The Impact of the Shale Oil Revolution on U.S. Oil and Gasoline Prices

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Abstract: This article examines how the shale oil revolution has shaped the evolution of U.S. crude oil and gasoline prices. It puts the increased production of shale oil into historical perspective, highlights uncertainties about future shale oil production, and cautions against the view that the U.S. may become the next Saudi Arabia. It then reviews how the ban on U.S. crude oil exports, capacity constraints in refining and transporting crude oil, and the regional fragmentation of the global market for crude oil after 2010 have affected U.S. oil and gasoline prices. In particular, the article discusses the reasons for the persistent wedge between U.S. and global crude oil prices in recent years, explains why domestic oil trading at a discount has not lowered U.S. gasoline prices, and discusses the role of shale oil in causing the 2014 oil price decline. Finally, the article explores the implications of the shale oil revolution for the U.S. economy and explains why increased shale oil production is unlikely to create a boom in oil-intensive U.S. manufacturing industries.

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INTRODUCTION

The term shale oil (also known as tight oil) is commonly used by the oil industry and by government agencies to refer to crude oil extracted from rock formations that are characterized by low permeability. The production of shale oil exploits three technological advances: horizontal drilling, microseismic imaging, and the hydraulic fracturing (or fracking) of underground rock formations containing deposits of crude oil that are trapped within the rock. The hydraulic fracturing causes cracks and fissures in the rock formation that allow the crude oil to escape and to flow into the borehole, where it then can be recovered. This process is used to extract crude oil that would be impossible to release through conventional drilling methods which are designed to extract oil from permeable rock formations.

The shale oil revolution refers to the surge in U.S. shale oil production starting in the mid-2000s, which in 2008 reversed the long-standing decline in U.S. crude oil production. This surge was stimulated by the high price of conventional crude oil after 2003 which made the shale oil technology cost-competitive when it was first introduced. Since then, the cost of producing shale oil has declined substantially, as shale oil producers have become more efficient.

The purpose of this article is to examine how the increased availability of shale oil has shaped U.S. oil and gasoline prices. I begin by putting U.S. shale oil production into historical perspective, highlighting uncertainties about future shale oil production and cautioning against the view that the United States will become the next Saudi Arabia. Next I examine how the ban on U.S. crude oil exports, capacity constraints in refining and transporting crude oil, differences in the quality of conventional and unconventional crude oil, and the regional fragmentation of the global market for crude oil have shaped the evolution of U.S. oil and gasoline prices. In particular, I discuss the reasons for the persistent wedge between U.S. crude oil prices and global
crude oil prices in recent years. I also examine why domestic crude oil trading at a discount relative to international oil prices has not translated into lower U.S. gasoline prices and what the role of shale oil has been in causing the 2014 oil price decline. Finally, I explore the implications of the shale oil revolution for the U.S. economy. The rapid expansion of U.S. shale oil production after 2008 quickly captured the imagination of policymakers and industry analysts, fueling visions of the United States becoming independent from oil imports, of a rebirth of U.S. manufacturing, and of net oil exports offsetting the U.S. current account deficit. I explain why none of these visions is likely to become a reality.

PUTTING THE RESURGENCE OF U.S. OIL PRODUCTION INTO PERSPECTIVE

In the early 1970s, U.S. oil production entered a long-term decline that was only temporarily offset by increased crude oil production in Alaska. The unexpected surge in U.S. shale oil production, which started in the mid-2000s, forced energy experts to revise their models and forecasts of U.S. oil production. By 2012, the International Energy Agency was projecting that the United States would overtake Saudi Arabia by the mid-2020s to become the world’s leading crude oil producer, evolving into a net oil exporter by 2030 (International Energy Agency 2012). The actual changes in U.S. oil production to date have been much more modest. It is useful to put these changes into historical perspective and to compare them with data from other oil-producing countries.

The left panel of Figure 1 tracks the average annual production of the world’s three largest crude oil producers from 1973 to 2014. It shows that Russia, Saudi Arabia and the United States all increased their oil production in recent years, but no country more so than the United States. Nevertheless, as of 2014, U.S. crude oil production remained below that of Saudi Arabia, with Saudi oil production in turn being surpassed by Russian oil production. The right panel of
Figure 1 indicates that in 2014 none of the three leading oil producers accounted for more than a modest share of global oil production, with the United States reaching 11%. Thus, the increase in U.S. oil production in recent years, although important from a domestic point of view, has been small relative to the size of the global oil market.

Moreover, the advantages of becoming the world’s leading oil producer are not as great as sometimes thought. Figure 1 shows that between 1973 and 2014 the United States had already been the world’s largest oil producer repeatedly. However, this fact did not protect the U.S. economy from being exposed to major oil price shocks, for example, during the oil crisis of 1973/74 or following the invasion of Kuwait in 1990. The vulnerability of the U.S. economy to the global oil price shocks of 1973/74 and 1990 is not surprising upon reflection. With U.S. domestic demand for crude oil exceeding U.S. oil production, the economy remains exposed to shocks to the price of imported crude oil, even if the United States is the world’s largest oil producer. These historical examples illustrate that becoming the world’s leading oil producer does not by itself ensure a country’s energy security. They also remind us that there is no reason to expect the United States to become the next Saudi Arabia, as long as the U.S. economy uses more oil than it produces.

THE EVOLUTION OF U.S. SHALE OIL PRODUCTION

The sharp reversal of the long-standing decline in U.S. oil production in 2008, shown in the left panel of Figure 1, can be directly traced to an increase in U.S. shale oil production. Figure 2 shows the evolution of U.S. shale oil production since 2000, both in the aggregate and by shale oil play. Two facts stand out. First, starting in 2004, overall shale oil production initially increased exponentially, with the trend growth becoming nearly linear after 2012. Second, much

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1 The term *shale oil play* refers to a geographical area suitable for shale oil production, whereas the term *oil field* refers to areas suitable for conventional crude oil production.
of U.S. shale oil production is concentrated in a small number of geographic regions. By far the most productive shale oil plays are Eagle Ford in Texas and the Bakken in Montana/North Dakota, which together account for more than half of the output. To put these production numbers into perspective, note that in March 2014 the U.S. economy produced an average 8.2 millions of barrels/day (mbd) of crude oil and imported an additional 7.3 mbd to meet its oil needs. Of the total 15.5 mbd of crude oil only about 3.6 mbd were produced from shale oil. In other words, as of March 2014, shale oil accounted for almost half of U.S. oil production, but only about a quarter of the total quantity of oil used by the U.S. economy. This magnitude is far from negligible, but to understand the excitement that shale oil has generated among policymakers one has to examine projections of future U.S. shale oil production.

