How Well, Which Well?

Well-level Oil Production Responses to Price in North Dakota

Introduction

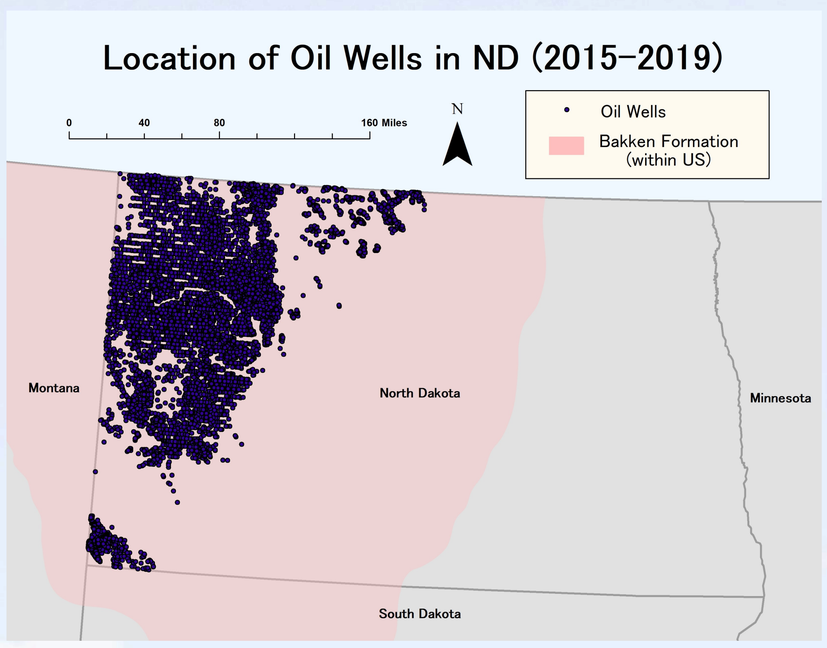
Understanding how oil producers respond to changes in oil prices is often of great interest to policymakers. For instance, the impact of any environmental policy affecting oil demand or oil supply (e.g. taxes/subsidies to oil production, EV and biofuel subsidies) depends crucially on oil producers' responsiveness to price.

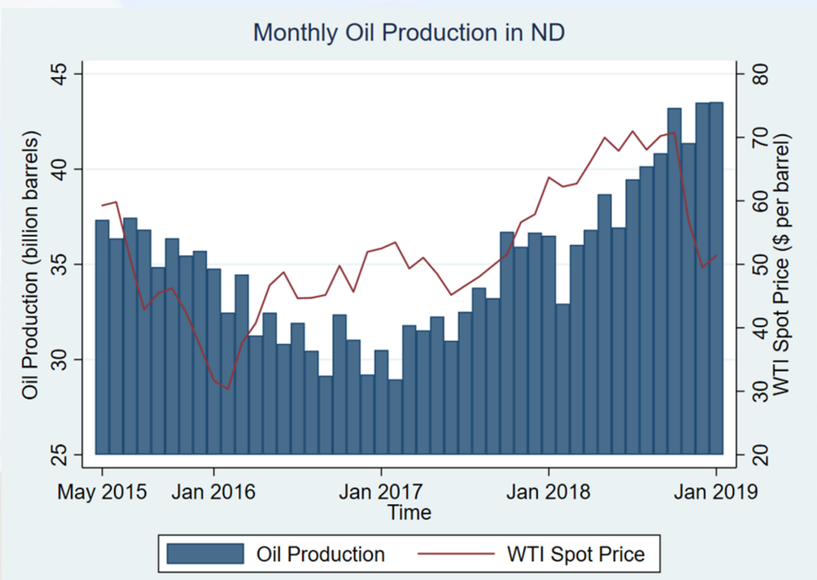
While previous studies focused on macro-level evidence, there is now an emerging literature analyzing this supply response using granular data at the oil well level. In this context, I believe it is highly relevant to conduct a micro-level spatial analysis of oil production and to investigate whether responses to price vary across locations, using publicly available well-level data from North Dakota (ND).

Data

I use well-level oil production data for ND, compiled from monthly reports issued by NDIC. Among other things, the dataset records latitude and longitude information, and monthly oil production levels for each well in ND. Data on monthly oil prices (WTI spot prices) were obtained from the EIA website. The sample period for this study is May 2015 to Jan 2019.

Geocoded locations of wells, trends in production volume and prices, and summary statistics are provided below.





Summary Statistics					
Variables	N	mean	sd	min	max
WTI Spot Price ($/bbl)	696,261	52.47	10.27	30.32	70.98
Oil Production (bbl/month per well)	696,261	2109	3675	0	133,711
No. of wells	17,723	-	-	-	-

References:

Anderson, S. T., Kellogg, R., and Salant, S. W. (2018). Hotelling under Pressure. *Journal of Political Economy*, 126(3):984-1026.

Bjornland, H. C., Nordvik, F. M., and Rohrer, M. (2017). Supply Flexibility in the Shale Patch: Evidence from North Dakota. *SSRN Electronic Journal*.

