Economics and Externalities of Moving Crude Oil by Pipelines and Railroads: Evidence from the Bakken Formation

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Our proposed research capitalizes on the dramatic increase in oil production from the Bakken formation in North Dakota between 2005 and 2015 to examine two of the "charge" questions in the RFP: i) What are the economic drivers of the shift to crude-by-rail? ii) How do the externalities of pipeline vs. rail transportation compare?

The proposed research will consist of three areas. First, we will explore how infrastructure, specifically railroad lines and pipelines, have responded to the Bakken oil supply shock. Next, we will test whether the observed increase in oil extraction has crowded out other goods typically shipped by rail. We plan to test for these inter-market externalities focusing at first on flows of coal shipped to power plants. Data permitting, the research will encompass other commodities such as grains for food and silage. Third, the analysis will quantify the environmental externalities associated with different means of transporting oil (rail and pipeline) with a particular focus on air pollution emissions. This area will track emissions from extant pipeline and rail routes through normal operations and low-frequency spills. In addition to monetization, this area will emphasize the spatial distribution of external costs from the two different transportation modes.

This research will also assemble data that is likely to provide useful for other research in this area. These include county-level data on energy fuel infrastructure paths including both oil pipelines and railways; county-level production data from the Bakken formation in North Dakota; shipments (in quantities and value) of various commodities via rail in areas potentially affected by oil-by-rail; air pollution emissions from pump stations and locomotives; the frequency, location, and magnitude of oil spills.

Background.

The Bakken field produced modest amounts of oil beginning in the 1950s, but large-scale production did not begin until 2007. As a result of rapid increases in production (Figure 1), North Dakota is currently the third largest producer of oil after Texas and the federal offshore region (PADD3). [1] The EIA notes "Since then [2007], advances in drilling methods and technology, a better understanding of the geology of the Bakken, higher crude oil prices, and the formation's large size and number of wells all have contributed to higher production and to the potential for continued future growth."[2]

We focus on Bakken both because of the supply shock and because it represented 70% of crude by rail movements in 2014.[3] What are the economic drivers of the shift to crude-by-rail? According to the Energy Information Administration (EIA), "Total CBR movements in the United States and

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1 http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_m.htm

2 http://www.eia.gov/todayinenergy/detail.cfm?id=17391

3 http://www.eia.gov/todayinenergy/detail.cfm?id=20592#tabs_Slider-5

between the United States and Canada were more than 1 million barrels per day (bbl/d) in 2014, up from 55,000 bbl/d in 2010."[4] In the early years of the Bakken field, the shock appears to have been addressed through some combination of excess capacity in pipelines and rail and crowd-out or delay of lower valued goods.[5] (Figure 2) As oil production grew, constraints posed by infrastructure caused a significant divergence in prices between Bakken and West Texas Intermediate prices during some periods, particularly in early 2012 (Figure 3). The EIA notes "Pipelines are the most cost-effective way to transport crude oil in the United States, but they are expensive to build and may face regulatory hurdles. For these reasons, companies have turned to rail transport to deliver crude oil across the nation. Total takeaway capacity from the Williston Basin grew from about 678,000 bbl/d at the end of 2011 to over 1.1 million bbl/d in 2012. Takeaway capacity via rail represented most of this expansion, increasing from an estimated 265,000 bbl/d in 2011 to approximately 660,000 bbl/d in December 2012."[6] Some expansion did occur in pipelines, since pipeline movements increased significantly from PADD2 after 2008, as did pipeline capacity out of the Williston Basin. (Figures 4-5)

The movement of Bakken oil to refineries and final markets has likely had measurable consequences in three areas: energy transportation infrastructure, effects on the shipments of other goods, and environmental and other externalities. Within in each area, our analysis will adopt a comparative approach by asking: How do the consequences of pipeline vs. rail transportation compare?

Market Externalities.

In an August 8th, 2014 memorandum, the Department of Energy reports that "On the BNSF Railway, which transports one-third of Bakken production, petroleum crude carloads grew 2118% from 2009 to 2013." In response to this trend, the memo notes that: "non-oil shippers are expressing growing concerns that the timely delivery of other commodities is being impacted as railroads favor crude-by-rail movements." We intend to quantify the market externality effects of the Bakken oil supply shock on delivered prices and quantities shipped for these other commodities.

To answer these questions, we consider order-level data collected for each electricity generation plant with capacity greater than 50MW from the Energy Information Administration on the quantity of coal purchased and prices paid upon delivery.[7] We also see both the county of origin as well as the location of the power plant. Our regression framework utilizes variation in the percentage of rail capacity used for Bakken crude oil shipments crossed with distance between the origin/destination of the coal shipment and the Bakken formation to identify coal price and quantity changes due to the Bakken supply shock.