**Projections of U.S. Shale Oil Production**

Figure 3 presents historical estimates and projections for all forms of U.S. crude oil production as of 2012, generated by the U.S. Energy Information Administration (EIA). The projections are based on the reference case (defined as the business-as-usual trend estimate, given known technology and technological trends). The figure indicates that there is no expectation that conventional onshore oil production (or for that matter off-shore oil production) will increase in the foreseeable future. At best they will remain stable at current levels. This means that all of the growth in U.S. oil production going forward, if there is to be any, must come from shale oil (labeled *tight oil* in the figure). In fact, Figure 3 projects a sharp increase in shale oil production from 2012 until 2015, followed by zero growth until 2020 and then a steady decline back to the 2013 production level by 2040.²

² Figure 3 also indicates that the peak level of U.S. oil production projected for the second half of this decade will match the level of U.S. oil production in 1970, shortly before the United States became heavily dependent on crude oil imports from the Middle East. Given that the size of the U.S. industrial sector has more than doubled since 1970,
In interpreting Figure 3, it must be kept in mind that these projections are sensitive to a number of implicit assumptions. Three concerns stand out. First, the projected flow of shale oil production in Figure 3 is based on estimates of the stock of shale oil that can be recovered using current technology. The EIA refers to these stocks as recoverable resources.³ It should be noted that the EIA estimates of recoverable resources have been based more on information provided by industry sources than on independent geological studies. Thus, these estimates are subject to substantial error.

For example, in the summer of 2014, the EIA reduced its estimate of the recoverable Monterey shale oil stocks from 15.4 million barrels to 0.6 million barrels, which implied a 64% reduction in previous estimates of recoverable U.S. shale oil stocks. Clearly, such reductions in the stock of recoverable shale oil also affect the expected flow of shale oil production. This particular revision resulted from the realization that the geology of the Monterey shale oil play made it technically more difficult and hence more costly to exploit than anticipated by the shale oil industry. It is important to stress, however, that revisions to estimates of the stock of shale oil will not all necessarily be downward. For example, there is evidence of significant productivity gains in shale oil production in 2014 (see Covert 2014). There is also the possibility of further technological breakthroughs. Thus, there is uncertainty in both directions. Nevertheless, the main point to take away from the EIA analysis in Figure 3 is that, unless new promising shale oil plays can be found or technology improves substantially, one would expect shale oil production to taper off in the 2020s.

A second concern is that the projected flow of shale oil production depends not only on...
the stock of recoverable shale oil below the ground, but also on the price of crude oil. Implicit in projections of the flow of shale oil production is the premise that the price of oil will remain high enough in the future such that investment in shale oil plays will continue. The sharp decline in the price of West Texas Intermediate (WTI) crude oil from $106 in June 2014 to $47 in January 2015, however, followed by a recovery to $60 by June and another drop below $50 in August 2015, serves as a reminder that the shale oil industry is vulnerable to downside oil price risk. Assessing this oil price risk is not straightforward. The price at which continued shale oil production becomes unprofitable not only differs across shale oil plays, but has also evolved over time, as shale oil producers have become more efficient. For example, whereas Platts (2013) suggested that it may take a price of oil below $50 per barrel to shut down production at Eagle Ford, more recent estimates are closer to $35.

A final concern is that Figure 3 is based on the assumption that we can count barrels of oil as though all crude oil is the same, ignoring the inherent differences in the quality of shale oil compared to conventional crude oil. The quality of crude oil can generally be characterized along two dimensions. One is the oil’s density (ranging from light to heavy), which is typically measured according to the American Petroleum Institute (API) gravity formula; the other is its sulfur content (with sweet referring to low sulfur content and sour to high sulfur content). Figure 4 summarizes the density and sulfur content of several commonly quoted crude oil benchmarks (including WTI and Brent). Conventional U.S. light sweet crude has an API value of less than 40, whereas shale oil consists of light sweet crude (at most 45 API), ultra-light sweet crude (about 47 API) and condensates (as high as 60 API). These quality differences matter because

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4 Data on the relative importance of shale oil production by API are not readily available, but the EIA recently published a report for annual U.S. crude oil production by API that sheds some light on this issue (see EIA 2015a). For 2013, the report shows that more than half of crude oil with at least API 40 was in the API 40-45 range and perhaps a quarter was above API 50. Regional disaggregates show that much of the ultra-light crude and condensate
they affect the yield of refined products obtained in the refining process. Moreover, there have been reports that refining shale oil may cause technical problems in running refineries not encountered with conventional crude oil (see, e.g., Baker Hughes 2013; Benoit and Zurlo 2014). The fact that not all shale oil is a good substitute for conventional light sweet crude oil such as the WTI or Brent benchmarks calls into question the implicit assumption underlying Figure 3 that all crude oil is the same, allowing us to add up production totals.

To conclude, whether the United States will ever become independent of imported crude oil seems highly uncertain at this point. Such predictions are based on the assumption of rapid growth in shale oil production in years to come as well as stable production levels for conventional U.S. crude oil. There is considerable risk that U.S. oil production could decline earlier than projected by the EIA. At the same time, it is also possible that technological improvements and efficiency gains could lower the cost of shale oil production and sustain the U.S. shale oil boom longer than anticipated by the current EIA projections. Even taking the projections in Figure 3 at face value, however, any aggregate analysis of the oil market is likely to be misleading given the regional and international fragmentation of the market for crude oil after 2010, as discussed next.

THE FRAGMENTATION OF THE MARKET FOR CRUDE OIL AFTER 2010

To understand the impact of the shale oil revolution on the U.S. price of oil, it is important to understand the structure of the U.S. refining market. Crude oil is purchased by refineries which convert the crude oil to refined products such as diesel, gasoline, jet fuel or bunker fuel. Not all refineries are alike. A refinery’s technical configuration determines which type of crude oil it can process. Light sweet crudes are well suited for the production of gasoline, whereas heavier and

is from the Gulf Coast region (most prominently from the Eagle Ford play) and none from the Northern Great Plains (which includes the Bakken).
sourer crudes are best suited for producing diesel fuel and heavy fuel oils. Refining heavier crudes into gasoline requires more advanced technologies and is more costly. Nevertheless, there are refineries that employ such expensive technologies because heavier and sourer crudes tend to be much lower priced than conventional light sweet crude oil such as the Brent or WTI benchmark.

