The Fracking Boom, U.S. Oil Export Ban and Refinery Operations: Evidence from Refinery Microdata

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Preliminary and incomplete – Comments welcome

1 Overview

Since 2008, U.S. oil production has increased by almost 80 percent, from 1.8 billion barrels in 2008 to 3.2 billion barrels in 2014. This resurgence is due entirely to the emergence of hydraulic fracturing, which opened up previously unrecoverable reserves trapped in shale formations. While the boom in domestic production has been remarkable, two impediments, one regulatory and one physical, have limited the market for this new crude oil: the US oil export ban and the constrained nature the nation's crude oil transportation infrastructure. These limitations, combined with heterogeneity in production capabilities across refineries and the relatively concentrated nature of the industry suggest that the realized benefits of fracking may be less than optimal. This research aims to understand who benefited from the fracking boom in order to estimate the benefits of alleviating these allocative distortions.

In the name of energy security, the United States prohibits the export of the vast majority of domestically produced crude oils.[1] While these measures have been in place since the 1970's, import and production patterns have been such that domestic crude prices moved in lockstep with foreign prices for most of this period. However, the rapid increase in domestic drilling has caused US prices to diverge from global prices. Figure 1 graphs the West Texas Intermediate spot price and the Brent spot price, which are the benchmark crude prices for the United States and Europe, along with the spread between the two spot prices. From 2000 to 2010, the WTI spot price was only $1.41 per barrel more expensive on average. Beginning with tight oil boom in 2011, the WTI spot price diverged from its historical position relative to Brent crude, averaging $12 per barrel less expensive.

[*]Both authors declare they have no interests, financial or otherwise, that relate to the research describe in this paper, nor do they have any current ties, directly or indirectly to the energy industry.

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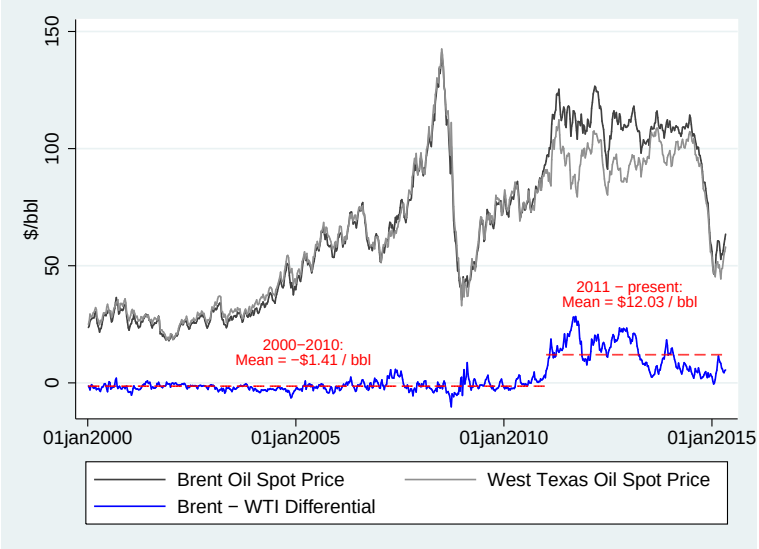
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[1]A handful of exceptions are allowed: (1) export of crude to U.S. territories, (2) export of North Shore crude, (3) export of California heavy oil, amongst others.

The extent of this divergence from global prices has varied considerably within the United States. One feature of the fracking boom is it's highly uneven geographic nature. In locations with oil-bearing shale deposits, oil production has increased tremendously. In the past five years, oil production in North Dakota rose 400 percent due from fracking the Bakken shale play. The state now accounts for approximately 15 percent of U.S. oil production. Production increased almost three-fold in Texas (from 400 million barrels annually in 2009 to 1.15 billion in 2015) and a similar fraction in Colorado (from 30 million barrels to 86 million barrels). In Oklahoma and New Mexico, production nearly doubled over the five years to 128 million barrels and 121 million barrels in 2014, respectively. In contrast, production continued to decline in other traditional oil deposits.[2]

