# The Secret Sauce: Disclosure and Strategic Interaction in Hydraulic Fracturing

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# Technical Change

## Natural Gas

Combination of technologies has expanded natural gas reserve base: hydraulic fracturing attracts most attention

- both experiential and social learning
- application to heterogeneous geology

Adoption has two major effects:

- allowed entry into E&P and servicing $\rightarrow$ competition for market share
- Public concern about environmental/social/local impacts of development
  - “fracking” has been the lightning rod

# Hydraulic Fracturing

## Stylized Facts

1. operators contract service companies to perform fracturing
   - extent of operational control?
2. frac recipes/formulas vary: companies, time, and space
3. perceptions of environmental risk from development/ fracking
   - housing market effects, even if damages not demonstrated
4. state-level disclosure requirements for frac ingredients
   - disclosure incomplete – allows for confidential “trade secrets”

# This Paper

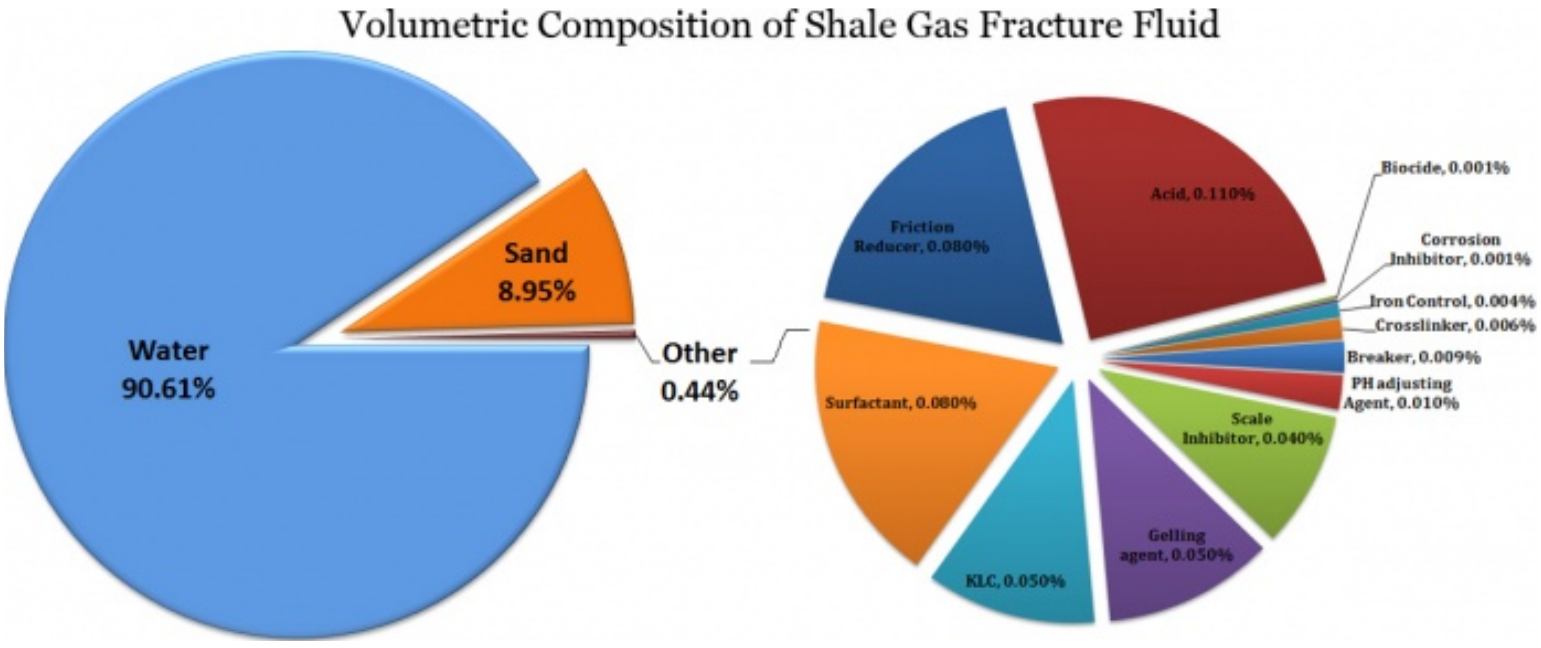
1. identify relationships between firms
   - operators and service companies
   - few firms in our empirical setting $\rightarrow$ opportunity for strategic interaction
2. use disclosures to identify recipes
   - estimate marginal productivities
   - including fluid chemistry
3. assess toxicity of frac ingredients
4. assess role of trade secrecy "loophole"
   - parse operator vs. service company
   - pertinent given possible mergers in servicing