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4 http://www.eia.gov/todayinenergy/detail.cfm?id=20592#tabs_Slider-5

5 http://www.nytimes.com/2014/10/09/us/as-trains-move-oil-bonanza-delays-mount-for-other-goods-and-passengers.html?_r=0http://www.nytimes.com/2014/08/26/us/grain-piles-up-waiting-for-a-ride-as-trains-move-north-dakota-oil.html

6 http://www.eia.gov/todayinenergy/detail.cfm?id=10431

7 The data are collected via Form 423 (prior to 2008) and Form 923 (2008-2012).

We note that the negative market externalities on agricultural commodities are also of primary concern to the Department of Energy. The best source of data to analyze these other commodities would be the Carload Waybill Sample collected by the Surface Transportation Board. These data are confidential. Our analysis would benefit greatly from access to these data.

Environmental and Security Externalities.

Our analysis of environmental externalities emphasizes the spatial patterns and distribution of risk. We will quantify the air pollution externalities associated with different means of transporting oil (rail and pipeline). Importantly, we intend to track emissions from extant pipeline and rail routes through normal operations and low-frequency spills. This area will emphasize the spatial distribution of external costs from the two different transportation modes. A point of focus will be the concentration or dispersion of the risk. Transporting oil by pipeline concentrates the risk, while shipping the oil via railroad generally diffuses the risk if the oil takes multiple paths to the same destination. Further, locomotives (the primary source of rail emissions) move, while pump stations (the primary source of pipeline emissions) are stationary. Policymakers and the general public likely care about concentration and dispersion of risk, since much of the opposition arises not from the relative risk, but from the concentration of risk.

Air Pollution Externalities.

We will estimate and compare the consequences air pollution from pipelines and rail transportation capitalizing on two data sources: the location of pipeline and rail networks, and emission rates for each transportation mode. More specifically, the investigators will gather data on the location of pipeline networks used to transport crude oil across the United States. (Figure 6 shows a map of oil pipelines.) In addition, the investigators have data on the location of rail networks. (Figure 7 shows a map of rail networks by ownership.) Locational information will be transferred from map to database at the county level of resolution.

The next source of data involves emission rates. These data are provided by the U.S. Environmental Protection Agency's National Emission Inventory (NEI). The USEPA publishes the NEI every three years and the most recent year available is 2011. Pollutants encompassed will include: volatile organic compounds (VOCs), sulfur dioxide (SO_2), nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$), and ammonia (NH_3). The NEI data for locomotives and pipelines is provided at the county level of detail. For pipelines, the USEPA NEI reports emissions from: pipeline leaks, venting, pump station operations, and pump station leaks. For locomotives, emissions encompassed are due to combustion of fuel in transit.

To model risks associated with air pollution emissions, the proposed research will use the AP2 model which is an established integrated assessment model (IAM), (Muller, 2011; 2014a, 2014b; Muller and Mendelsohn, 2009; Muller, Mendelsohn, Nordhaus, 2011; NAS NRC, 2010). The AP2 model connects emissions of each of the pollutants listed above to county-level concentrations, human exposure, health effects, and monetary damage. Because the model is calibrated to the county level, it is able to detect differences in exposure risk due to the specific path of rail networks relative to pipeline networks. This will be a critical factor in determining the relative risk of the two energy transportation modes.

Oil Spills.

We compare oil spills per barrel mile from pipelines and rail transportation. Data from the American Petroleum Institute suggests that the barrels spilled per billion ton miles during 2002-2007 was significantly lower for rail than for pipelines.[8] The quality of this data is difficult to evaluate, because the CRS reports (p. 10) that "CRS is not aware of any database that tracks oil spills from rail transport." In contrast, the Pipeline and Hazardous Materials Safety Administration (PHMSA) collects detailed data on pipeline spills. Between 2002 and 2012, it had 1,692 reported incidents, of which the vast majority, 1,340, involved 50 barrels or less. Only 70 involved more than 1,000 barrels. Our analysis will use these and more recent PHMSA data to examine the effect of the Bakken supply shock on the incidence and severity of pipeline spills, particularly spills that are plausibly related to Bakken.[9] Such spills would include spills in North Dakota and in PADD2. The CRS report lists six major oil by rail derailments that occurred in Canada or the United States between July 2013 and January 2014. Three of this occurred in the United States, including derailments in Aliceville, AL; Casselton, ND; and Philadelphia, PA. These and other more recent examples will be analyzed, to better understand the relative risks of moving oil from Bakken by rail and by pipeline.