U.S. refineries are heavily concentrated along the Gulf Coast and along the East Coast with additional refineries located near major population centers. Not all of these refineries are able to process heavier and sourer crudes. For example, whereas many refineries along the Gulf Coast rely on advanced technologies to produce gasoline from low-priced medium and heavier crudes imported from Saudi Arabia, Venezuela and Mexico, U.S. refineries along the East Coast specialize in processing light sweet crude oil, which can be refined using more conventional technology. These institutional constraints are important for understanding the impact of the shale oil revolution. Most shale oil is well suited for the production of gasoline and thus one might have expected that this additional supply of light sweet crude would have been easily absorbed by U.S. refiners. In fact, however, the surge in shale oil production caught the U.S. refining industry off guard.

**How Refiners Were Caught Off Guard by the Shale Oil Boom**

For many years prior to the shale oil boom, there had been signs that light sweet crude oil was becoming increasingly scarce in the world. As the composition of the grades of crude oil available in the oil market shifted toward heavier and sourer crudes, many refiners in Texas invested in new technology that enabled them to become the world leader in processing heavier crudes, despite their higher sulfur content. In contrast, European refiners, much like the U.S. refineries along the East Coast, continued to rely on imports of light sweet crude oil from
countries such as Nigeria, Angola and Algeria. In some cases, East Coast refineries even reduced their capacity in anticipation of a shortage of light sweet crude.

When shale oil was shipped in ever increasing quantities to the U.S. oil market hub in Cushing, Oklahoma, in the central United States, the refineries most naturally suited to taking advantage of this opportunity were the refineries along the East Coast. Because traditionally these refineries supplied the interior of the country with refined product produced from imported light sweet crudes, however, there was no pipeline infrastructure in place to transport the shale oil from the central United States to the East Coast for refining. Nor was there enough rail or barge transportation capacity available to transport this crude oil to the East Coast.

Likewise, it proved difficult to sell the shale oil to Gulf Coast refineries. Not only were many of those refineries not well-equipped to process light sweet crude oil on a large scale, given their investment in technologies for processing heavier crudes; there were also not enough oil pipelines running from Cushing to Texas as of 2010. The system of oil pipelines in the region was traditionally designed to transport imported crude oil from the Gulf Coast ports to the interior, not from the interior to the refineries along the Gulf Coast. Because reversing and extending existing oil pipelines or building new pipelines is expensive and time consuming, and because rail and barge transport could not accommodate the required volume of shipments to the Gulf Coast, a glut of light sweet crude oil developed in Cushing.

The glut was not limited to light sweet crude oil. The rise in shale oil production coincided with a rise in imports of heavy Western Canadian crudes extracted from oil sands in Alberta and Saskatchewan. Just as the production of shale oil was stimulated by high global oil prices, so too was the production of heavy crudes from Canadian oil sands. Because Canada lacked both the refining infrastructure to process its heavy crudes domestically and the
transportation infrastructure to export them directly to buyers outside the United States, it had little choice but to ship its heavy crudes to the central United States. Like most shale oil, Canadian crude oil was shipped by pipeline, rail, or barge toward the hub of U.S. oil trade in Cushing, OK, where it failed to find enough buyers. One reason was that most East Coast refiners would not have been able to process heavy crudes, even if there had been a way of shipping the Canadian oil there. The other reason was that there was not enough transportation capacity from Cushing to those Texas refineries that would have actually been interested in purchasing heavy crudes from Canada as a low-cost alternative to the heavier crudes from Venezuela or Saudi Arabia.

The Oil Glut in Cushing

By the end of 2010, the continued influx of light sweet crude created enough local excess supply in Cushing to put downward pressure on the U.S. price of light sweet crude oil, as measured by the WTI price, relative to the Brent price benchmark. The corresponding discounts on the price of heavy crude went unrecorded by conventionally used measures of the U.S. price of oil, but were even steeper. It is important to emphasize that this downward pressure on the U.S. price of oil in Cushing arose not because unconventional crude oil was helping to satisfy the world’s demand for gasoline, but rather because of a lack of demand for oil in Cushing from refineries operating in this market. In fact, the oil glut that emerged in Cushing in 2011 coexisted with high demand for imported crude oil along the East Coast and Gulf Coast. In other words, the U.S. oil market had become regionally fragmented as well as distinct from the global oil market.

It is useful to review the origins of this development in more detail. Specifically, the fragmentation of the oil market can be traced to three determinants: the U.S. oil export ban, capacity constraints in oil transportation, and capacity constraints in refining. As the relative
importance of these determinants has evolved since 2010, so has the degree of global oil market integration, as measured by the Brent-WTI price spread.

**Understanding the Evolution of the Brent-WTI Price Spread**

As the shale oil boom unfolded, the main challenge for the refining industry was that – with the increased production of unconventional oil in the interior of the continent – many existing pipelines were in the wrong location or were running the wrong way, sustaining local oil shortages in some locations, while creating gluts in others. Initially, the glut was concentrated in Cushing, OK, the hub of U.S. oil pipelines. Cushing had effectively become landlocked, with more and more oil flowing in from the Bakken and other shale oil plays as well as from Canada. This oil had to be sold at a discount or stored in inventories in the absence of a buyer.

One indication of this bottleneck in the transportation infrastructure was that, starting in 2011, the WTI price fell below the global price of crude oil, as measured by the Brent price (see Figure 5). This price differential reflected the excess supply of light sweet crude in Cushing, Oklahoma, where the WTI price is measured. Another indication was the unprecedented spread between the prices of Louisiana Light Sweet (LLS) and WTI crude oil beginning in 2011. The LLS benchmark refers to light sweet crude oil produced on the Gulf Coast close to where many U.S. refineries are located. Because there was a shortage of light sweet crude oil along the coast, LLS traded at a premium that reflected the price of oil imports into the Gulf region. As a result, the price of LLS closely tracked the price of Brent crude oil with the relatively high price of Brent reflecting the tightness of global oil markets, as Asia came to rely on Brent oil imports. In contrast, the price discount on WTI crude oil after 2011 reflected the fact that this oil was stored in a location where it could not compete with imports.