# This Paper

## 1000 Words

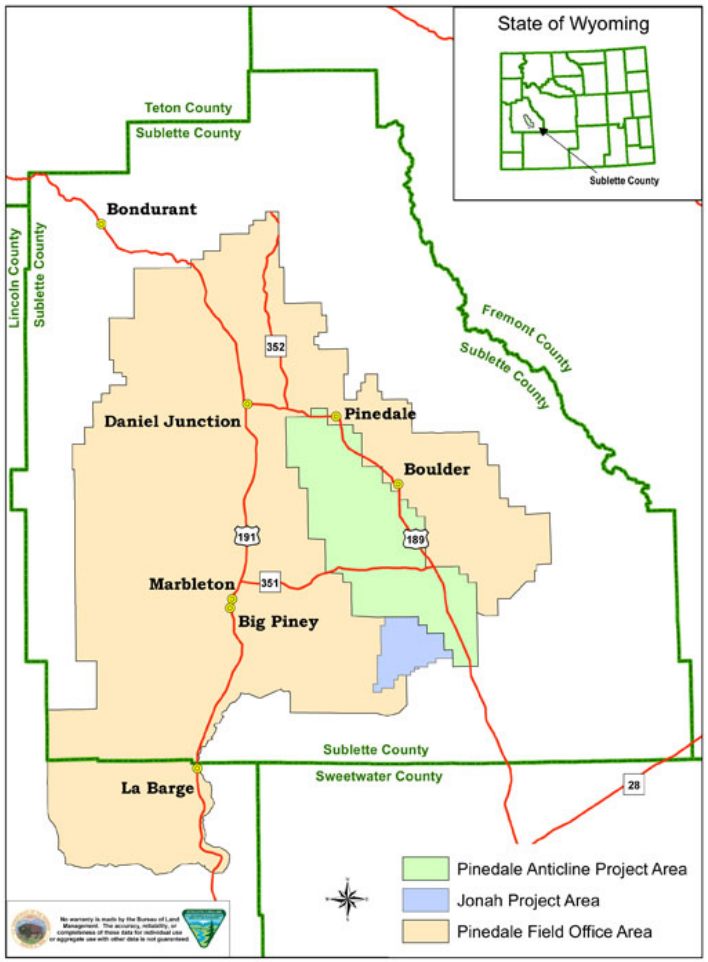

Cartoon from Columbus Dispatch

# Hydraulic Fracturing




- injected fluid largely water, proppant
- lots of attention to small share of chemical additives with more potential environmental/health harm

# Sublette County




Source: Pinedale Anticline Project Office, Wyoming BLM

- very rural area with some historic (oil) development
- distant from consumer markets—large basis differentials for gas (Oliver et al. 2014)
- fracking used since 1990s, though technology evolved substantially
- mostly vertical wells in tight sandstone (not horizontal, not shale)
- commuting distance to SW Wyoming oil and gas centers

# Data

- WY regulation (17 Aug, 2010)
  - components of frac jobs must be reported to Wyo Oil & Gas Commission
  - trade secrets exception
- FracFocus reports records for frac jobs in Sublette County, WY
- Combined data: 569 frac jobs (333 records from both sources)
- frac job typically has multiple stages
- three firms conduct fracking operations
  - “oil service companies”

