Hydraulic Fracturing Regulation:

State-Level Policy Factors and Regulatory Stringency

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Abstract Hydraulic fracturing is a method of oil and natural gas extraction that allows access to new sources of fossil fuels, but raises new and difficult questions of environmental damage. Due to the Energy Policy Act of 2005 and historic trends, states are the primary regulators of this new type of drilling. This paper estimates what state-level factors determine the stringency of state rules. To do this, a measure of regulatory stringency is created and incorporated in an econometric model. The results of this model are inconclusive due to the small sample size, but preliminary results indicate that current and historic trends in resource extraction in a state contribute to stronger "on-paper" regulation.

I. Introduction

Over the course of the last several years, there has been a substantial amount of work done examining the policy issues surrounding hydraulic fracturing, or the process of extracting unconventional – or shale – gas through the use of highly pressurized treated water. The majority of that work seems to be focused on a small and specific group of states that are currently at the forefront of the current growth of unconventional gas extraction. However, given the recent surge of fracturing in North Dakota and the potential for other states to follow suit, a wider examination of state-level regulation of the process of shale gas extraction is warranted. The task of this paper is to determine what state level factors affect the emergence of stringent state level regulation of fracking, in order to better understand the regulatory landscape that will determine how hydraulic fracturing will evolve over the next few decades. The results indicate that the most promising area for future work is the presence (past or present) of the resource extraction industry in a state.

The first section of this paper will outline the process of hydraulic fracturing, and speak briefly to the economic and social factors that may affect the decisions of state governments to support or oppose hydro-fracturing development. It will also speak to the current regulatory arena, focusing on the primacy of state governments since 2005. Section two will focus on the available data, and will include a discussion of three hypotheses on factors that influence regulatory stringency. Section three will briefly touch on the econometric methods used, and section five will explain the empirical results. I will conclude with a discussion of future research, data problems, and the limited conclusions I can draw. Business enterprise not only grew in scale, but also in sophistication (Chandler 1984).

II. Hydraulic Fracturing

The process of hydraulic fracturing – often paired with horizontal drilling – is a method for extracting natural gas and oil from shale plays that previously were unreachable via conventional extraction methods. This process has some clear advantages, as it greatly increases the accessible natural gas, and reduces the use of more harmful petroleum and coal products. There are numerous examples of states that have sustained large job growth based on what some have deemed a "shale gas revolution", with North Dakota serving as the most recent example. In addition, there are claims that natural gas can serve as a substitute for coal products that are more destructive to the environment. Stephenson, Doukas and Shaw (2012) conduct a literature review on the empirical work on the lifetime emissions of shale gas, and use the case of British Columbia to discuss how Natural Gas fits into a "clean energy system". Their results are inconclusive, for "while natural gas combustion has environmental benefits over coal or oil in virtually all areas—greenhouse gas emissions, particulate emissions, flexibility and scalability—the impacts of natural gas production, including climate impacts, are contested" (Stephenson, Doukas, & Shaw, 2012). In general, there are indicators that there are benefits to natural gas production.

A major concern regarding hydraulic fracturing is water pollution, particularly from fracturing fluid that can enter water supplies surrounding wellheads. There are multiple studies that discuss this risk in depth. Rozell and Reaven identified five pathways, "of water contamination: transportation spills, well casing leaks, leaks through fractured rock, drilling site surface discharge, and wastewater disposal" (Rozell & Reaven, 2012) and draw particular attention to the final category for further research. Osborn et al. focus on the potential for methane contamination of water supplies near extraction points, and find evidence of such contamination in multiple areas (Osborn, Vengosh, Warner, & Jackson, 2011). Jenner and Lamadrid focus on the tradeoff between water safety and air pollution in the choice between shale gas and coal products, and speak to the potential role of gas as a tool to "transition to an age of renewable energy" (Jenner & Lamadrid, 2013). In summary, the extraction process for shale gas comes with certain costs – water pollution, methane, etc. – that call into question value of hydraulic fracturing and place a special emphasis on regulation.

Given the political reality of the gridlocked congressional process, and the limitations imposed on federal regulators by the Energy Policy Act of 2005, for the foreseeable future the states will be the major regulators of unconventional natural gas extraction. Oftentimes, existing resource extraction regulation concerning inspections, permitting, and safety standards have been adjusted to address hydraulic fracturing. Thus, it seems worthwhile to closely examine what factors lead to differences in regulatory stringency between states.