Crude oil transportation infrastructure has not kept up with this dramatic shift in domestic production, limiting the ability of oil producers to move product to locations with greater refining capacity. In Figure 2, we plot the average acquisition price for crude oil consumed at refineries by Petroleum Administration Defense District (PADD).[3]. Prior to 2010, crude acquisition prices in all five regions are reasonably close to the Brent spot price. After 2011, though, refinery acquisition costs in PADDs 2 (Midwest) and 4 (Rocky Mountain) diverge the most, consistent with production of crude exceeding refinery and transportation capacity in these PADDs. As further evidence, Figure 3 plots monthly exports of crude oil from the PADD 2 to the other four PADDs. By 2014, PADD2 exported approximately 300 million barrels per year to Gulf Coast refineries.

Figure 1: Crude Oil Spot Prices ($/bbl)



Once "exported" to PADD 2, crude oil from the Bakken and other oil-bearing shale deposits are refined into finished products. The export ban places no constraints on the export of refined

[2]Production from the Alaska and federal offshore deposits fell approximately 20 percent over same period.

[3]Petroleum Administration Defense Districts (PADDs), are a commonly used geographic aggregation for the industry dating back to World War II. The regions correspond to: (1) East Coast, (2) Midwest, (2) South, (4) Rockies, and (5) West Coast

Figure 2: Average Refinery Crude Price by PADD

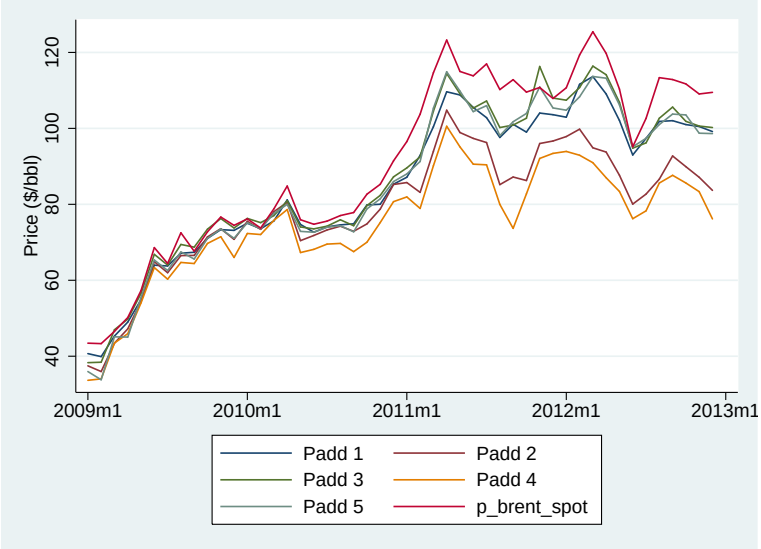
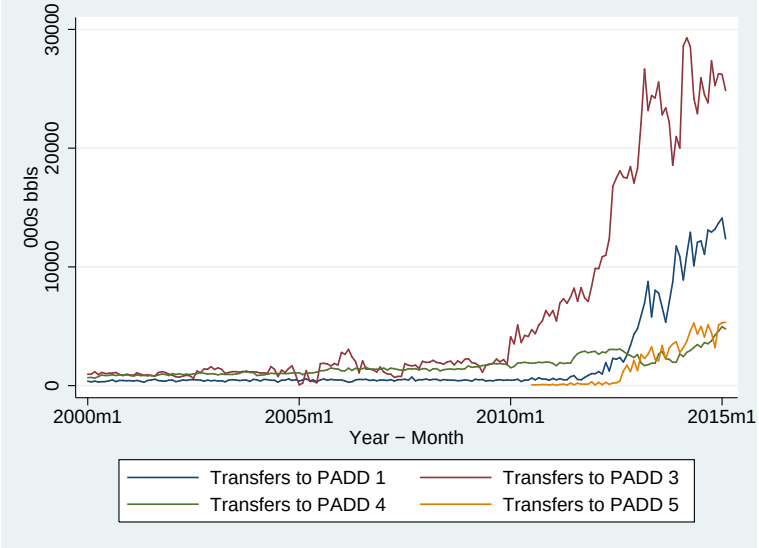
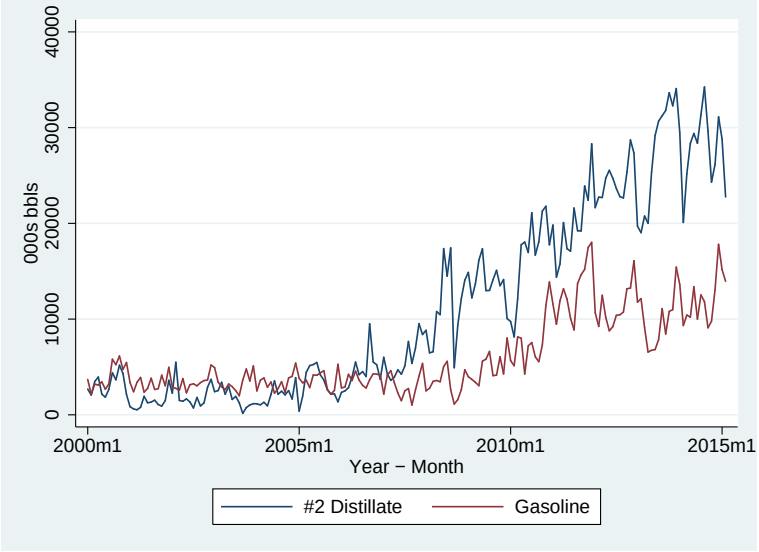