# FracFocus

## Injection Data

- detailed, well-specific, injection information
- 13.2 percent proppant
- 86.0 percent water
- provided via FracFocus


| Purpose | Number | Percent | Toxic Count | Secret Count |
|---|---|---|---|---|
| Additives | 8 | 0.0677 | 3 | 3 |
| Biocides | 9 | 0.0119 | 0 | 4 |
| Breakers | 9 | 0.1718 | 2 | 2 |
| Gel | 3 | 0.1479 | 0 | 2 |
| Slicks | 4 | 0.0361 | 0 | 1 |
| Other | 51 | 0.3644 | 0 | 4 |

# Specifying Production Function

## Six categories of additives

- Balancing Additives
  - pH control, clay stabilizers, buffers
- Biocides
  - bactericides to prevent naturally-occurring bacteria from multiplying and impeding flow
- Breakers and Crosslinkers
  - create, then destroy cross-linked (rather than linear) gels to increase viscosity and transport more proppant
- Gels & Foamers
  - increase viscosity
- Slicks
  - friction reducers and surfactants
- Unspecified
  - none of the above
- Production data furnished by DrillingInfo

# Completion Reports

## WOGCC

Operators required to report completions to state regulator

- Form 3

Includes similar information to FracFocus – also:

- treated footage
- number of stages of treatment

# Toxicity

OSHA Occupational Chemical Database

- match CAS numbers from FracFocus
- information on 751 chemical compounds that pose workplace hazards
- originally compiled with help from EPA
- considered EPA IRIS database

Currently only using match onto list

- may be able to implement relative toxicity measures
- concentrations are relevant

# Toxicity vs. Secrecy

When firms invoke “trade secret”

- do not observe CAS numbers

What dictates choice of secrecy?

- as opposed to revealing highly toxic ingredient...

Which firm (operator or service company) determines what is secret?

# Summary statistics for frac Jobs

| | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| $H_2O$ Volume (gal) | 1,562,927 | 1,010,253 | 364,433 | 5,614,448 |
| Sand/Water Ratio | 0.149 | 0.070 | 0.023 | 0.370 |
| Ingredients (count) | 84.6 | 11.7 | 28 | 90 |
| Stages | 15.66 | 4.87 | 3 | 27 |
| Treated Interval (ft) | 4,381.5 | 1,475.9 | 0 | 6,324 |
| Total Depth (ft) | 13,424.4 | 871.3 | 10,491 | 14,914 |

*Notes*: Data compiled from FracFocus records and WOGCC completion reports. $N$=333

# Number of toxic ingredients reported

| | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Additive | 1.81 | 1.03 | 0 | 4 |
| Biocide | 0 | 0 | 0 | 0 |
| Breaker | 1.92 | 1.44 | 0 | 7 |
| Gel | 1.20 | 0.69 | 0 | 3 |
| Proppant | 1.96 | 1.30 | 1 | 8 |
| Slicks | 0.29 | 0.46 | 0 | 1 |
| Unspecified | 0.24 | 0.52 | 0 | 3 |
| Total | 7.44 | 3.26 | 2 | 17 |