Mason, C. F. and Roberts, G. (2018). Price Elasticity of Supply and Productivity: An Analysis of Natural Gas Wells in Wyoming. *The Energy Journal*, 39(01).

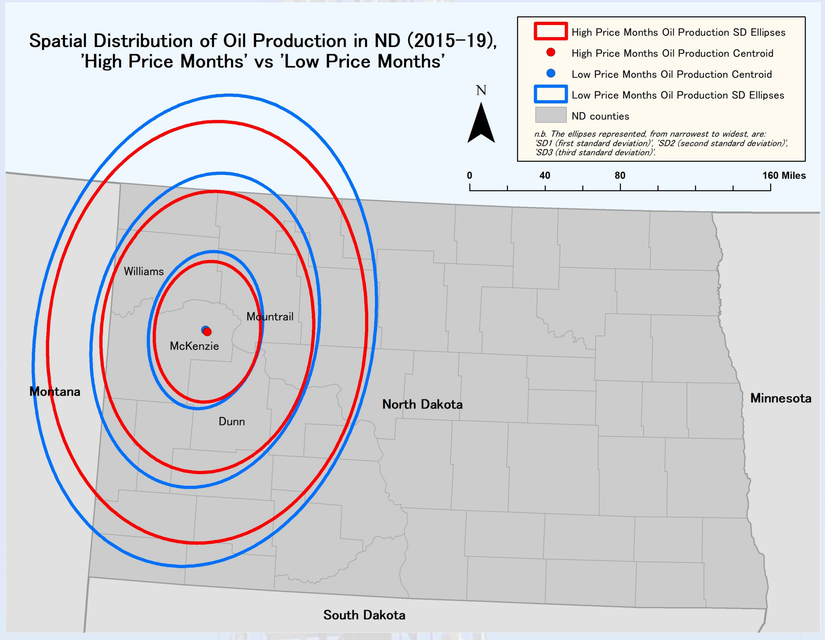
Slade, M. E. and Thille, H. (2009). Whither Hotelling: Tests of the Theory of Exhaustible Resources. *Annual Review of Resource Economics*, 1(1):239-260.

Smith, James. (2017). Estimating the Future Supply of Shale Oil: A Bakken Case Study. MIT Center for Energy and Environmental Policy Research.

Methodology and Results

1. Location matters: Wells near the center are more responsive to price

I focus on observations for 'high price months' (year-months for which spot price > 1SD above mean) and 'low price months' (< 1SD below mean). I then compare centroids and SD ellipses, weighted by production volume, for the two types of months.

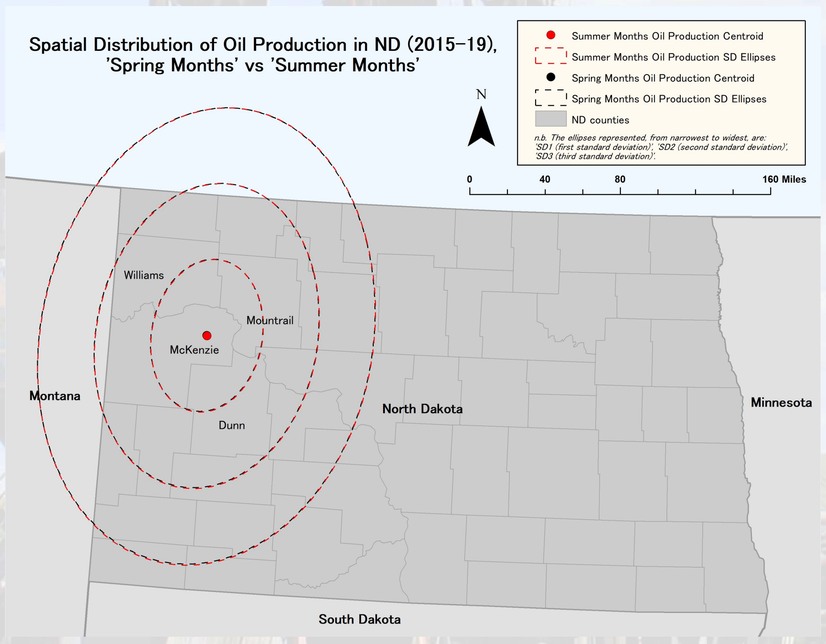


The mean center remains more or less constant, and a large share of production consistently takes place in four counties: Williams, McKenzie, Dunn, Mountrail. However, we observe that SD ellipses are noticeably narrower in 'high price months'. As price goes up, proportionately more of the production takes place near the centroid.

Thus, oil wells in different locations within ND respond differently to price changes, with wells located near the center seemingly able to adjust their production relatively more than wells in outer areas.

2. Location does not matter for other factors

To check whether the heterogeneous spatial responses observed above are not caused by other factors, in particular seasonal variation, I split observations into 'spring', 'summer', 'fall' and 'winter' months, and conduct similar analyses.



Encouragingly, the weighted centroids and SD ellipses remain virtually unchanged for spring and summer. (The results carry through across all seasons.) Unlike price, seasonal changes do not seem to influence the distributional pattern of oil production in ND.