Beginning in mid-2013, the growing oil glut in Cushing was finally alleviated when
some existing oil pipelines originally running from Texas to Cushing were reversed, new pipelines to Texas refineries opened, and rail transport of oil increased (see Platts 2013). As the new pipelines from Cushing to the Gulf Coast allowed oil to flow more freely to the Texas refineries, oil inventories in Cushing declined. At the same time shale oil production at Eagle Ford, Texas, accelerated and began competing with LLS along the Gulf Coast. At this point, a sellers’ market from the point of view of Gulf Coast oil producers turned into a buyers’ market from the point of view of refiners. With the increased availability of both light sweet and heavy crude oil along the Gulf Coast, refineries chose to pay less for this oil rather than match high prices for oil imports. Because domestic oil producers were unable to export their oil production, given the U.S. oil export ban, which had been put in place in the 1970s, they had little choice but to acquiesce. The continued influx of shale oil resulted in domestic light sweet crude, including both the WTI and LLS benchmarks, trading at a discount relative to the Brent price starting in late 2013. Put differently, whereas previously the LLS price mirrored the fluctuations in the Brent price, it now mirrored those in the WTI price (see Figure 5). In contrast, high-priced imports of crude oil declined, freeing up this crude for markets abroad, and reducing U.S. net crude oil imports.

The overall oil glut in the central part of the United States was compounded by the opening of an important segment of the Keystone XL pipeline in January 2014. The Keystone XL pipeline project consists of several distinct parts. One is a pipeline connecting the oil sands in Alberta with Cushing, Oklahoma. The construction of this pipeline was vetoed in 2015 by the Obama administration. This fact has not prevented Canadian oil from being transported along the less direct route from Alberta via Saskatchewan and Manitoba. Another (and arguably more important) part of the Keystone XL project is a pipeline connecting Cushing with the oil
refineries in Texas. This part of the pipeline started operating in early 2014, with an additional extension to Houston scheduled to be completed in 2016. The additional transport capacity enhanced the flow of crude from Cushing to the Texas Gulf Coast, sustaining the price wedge between the global price and the U.S. price of light sweet crude oil.

The U.S. Oil Export Ban

Given the glut of crude oil along the U.S. Gulf Coast starting in 2013, a natural question is why the United States did not simply export some of its domestically produced crude oil, given the continued high demand for light sweet crude oil abroad. The main reason was the existence of a U.S. law prohibiting the export of domestically produced crude oil (with some exemptions at the discretion of the Commerce Department). This law was enacted in 1975, after the 1973/74 oil crisis, in an attempt to insulate the United States from foreign oil price shocks. It remained in effect until early 2016. There had been earlier calls for rescinding the oil export ban, especially from oil producers, but these calls were steadfastly ignored by the Obama administration. In fact, there was no fundamental change in U.S. policy on this matter until late 2015, at which point the oil export ban had become largely irrelevant, as discussed later. It is important, however, not to overstate the impact of the oil export ban in the early years of the shale oil boom. The case can be made that even if the ban had been lifted much earlier, large-scale U.S. oil exports would have been impeded by the lack of oil transportation capacity.

Constraints on the Refining Infrastructure

There have been several market responses to the glut of shale oil in the central United States. One response has been to build new refineries in close proximity to shale oil plays. These refineries supply high-end products such as diesel (which is used both by locomotives, trucks and drilling rigs) to the local economy with the residual sold as feedstock to other refineries.
They are too small, however, to absorb the excess supply of shale oil. One difficulty in scaling up these refinery operations has been the lack of a suitable transportation infrastructure; another has been the fact that environmental regulations become more stringent, the larger the refinery. Moreover, concerns that the export ban on oil might be lifted (or that shale oil production in a given location might diminish for one reason or another) have prevented larger-scale investments in the refining infrastructure near shale oil plays. Finally, building large-scale refineries far from population centers would make economic sense only if the refined product could be shipped by product pipeline to where it is needed, adding to the cost of such projects. Thus, the key to absorbing increased shale oil production has not been the construction of new refineries, but the development of a suitable transportation infrastructure for crude oil to allow the oil to reach existing refineries capable of processing the type of crude in question.

**Constraints on the Oil Transportation Infrastructure**

Developing new infrastructure for transporting crude oil has been a slow and costly process. Efforts to alleviate oil transportation bottlenecks have focused on pipelines, rail transport and barge traffic. All indications are that changes in the transportation infrastructure have been incremental only.

*Oil Pipelines*

For example, in recent years, there has been considerable investment in expanding, reversing and converting existing pipelines to increase the flow of crude oil to the refineries along the Gulf Coast. Yet – with the exception of several new pipelines connecting to Texas refineries (including the lower segment of the Keystone XL pipeline) – there has been remarkably little new construction of oil pipelines in the United States. The reasons for the lack of pipeline construction are numerous. Building a crude pipeline to the refiners in the Philadelphia area, for
example, is a challenge due to terrain, legal permits and distance from crude production. A review of ongoing and proposed pipeline projects can be found in Platts (2013). It remains to be seen how many of these projects will be approved and how many will remain economically viable at the current much lower price of oil. It is worth noting that none of these projects address the problem that there is no pipeline network capable of transporting crude oil from Cushing to the East Coast. The focus of the industry instead has been on alternative means of transportation such as rail and barges.

**Oil Transport by Rail**

In 2013, nearly twice as many carloads of crude oil were transported by rail than in 2012 and more than 40 times as many as in 2008 (see Esser 2014). Although only 10% of U.S. crude oil production moves by rail, the shipping of shale oil relies heavily on rail (and to a much lesser extent on trucks). In particular, many refineries along the East Coast and Pacific Coast have favored leasing rail cars to move shale oil to refineries. For example, nearly 70% of crude oil produced in North Dakota is moved by rail (see Esser 2014).