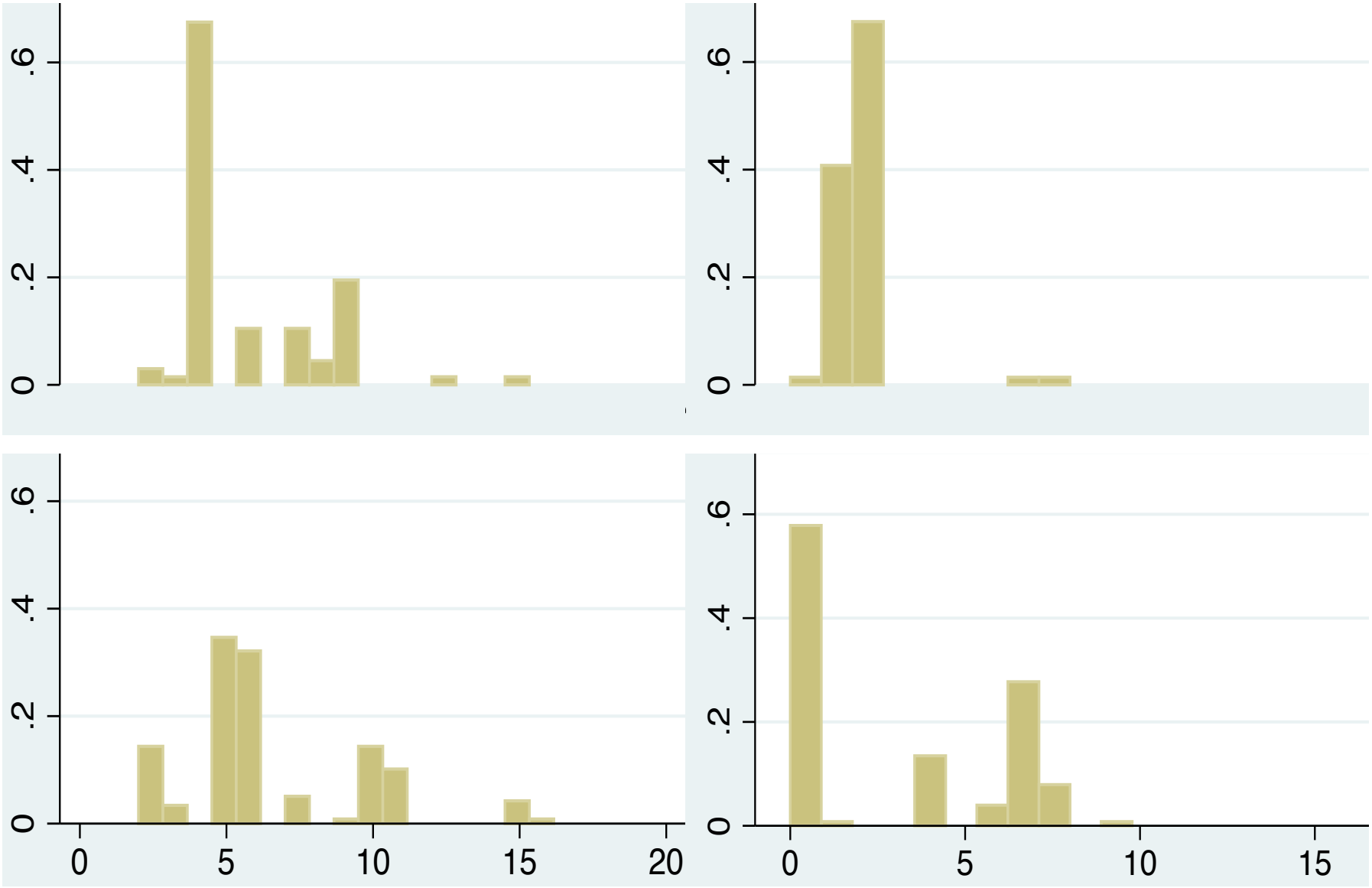
*Notes*: Estimation sample only, with undisclosed additives excluded. Data compiled from FracFocus records, as matched to OSHA Occupational Safety Database. $N$=333.