National Security.

Both railroads and pipelines are both potentially vulnerable to terrorist attacks. According to a 2010 Transportation Security Administration report: "Since September 11, 2001, numerous Federal warnings have been issued specifically mentioning pipelines as terrorist targets. Many pipelines carry volatile and flammable materials that have the potential to cause serious injury to the public and the environment. The pipeline system is uniquely vulnerable to terrorist attacks because of the products transported, and because pipeline networks are widely dispersed across both remote and urban portions of the country. A pipeline facility could be vandalized or attacked with explosive devices, resulting in flow disruption or the release of its contents."[10] The most recent U.S. federal threat assessment concludes "with high confidence that the terrorist threat to the U.S. pipeline industry is low."[11] A recent congressional hearing examined terrorist threats to crude by rail.[12]

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8 Frittelli, John, et al. "US rail transportation of crude oil: Background and issues for congress." (2014). https://fas.org/sgp/crs/misc/R43390.pdf

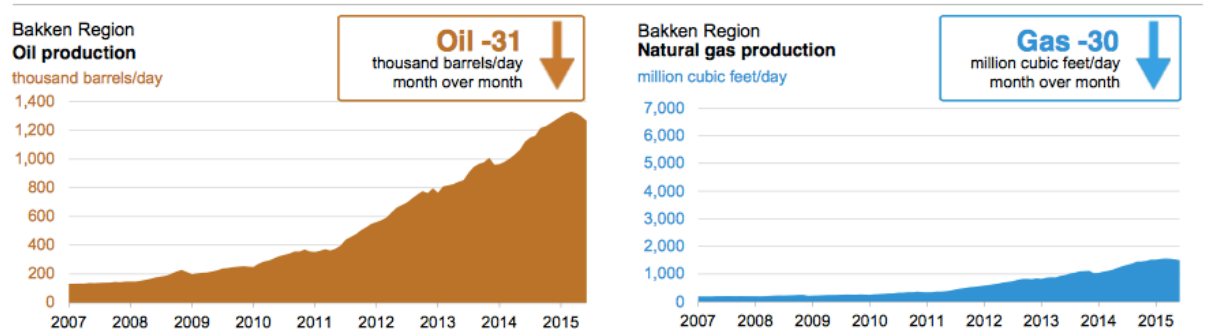
9 http://keystonepipeline-xl.state.gov/documents/organization/205578.pdf

10 https://www.tsa.gov/sites/default/files/assets/pdf/Intermodal/pipeline_sec_incident_recvr_protocol_plan.pdf

11 http://fpc.state.gov/documents/organization/187393.pdf

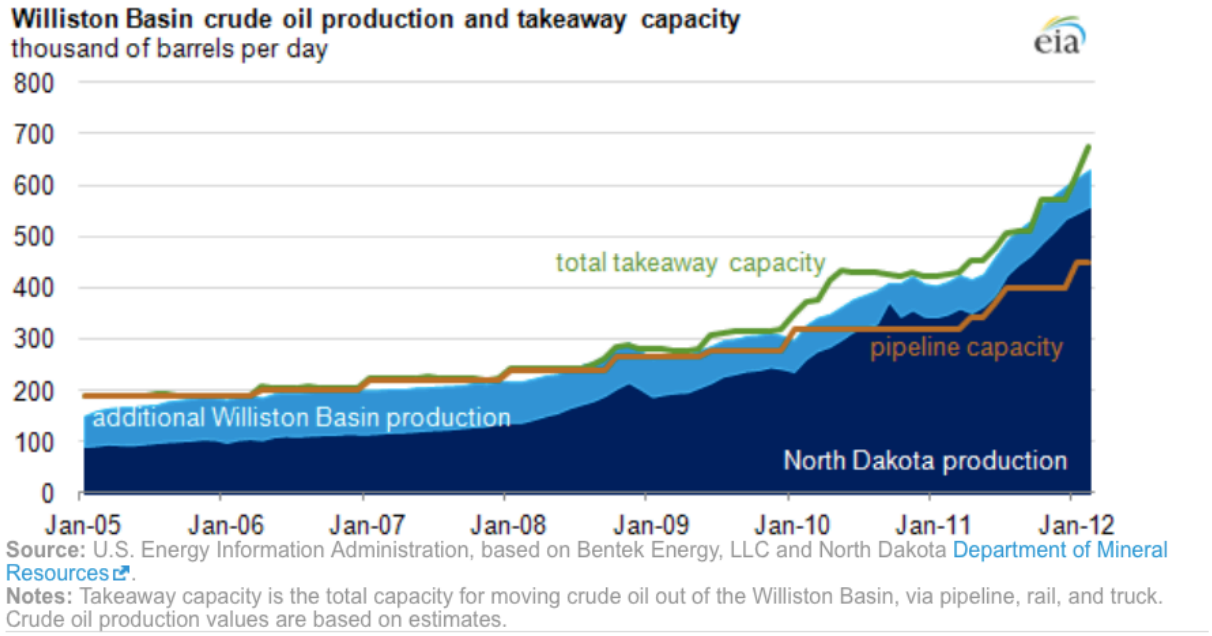
12 http://seanmaloney.house.gov/media-center/press-releases/maloney-grills-executives-on-potential-terrorist-threats-to-rail-lines