One explanation for this surge is the greater flexibility of rail transport. Although it is more costly to transport oil by rail than by pipeline, it is easier to obtain regulatory approval and to adjust the volume of shipping, as needed. Another likely reason is the uncertainty about the future prospects for shale oil. Pipeline construction requires a commitment from producers and financiers for many years. A particular concern in building new pipelines to connect shale oil plays to existing crude oil pipelines in the center of the country has been that production in shale oil plays declines at a faster rate than in conventional oil fields and may cease before the capital costs of a new pipeline will have been recouped. The use of rail transport is not without drawbacks, however. For example, the ability to use rail cars is limited by the current rail
infrastructure, including the condition of the tracks and the rolling stock as well as the availability of sidings to speed up traffic. It is also limited by the lack of competition on some routes.

*Oil Barges*

There has also been a surge in the use of barges for shipping oil both on rivers and in coastal waters. For example, shale oil is increasingly being shipped from the port at Corpus Christi, Texas, up the Gulf Coast and even to the East Coast, following the conversion of some refineries which used to process imported light sweet crude (see Platts 2013). The oil tankers used for this purpose are U.S. flagged Panamax vessels (i.e., vessels small enough to fit through the Panama Canal rather than the much larger carriers used for long-distance oil shipping). Platts (2013) notes that additional docks and tankers may be needed to relieve the bottleneck in shipping that is already developing at Corpus Christi. One constraint on transporting domestically produced oil in U.S. coastal waters has been the Jones Act, which necessitates the use of U.S.-flagged vessels for transporting goods between U.S. ports. This regulation has restricted the number of vessels available and inflated oil tanker rates on these routes.

*Synthesis*

With rail and barge shipping expanding over time, more and more light sweet crude oil that used to be landlocked in the center of the country in recent years has been reaching refineries along the Gulf Coast and even along the East Coast, alleviating the oil glut in the Midwest and in Texas. This fact helps explain the gradual erosion of the spread between the WTI and LLS prices on the one hand and the Brent price on the other in 2014 and 2015 (see Figure 5). This convergence process was further strengthened by lower U.S. demand for imports of crude oil and higher U.S. exports of refined products to Europe and Latin America, which allowed more oil to be shipped
to Asia, causing the Brent price to decline. With the lifting of the oil export ban in early 2016, the Brent-WTI price spread has narrowed to about $1 per barrel. As U.S. crude oil exports increase in 2016 and beyond, one would expect the distinction between Brent and WTI prices to become moot once again.

**Implications of the Brent-WTI Spread for the Price of Gasoline**

At first sight, lower U.S. oil prices relative to international oil prices might seem welcome from the point of view of U.S. gasoline consumers. A decline in WTI and LLS prices below the global oil price, however, does not necessarily mean that U.S. gasoline prices will fall. For example, a recent study by Borenstein and Kellogg (2014) shows that to the extent that the marginal gallon of gasoline consumed in the Midwest is still produced on the East Coast, gasoline produced in the Midwest from low-cost domestic crude oil will cost the same as gasoline produced on the East Coast from high-cost imported crude oil.

This argument can be taken a step further. The export ban on crude oil that remained in effect until the end of 2015, did not extend to refined products. In fact, starting in 2013, U.S. exports of diesel fuel and gasoline surged, as U.S. refiners with access to relatively low-cost domestic crude oil began competing with foreign refiners in European and Latin American product markets. This point is important because, if fuel produced in the United States may be exported abroad, refiners will charge the same high fuel price in the Midwest at which they could sell in world markets, adjusted for transportation costs. Thus, all rents from lower crude prices in the United States accrue to refiners. The U.S. consumer does not get a reprieve at the gas pump because gasoline and diesel markets remain integrated with the global economy, even as the global market for crude oil becomes fragmented.

**The Role of U.S. Exports of Refined Products**
The role of trade in refined products is thus important for understanding the impact of the shale oil revolution on U.S. gasoline prices and global oil prices. Exports of refined products made from domestically produced oil are a substitute for exports of crude oil because they reduce foreign demand for crude oil traditionally satisfied by foreign oil producers, as though the U.S. crude oil had been exported. This fact allowed the oil market to bypass the U.S. oil export ban that was in place until the end of 2015, which helps explain the diminishing spread between Brent and WTI prices starting in 2014. Moreover, in the absence of these refined product exports, the global price of crude oil would have been higher than actually observed, as discussed in Kilian (2016).

**Policy responses**

As improvements in the oil transportation infrastructure in early 2014 allowed more shale oil to reach refiners along the East Coast, sustaining the U.S. exports of refined products, there was growing concern in the United States about the prospect of capacity shortages in refining light sweet crude oil, which in turn prompted increased flexibility in the U.S. position on crude oil exports. For example, in June 2014 the Obama administration approved exports of lightly processed condensates, which as refined products were technically not covered by the oil export ban. In December 2014, the Obama administration cleared the way for exports of as much as a million barrels a day of ultra-light crude oil to the rest of the world. Finally, in August 2015, the Obama administration on a case-by-case basis approved swaps of light sweet U.S. crude oil for similar quantities of heavier Mexican crude more suited for many Texas oil refineries. Although these waivers helped alleviate the glut of light sweet crude oil in the United States on the margin, none of these decisions represented a fundamental departure from the oil export ban. When in
late 2015 the Obama administration finally agreed to lift the oil export ban as part of a larger political deal with Congress, the Brent-WTI price spread had already diminished substantially.

**WAS SHALE OIL RESPONSIBLE FOR THE DECLINE IN THE PRICE OF OIL SINCE JUNE 2014?**

Although the most visible effect of the shale oil revolution until June 2014 was the widening spread between the Brent price and the WTI price of crude oil, the expansion of shale oil production also put downward pressure on the global price of oil by reducing U.S. oil imports and by reducing foreign demand for oil in response to rising U.S. exports of refined products. Indeed, the sharp decline in the Brent price of crude oil after June 2014 (and the resulting more modest decline in U.S. gasoline prices) has often been attributed at least in part to the shale oil revolution. Baumeister and Kilian (2016) provide a detailed quantitative analysis of this episode and show that as much as $16 of the $49 cumulative decline in the Brent price between June and December 2014 may be explained by the cumulative effects of positive surprises about the supply side of the oil market, including the effects of shifts in expectations about future oil production as well as actual oil supply shocks. Of course, these supply shifts are global and reflect the actions of many other crude oil producers as well. In addition, there is evidence of a shift in oil price expectations in July 2014. This shift may have reflected developments on the supply side or the demand side of the oil market, and accounts for another $9 decline in the Brent price. The remaining $24 of the cumulative decline is unambiguously explained by a weakening of the global economy, which resulted in lower demand for crude oil.