# Number of ingredients withheld as “Trade Secrets”

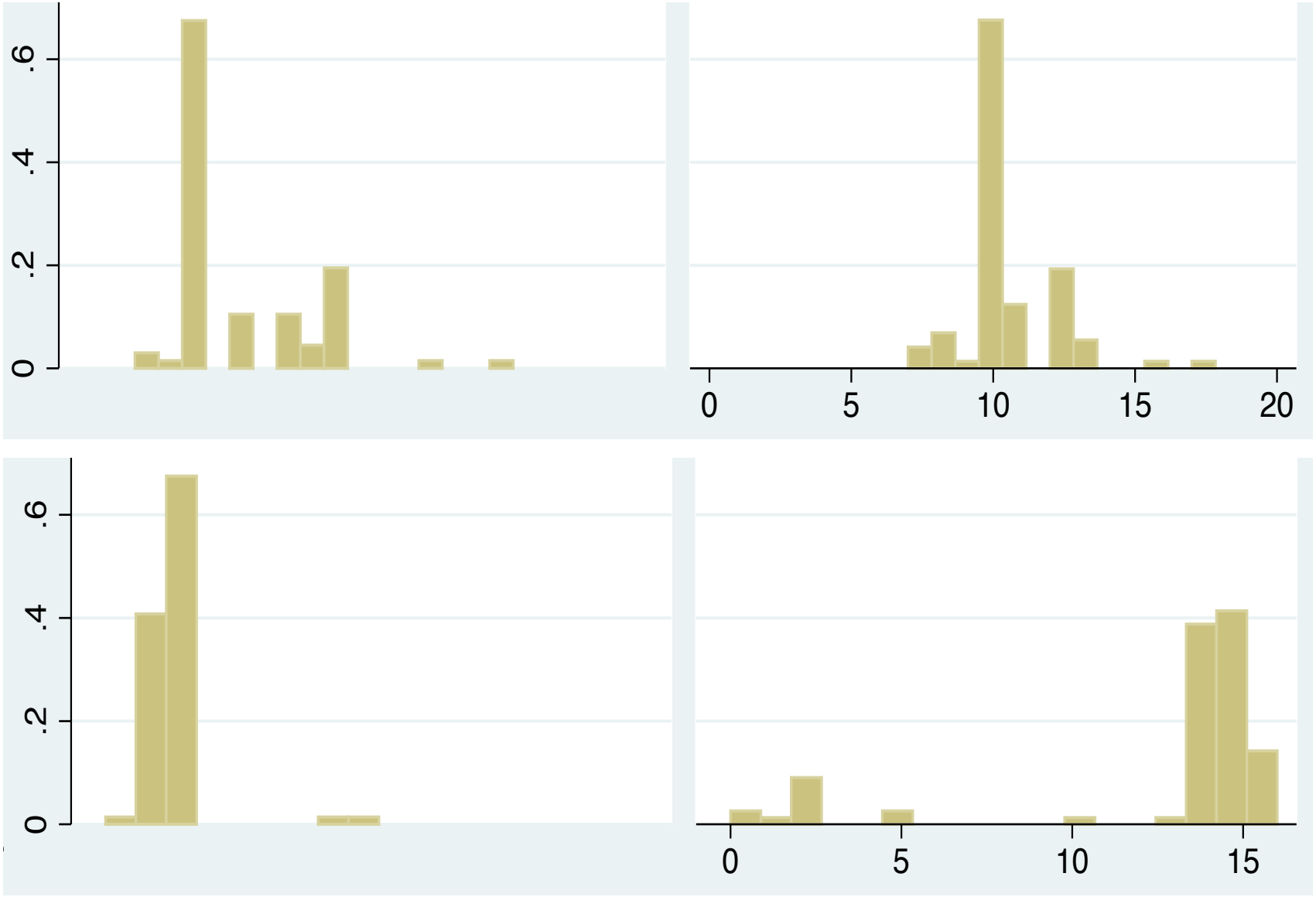
| | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Additive | 0.69 | 1.25 | 0 | 4 |
| Biocide | 1.10 | 1.60 | 0 | 4 |
| Breaker | 0.58 | 0.82 | 0 | 3 |
| Gel | 0.38 | 0.71 | 0 | 3 |
| Slicks | 0.58 | 0.74 | 0 | 2 |
| Unspecified | 1.75 | 2.07 | 0 | 6 |
| | | | | |
| Total | 5.11 | 5.71 | 0 | 16 |

*Notes*: Estimation sample only. Data compiled from FracFocus records. $N$=333. Total includes undisclosed proppants.

# A (T) vs. C (B)  [L: toxics; R: withheld]



# A (L) vs. B (R)  [T: toxics; B: withheld]



# Differences Across Firms

Table: Trade Secrets and Toxicity, per Well by Service Company and Operator

| | Trade Secrets | | | | Toxic Additives | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Min | Max | Mean | Std. Dev. | Min | Max |
| *Service Company* | | | | | | | | |
| A | 1.769 | 1.068 | 0 | 8 | 5.538 | 2.432 | 2 | 15 |
| B | 12.920 | 4.475 | 0 | 16 | 10.483 | 1.576 | 7 | 17 |
| C | 2.608 | 3.266 | 0 | 9 | 6.717 | 3.200 | 2 | 16 |
| *Operator* | | | | | | | | |
| I | 2.541 | 3.202 | 0 | 9 | 6.939 | 3.198 | 2 | 16 |
| II | 13.422 | 3.892 | 1 | 16 | 10.277 | 1.233 | 7 | 13 |
| III | 1.762 | 0.429 | 1 | 2 | 4.619 | 1.430 | 2 | 9 |
| IV | 2.500 | 2.887 | 0 | 5 | 14.750 | 2.062 | 13 | 17 |

*Notes*: Data compiled from FracFocus records, as matched to OSHA Occupational Safety Database. Total $N$=331.