Data Sources:

Spot prices for petroleum & other liquids (EIA)

Monthly production reports (North Dakota Industrial Commission, Oil and Gas Division)

2010 US Census boundaries (ESRI)

*Background image from Smith (2017)

Projection:

USA Contiguous Albers Equal Area Conic

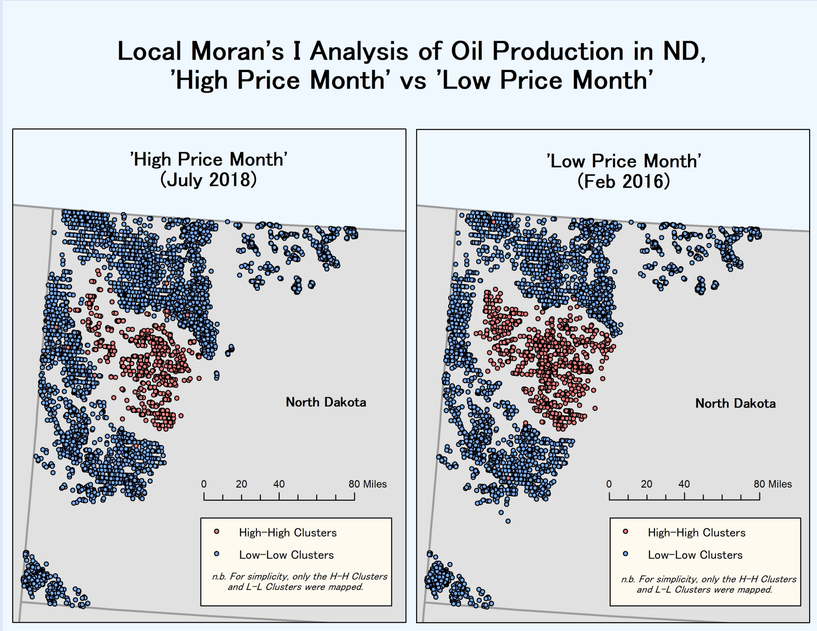
Tufts UNIVERSITY

Cartographer: Michiyoshi TOYA

December 2019 | UEP 232

3. Large wells are clustered near the center

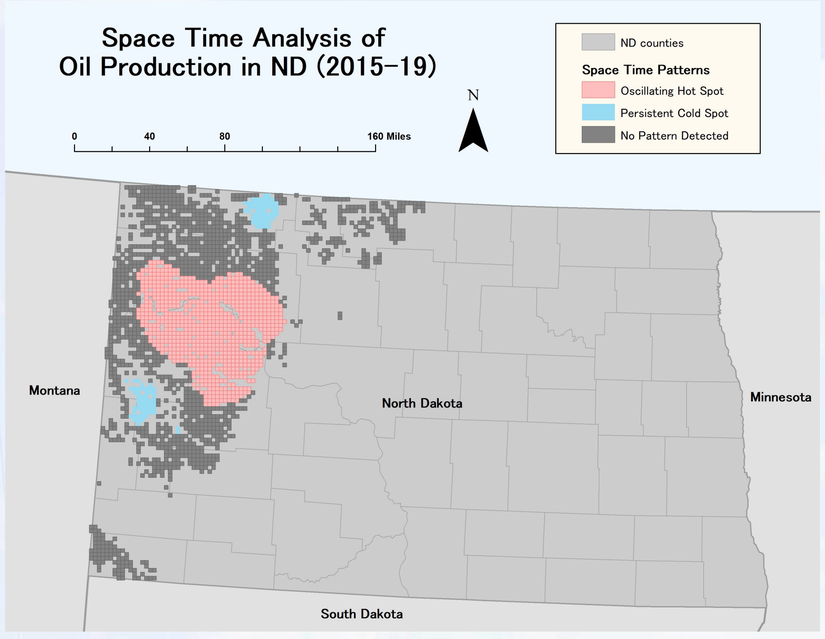
Suggestive evidence that wells near the 'center' respond more to price points to the importance of comparing well characteristics across locations. I conduct a local Moran's I analysis on well-level production, focusing on a 'high' vs 'low' price month.



We see that large wells are predominantly clustered in the central area (HH clusters), and that outer areas are mostly clusters of small wells (LL clusters). This pattern does not seem to vary with price or time. Well size may thus be an important underlying well-characteristic behind the spatial heterogeneity in price responses.

4. Large wells are more responsive to price

I extend the analysis to space-time dimensions over the whole sample period, by creating space time cubes (at one-month intervals) and analyzing clustering patterns.



The idea that clusters of large wells exist in the center is reinforced by the fact that this area is almost entirely classified as 'hot spots'. More importantly, production in these hot spots 'oscillate', as opposed to surrounding areas that tend to either exhibit persistently low production or no significant trends, which lends further support to the view that large wells respond more to price changes over the sample period.

Conclusion

Wells near the central region (Williams, McKenzie, Dunn, Mountrail) respond more to prices than wells in surrounding areas. This spatial heterogeneity seems to be a result of clustering and of large wells being able to adjust more flexibly to price changes.

Investigating factors that enable large wells to respond more (e.g. there may be costs associated with altering production levels which large producers can spread out better) may be an interesting area for future research.