdependence (i.e., imports and exports) can actually enhance energy security. Similarly, Ebinger and Greenley state that oil price volatility should not be misunderstood as physical scarcity of oil.[124] They contend that the

[121] Ebinger and Greenley, *Changing Markets: Economic Opportunities from Lifting the U.S. Ban on Crude Oil Exports*, 27.
[122] Plante, *Crude Oil Export Ban Benefits Some … but Not All*; Bordoff and Houser, *Navigating the US Oil Export Debate*, 4; Brown et al., *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*.
[123] Bordoff and Houser, *Navigating the US Oil Export Debate*, 48.
[124] Ebinger and Greenley, Changing Markets: Economic Opportunities from Lifting the U.S. Ban on Crude Oil Exports, 7.

problem of energy is not one of shortage but one of high prices, high price volatility, high market power of oil suppliers, and low diversity of oil supplies. Both argue that U.S. crude oil exports would be beneficial for U.S. energy security on these dimensions.

Prior research has identified three mechanisms by which U.S. crude exports would reduce crude oil price volatility. First, unlike many oil suppliers, North America is geopolitically stable.[125] Thus, increased North American oil production would decrease the fraction of world oil production that comes from unstable sources. Second, countries tend to use crude oil from nearby exporters before calling on OPEC.[126] Thus, U.S. exports would displace some OPEC supply, creating spare OPEC capacity that could re-enter the market in response to a shortage[127] and thereby lower world price volatility. That fraction of additional U.S. supply which did not displace OPEC supply would instead increase the world supply of oil, lowering its price. And third, permitting crude exports would allow domestic shale oil to mitigate the effect of crude oil supply disruptions. To the extent that the crude export restrictions successfully disconnect the domestic and world crude markets, it reduces the incentive for domestic production to increase in response to world crude price increases. This is especially import for shale, as its production can respond much more quickly to price changes than production from conventional wells can.[128]

Increased domestic production would also confer a number of other benefits. It would decrease U.S. net oil imports, even if gross imports increase.[129] This would make the United States less vulnerable to international oil supply shocks, as larger oil net imports translate into larger GDP drops when world oil prices increase.[130] Increased U.S. production would also lead to greater diversity of world oil suppliers and a reduction in their market power.

The aforementioned energy security issues primarily apply to supply disruptions that increase global prices but do not result in widespread physical scarcity.[131] But what about catastrophic scenarios, such as if supply from a top producer like Saudi Arabia or Russia was lost and the United States could not import crude oil at any price? Bordoff and Houser note that in such a case, the United States would still retain the ability to reinstate the ban, and so the main cost in such a scenario of not having the ban already in place would be the adjustment cost of temporarily running a non-optimal crude mix through U.S. refineries.[132] While having the ban already in place might have been desirable in such a scenario, they argue that the oil export ban

[125] 2014 Brown et al., *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*.
[126] Brown et al., *US Crude Oil Export Policy: Background and Considerations*, 20.
[127] Ibid.
[128] Maugeri, *The US Shale Oil Boom: A U.S. Phenomenon*, 11.
[129] Bordoff and Houser, *Navigating the US Oil Export Debate*, 49.
[130] Council of Economic Advisers, "The All-Of-The-Above Energy Strategy as a Path to Sustainable Economic Growth."
[131] Bordoff and Houser, *Navigating the US Oil Export Debate*, 50.
[132] Ibid.

is high-cost insurance for such a catastrophe and that a reconfigured strategic petroleum reserve would be a more cost-efficient hedge.

It is also important to note what a crude oil export ban does not do: Bordoff and Houser and the literature cited in table 7 argue that it does not cause finished petroleum products (such as gasoline) to be cheaper in the United States than in the rest of the world. Even if the United States achieves crude self-sufficiency and maintains a crude oil export ban, firms are free to export refined products to the rest of the world and thus refined product prices in the United States are set by the global market.[133] And as a result, American consumers are still vulnerable to global oil supply disruptions as such a disruption will still impact world (and thus domestic) refined product prices.[134]

NERA found that greenhouse gas emissions are the one area where lifting the ban would have negative effects, although the impact that they found is small compared to the other benefits. Specifically, they project that lifting the ban would increase oil extraction in the United States, which would lead to increased GHG emissions in the United States.[135] In order to compare the environmental costs of oil exports to their economic benefits, NERA calculates the hypothetical social cost of carbon necessary for the environmental cost of increased emissions to reduce the economic benefits of lifting the ban to zero (i.e., the welfare cost of abatement). They find that the zero net-benefit social cost of carbon ranges from $1,200 to $1,400 per ton of CO2. However, they note that the U.S. Environmental Protection Agency (EPA) estimates that the true social cost of carbon is around $30 per ton of CO2. This means that the economic costs of using the oil export ban as a means of limiting emissions are 30 to 45 times as large as the environmental benefits.[136]

In summary, prior research has found that lifting the crude oil export ban would benefit the United States. The United States would gain greater employment, higher GDP, lower gasoline prices, and higher domestic crude oil production. This production growth would also lead to increased energy security. Environmental harm would likely occur through increased greenhouse gas emissions, but it is estimated to be small compared to the economic benefits.