Figure 3: Crude Oil Shipments from PADD 2



products - consequently, many of the these finished products are exported internationally. Figure 4 plots monthly diesel (#2 Distillate) and gasoline exports from the Gulf Coast. The substantial increase in exports concurrent with the drop in domestic crude prices undermines the common claim that the crude oil export ban benefits drivers in the United States.

Figure 4: PADD 3 Exports of Distillate and Gasoline



2 Research Agenda

Motivated by that background, we propose to examine three questions:

1. How has the shale oil boom affected refinery operations?
2. Are the benefits of shale oil equally captured by all refiners or do some refiners benefit disproportionately?
3. To what extent does the oil export ban transfer rents from oil producers to oil refiners who are able to refine below market price oil and then export the refined product?

The most closely related to work to that proposed here is Borenstein and Kellogg (2014), which focuses on the pass-through of oil prices to aggregate product prices in the Midwest during the fracking boom. The paper finds little evidence that lower oil prices in PADD 2 translated into lower product prices and interprets the results as evidence that Gulf Coast refineries supply the marginal gallon of fuel in the Midwest. The authors further concludes that refiners on average capture the majority of the benefits of the glut of tight oil. In addition, a larger literature studies pass-through of input costs to retail fuel prices, focusing on asymmetric pass-through (see, e.g., Bacon (1991), Borenstein et al. (1997),Bachmeier and Griffin (2003)) and pass-through of fuel taxes (see, e.g., Marion and Muehlegger (2011)).

Relative to prior work related to pass-through and motor fuels that relies on geographically aggregated prices, we propose to use a novel dataset that allows us to examine responses at the refinery-level. Our data consist of the universe of domestic crude oil procurement, operation and sales collected by the Energy Information Administration (EIA) at the *refinery-level*. The EIA collects a number of detailed surveys on the petroleum industry in the United States. Previous studies on the subject of pass-through have relied on the publicly available aggregations of this data. Through a confidential data request, we have obtained access to the disaggregated survey responses, which allow for us to examine adjustments, costs and benefits at the refinery-level. Table 1 summarizes the data.[4]

