Prices, Quantities, and Gas Capture Infrastructure: Reducing Flaring in North Dakota

Research Track: Energy Infrastructure and Policy

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Motivation:

Oil wells often produce natural gas liquid co-products in addition to crude oil. In the absence of onsite infrastructure to process, use, or capture and transport these lighter hydrocarbon products, firms typically resort to flaring them. Worldwide, flaring results in 300 million tons of CO_2 emissions annually, which is equivalent to the emissions of around 50 million cars (World Bank, 2015). In addition to damages from unpriced greenhouse gas emissions, flaring produces a range of other pollutants that may have substantive health impacts on both oil field workers and nearby populations.[i] In response to these concerns, several countries have enacted a range of policies aimed at decreasing flaring, and the World Bank has launched a 'Zero Routine Flaring' initiative seeking to eliminate routine oil well flaring by 2030.

Flaring has increased substantially in the United States with the advent of unconventional oil production, or fracking. The problem is particularly acute in the North Dakota Bakken and Three Forks shale formations where flaring in the oil patch is so widespread that it is visible from space at night. Oil production in the Bakken has increased tremendously in the past decade from 18,500 oil barrels per day (bpd) in 2007 to over 700,000 bpd in 2013. While North Dakota shale formations are valued primarily for their significant oil reserves, wells in the state also produce significant volumes of natural gas liquids (NGLs). In addition to 'dry' natural gas, NGLs include a range of other light hydrocarbon products such as propane, butane, and isobutene that are much more valuable than natural gas alone. For example, while the Henry Hub price of natural gas in 2015 was $2-$3/MMBtu, propane prices were over $5/MMBtu (EIA, 2015). The commercial value of NGLs flared in May 2013 was estimated to be $3.6 million. Compared to an estimated $73 million value of oil produced in the same month, however, their private value remains low relative to oil (Ceres, 2013).

In July 2014, the North Dakota Industrial Commission (NDIC) passed provisions aimed at curbing flaring in the state. The regulations specify key gas capture goals, with an ultimate objective of capturing 90% of produced NGLs by 2020.[ii] With aggregate flaring above 30% for all wells in 2013, the new flaring regulations are binding for many producers, and as a result have been the subject of several lawsuits from industry stakeholders. 2015 is the first full year that the policy has been in effect, and the NDIC specified a 77% gas capture goal for all new wells in 2015. Producers must meet these targets within 90 days of first production, otherwise the NDIC may order the firm to curtail oil production at the well to as low as 100 bpd until gas capture technologies are installed.

We propose to study the effects of the NDIC's flaring restrictions on the total amount of NGLs flared, as well as on the development of infrastructure to capture and process NGLs. In addition, we plan to explore potential effects of the regulation on well productivity and industry market structure. To conduct the analysis, we will take advantage of a unique, well-level production dataset that has been collected from the NDIC. The dataset reports

monthly oil production, gas production, and flaring over time.[iii] The data are comprised of nearly 10,500 horizontal wells drilled in the North Dakota since 2007. These will be combined with data on relevant well and firm characteristics, product prices, and distance of wells to natural gas processing plants to conduct our analyses.

Reducing flaring in the Bakken formation constitutes an environmental externality problem with several novel characteristics. First, natural gas byproducts of oil production have direct economic uses, and are therefore not pure economic bads. Second, firms do not necessarily have a continuous abatement technology to reduce flaring. The primary method to curb the volume of NGLs flared is to connect a well to a gathering line that transports the products to natural gas processing facilities. As a result, most firms face lumpy abatement costs involving large, upfront investments of natural gas capture and processing technologies.[iv]

Absent a regulation pricing all externalities associated with flaring, firms will install gathering lines and take abatement action at lower than socially optimal levels.[v] The classical policy prescription would be to tax firms according to the relative damages of all flared pollutants.[vi] Rather than pursuing a market-based mechanism, the NDIC has instituted a command and control, well-by-well policy. When wells do not meet strict flaring limits, firms potentially face heavy-handed curtailment orders. If firms have differential costs to reduce flaring, the regulation may impose large, differential costs on well operators, thereby reducing social welfare.

In addition to studying the effects of the NDIC's current regulations, it is also of economic interest to contrast how a market based mechanism like an effluent tax would affect flaring rates. To this end, we also plan to take advantage of historical policy variation and variation in the relative prices of natural gas and oil since 2007 to study the potential efficacy of price-based instruments in reducing flaring and spurring investments in natural gas infrastructure in North Dakota.