Areas for Future Research on Crude Oil Exports

Although removing restrictions on U.S. crude oil exports has been well research, there are still some opportunities for future research that appear to be quite promising, such as policy

[133] Ibid., 48.
[134] Ibid.
[135] NERA estimates that annual domestic CO_2 emissions would increase by 4.7 to 26.2 million metric tons. RFF estimates annual domestic emissions would increase by 21.98 million metric tons. Neither source provides a numerical estimate for the impact on world GHG emissions, but RFF notes that domestic emission increases would be partially offset by reductions in other countries due to their substitution of oil for coal.
[136] Baron et al., *Economic Benefits of Lifting the Crude Oil Export Ban*.

alternatives to eliminating all export restrictions. Prior research has focused on the effects of a full repeal of the ban, but such legislation could be extremely difficult to pass. However, even if it is politically untenable to fully repeal the ban, there are other policy options that could improve the match of crude types to refineries.[137] For example, one exception to the export ban is crude swaps, by which firms could exchange light domestic crude for heavy Mexican or Canadian crude and thus allow for refinery optimization. Alternatively, the federal government could allow more exports of lease condensate, a petroleum product with a blurry dividing line between it and crude oil. Research in this area could show which strategies could provide some or all of the benefits of repeal without official repeal of the ban.

Other Domestic Issues

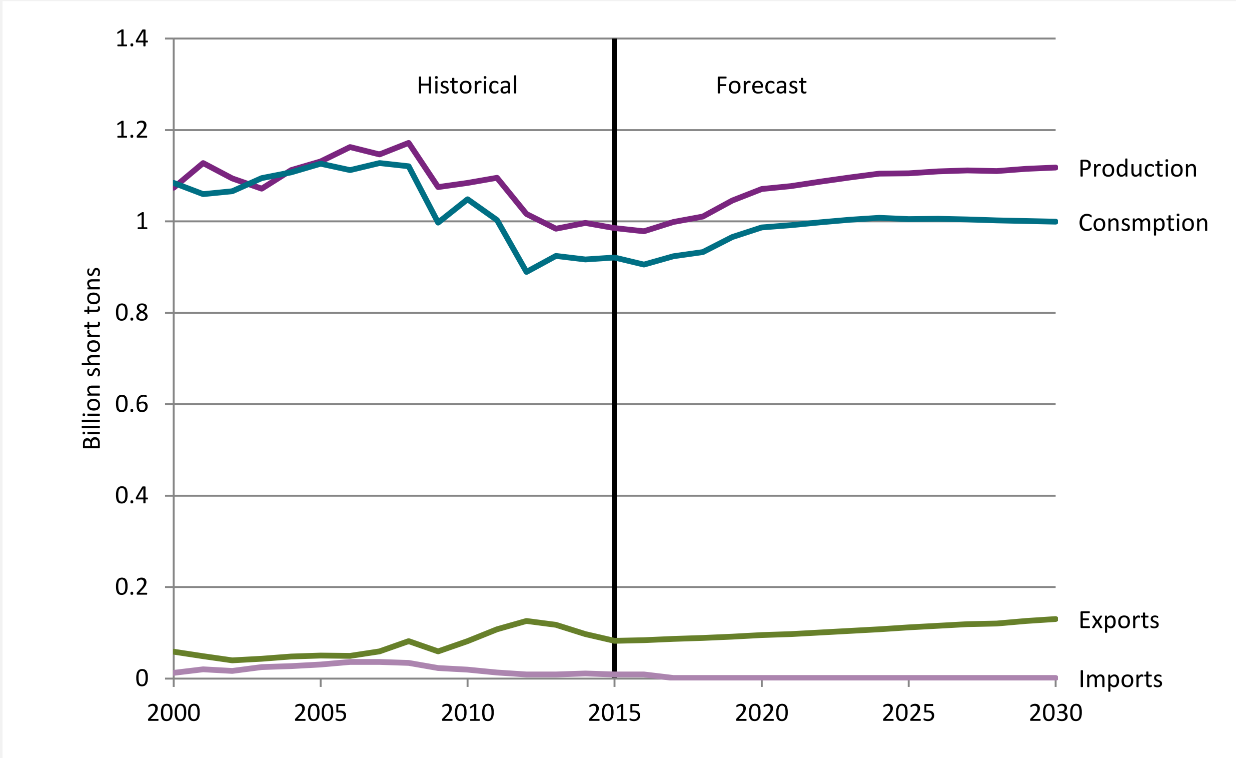
Coal

The U.S. coal industry faces a number of challenges. In response to falling U.S. coal consumption, U.S. coal producers have been forced to decrease production and focus on increasing exports. Moving forward, the trajectory of future U.S. coal trade depends heavily on whether further environmental regulations are passed.