III. Data

In order to assess the strength of individual state regulations, a mechanism is needed to measure the stringency of each state's environmental regulations, as well as data on relevant explanatory variables. The literature on the emergence and strength of Renewable Portfolio Standards - state level political tools for encouraging the development of renewable energy – was particularly useful. The state-level variation of RPS construction made it a good match for examining hydraulic fracturing regulation. Both are attempting to measure the reasons why a state might adopt stronger or weaker policy. Derived from a range of studies on RPS (Carley & Miller, 2012; Chandler, 2009) the following model was constructed:

$$S_i = \beta_1 + \beta_2 P_i + \beta_3 IG_i + \beta_4 N_i + \beta_2 W_i + \beta_5 C_i + e_i$$

This model was applied to a cross-sectional dataset of the 29 or 28 states[1] in 2010 that had evidence of hydraulic fracturing, using both a Poisson and Probit model. New York, which has placed a moratorium on all sorts of hydraulic fracturing, is omitted from the sample. Washington is omitted from half the regressions, given its regulatory score of 0. Following is a description of data collection methods employed in the model above. For a full list of variables, see table 1 (on following page).

Stringency of Regulation

The first step of the data collection was to read and code the oil and natural gas regulation for each state with hydraulic fracturing going on within its borders. Information from both Resources for the Future and the United States Energy Information Administration (EIA) were used to compile this list. It included states that had at one point extracted unconventional natural gas, or states that could, but were choosing not to due to regulatory constraints. For each of these states, fracfocus.org – a government sanctioned chemical disclosure registration website – was used to find the current set of regulations for each state. After a thorough review, each state regulation was coded based on five basic categories: setback restrictions, casing

[1]Washington State is excluded in several versions of the model as a robustness check, as that state has a stringency score of 0.

Table 1: Variable Summary Statistics

Variable Name	Variable Description	Obs.	Mean	Std. Dev.	Min	Max
totscore	Total score of regulatory stringency from (0-38).	29	14.21	4.90	0	24
msi2008	State political ideology score from (0-3)[2].	30	1.83	0.13	1.61	2.14
Env_Index	Measure of environmental interest group strength (including donations).	30	-1.24e-10	1.56	-1.20	5.67
Env_Index_SubD	Measure of environmental interest group strength (excluding donations).	30	-8.62e-09	1.35	-1.17	4.35
Energy_Index	Measure of energy interest group strength (including donations).	30	-2.61e-09	1.36	-1.60	3.90
Energy_Index-SubD	Measure of energy interest group strength (excluding donations).	30	-4.22e-09	1.30	-1.34	4.35
stategdp_coaloilgas_1963	Proportion of state GDP in 1963 that resulted from resource extraction.	30	0.04	0.06	0	0.23
natgaswell_growth	The growth in natural gas wells between 2007 and 2010.	30	15852.20	21368.59	0	
natgaswell_mean	The mean number of natural gas wells aggregated from 2007 to 2010 data.	30	0.92	0.32	0	1.19
percapincome	Mean per capita income (divided by 1000).	30	37.76	4.73	30.84	49.12
pop_urban_percentage	Proportion of a state's population living in urban areas.	30	0.71	0.12	0.49	0.94

requirements, fluid disclosure, storage pits, and fluid disposal. Each category had between 9 and 2 sub-categories of specific regulation for which points could be awarded. An example is casing restrictions; if the regulation mentioned building setbacks (wells must be located some distance from buildings) one point was awarded. If that setback specifically mentioned a distance requirement another point was awarded, with one additional point for having a distance above the mean building setback distance. This way, a state with a strong, specific setback restriction was awarded 3 points.

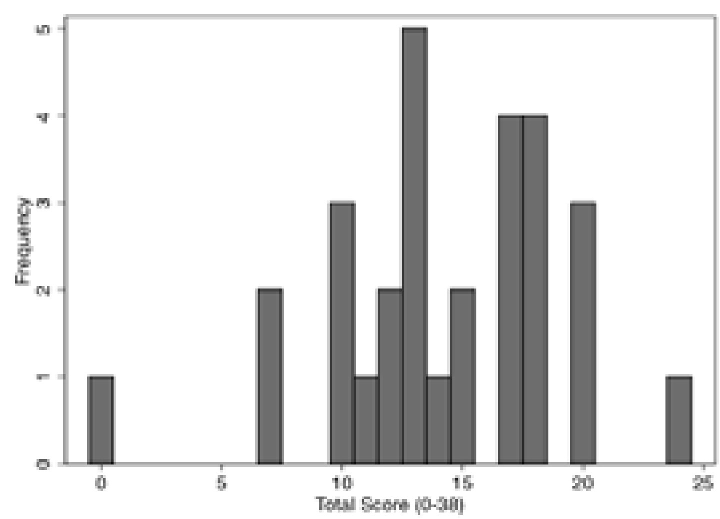

Figure 1: Histogram of Total Score Measure

[2] 0 indicates conservative, 3 indicates liberal.