It is difficult therefore to pin down the precise effect of the shale oil revolution on the Brent price. The best we can say is that the cumulative effect of expected and unexpected increases in shale oil production on the Brent price in the second half of 2014 must lie
somewhere between $0 and $25. Given related empirical evidence that oil supply shocks tend to have only modest effects on the price of oil, the actual cumulative effect of the shale oil revolution is likely to be closer to the lower end of this range (see Kilian 2014). This view is consistent with a simple back-of-the envelope calculation. We know that the U.S. share in global oil production increased from 7% in 2008 to 11% in 2014 (see Figure 1). We also know that the outbreak of the Iran-Iraq War in 1980 was followed by an oil supply disruption of roughly the same magnitude as the supply increase associated with shale oil, when expressed as a share of world oil production. This earlier event was followed by an increase in the U.S. price of crude oil of about 10%. On this basis, one would expect the effects of U.S. shake oil production increases on the global price of crude oil to be near $10 per barrel.

The Effect of Lower Oil Prices on Future Shale Oil Production

Regardless of the determinants of the 2014/15 oil price decline, an important question is how the current much lower level of oil prices will affect future U.S. shale oil production. It has become evident that large productivity gains in 2014 and early 2015 have lowered the operating costs of most U.S. shale oil producers sufficiently, so companies can weather oil prices under $50 – at least temporarily. This view is consistent not only with anecdotal evidence and with data on drilling productivity, but also with the evolution of actual shale oil production, which continued to grow until early 2015. Thus far the U.S. shale oil industry has survived the 2014/15 decline in the price of oil largely intact, although there has been a sharp decline in the U.S. oil rig count since September 2014, many companies that provide support services to the oil industry have reduced their workforce, and there are increasing reports of shale oil producers under financial stress. All indications are that there will be a consolidation of the shale oil industry and lower shale oil production going forward until the global price of oil has recovered.
HAS THE SHALE OIL BOOM REDUCED U.S. EXPOSURE TO OIL PRICE RISK?

The shale oil boom has made the U.S. economy less dependent on imported crude oil, reducing its exposure to the upside oil price risks that have traditionally concerned U.S. policymakers. It has also increased exposure to downside oil price risks, however. Rather than making the U.S. economy unambiguously less dependent on global oil markets, the shale oil boom has altered the nature of the U.S. exposure to global oil price shocks.

Upside Oil Price Risks

Consider first the upside risks to the price of crude oil. Unexpected global oil price increases matter for U.S. real output mainly because domestic wealth is being transferred abroad, when the price of imported crude oil (and hence the price of domestic fuel) increases (see Kilian 2014). In other words, higher fuel costs act as a tax on the U.S. economy. Some of that tax may be rebated, as foreign oil producers import goods from the United States, but there remains a loss of welfare. Given that net imports of crude oil have declined with increased shale oil production, this tax and its recessionary effect would be expected to diminish. Moreover, increased U.S. exports of refined products have further improved the terms of trade compared with the past. There still will be a redistribution of wealth within the U.S. economy, of course, but these distributional effects are far less clear-cut than the effects of a reduction in domestic aggregate demand associated with higher costs of oil imports. Thus, the shale oil revolution is good news from the point of view of policymakers concerned with positive global oil price shocks.

Figure 6 illustrates the degree to which the U.S. economy has become less vulnerable to such shocks. It shows the evolution of U.S. net petroleum imports (defined to include both crude oil and refined products) since 1973. Not too long ago, net petroleum imports were rising steadily. After 2005, however, a dramatic decline set in. This decline reflected in part reduced
U.S. consumption of oil products in response to higher prices. It also reflected in part the recessionary effects of the U.S. and global financial crisis in 2007-09, just as the Volcker Recession of the early 1980s reduced net petroleum imports. The main driving force, however, appears to be the increase in U.S. shale oil production, which has alleviated the need for imports of light sweet crude oil in recent years and allowed a surge in exports of refined products such as gasoline and diesel to Latin America and Europe. As discussed earlier, these product exports have served as a substitute for U.S. crude oil exports. Unlike recessions and unlike attitudes toward driving, this structural shift is likely to continue. Thus, the trajectory for net petroleum imports going forward has changed in ways that were inconceivable just a few years ago.

**Downside Oil Price Risks**

The decline in net petroleum imports in Figure 6 also reflects the fact that the U.S. oil and refining industry effectively bypassed the ban on exports of crude oil by exporting refined products instead. Rather than shipping crude oil to Asia or to Europe, the United States refined the excess oil locally, taking advantage of access to low-cost crude oil, and sold the refined product at a competitive price abroad. The primary export destination for distillate, diesel, and gasoline products has been Western Europe, with Latin America and the Asia-Pacific region a potential growth market. It remains to be seen to what extent the lifting of the oil export ban in early 2016 will change the composition of U.S. exports from refined products toward crude oil. For the purpose of assessing the exposure of the U.S. economy to oil price risks, the composition of petroleum exports makes little difference, however. What matters is the overall increase in petroleum exports.

A fact that did not receive much attention until the sharp drop in the price of crude oil in late 2014 is that the increased reliance on shale oil production and petroleum exports is not
without a downside, because the U.S. economy has now become more exposed to unexpected declines in the price of crude oil. Whatever the stimulating effect of shale oil production on the economy is when the price of oil is high, this effect is reversed when the price of crude oil drops enough to make shale oil production unprofitable. This point is important because it suggests that energy independence is an illusory concept in an integrated global economy, no matter how much oil the U.S. economy produces. Rather than decoupling itself from the global oil market, the U.S. economy has simply traded one kind of exposure to oil price risks for another.

THE SHALE OIL BOOM AS AN ECONOMIC STIMULUS?

The shale oil boom occurred in the aftermath of the housing and financial crisis of 2007/08, at a time when U.S. policymakers were eagerly searching for any form of economic stimulus. To many observers it seemed that shale oil production would be able to provide just such a stimulus to the U.S. economy, but that view appears to have been overly optimistic. In discussing the implications of the shale oil revolution for the U.S. economy, it is useful to distinguish the effects arising from a positive spread between the global and the domestic price of oil from the effects of the shale oil revolution on the global price of oil, beginning with the former question.

A Revival of U.S. Manufacturing?