U.S. coal consumption has fallen in recent years due to both increased competition from natural gas and new environmental regulations.[138] The shale revolution greatly reduced the price of natural gas, causing consumers to use more natural gas and less of alternative fuels, such as coal. In addition, in 2011 the EPA finalized new Mercury and Air Toxics Standards[139] that will take effect in 2016.[140] These factors have led to the retirement of a large amount of coal power generation capacity.[141] In 2012 alone, 3.2 percent of coal-fired capacity was retired.[142] As a result, from 2008–2014, domestic coal consumption fell by 18 percent and production fell by 14 percent (see figure 17).

[137] For a more thorough review of alternative policy options, see Bordoff and Houser, *Navigating the US Oil Export Debate*, 58–60.
[138] Johnson, "Planned Coal-Fired Power Plant Retirements Continue to Increase."
[139] EPA, "Cleaner Power Plants."
[140] Johnson, "Planned Coal-Fired Power Plant Retirements Continue to Increase."
[141] Ibid.
[142] Brown and Leff, *AEO2014 Projects More Coal-Fired Power Plant Retirements by 2016 than Have Been Scheduled*.

Figure 17: U.S. coal trade



Source: EIA, Annual Energy Outlook 2015; EIA, Short-Term Energy and Summer Fuels Outlook, table 6.
Note: Data for 2015 and later years are forecasts.

As domestic coal demand has fallen, coal exports have surged and then fallen. Falling domestic consumption and rising foreign demand caused coal exports in 2012 to reach an all-time high of 125.7 million short tons. Total coal imports from all countries by China, Korea, India, and Japan has increased from 419 million short tons in 2007 to 754 million in 2012.[143] As a result, U.S. coal exports to these countries greatly increased. In particular, U.S. exports to Korea increased 28 fold from 2002–2013 (see table 8). U.S. coal exports to European countries have also seen large increases in this time period. However, in 2014 U.S. exports fell to 97 million short tons due to lower international coal demand and prices and higher coal output in other coal-exporting countries.[144]

Table 8: Exports to the top 10 destinations for U.S. coal (million short tons)

Country	2002	2013	2014
Brazil	3.5	8.6	8.0
Canada	16.7	7.1	6.7
China	1.0	5.5	4.8
France	3.1	6.6	5.9
Germany	1.3	5.4	5.0

[143] EIA, "International Energy Statistics."
[144] EIA, Short-Term Energy and Summer Fuels Outlook, 12.

Country	2002	2013	2014
Italy	0.8	5.6	4.7
Japan	1.6	12.7	12.5
Korea	0.3	8.4	8.0
Netherlands	0.6	5.0	4.5
UK	1.9	13.5	9.8
Other	8.9	39.2	27.5
All Countries	39.6	117.7	97.3

Source: EIA, "U.S. Coal Exports by Year, Quarter, and Customs District, 2002–2014."

Despite recent growth, projections of future coal trade depend significantly on government policy decisions. Under the assumption that current laws and regulations are maintained throughout the projections, the EIA forecasts modest increases in U.S. production and consumption of coal (see figure 18). However, this assumption may not hold. The Cross-State Air Pollution Rule, which sets new emission standards for power plants, went into effect on January 1, 2015,[145] but is not included in the EIA's baseline forecast.[146] In addition, the EPA is proposing significant new carbon emission regulations for coal. EPA projects that by 2020, the new carbon regulations would reduce the quantity of coal used for electricity generation in the United States by 25 percent.[147] Thus, U.S. coal production is likely to face a challenging future due to new environmental regulations.

Further research on coal exports could clear up some of the lingering policy questions. For example, if environmental regulations in the United States were tightened even further, where does the coal go? GHG emissions are only reduced if more coal stays in the ground, rather than being used: any coal that is mined but then exported from the United States still affects world GHG emissions. If U.S. coal is consumed abroad instead of domestically, what are the economic and environmental costs and benefits? Riker looked at some of these export spillover effects with an econometric model, and that paper may provide a useful framework for further econometric or CGE research.[148]

Keystone XL

Keystone XL is a proposed expansion of the existing Keystone Pipeline System. The Keystone pipeline currently runs from oil sand fields in Alberta, Canada to the U.S. Gulf Coast. The Keystone XL expansion consisted of a southern and a northern part. The southern part went into operation in January 2014 but the northern leg, from Alberta to Texas, ran into opposition.

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[145] EPA, "Cross-State Air Pollution Rule (CSAPR)."
[146] EIA, Annual Energy Outlook 2015, 24.
[147] EPA, *Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants*, 3–36.
[148] Riker, "International Coal Trade and Restrictions on Coal Consumption."