Figure 1: Oil and Gas Production in the Bakken Region



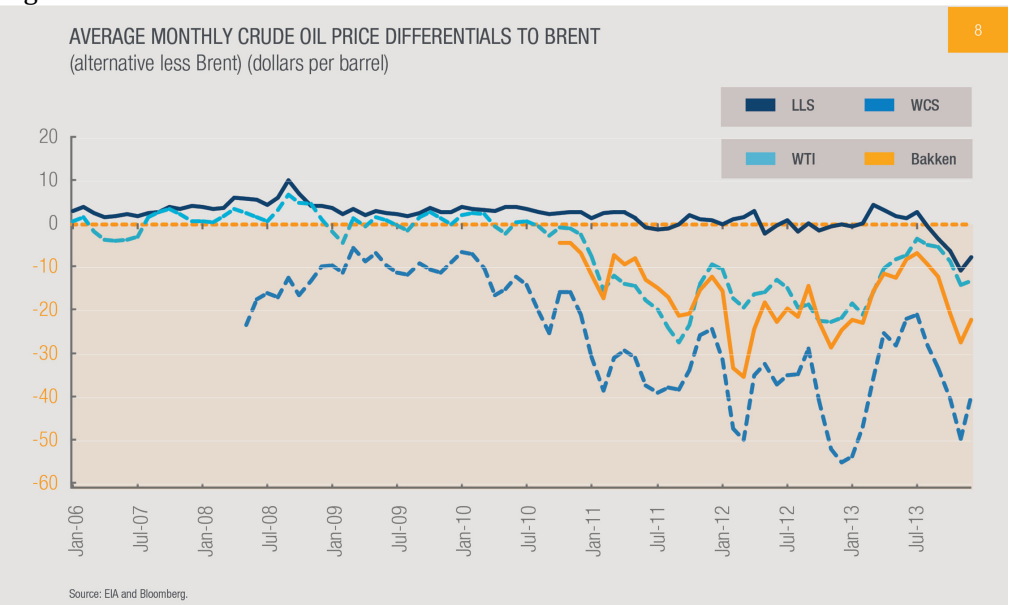
Source: http://www.eia.gov/petroleum/drilling/pdf/bakken.pdf

Figure 2: Pipeline and Rail Takeaway Capacity



Source: http://www.eia.gov/todayinenergy/detail.cfm?id=5870

Figure 3: Bakken Crude Oil Price Differentials



Source/Notes: Brent is European; WTI is West Texas, Bakken is Bakken, WCS is Western Canadian Sands and LLS is Louisiana Light Sweet
http://www.api.org/~/media/files/oil-and-natural-gas/crude-oil-product-markets/crude-oil-primer/understanding-crude-oil-and-product-markets-primer-high.pdf

Figure 4: Pipeline Movement of Oil

Movements by Pipeline between PAD Districts

Product: Crude Oil and Petroleum Products **Period-Unit:** Monthly-Thousand Barrels

Download Series History | Definitions, Sources & Notes

Show Data By: Product / Areas	Graph / Clear	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	View History
From PADD 1 to								
PADD 2	☐	11,352	12,271	12,038	12,297	11,789	9,894	1986-2015
PADD 3	☐	159	389	74	178	41	20	1986-2015
From PADD 2 to								
PADD 1	☐	1,769	2,062	1,938	2,544	2,228	2,074	1986-2015
PADD 3	☐	28,246	32,285	29,010	30,259	32,641	29,794	1986-2015
PADD 4	☐	7,776	7,858	8,359	8,456	8,780	8,469	1986-2015
From PADD 3 to								
PADD 1	☐	80,996	81,670	79,741	80,080	80,843	77,021	1986-2015
PADD 2	☐	48,446	42,318	45,889	46,480	41,604	39,203	1986-2015
PADD 4	☐	0	0	0	0	0	0	1986-2015
PADD 5	☐	4,739	4,535	4,960	4,823	4,697	4,216	1986-2015
From PADD 4 to								
PADD 2	☐	12,617	12,949	12,386	13,755	14,229	13,039	1986-2015
PADD 3	☐	7,177	7,010	6,797	6,068	5,671	5,587	1986-2015
PADD 5	☐	1,380	1,297	1,546	1,962	2,037	1,661	1986-2015
From PADD 5 to								
PADD 3	☐	0	0	0	0	0	0	1986-2015
PADD 4	☐	0	0	0	0	0	0	2004-2015

- = No Data Reported; -- = Not Applicable; **NA** = Not Available; **W** = Withheld to avoid disclosure of individual company data.

