ON THE REPORTING OF WATER USE AND THE EFFECTS OF HYDRAULIC FRACTURING ON GROUNDWATER LEVELS IN TEXAS

Jesse Backstrom, PhD Candidate
Deptartment of Agricultural Economics
Texas A&M University
jessebackstrom@tamu.edu
612-384-9321

Overview

Hydraulic fracturing (HF) activity has increased rapidly in the U.S. over the last decade, where the arid Permian Basin in west Texas has experienced the largest growth. A growing literature in economics has studied many of the local impacts of the "shale boom," which have included effects on: the housing market (e.g. Muehlenbachs et al. 2015); employment, wage, and tax and royalty revenues (e.g. Feyrer et al. 2017); health (e.g. Currie et al. 2017); and others. Aside from these more 'general' economic studies, there is a growing literature on the localized environmental effects of HF, such as those on air quality and greenhouse gas emissions (e.g. Knittel et al. 2015); induced seismic activity associated with wastewater disposal (Ellsworth 2013); and agricultural production (e.g. Farah 2017). Two interrelated issues that have escaped the empirical economics literature however, are the effects of water use in HF on *local* groundwater availability and the reporting of water use in HF stimulations. These issues are important because water scarcity is one of the biggest constraints imposed on social and economic development. Evidence of this are the tax write-offs available in certain counties in Texas that compensate landowners for aquifer drawdown below their properties. Further, an increasingly large volume of water is needed to stimulate a well drilled for hydrocarbon production from shale (11,779,194 gallons was the median in our sample in 2016), yet the reporting of water use in the industry is not impressively transparent.

Our contributions in this paper are twofold. We are the first to make use of a unique data set of hydraulically fractured wells, which we use to examine trends in the volume of water used in well stimulations in Texas and analyze spillovers of localized groundwater management regimes on HF activities. Specifically, we investigate how the propensity to voluntarily report detailed water use information by operators of oil and gas wells located within the jurisdiction of a groundwater conservation district (GCD) varies relative to water use reporting for wells not located within a GCD. Second, to highlight the importance of transparency in water use reporting, we also estimate the effects of water use in HF stimulations on local groundwater availability in Texas using a high frequency data set on groundwater levels. Our analysis is a significant improvement over previous studies (particularly in the natural sciences), which have only investigated general trends in groundwater levels in regions with HF. These studies also used groundwater level data that was reported infrequently, usually at annual or bi-annual time stamps and with less spatial concentration, which inhibited their ability to infer a causal relationship.

Methods

To analyze the reporting of water use, we obtained a proprietary data set from a company in Houston that provides unique analytical tools and data on the use of water, proppant, and chemicals in HF fluids. The data set was constructed by downloading data from fracfocus.org and complementing it with data from other public agencies such as the Texas Railroad Commission. The initial data set included well-level information on nearly 60,000 hydraulically fractured wells in Texas over 2011-2016. With respect to House Bill 3328, HF operators in Texas are required to report information on the total water volume and chemical compositions used in stimulations for wells permitted after January, 2012, so we only include well records after that in our analysis of the reporting of water use.

Although some operators voluntarily report to FracFocus the proportions of freshwater, recycled wastewater, brackish, and other types used to stimulate each well, the company used this information on water type (where available) combined with density estimates for each water type and chemical additive in order to calculate reasonably accurate estimates of a total HF fluid mass (HFFM) for most wells. However, when insufficient information was available to calculate a HFFM for certain wells in the database, the HFFM for these wells was coded as 'unknown'. The company also verified that the unknown HFFM values were due to information on the water type not being reported by the operator and they were unable to be obtained in additional searches of other databases. This information is important to our analysis since it contributes to what we refer to as voluntarily reporting *less* information on water use relative to more, which we use as our binary (0 or 1) dependent variable.

We first estimate a linear probability model (LPM) in order to obtain results that are more easily interpretable, and we then use a predictive logistic regression model as a robustness check since we are making functional form assumptions in the LPM. In both models, our outcome variable is an indicator for whether a HFFM was calculated for a well observation:

$$Y_i = \begin{cases} 1 \; if \; a \; HFFM \; could \; be \; calculated, based \; on \; the \; water \; use \; information \; reported \\ 0 \; if \; a \; HFFM \; could \; not \; be \; calculated \end{cases},$$

which we model as a function of an indicator for whether the well was drilled in a GCD or non-GCD area, the well's orientation (horizontal or vertical), total reported water volume, and month-of-sample fixed effects. Since four GCDs were established during our period of study, we use the variation in GCD establishment date as a means of identifying an effect on the propensity to voluntarily report information on water use.