This northern leg of the Keystone Pipeline System is the project often discussed in mass media and colloquially referred to as "the" Keystone pipeline.

Because the northern leg crosses the U.S.-Canada border, a presidential permit is necessary for its construction. TransCanada, the pipeline's owner, has unsuccessfully attempted to get such a permit for various forms of the northern leg of the project since 2008.[149] However, the Obama administration has neither approved nor rejected the current project, but has in fact extended the deadline to make a decision on the project indefinitely.[150] State Department analysis found that the project is unlikely to have a significant impact on GHG emissions under expected conditions[151] and that construction alone would increase U.S. GDP by $3.4 billion.[152] Nonetheless there are many advocates both for and against the pipeline (as well as critics of the State Department paper).

Energy Tax Reform

Energy tax reform is another emerging issue with important policy dimensions. The U.S. federal government provides many different types of financial support for energy industries. That support includes direct spending but it also includes tax preferences, which are special provisions of tax law that reduce tax liabilities for specific activities, entities, or groups of people.[153] The Congressional Budget Office notes that until 2005, the bulk of energy-related tax preferences were for fossil fuels.[154] However, the Energy Policy Act of 2005 and the Emergency Economic Stabilization Act of 2008 created or expanded provisions promoting energy efficiency and renewables,[155] and these sources now receive the majority of energy-related spending and tax preferences (see figure 18). In total, expenditures for all energy related tax preferences amounted to $16.4 billion dollars in 2013.[156] However, the existence of these tax preferences is contentious. The president's budgets for recent years have proposed to eliminate many of the fossil fuel preferences. In addition, renewable tax preferences are constantly lapsing and being retroactively reinstated. If implemented or made permanent, either of these tax reforms would

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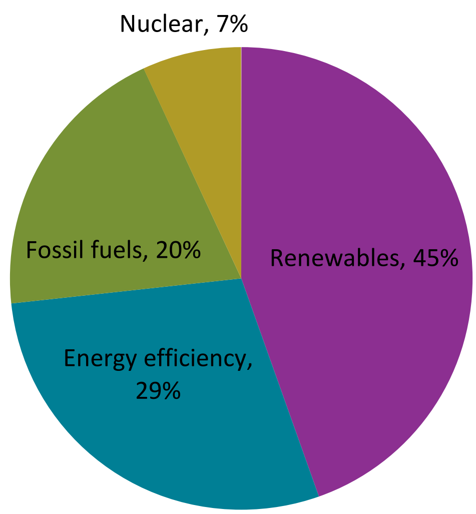
[149] TransCanada Keystone Pipeline, L.P., "Application of Transcanada Keystone Pipeline, L.P. for a Presidential Permit Authorizing the Construction, Connection, Operation, and Maintenance of Pipeline Facilities for the Importation of Crude Oil to Be Located at the United States-Canada Border."
[150] CBS/AP, "Obama Administration Delays Keystone XL Pipeline Review."
[151] U.S. Department of State. Final Supplemental Environmental Impact Statement for the Keystone XL Project, ES-16.
[152] Ibid., ES-19.
[153] Dinan, *Federal Financial Support for Fuels and Energy Technologies*.
[154] Ibid.
[155] Dinan and Webre, *Federal Financial Support for the Development and Production of Fuels and Energy Technologies*.
[156] Dinan, *Federal Financial Support for Fuels and Energy Technologies*.

have important implications for energy production and trade by influencing the cost of U.S. production of energy products.[157]

Figure 18: Allocation of energy-related tax preferences in fiscal year 2013



Source: Dinan, Federal Financial Support for Fuels and Energy Technologies.
Notes: Numbers do not add up to 100 percent due to rounding.

Formal economic models are necessary to analyze the effect of such tax reforms on trade. For example, in regards to fossil fuels, because these changes would increase taxes on fossil fuel production, basic microeconomic theory predict that these changes would decrease domestic production and consumption, but have an ambiguous impact on imports and exports. Almost any combination of imports and exports increasing or decreasing is, in theory, possible. However, general equilibrium models are able to resolve the ambiguity concerning the signs of the changes in imports and exports that these policies would induce, as well as determine the magnitudes of these effects.

Oil Price Drop

From 2010 until mid-2014, crude oil prices had been fairly stable at between $80 and $110 per barrel. However, the price of crude oil began to fall dramatically in July 2014, and by January 2015, oil was trading at less than $50 a barrel (see figure 15). Such a large price drop will have similarly large economic and political effects. However, the extreme recentness of this price drop means that there has not been time for a scholarly literature to develop around it and

[157] For a detailed explanation of what these tax preferences are and how they might be changed, see Barbe, "Tax Policy Analysis in a Flexible Computable General Equilibrium Model: Applications to Energy and Gross Receipts Taxation"; Joint Committee on Taxation, "Present Law and Analysis of Energy-Related Tax Expenditures."

reach a consensus on its causes and effects. This means a review of the issues concerning the price drop is necessarily incomplete, but it also provides an opportunity for original research. One obvious tactic would be to compare this oil price drop to other major oil price drops in the early 1980s or late 2000s.