# Production Cross-section

Estimate preliminary models of impact of completion formula on production over different time periods

- productivity of different additives $X_i$
- impact of secret or toxic ingredients through interaction

$$lny_j = \beta_0 + \beta_1 WATER_j + \beta_2 SANDRATIO_j + \beta_3 lnFOOTAGE_j + \sum_i \alpha_i lnX_i + \varepsilon_j$$

$$lny_j = \beta_0 + \beta_1 WATER_j + \beta_2 SANDRATIO_j + \beta_3 lnFOOTAGE_j + \sum_i \alpha_i lnX_i \times TOXIC_i + \varepsilon_j$$

$$lny_j = \beta_0 + \beta_1 WATER_j + \beta_2 SANDRATIO_j + \beta_3 lnFOOTAGE_j + \sum_i \alpha_i lnX_i \times SECRET_i + \varepsilon_j$$

# Production Panel

Also able to use well-month panel

$$lny_{jt} = \gamma AGE_{jt} + \beta' A_j + \sum_i \alpha_i lnX_i + \varepsilon_{jt}$$

# Toxicity Counts

Toxicity is a lightning rod:

- estimate count models: Poisson, negative binomial

$$\sum TOXIC_i = f\left(A_i, SECRET_i, OPERATOR_i, SERVICE_i, YEAR_i\right)$$

# Table: Various Fixed Effect Results, First Six Months' Gas

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Log $H_2O$ Volume | 0.12 | 0.12 | 0.20* | 0.40*** | 0.43*** | 0.46*** |
| | (0.093) | (0.096) | (0.10) | (0.15) | (0.16) | (0.16) |
| Sand/Water Ratio | -1.52* | -1.44 | -0.26 | -0.29 | 0.053 | 0.048 |
| | (0.90) | (0.87) | (1.04) | (1.01) | (1.13) | (1.05) |
| Log Treated Interval | 0.66*** | 0.58*** | 0.54*** | 0.021 | 0.0055 | 0.27 |
| | (0.088) | (0.12) | (0.11) | (0.19) | (0.21) | (0.21) |
| Stages | | 0.014 | 0.0086 | 0.0038 | 0.0045 | 0.0056 |
| | | (0.014) | (0.014) | (0.015) | (0.015) | (0.014) |
| Operator II | | | | 0.73*** | | |
| | | | | (0.23) | | |
| Service Company B | | | | | 0.95*** | |
| | | | | | (0.30) | |
| Service Company C | | | | | 0.22 | |
| | | | | | (0.17) | |
| $N$ | 204 | 204 | 204 | 204 | 183 | 204 |
| $R^2$ | 0.21 | 0.22 | 0.25 | 0.30 | 0.31 | 0.36 |

*Notes*: Constant included. Robust standard errors in parentheses. Operator I is the excluded group: operators III and IV are dropped from the trimmed sample. Column 3 included year fixed effects, which were not significant. Column 6 has spatial fixed effects, which are jointly significant.