Some pundits have expressed the hope that shale oil would help revive the U.S. manufacturing sector. Many U.S. manufacturing jobs in recent decades have moved to emerging economies in response to lower labor costs abroad. The case for an industrial revival in the United States is based on the premise that manufacturing relies on energy and that shale oil provides a source of inexpensive energy, which could give the United States a competitive edge over emerging economies. Proponents of this view anticipate a return of blue collar jobs to the United States, as firms reevaluate the costs and benefits of outsourcing. The flaw in this argument is that it
assumes that fuel costs will be lower in the United States than abroad, but, as has been shown earlier, there is no reason for the U.S. prices of gasoline and diesel to mirror the decline in the price of domestic crude oil relative to international benchmarks. With U.S. fuel prices remaining at international levels, there is little reason for the shale oil revolution to stimulate oil-intensive industrial activities in the United States.

**Why the Effects of the Shale Gas Boom are Different**

This conclusion stands in marked contrast to the natural gas sector. Although at first glance the shale oil revolution appears to be closely related to the shale gas revolution discussed in Hausman and Kellogg (2015), there is actually an important difference. Unlike in the gasoline and diesel market, there has been a noticeable decline in the U.S. wellhead price of natural gas since 2008 relative to natural gas prices abroad (notwithstanding a partial reversal in recent years). Access to inexpensive natural gas benefits the petrochemical industry, for example. U.S. natural gas prices have been low because the natural gas market has never been a global market, but a regional market. Natural gas is transported by pipeline. Although natural gas may be cooled down and liquefied, allowing it to be shipped as liquefied natural gas (LNG) to any port in the world, the cost of LNG shipping is high and the infrastructure required to load and unload LNG is expensive. This fact has prevented the integration of regional natural gas markets and the emergence of a global price thus far. This means that, for the time being, the price of U.S. natural gas has been determined by domestic demand rather than global demand, allowing for a greater price response to increased domestic supply.

**Who Has Benefited from the Shale Oil Boom?**

As noted earlier, the main beneficiary of the U.S. shale oil revolution thus far has been not gasoline consumers or shale oil producers, but rather the U.S. refining industry, which enjoyed a
competitive advantage over diesel and gasoline producers abroad because of its access to low-cost crude oil. Thus, between 2011 and 2015, there was a clear conflict between the interests of U.S. refiners and U.S. crude oil producers. As long as the Brent-WTI differential remained high, refiners had strong incentives to preserve the status quo and to prevent a lifting of the U.S. ban on exports of domestically produced crude oil. An additional beneficiary of the shale oil revolution has been the transportation sector, notably the railroad industry, and the industries directly serving the oil sector.

**The Broader Macroeconomic Effects of the Shale Oil Boom**

Although the effects of the shale oil boom on output and employment are concentrated in the oil and refining sector of the economy, this does not mean that increased shale oil production has no broader macroeconomic effects. For example, the oil producing sector directly contributes directly to the value added of the U.S. economy. The magnitude of this contribution is comparatively small, however. Although there are no data on real value added in shale oil extraction, it can be shown that even the contribution to the U.S. economy of all mining activities (which includes in addition conventional oil, conventional and unconventional natural gas, coal, metals and minerals) is negligible, with a share of 2.7%. Moreover, there has been no noticeable increase in this contribution since shale oil production took off, so one would not expect large direct effects of shale oil production on aggregate output.

Quantifying the indirect spillover effects from the oil and refining sector to other sectors of the economy is more challenging and requires the use of quantitative macroeconomic models. The International Monetary Fund (2013) and Manescu and Nuño (2015), among others, have examined the quantitative effects of the shale oil revolution on economic growth in the United States and elsewhere. These studies rely on stylized general equilibrium models of the global
economy which make no allowance for differences in the quality of crude oil from different sources or for transportation and refining bottlenecks. Hence, their results are illustrative at best. Nevertheless, the multiplier effects on the U.S. economy generated by increased shale oil production appear modest at best.

**State and Local Effects**

Even in the absence of large aggregate effects on U.S. economic growth, there are important effects on the economy at the state and local level in those areas where shale oil plays are located (see, e.g., Hunt and Keniston 2014). The employment effect of increased shale oil production has been of particular interest to policymakers. These local employment gains are not always as large as the public debate would suggest, however. In one example, industry and government estimates of new jobs created by shale drilling differed by a factor of 12.\(^5\)

Apart from the effect on employment, states containing shale oil plays also benefit from substantial increases in tax revenues. In addition, there are more subtle spillovers from the shale oil boom. For example, someone living outside of Texas, Oklahoma, New Mexico, Colorado, North Dakota or Montana can profit from shale oil by owning stocks of the refining companies that are able to buy crude oil at discounted prices, but sell gasoline at undiscounted prices. Another way to partake in the boom would be through private ownership of mineral rights. Fitzgerald and Rucker (2014) estimate that as of 2012 gross royalties to private owners from oil and natural gas production combined were $22 billion per year. These royalties are paid to U.S. citizens residing in every U.S. state. It has been suggested that perhaps 3% of the U.S. population are recipients of such royalties, although the distribution is unclear.

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\(^5\) A detailed review of common errors in measuring the employment effects of shale drilling can be found in Mauro et al. (2013).
Does the Shale Oil Boom Stimulate the U.S. Economy by Lowering the Global Price of Oil?

Notwithstanding these qualifications, the aggregate effects on the U.S. economy of a drop in the WTI price relative to the Brent price would appear negligible. What then about the impact of the decline in the Brent price that is due to the shale oil revolution? One might expect this price decline to stimulate consumers’ discretionary spending to the point of causing a strong expansion of U.S. economic activity. However, a quick back-of-the-envelope calculation suggests that such an outcome is unlikely. Crude oil accounts for about half the cost of gasoline (see Hamilton 2009). If we attribute a $10 cumulative drop in the Brent price to the shale oil revolution – which is equivalent to a 9% cumulative decline in the Brent price – the expected reduction in the U.S. gasoline price would be 4.5%. Given a 3.5% share of fuel expenditures in total expenditures, this 4.5% reduction would yield a 0.116% increase in discretionary spending by U.S. consumers, which, in turn, has to be weighted by the share of consumption in U.S. output, implying a one-time increase in U.S. real output of only about 0.1%. Thus, it seems fair to conclude that the U.S. shale oil boom is not likely to be a game changer for the U.S. economy.