Empirical Approaches & Preliminary Results:

A number of features of the NDIC's flaring regulations lend themselves to an evaluation of the causal effects of the policy on well production and flaring. First, wells do not have to meet the gas capture targets until 90 days after first production of oil from the well. Thus, well operators face a discontinuous decrease in the maximum percent of NGL flaring allowed, and a discontinuous increase the probability of enforcement action, between the third and fourth months of production. This change provides an appropriate setting for a regression discontinuity research design, comparing production effects of the regulation for wells subject to the regulation just before and after the regulation binds using production time as the forcing variable.

In addition, the regulation includes exemptions for wells with certain characteristics. For example, the first well drilled in a spacing unit is exempt from flaring restrictions. To the extent that the first well in a spacing unit constitutes a proper control group, production and flaring at these wells can be compared to those that face the regulation using a differences-in-differences estimation strategy. Continued conversations with regulators at NDIC may reveal other such exemptions that could be exploited.

The discontinuous change in the probability of enforcement action after 90 days and these regulatory exemptions introduce quasi-experimental variation in the enforcement mechanism. We plan to take advantage of these opportunities to study the effects of the regulations on oil and gas production, the probability that a well connects to a gathering line to capture natural gas, and well productivity.

We will study how price-based policies would affect flaring rates in two ways. First, prior to the NDIC's latest regulations, firms were allowed to flare NGLs for one year, after which they may be subject to paying taxes and/or royalties. Subject to the regulators enforcing this provision in the NDIC rulebook, the rule may introduce a discontinuous jump in the price of flaring similar to the flaring quantity restrictions from which we can study the effects of the tax and royalty price instruments.

Second, there has been substantial variation in the relative price of oil, natural gas, and other hydrocarbons since 2008. Figure 1 plots the wholesale price of natural gas and crude oil in the United States since 2008. We plan to take advantage of changes in the relative values of NGLs and oil to study how a tax on flaring would affect production and flaring. Similar methods have been used to estimate the price elasticity of carbon abatement at US coal plants (Cullen and Mansur, 2015) and coal-to-gas fuel switching behavior at U.S. power plants (Knittel, Metaxoglou, and Trindade, 2015).[vii] These methods would allow us to estimate the price elasticity of natural gas capture technologies at shale wells, and perform a counterfactual simulations to compare a tax to the NDIC's regulations.