# Table: Panel Results, Log Monthly Gas Production

| | log Gas | log Gas | log Gas | log Gas |
|---|---|---|---|---|
| Well Age | -0.075** | -0.076** | -0.076** | -0.076** |
| | (0.010) | (0.011) | (0.011) | (0.011) |
| Log Water Volume (gal) | 0.27*** | 0.50*** | 0.33*** | 0.28*** |
| | (0.0083) | (0.011) | (0.020) | (0.021) |
| Sand/Water Ratio | 0.44*** | 0.52*** | -0.24 | 0.30** |
| | (0.027) | (0.049) | (0.34) | (0.032) |
| Log Treated Interval | -0.055** | -0.020 | -0.083 | -0.0094 |
| | (0.0099) | (0.022) | (0.032) | (0.0069) |
| Stages | 0.038*** | 0.027*** | 0.046*** | 0.040*** |
| | (0.00084) | (0.0024) | (0.0014) | (0.0012) |
| Additive | | 0.12** | | |
| | | (0.017) | | |
| Breaker | | 0.11** | | |
| | | (0.017) | | |
| Unspecified | | 0.052*** | | |
| | | (0.0025) | | |
| Additive $\times$ Toxicity | | | 0.0046 | |
| | | | (0.0044) | |
| Breaker $\times$ Toxicity | | | -0.0076 | |
| | | | (0.0035) | |
| Unspecified $\times$ Toxicity | | | -0.036 | |
| | | | (0.017) | |
| Breaker $\times$ Secret | | | | -0.0049* |
| | | | | (0.0015) |
| Unspecified $\times$ Secret | | | | -0.0020 |
| | | | | (0.0016) |
| Constant | 6.97*** | 5.69*** | 6.34*** | 6.44*** |
| | (0.18) | (0.14) | (0.39) | (0.39) |
| Observations | 1868 | 1664 | 1664 | 1664 |
| $R^2$ | 0.35 | 0.37 | 0.35 | 0.35 |

*Notes*: Operator clustered standard errors in parentheses.

# Table: Count Model Results (294 Obsns)

| | Poisson | Negative Binomial | OLS |
|---|---|---|---|
| Log Water Volume (gal) | -0.39*** | -0.39*** | -2.42*** |
| | (0.061) | (0.061) | (0.54) |
| Sand/Water Ratio | 0.82* | 0.82* | 8.37 |
| | (0.49) | (0.49) | (5.80) |
| Stages | 0.011* | 0.011* | 0.094** |
| | (0.0058) | (0.0058) | (0.045) |
| Secret Gel Count | 0.13*** | 0.13*** | 0.50* |
| | (0.044) | (0.044) | (0.30) |
| Secret Slicks Count | 0.15** | 0.15** | 1.02** |
| | (0.066) | (0.066) | (0.45) |
| Secret Unspecified Count | -0.044** | -0.044** | -0.32** |
| | (0.021) | (0.021) | (0.14) |
| Operator I | 0.94*** | 0.94*** | 6.53*** |
| | (0.12) | (0.12) | (1.04) |
| Operator II | -0.65*** | -0.65*** | -4.42*** |
| | (0.17) | (0.17) | (1.53) |
| Service Company A | -1.36*** | -1.36*** | -10.2*** |
| | (0.13) | (0.13) | (0.98) |
| Service Company C | -1.51*** | -1.51*** | -10.8*** |
| | (0.18) | (0.18) | (1.68) |
| 2011 | -0.12 | -0.12 | -0.64 |
| | (0.085) | (0.085) | (0.68) |
| 2012 | 0.34*** | 0.34*** | 1.92*** |
| | (0.096) | (0.096) | (0.73) |
| 2013 | 0.42*** | 0.42*** | 2.37*** |
| | (0.11) | (0.11) | (0.84) |
| Individual Heterogeneity | | -17.1*** | |
| | | (0.14) | |
| Pseudo-$R^2$ [$R^2$] | 0.18 | 0.17 | [0.64 ] |

*Notes*: Dependent variable is count of all injected additives that appear on OSHA Occupational Chemical Database as potentially toxic hazards. Point estimates with robust standard errors reported in parentheses.