Moreover, a reduction in global oil prices favors all oil importers, not just the United States, thus providing no incentive for a return of U.S. manufacturing jobs from abroad. This observation reinforces our earlier conclusion that the shale oil boom will not trigger a revival of the U.S. manufacturing sector.

WHAT ARE THE PROSPECTS FOR SHALE OIL PRODUCTION OUTSIDE THE UNITED STATES?

According to the U.S. Energy Information Administration, as of 2014 there were many countries with substantial technically recoverable shale oil resources with the United States ranking only second in the world after Russia, but ahead of China, Argentina, Libya and Australia. No EU
member country is included in the top 10 (see EIA 2015b). At the same time, as of 2014, commercial shale oil production took place in only two countries besides the United States: Argentina, with a volume of 0.02 mbd, and Canada, with a volume of 0.4 mbd, which is dwarfed by the almost 4 mbd of commercial production in the United States (see EIA 2015b).

There are many reasons why shale oil production has been primarily a U.S. phenomenon thus far. One likely reason is that shale oil production is politically easier to defend in regions of low population density such as North Dakota or parts of Texas than in central Europe, given the risk of increased seismic activity and the risk of ground water contamination due to improper handling, especially in the absence of effective regulation. Recent evidence suggests that increases in seismic activity are not linked to fracking itself, but to the disposal wells used to store the waste water left over after a fracking job. Of course, this fact does not alleviate the underlying safety concern or address the resulting losses in property values. Other key differences between the United States and other potential shale oil producers include the availability of drilling rigs and support services in the United States, the fact that mineral rights are more easily acquired in the United States, and the fact that U.S. firms have easy access to credit markets to finance capital-intensive shale oil projects.

Shale oil production in China, in contrast, has been hampered by geological and topological challenges, by China’s comparative lack of experience in producing shale oil, and even by water shortages. Although one would expect China to be able to overcome these technological and practical challenges, it may take many years for shale oil production in China to become commercially viable. Russia faces similar technological challenges in developing its shale oil resources. Moreover, the sanctions imposed after the invasion of the Ukraine have impeded Russia’s access to foreign expertise and global capital markets, making it unlikely that
these resources will be developed anytime soon. In short, there is little reason to expect the shale oil revolution to spread to other countries in the near future.

CONCLUDING REMARKS

This article has examined the effects of the shale oil boom on U.S. oil and gasoline prices. I have emphasized that these effects cannot be understood without taking into account the institutional features of crude oil and refining markets. I have discussed how the U.S. oil export ban in conjunction with infrastructure bottlenecks in the U.S. refining industry and in crude oil transportation lowered the U.S. price of crude oil relative to global price benchmarks after 2010, as arbitrage across these markets broke down. I have shown that U.S. gasoline consumers did not benefit directly from the availability of lower-cost crude oil in the United States. Instead much of the surplus created by the shale oil boom accrued to U.S. refiners. I have also argued that the indirect effect of increased U.S. shale oil production on the global price of oil is likely to have been near $10 per barrel. This view has been corroborated more recently in Kilian (2016) using a formal quantitative model. Finally, I have documented that endogenous market responses to the glut of shale oil in the United States over time substantially reduced the difference between U.S. and global oil prices, even before the U.S. oil export ban was lifted in early 2016. Since the lifting of the export ban in early 2016, the Brent-WTI price spread has shrunk to about 1$ per barrel, with the remaining spread presumably reflecting bottlenecks in shipping domestically produced crude oil.

The issue that has perhaps attracted the most attention from the general public is what the implications of the shale oil boom are for the U.S. economy. The rapid expansion of U.S. shale oil production after 2008 initially raised hopes that the United States would become independent of oil imports, that there would be a rebirth of U.S. manufacturing, and that net oil exports would
alleviate the perennial U.S. current account deficit. None of these visions holds up to closer
scrutiny. My analysis suggests that the shale oil boom will not make the United States
independent of global oil markets. It also demonstrates that the shale oil boom is not likely to
create a resurgence in the U.S. manufacturing sector or to provide a major economic stimulus.
Nor is there evidence that the shale oil boom will enable the United States to finance its current
account deficit, notwithstanding the substantial reduction in the petroleum trade deficit since
2005.

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Figure 1: The World’s Largest Oil Producers, 1973-2014

Source: All data are from the EIA’s *Monthly Energy Review*.

Notes: Production data for the former Soviet Union have been excluded to maintain consistency over time and because the Soviet Union was not a major participant in the global oil market. Production data are for crude oil and lease condensate, but exclude natural gas plant liquids. Because natural gas liquids tend to be used as feedstocks for the petrochemical industry rather than for producing fuel, they are excluded from our analysis of the crude oil and gasoline markets. It should be noted, however, that some natural gas liquids can be used in gasoline blending and as feedstocks in gasoline production.
Figure 2: EIA Estimates of U.S. Shale Oil Production

Source: Official EIA estimates derived from state administrative data collected by DrillingInfo Inc. as reported in Sieminski (2014).
Notes: CA=California, CO=Colorado, LA=Louisiana, MT=Montana, ND=North Dakota, NM=New Mexico, OH=Ohio, OK=Oklahoma, PA=Pennsylvania, TX=Texas, WV=West Virginia, WY=Wyoming
Figure 3: 2014 EIA Outlook for U.S. Crude Oil Production

U.S. crude oil production
million barrels per day

History 2012 Projections

U.S. maximum production level of 9.6 million barrels per day in 1970

Tight oil
Lower 48 offshore
Alaska
Other lower 48 onshore

Figure 4: Conventional Crude Oil Benchmarks

Source: U.S. Energy Information Administration.

Notes: MARS refers to an offshore drilling site in the Gulf of Mexico. WTI = West Texas Intermediate. LLS = Louisiana Light Sweet. FSU = Former Soviet Union. UAE = United Arab Emirates.
Figure 5: Monthly Spot Price of Crude Oil, January 2008- May 2015

Source: Based on EIA data.

Notes: LLS=Louisiana Light Sweet (first purchase price), WTI=West Texas Intermediate.
Figure 6: U.S. Net Petroleum Imports, 1973-2014

Source: All data are from the EIA’s Monthly Energy Review.

Notes: Petroleum is defined to include both crude oil and refined products.