Foreign Energy Issues

Europe and Russia

The European Commission is looking to diversify its energy supplies away from Russia as part of its Energy Union Package of proposals.[158] Large U.S. energy resources mean that the United States may be in a position to assist in this goal. Specific U.S. policy responses involving the export of crude oil or liquefied natural gas are discussed in Sections 4 and 5, respectively.

Japan and Fukushima

In March 2011, Japan was struck by a 9.0 magnitude earthquake which caused a nuclear meltdown at the Fukushima Daiichi Nuclear Power Plant.[159] In response, Japan shut down all nuclear power plants in the country. Before the disaster, nuclear power supplied 31 percent of Japan's electricity[160] and was one of the country's least expensive energy sources.[161] This lost capacity was largely replaced with oil and LNG, which now generate 16 percent and 48 percent, respectively, of Japan's electricity.[162] Japan, already the world's largest LNG market,[163] saw LNG imports increase by 25 percent from 2010 to 2012.[164]

The fate of Japan's nuclear power plants is the key question for determining Japan's energy future and the answer has major implications for global oil and LNG trade. Japan's current government wishes to resume nuclear power generation[165] and the first nuclear power plant

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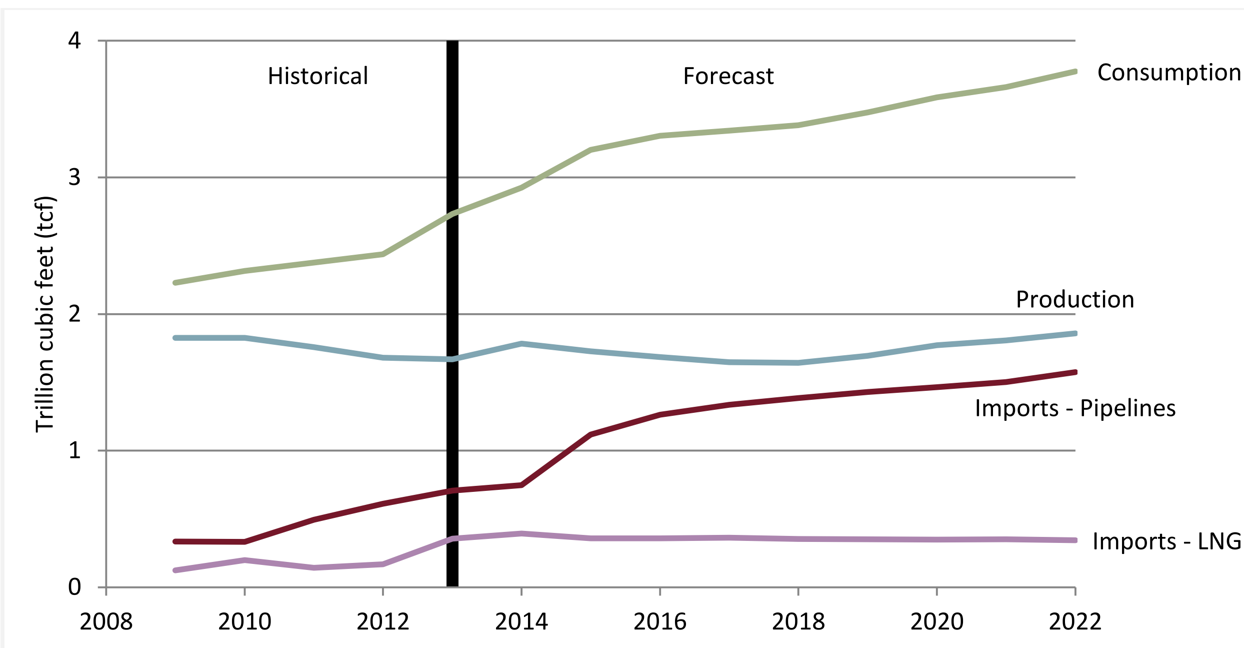
[158] Stratfor, "The European Commission Unveils Its Energy Union Plan."
[159] No deaths during the disaster itself were attributed to radiation exposure. Over the longer term, the World Health Organization found that radiation exposure will lead to increased cancer rates among a third of emergency responders but they anticipate no observable increases in cancer rates for the general population (World Health Organization, "Global Report on Fukushima Nuclear Accident Details Health Risks"). Other effects such as increased stillbirths, miscarriages, or physical or mental impairments are also not expected.
[160] Hayashi and Hughes, "The Policy Responses to the Fukushima Nuclear Accident and Their Effect on Japanese Energy Security."
[161] EIA, "Japan."
[162] Ibid.
[163] GTIS, "Global Trade Atlas," Import Statistics for Commodity 271111.
[164] Ibid.
[165] EIA, "Japan."