# Summary of Results

- substantial differences across firms (operators and service companies) in usage of
  - trade secrecy provisions
  - toxic additives
- little evidence that these have large productive impacts
- toxicity concentrated amongst proppants, crosslinkers/breakers, chemical balancer s
- harder to pin down usage of trade secrets, but biocides are important
- firms may be able to react to regulation by substituting fluid chemistry, but gross benefits are not delineated

# Table: Toxicity Results (204 obsns)

| | Log 6 Month Gas | Log 6 Month Gas | Log 12 Month Gas | Log 12 Month Gas |
|---|---|---|---|---|
| Log Water Volume (gal) | 0.41* | 0.51** | 0.49** | 0.64** |
| | (0.21) | (0.25) | (0.22) | (0.25) |
| Sand/Water Ratio | -0.027 | -1.50 | 0.57 | -0.97 |
| | (0.94) | (1.00) | (0.95) | (0.98) |
| Log Treated Interval | 0.29* | 0.19 | 0.21 | 0.094 |
| | (0.17) | (0.19) | (0.16) | (0.15) |
| Additive | 0.0045 | | 0.0094 | |
| | (0.049) | | (0.048) | |
| Biocide | 0.047 | | -0.064 | |
| | (0.17) | | (0.15) | |
| Breaker | 0.12 | | 0.12 | |
| | (0.076) | | (0.076) | |
| Gel | 0.0058 | | 0.045 | |
| | (0.12) | | (0.12) | |
| Slicks | -0.024 | | -0.015 | |
| | (0.087) | | (0.080) | |
| Unspecified | 0.19 | | 0.20 | |
| | (0.12) | | (0.12) | |
| Additive × Toxicity | | -0.029** | | -0.030** |
| | | (0.013) | | (0.013) |
| Breaker × Toxicity | | 0.010 | | 0.0067 |
| | | (0.0070) | | (0.0069) |
| Gel × Toxicity | | -0.0089 | | -0.0039 |
| | | (0.017) | | (0.016) |
| Slicks × Toxicity | | 0.12** | | 0.13** |
| | | (0.052) | | (0.052) |
| Unspecified × Toxicity | | -0.073 | | -0.089 |
| | | (0.055) | | (0.055) |
| Constant | 6.79*** | 4.00 | 6.22** | 3.36 |
| | (2.59) | (3.16) | (2.46) | (3.11) |
| $R^2$ | 0.30 | 0.33 | 0.26 | 0.32 |

*Notes*: Robust standard errors in parentheses. Biocide is excluded due to collinearity.

# Table: Trade Secret Results (204 Obsns)

| | Log 6 Month Gas | Log 6 Month Gas | Log 12 Month Gas | Log 12 Month Gas |
|---|---|---|---|---|
| Log Water Volume (gal) | 0.41* | 0.36*** | 0.49** | 0.42*** |
| | (0.21) | (0.12) | (0.22) | (0.13) |
| Sand/Water Ratio | -0.027 | -0.86 | 0.57 | -0.043 |
| | (0.94) | (1.03) | (0.95) | (1.07) |
| Log Treated Interval | 0.29* | 0.13 | 0.21 | 0.026 |
| | (0.17) | (0.17) | (0.16) | (0.13) |
| Additive | 0.0045 | | 0.0094 | |
| | (0.049) | | (0.048) | |
| Biocide | 0.047 | | -0.064 | |
| | (0.17) | | (0.15) | |
| Breaker | 0.12 | | 0.12 | |
| | (0.076) | | (0.076) | |
| Gel | 0.0058 | | 0.045 | |
| | (0.12) | | (0.12) | |
| Slicks | -0.024 | | -0.015 | |
| | (0.087) | | (0.080) | |
| Unspecified | 0.19 | | 0.20 | |
| | (0.12) | | (0.12) | |
| Additive × Secret | | 0.00024 | | 0.0034 |
| | | (0.014) | | (0.011) |
| Biocide × Secret | | -0.011 | | -0.0048 |
| | | (0.012) | | (0.0092) |
| Breaker × Secret | | 0.0029 | | -0.0093 |
| | | (0.012) | | (0.0079) |
| Gel × Secret | | 0.013 | | 0.0082 |
| | | (0.013) | | (0.010) |
| Slicks × Secret | | -0.036 | | -0.059* |
| | | (0.040) | | (0.032) |
| Unspecified × Secret | | -0.0054 | | -0.0047 |
| | | (0.0080) | | (0.0068) |
| Constant | 6.79*** | 6.34*** | 6.22** | 6.76*** |
| | (2.59) | (1.58) | (2.46) | (1.54) |