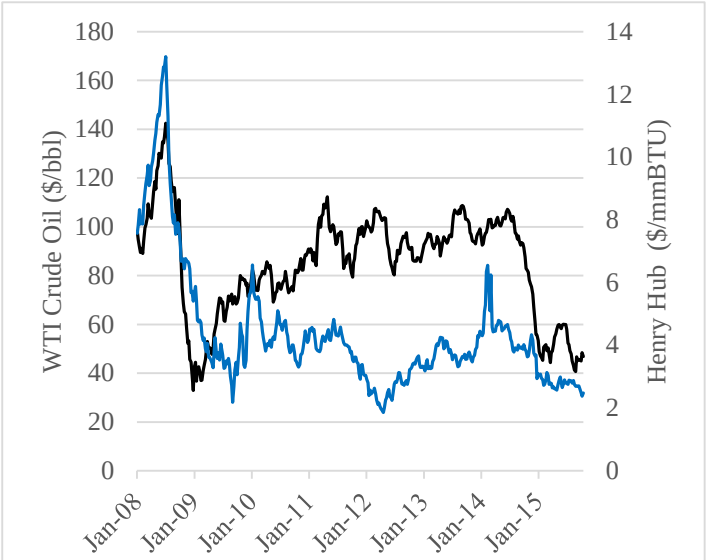


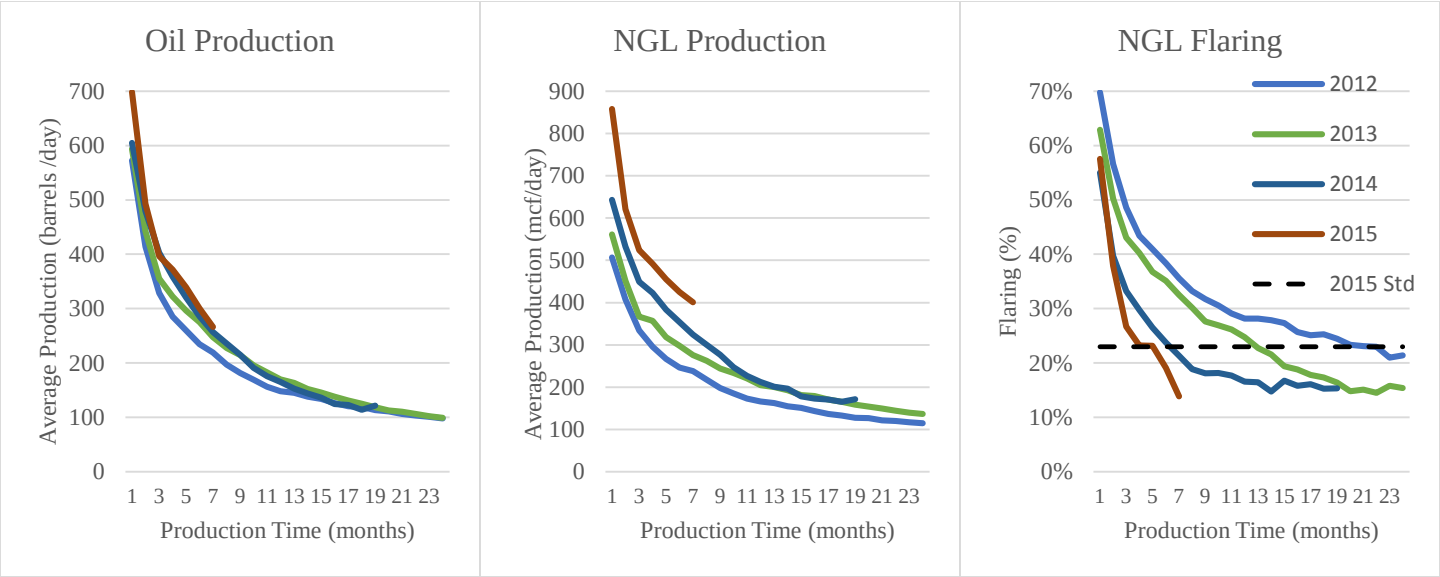
Figure 1 - WTI crude oil (black) and Henry Hub natural gas (blue) wholesale prices

All wells drilled in 2015 are subject to the new flaring restrictions, and a number of producers have been ordered to curtail oil production (NGI, 2015). Preliminary evidence suggests that the NDIC regulations have already affected well operations in 2015. Over nine hundred wells drilled in 2015 currently report their production to the NDIC. Many more wells' production statistics will soon be available, as the NDIC only publishes well statistics after a six month confidentiality period.

Figure 2 graphs the average oil and natural gas production profile as well as the average flaring rate for wells drilled in each year since 2012 over the first two years of their production lifetime. Thus, month 1 in the figures corresponds to the first month a well drilled in the year reported positive oil production. In Figure 1(c), the dashed horizontal line corresponds to the NDIC's 2015 gas capture standard. A few notable features of production in North Dakota are evident from the figures. First, oil wells drilled in North Dakota on average have very high initial production levels that decrease exponentially over the well lifetime. The profile is consistent with the 'Arps' model used by petroleum engineers to model oil well productivity (Fetkovich, 1980). Second, new wells have become more productive in producing both oil and natural gas over time, consistent with technological progress resulting from a combination of firms being more efficient at recovering oil from wells and identifying more productive plays.[viii] This appears to be particularly true for NGL production in 2015.

Flaring rates follows a similar exponential declining trajectory over the well production lifetime, and the level of flaring has decreased on average over time. Prior to 2015, initial production months were associated with high flaring that decreased smoothly and fell below 30% typically within a year of first production. The path of flared NGL decreased more rapidly between 2012 and 2014, with firms hooking up to natural gas gathering lines more rapidly in 2014 than in 2012. Flaring in 2015 shows a different path than previous years. Flaring thus far has decreased more dramatically in the first months of production, and flaring rates in months three and four are almost precisely equal to the 2015 standard at 23%, after which flaring falls below the NDIC standards. The graph suggests that while the regulations may not affect the initial level of flaring, they appear to have moved up the timing, on average, that wells are connected to gathering lines.

The flaring statistics in Figure 2(c) hide substantial variation in flaring at the well level. In the first month of production, most wells flare 100% of associated natural gas produced. By the second production month, many firms have installed gathering pipelines and sell the majority of NGLs produced; however, a substantial number



2(a) *2(b)* *2(c)*

Figure 2- Average Production Profiles and Flaring of Wells Drilled (2012-2015)

continue to flare all natural gas. Interestingly, even after the regulations should bind, a number of firms continue to flare more than 23% of produced NGLs, with a few firms continuing to flare all gases.