has been cleared for restart in 2015.[166] The International Energy Agency (IEA) predicts that Japan will restart its nuclear power plants during the time period 2015–2020, and that by 2020, nuclear will have almost entirely displaced oil for electricity generation in Japan.[167]

Mexico

Mexico is importing more natural gas from the United States than ever before, and these imports are projected to only increase in the near future. Mexican natural gas consumption from its industry and electricity generators is on the rise while its production remains flat (see figure 19). Combined with increased U.S. natural gas production, this has resulted in U.S. pipeline exports of natural gas to Mexico doubling between 2009 and 2013 (from 0.33 tcf to 0.71 tcf). Mexico's national energy ministry predicts that U.S. pipeline exports to Mexico will more than double again by 2019 (to 1.43 tcf) and continue to increase through 2026, reaching 1.78 tcf at that time.

Figure 19: Mexican natural gas trade



Source: EIA, Mexico's Energy Ministry Projects Rapid near-Term Growth of Natural Gas Imports from U.S.
Notes: Data for 2013 and later is a forecast.

However, exports require new pipelines and, since they cross national boundaries, these pipelines require approval by the U.S. federal government. Experience with Keystone XL shows that these approvals can add years of delays or even derail a pipeline project completely. One

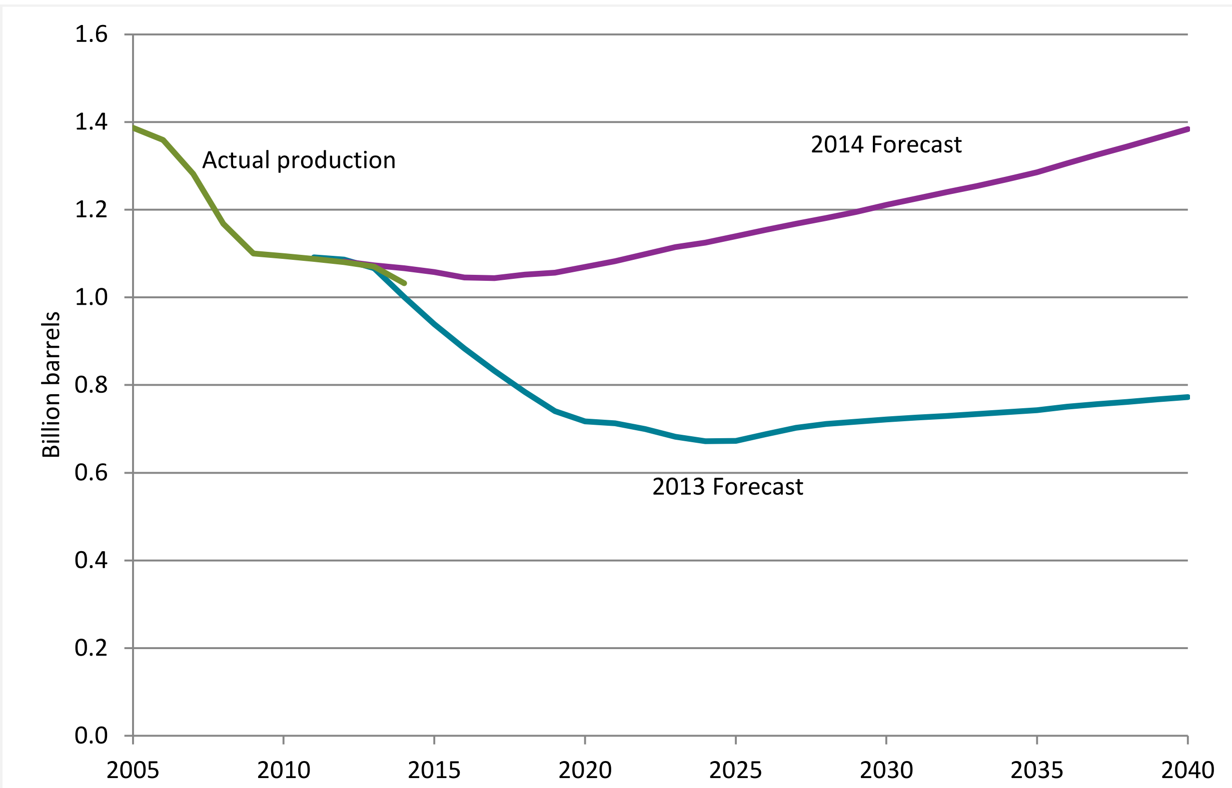
[166] British Broadcasting Corporation, "Japan Governor Approves Sendai Reactor Restart."
[167] IEA, "World Energy Outlook 2014," 228.

possible research topic would be to examine the impact of Mexican gas exports on the U.S. economy and U.S. gas production and prices.