Notes: RBOB with Ether and RBOB with Alcohol are discontinued as of the January 2010 reporting period. See Definitions, Sources, and Notes link above for more information on this table.

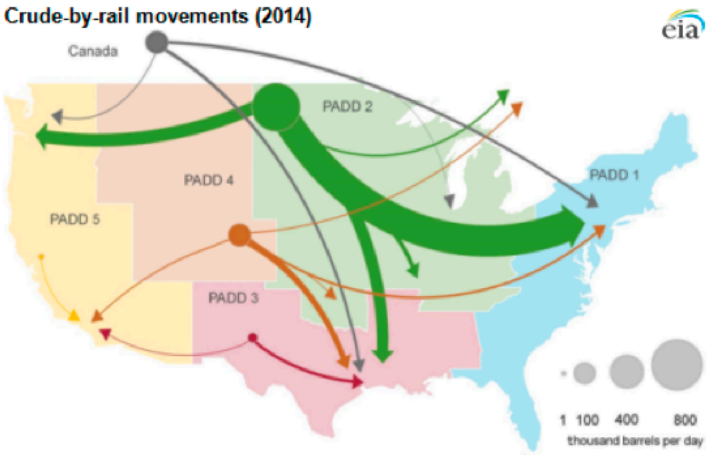
Release Date: 4/29/2015
Next Release Date: Last Week of May 2015

Source: http://www.api.org/~/media/files/oil-and-natural-gas/crude-oil-product-markets/crude-oil-primer/understanding-crude-oil-and-product-markets-primer-high.pdf

Figure 5: Crude by Rail Movement of Oil

MARCH 31, 2015

New EIA monthly data track crude oil movements by rail



Source: U.S. Energy Information Administration based on data from the Surface Transportation Board and other information
Note: Crude-by-rail movements greater than 1,000 barrels per day are represented on the map; short-distance movements between rail yards within a region are excluded. PADD denotes Petroleum Administration for Defense District.

Source: http://www.eia.gov/todayinenergy/detail.cfm?id=20592#tabs_Slider-5

Figure 6:

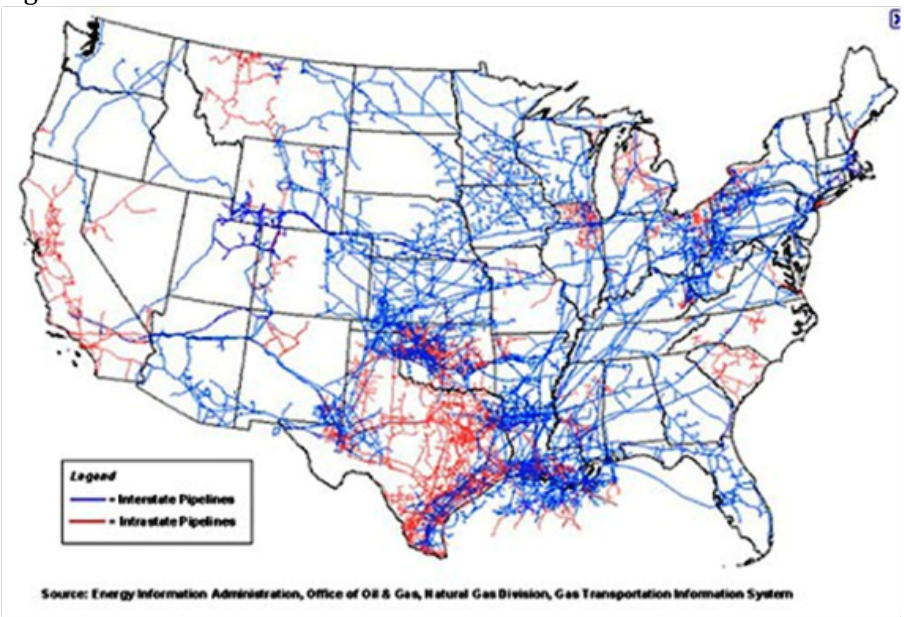


Figure 7.