Contribution & Future Work:

Analyzing policy effectiveness of flaring is a novel frontier in the economics of the shale revolution. Other work has studied health and pollution impacts of fracking (Hill, 2012; Olmstead, et al., 2013), how nearby shale drilling operations are capitalized into housing values (Muelenbachs, et al., 2014), and the welfare impacts of these newly reachable shale resources (Kellogg and Wolfram, 2015). Only recently have others begun to analyze firm decision making, specifically learning, in this setting (Covert, 2015). The shale oil and gas industry has many market imperfections that make it removed from conventional economic models. Understanding how the market imperfections interact with firm behavior and alternative policy instruments is crucial for any potential future regulations of the industry.

Substantial data cleaning and collection must continue before pursuing this work further. More research into the design of the flaring policy is also necessary. For example, in the post-flaring regulation period there exist a number of wells in clear violation of the flaring policy. It will be necessary to determine why this is the case, whether it is a policy exemption or a lack of policy enforcement.

In addition to the topics discussed above, there exist a number of promising future research directions for our work. First, recent research suggests that well productivity is primarily affected by reservoir pressure (Anderson, Kellogg, and Salant, 2015). As a result, restrictions on well production may affect total recoverable reserves from wells and decrease productivity. If this is true, the NDIC's regulations may induce further welfare losses by affecting the volume of total recoverable oil from wells subject to curtailments.

Our data also includes ownership of all wells. Recent work studying the Texas oil and gas industry shows that a failure to internalize environmental risks due to bankruptcy protections shifts industry structure towards smaller firms (Boomhower, 2015). Small firms may also take advantage of the benefits of limited liability in the North Dakota shale fields. The introduction of new, stringent flaring standards may therefore act to increase capital costs for drilling new wells. If these new, larger upfront costs affect firms' entry decisions, the new standard may have the effect of pricing smaller, capital constrained firms out of the market. Alternatively, the regulations may

incentivize some firms to drill wells in areas that may be less productive in terms of NGLs, but also in terms of oil. Wells that are less productive in NGLs face a lower shadow price of the regulation than more productive wells since less NGLs need to be captured in terms of absolute quantities to meet the flaring ratio regulation. Therefore flaring regulations may lead to decreased well productivity on both intensive and extensive margins.

Research Team:

Our research team will be composed of Gabriel Lade and Ivan Rudik. Both are Assistant Professors at Iowa State University. Funds for a summer RA to support a student from the ISU PhD economics program are requested.

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[i] For example, in August 2014 the San Antonio Express News published a four-part series highlighting the rapid increase in flaring from oil production in the Eagle Ford shale play in south Texas. The article cited that emissions from flaring in the Eagle Ford resulted in more particulate emissions that the six oil refineries located in Corpus Christi, TX, and that local residents report a number of health problems due to nearby flaring (Hiller and Tedesco, 2014).

[ii] Specifically, the NDIC passed Order 24665 requiring firms to capture 77% of all NGLs in 2015, have 85% capture from 2016 through 2020, and capture 90% of all NGLs after 2020. Implementation of the 2016 target has been delayed until November 2016 due to industry pressures to delay implementation while NGL gathering infrastructure is expanded across the state.

[iii] The data were also used by Covert (2015) to study learning by firms and well productivity in fracking.

[iv] NGLs can also be used onsite at the well for power or heat; however, such uses can only consume small amounts of NGLs.

[v] Natural gas processing capacity in North Dakota has expanded rapidly from just over 200 mcf/day in 2006 to 1,600 mcf/day in 2015 with more capacity anticipated to come online in coming years (NDPA, 2015). Despite this rapid growth in NGL processing capacity, the recent expansions in the number of drilling operations has pushed up on the limits of how much natural gas is able to be processed at the natural gas processing plants.

[vi] Alternatively, a regulator could limit the total volume of flaring or greenhouse gasses (GHGs) and allowing well operators to trade rights to flare or emit.

[vii] While the dramatic decreases in both prices has been attributed in part to the advent of fracking, it seems unlikely that a single well's production in North Dakota would affect market natural gas or crude oil prices; however, we plan to test these assumptions when conducting any such analysis.

[viii] Firms may also be moving to less productive wells, but technological progress and efficiency gains in extraction at any given well may dominate effects of being at a less productive location. Conversely, it may be the case that firms are learning to identify more productive wells before drilling, then all these effects tends to increase well productivity over time.

Disclosure Statement – Gabriel E. Lade

The author declares that he has no relevant or material financial interests that relate to the research described in this proposal. In particular, the author has no financial ties to the energy industry.

Disclosure Statement – Ivan Rudik

The author declares that he has no relevant or material financial interests that relate to the research described in this proposal. In particular, the author has no financial ties to the energy industry.