To analyze the effects of water use in HF on groundwater availability, we obtained an unbalanced panel data set on groundwater levels from the Texas Water Development Board. These data were collected daily via 273 automated monitoring stations located throughout the state over 2011-2017. Using a fixed effects model, we treat the monitoring stations as the units of observation and estimate an average treatment effect for aquifer drawdown, which we hypothesize is due to withdrawals for HF stimulations. We use daily observations to create a monthly average distance to the groundwater level below each monitoring station, which we model as follows:

$$DistGW_{i,t} = \beta_1 TWVradius20_{i,t} + \sum_{j=1}^{n} \beta_k TWVring_{k,i,t} + x_{i,t}\beta + \lambda_t + \gamma_i + \varepsilon_{i,t},$$

where, the outcome variable is the distance (in feet) from the surface to the groundwater level for monitoring station i at time t, $TWVradius20_{i,t}$ is the total water volume (in gallons) used in oil and gas wells within 20 miles of monitoring station i at time t, $TWVring_{k,i,t}$ is the total water volume (in gallons) used in oil and gas wells within ring k of monitoring station i at time t (i.e., we created additional rings, or annuli, in increments of 10 miles around the initial 20-mile radius of each monitoring station), and $x_{i,t}$ is a set of controls for drought severity in the county of monitoring station i at time t. We include a set of month-by-year fixed effects, λ_t, to absorb time-specific confounders, and station-level fixed effects, γ_i, to account for differences in average groundwater levels between monitoring stations, and $\varepsilon_{i,t}$ is an error term. Our identifying assumption is that in the absence of HF activity, groundwater water levels in areas with HF would have trended similarly to groundwater levels in areas without HF activity.

Results

Our analysis of the reporting of water use provides evidence that in areas where a GCD exists, HF operators are more likely (by ~1.5 percentage points) to voluntarily report *less* detailed information on water use for a well record. A similar relationship was found as *less* detailed information on water use was more likely to be reported for an increase in total water volumes used in HF stimulations, and for horizontal versus vertically-drilled wells. As an additional robustness check we excluded all observations for operators who did not have wells in both GCD and non-GCD areas, and ran a fixed effects logit model that provided the same results.

In our analysis of the effects of water use in HF on groundwater availability, we find a clear association between water use in HF and groundwater levels. As expected, for an increase in the volume of water used in HF within the initial 20-mile radius and also within each distant ring, we found an associated decline in the groundwater level relative to monitoring stations without nearby HF activity. The magnitudes of parameter estimates on more distant rings also declined with distance. Relative to nearer water withdrawals, the cone of depression from more distant water withdrawals should have less of an effect on the groundwater level read by the monitoring station.

Conclusions

Our findings are important for groundwater management as they provide some insight on the reporting tendencies of HF operators in Texas, and allude to several policy options aimed at making water use reporting more transparent. We believe that relevant questions might center on creating GCDs where none currently exist, and possibly expanding the water use reporting requirements of House Bill 3328 to include information on water use by source and type (similar to Louisiana). This would be helpful in order to better understand water sources and types used in HF stimulations in Texas and also incentivize the use of alternatives to freshwater. Transparency of water use is important because if many new wells in a water-scarce area are due to be stimulated and all water is obtained from the same source, there is potential for aquifer drawdown, which becomes even more pronounced during drought and during the summer months.

References

1. Currie, J., M. Greenstone, and K. Meckel. 2017. "Hydraulic Fracturing and Infant Health: New Evidence from Pennsylvania." Science Advances. 3(12): 1-9.
2. Ellsworth, W.L. 2013. "Injection-Induced Earthquakes." Science. 341: 1225942.
3. Farah, N. 2017. "The Effects of Hydraulic Fracturing on Agricultural Productivity." Working Paper. Available at: https://drive.google.com/file/d/0Bxp0L418FENjWklucjI3RzFvVkE/view. [Accessed 11/10/17].
4. Feyrer, J., E.T. Mansur, and B. Sacerdote. 2017. "Geographic Dispersion of Economic Shocks: Evidence from the Fracking Revolution." American Economic Review 107(4): 1313-1334.
5. Knittel, C.R., K. Metaxoglou, and A. Trindade. 2015. "Natural Gas Prices and Coal Displacement: Evidence from Electricity Markets." NBER Working Paper No. 21627 - Oct 2015.
6. Muehlenbachs, L.A., E. Spiller, C. Timmins. 2015. "The Housing Market Impacts of Shale Gas Development." American Economic Review. 105(12): 3633-3359.