Table 1: Summary of Data Sources

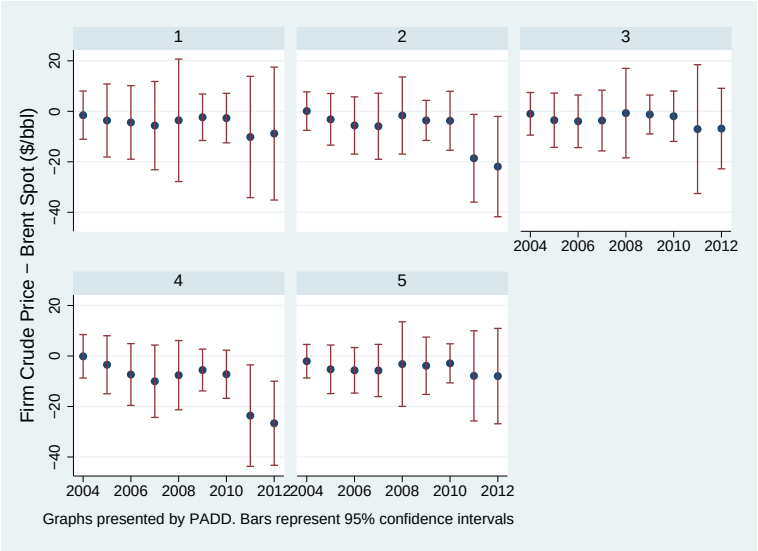
Survey	Dates	Report Level	Description
Monthly Refinery Report (EIA-810)	Monthly 1986-2012	Refinery	Crude oil input volumes and characteristics. Balance of refined product supply, including beginning stocks, receipts, inputs, production, shipments, and ending stocks.
Annual Refinery Report (EIA-820)	Annual 1986-1995 1997 1999-2012	Refinery	Annual refinery energy purchased (fuel, electricity, and steam) for consumption at the refinery. Refinery receipts of crude oil by method of transportation. Current and projected capacities all atmospheric crude oil distillation and downstream units.
Refiners' Monthly Cost Report (EIA-14)	Monthly 2002-2012	Firm - PADD	Collects data on the weighted cost of crude oil booked into refineries in each PADD.
Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report (EIA-782A)	Monthly 1986-2012	Firm - State	Price and volume data, by state, for 14 petroleum products at various retail and wholesale marketing categories. Reported by the universe of refiners and gas plant operators.
Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption (EIA-782C)	Monthly 1986-1990 1992-2012	Firm - State	Prime supplier sales volumes of selected petroleum products into the state of ultimate consumption. Reported by all refiners, gas plant operators, importers, petroleum product resellers, and petroleum product retailers that produce, import, or transport product across state boundaries.

As very preliminary evidence suggesting that refinery-level heterogeneity may be an important consideration, we calculate the average domestic crude oil acquisition price for each refiner, by PADD. Although the refinery-level data allows us to examine response along other dimensions,

[4]We currently have access to the data through 2012, but are in the process of applying for access to the same surveys through 2014.

for purposes of this proposal, we examine this single measure as an illustration of the value of refinery-level data. Figure 5 summarizes the distribution of domestic crude oil acquisition price over time within each PADD. We calculate crude oil acquisition costs relative to the Brent spot price - thus, declining values correspond to domestic acquisition costs at a greater discount relative to the the Bren crude spot price. Consistent with Figure 2, in the post-fracking era (2011 - present) refiners acquired domestic crude at a greater discount relative to Brent in 2011 and 2012 in all five PADDs. Acquisition costs were especially low in the Midwest (PADD 2) and Rocky Mountain states (PADD 4) where oil-bearing shale deposits increased oil production to the greatest degree and infrastructure to transport oil out of the PADDs was the most limited.

Figure 5: Average Refinery Crude Price by PADD



Importantly, average acquisition costs obscure within-PADD heterogeneity. In the pre-fracking period, domestic acquisition costs vary significantly across refiners within each PADD. In 2011 and 2012, the variation in acquisition costs increases, suggesting that lower prices of domestic crude were captured disproportionately by a subset of refiners.