In addition to changes resulting from the shale revolution, the Mexican energy sector is also being reshaped by domestic economic reform. In December 2013, Mexico amended its constitution to end the 75-year monopoly of the state-owned oil company. In order to reverse declines in Mexican oil production, the government is opening up Mexican energy resources to foreign investment.[168] EIA is highly optimistic about these reforms and predicts that instead of previously projected sharp declines, Mexican oil production will stabilize and then begin to increase over the coming years (see figure 20).

Such substantial increases in Mexican production could have a variety of implications for the United States, depending on where this new Mexican production goes and what it displaces.

Figure 20: Mexican production of petroleum and other liquid fuels



Source: EIA, International Energy Outlook 2014; EIA, International Energy Outlook 2013; EIA, International Energy Statistics.
Notes: The forecasts and actual production combine production by Mexico and Chile together. However, disaggregated actual production data shows that Chilean total oil production is negligible compared to Mexican production: in 2014, Mexico produced 1,026 million barrels of total oil while Chile only produced 5.6 million. Therefore, using the forecast of Mexico and Chile combined is effectively identical to using a forecast of Mexico alone.

[168] EIA, Mexico's Energy Ministry Projects Rapid near-Term Growth of Natural Gas Imports from U.S.

International Shale

Thus far, shale oil and gas have been a U.S. phenomenon. However, that may change in the future, as over 90 percent of the world's technically recoverable shale oil and gas resources are located outside of the United States.[169] If other countries are able to develop these resources, it could lead to large changes in international energy trade flows. Because although many of the countries with large shale reserves are already major energy producers (e.g., the United States, Canada, Russia, and Australia), many others are not.[170] Notably, many of the countries with large shale gas reserves (e.g. France, Poland, China, and Argentina) are major energy importers.[171]

However, a variety of factors suggest that shale extraction outside the United States may be extremely difficult.[172] [173] Poor geology and environmental opposition are likely to prevent shale development in many countries. For example, Norway's shale gas assessment dropped from 83 trillion cubic feet in 2011 to 0 in 2013 after results from three Alum Shale wells showed that drilling would be far more difficult than anticipated.[174] And while France's technically recoverable shale resources are estimated at 137 tcf of gas and 4.7 billion barrels of oil, France has banned all hydraulic fracturing in the country.[175] In addition, shale extraction requires extremely high drilling intensity[176] but there is a severe lack of drilling rigs and the associated infrastructure outside of North America. In 2014, the United States had 52 percent of the world's active drilling rigs, with another 11 percent in Canada, compared to only 11 percent for the entire Middle East.[177] Experience in drilling provides a similar problem, with 45,468 oil and gas wells completed in the United States in 2012, versus 3,921 in the entire rest of the world, except Canada.[178] For these reasons, Maugeri states that a U.S.-style shale revolution is not likely to occur internationally in the foreseeable future.[179]

An interesting research topic would be to examine the impact on trade of shale development in other countries through a CGE model with scenario analysis. Scenarios could include both

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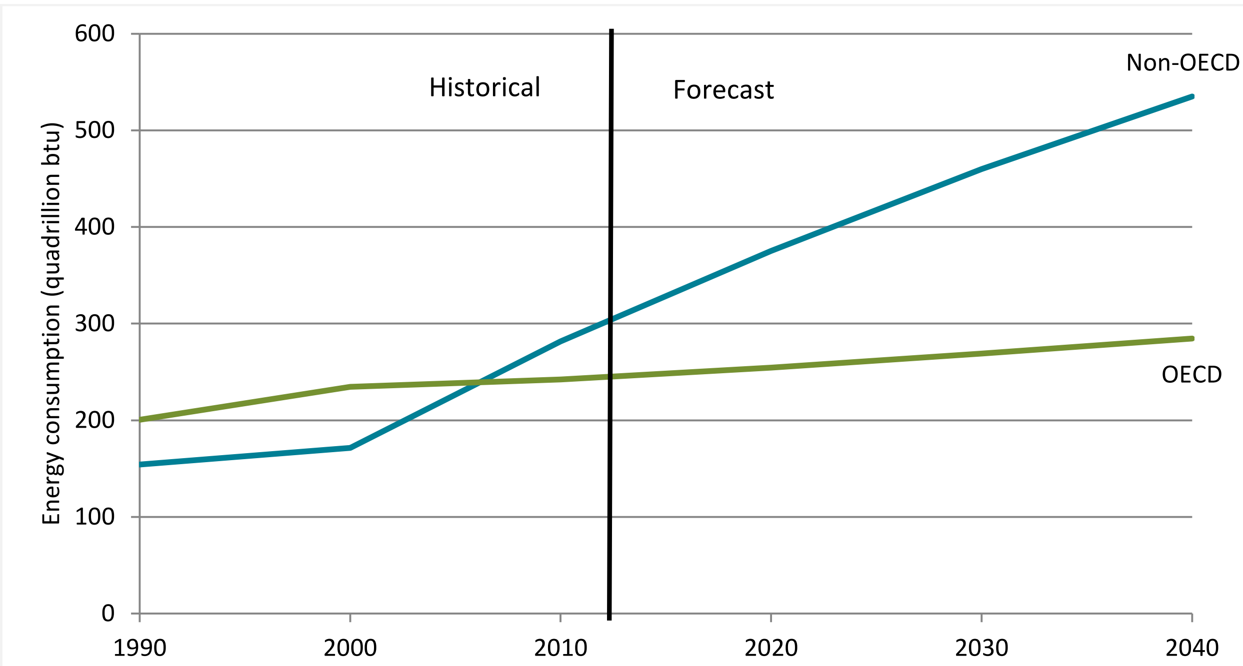
[169] EIA, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*.
[170] Ibid.
[171] Ibid.
[172] For a review of problems facing international shale development, see Maugeri, *The US Shale Oil Boom: A U.S. Phenomenon*.
[173] For a review of problems facing European shale development, see Chyong and Reiner, "Economics and Politics of Shale Gas in Europe."
[174] EIA, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*, 14.
[175] Patel and Viscusi, "France's Fracking Ban 'Absolute' After Court Upholds Law."
[176] Analysis from IHS-CERA data in Maugeri, *The US Shale Oil Boom: A U.S. Phenomenon*.
[177] BakerHughes, "International Rig Count."
[178] Maugeri, *The US Shale Oil Boom: A U.S. Phenomenon*, 2.
[179] Ibid., 25.