We examine whether the subset of refiners capture the full benefit of lower oil prices by estimating pass-through of refinery-level acquisition costs to the prices at which the refiner sells finished products. At the monthly-level, we regress the average price of refined products sold by a refiner on own-crude acquisition costs and sets of fixed effects. The prices of both crude oil and finished products are reported on a common basis ($/gallon). Table 2 presents the results. Controls common across all specifications are time FE, PADD FE and product FE (e.g., gasoline or diesel). In columns (2) and (5) we add firm FE and in columns (3) and (6) we add firm*padd FE.

Similar to Borenstein and Kellogg (2014), we do not find strong evidence lower oil prices manifest in lower prices of refined products. Although some of our point estimates are significant, the point estimates are all close to zero, suggesting that within a PADD, firms receive relatively similar prices for refined product and that infrastructure is sufficient to arbitrage away much of within-PADD

Table 2: Pass-through of oil prices

	(1)	(2)	(3)	(4)	(5)	(6)
Crude Price	0.0443	0.0489	0.00371			
	(0.0330)	(0.0428)	(0.0123)			
Padd 1 * Crude Price				0.0549**	0.0664*	0.0308*
				(0.0258)	(0.0377)	(0.0166)
Padd 2 * Crude Price				0.0469	0.0669	0.0196
				(0.0297)	(0.0468)	(0.0162)
Padd 3 * Crude Price				0.0487*	0.0619	0.0236*
				(0.0277)	(0.0385)	(0.0140)
Padd 4 * Crude Price				0.0656*	0.0792*	0.0292
				(0.0330)	(0.0467)	(0.0182)
Padd 5 * Crude Price				0.0393	0.0386	-0.0121
				(0.0455)	(0.0532)	(0.0123)
R2	0.957	0.962	0.965	0.957	0.962	0.965
Firm FE	N	Y	N	N	Y	N
Firm-Padd FE	N	N	Y	N	N	Y

Standard errors clustered at the firm level in parentheses.
Dependent variable in all regressions is the average price of gasoline or diesel
All models contain product, padd, and time dummies

variation in input prices. Combined with the previous results, this suggests that refiners capture the majority of the benefit of lower oil prices, but that the benefits are unevenly distributed. Some refiners capture a disproportionate share of the benefits of lower oil prices.

Although we have not yet collected the data, a second margin that we will examine are exports of refined products. To examine this, we propose to use data on refinery operation with publicly-available trade data provided by the U.S. census bureau that reports monthly exports at a highly disaggregated geographic and product level.

3 Conclusion

The advent of fracking has lead to a remarkable increase in domestic crude oil production. At the same time, the presence of regulatory and infrastructure constraints, combined with private constraints and incentives among refiners suggests that the social benefits of this boom may not have been fully realized. We provide graphical evidence that crude oil prices have diverged both internationally and domestically as a result of these constraints, and preliminary evidence consistent with the rents from this divergence being captured by refineries rather than being passed on to domestic consumers. Going forward, we plan to use detailed micro data on refinery operations, firm prices, and regional exports to quantify the costs of these restrictions.

References

Bachmeier, Lance J and James M Griffin, "New evidence on asymmetric gasoline price responses," *Review of Economics and Statistics*, 2003, *85* (3), 772–776.

Bacon, Robert W, "Rockets and feathers: the asymmetric speed of adjustment of UK retail gasoline prices to cost changes," *Energy economics*, 1991, *13* (3), 211–218.

Borenstein, Severin, A Colin Cameron, and Richard Gilbert, "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?," *The Quarterly Journal of Economics*, 1997.

_ **and Ryan Kellogg**, "The Incidence of an Oil Glut: Who Benefits from Cheap Crude Oil in the Midwest?," *The Energy Journal*, 2014, *35* (1), 15–33.

Marion, Justin and Erich Muehlegger, "Fuel tax incidence and supply conditions," *Journal of Public Economics*, 2011, *95* (9), 1202–1212.