successful shale development in countries and alternatively, no shale development. Such scenarios could determine the impact of either discovering suitable geological conditions or lifting extraction bans.

Developing Countries

One of the major trends in the world economy today is the rise of developing countries, and energy markets are no exception. Developing countries will be the main drivers of growth in world energy demand in the coming decades.[180] Energy consumption by non-OECD countries is projected to rise by 33 percent from 2010 to 2020 and a further 22 percent from 2020 to 2030 (see figure 21). By contrast, OECD energy consumption will only increase by 11 percent for the entire time period of 2010 to 2030.

Figure 21: World energy consumption



Source: EIA, International Energy Outlook 2013, table A1.
Notes: Data after 2010 is a forecast.

Fossil Fuel Subsidies

Many developing countries heavily subsidize the price of consumer fossil fuel products. For example, in 2012, gasoline in Venezuela cost $0.08 per gallon while gasoline in the United States was $3.67 per gallon.[181] According to the IEA, global expenditures on such subsidies

[180] EIA, Today in Energy, December 3, 2013.
[181] World Bank, "Pump Price for Gasoline."

totaled $548 billion in 2013[182] and on average it cost 5 percent of the subsidizing country's GDP.[183] For many of these countries, this is a larger expense for the government than public provision of education or health care.[184] Because of their size, reform that eliminated these subsidies could substantially reduce fossil fuel consumption. And because oil is traded on a world market where different country's production is highly substitutable, reform would materially impact both global production and world trade flows. However, prior studies examining the impact of reform have focused on modeling the effects on GDP or the environment, not trade.[185] Further research could fill this niche.

Conclusion

World energy trade is changing due to both domestic and international trends. Driven by the shale revolution, U.S. fossil fuel production is growing substantially. Although conventional production has fallen, rising shale gas and tight oil have more than compensated for it. As a result, U.S. energy forecasts are far more optimistic than they were just a few years ago, with expectations of large net imports turning into small net imports or even net exports. This has led to increased interest in modifying U.S. export policies for LNG and crude oil. In both cases the United States would benefits from exports, but the situation for crude oil is especially noteworthy because lifting the crude oil export ban would actually reduce domestic gasoline prices. Policy decisions also drive other major domestic energy issues such as the effect of environmental regulation on coal, the Keystone XL pipeline, and energy tax reform. Internationally, energy trade is shaped by natural gas geopolitics, Mexican energy reform, international shale development, fossil fuel subsidies, and the ever increasing energy consumption of developing countries.

These trends present a number of opportunities for interesting original research:

- More robust estimates of the macroeconomic impact of the shale revolution.
- Quantification of the effects of LNG exports both on regional economies and world GHG emissions.
- The examination of alternatives to full repeal of the crude oil export ban could provide policymakers with more politically feasible options.
- The impact of the repeal of energy tax preferences.

[182] IEA, "World Energy Outlook 2014," 314.
[183] Ibid., 321.
[184] Ibid.
[185] For a review of studies on fossil fuel subsidies, see Ellis, "The Effects of Fossil-Fuel Subsidy Reform: A Review of Modelling and Empirical Studies."

- The environmental impact of foreign versus domestic coal consumption and where coal would go if environmental regulations were tightened.
- Analysis of Mexican natural gas exports could help forestall problems like those faced by the Keystone XL pipeline.

Any of these topics would answer important, policy-relevant questions in international energy trade.

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