There were 34 available points within this scheme. The maximum score was for North Dakota, with 24, and the smallest was 0, held by Washington State. The end results of this data collection can be seen in figure 1, and represents the dependent variable S_i. This method of coding allows for empirical analysis of the regulations. It is important to note the possibility that this scheme fails to capture all relevant aspects of regulations. For example, it is outside the scope of this paper to catalogue all potentially relevant government documents. Additionally Pennsylvania has a complex permitting process that could serve as a pseudo regulation, which might be indicative of further bureaucratic structures that might further alter the stringency of fracturing regulation, but these systems are also external to this paper.[3]

Explanatory Variables

The independent variables selected for this analysis follow the dominant strands of the existing energy and environmental policy literature. Carley and Miller – as well as most of the literature in question – divide their independent variables into two categories: factors that exist within a state and effects states' have on each other. This project will look solely at factors within a state, given data limitations (Feirick, 2000; Wiseman, 2011). The literature also further divides the explanatory variables into three sub-categories: state level ideology, economic, and socioeconomic. This paper considers all three categories, but given limited degrees of freedom, few can be included.

State Political Ideology

Thomas Carsey and Jeffrey Harden have collected and tabulated a measure of state ideology, which is used in this paper. They collected public opinion data from the National Annenberg Election Survey and the Cooperative Congressional Election Study, and collapse that data down to a three point scale, with one indicating conservatives, and three indicating liberal (Carsey & Harden, 2010). This measure – from 2008- is used in this analysis as P_i. In this way, the measure the authors have put together is ideally suited for gauging the impact a state's general political leaning has on the strength of its natural gas regulation. A priori, states that are more liberal should have stronger regulations.

State History of Resource Extraction

The state regulatory data collected for this study indicates that many current hydraulic fracturing regulations are based on older mining and extraction rules. It is worthwhile to consider how a state's history of resource extraction might effect the development of regulatory tools. If a state historically relied heavily on mining or drilling, then the early regulations – and the political attention those rules received – would be different. Including a metric for the role of resource extraction in a state's economic history is therefore worthwhile. The first two variables, resource extraction and political culture, can be seen in Figure 2 (see following page);.

The earliest year with available data from the Bureau of Economic Analysis[4] on both the extraction of oil, coal, and natural gas and state GDP is 1963. The percentage of state GDP made up of the energy resource extraction industry was calculated, resulting in a percentage value that could use to stand in for the industries

[3]For more information on the effect of different regulatory areas, please review the new risk matrix from Resources For the Future: http://www.rff.org/centers/energy_economics_and_policy/Pages/Shale-Matrices.aspx

[4] After a comprehensive review of other data sources including the EIA and Statistical abstracts, 1963 was the earliest year where adequate data was available.

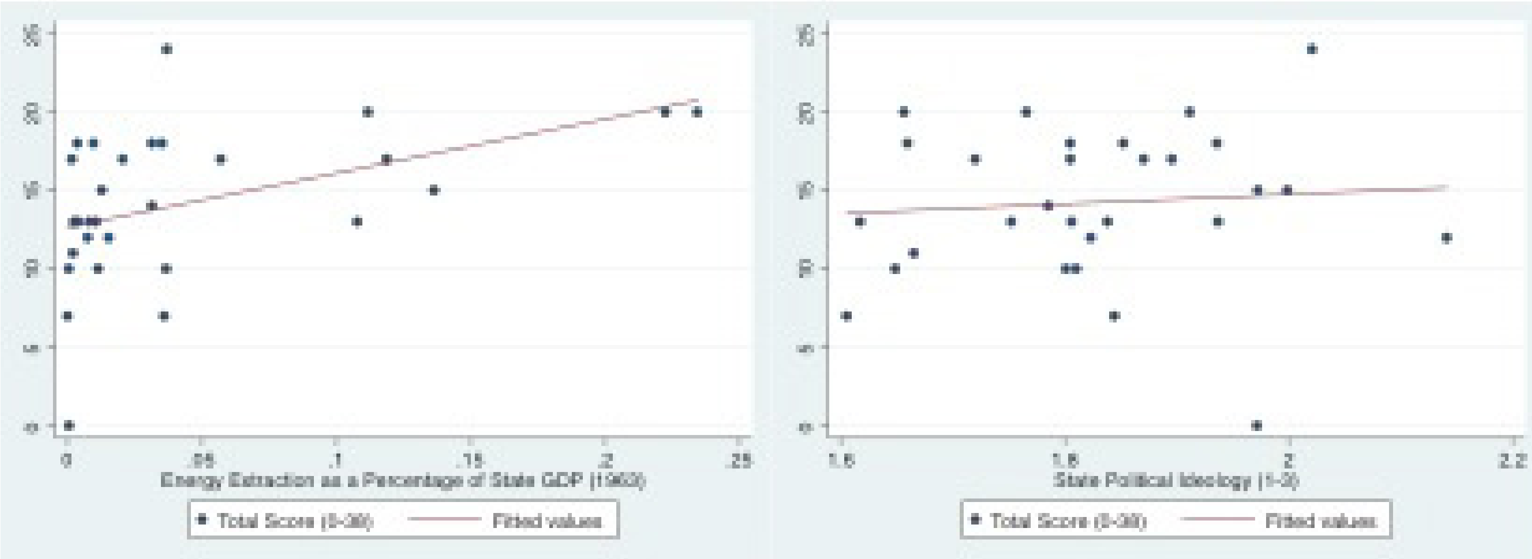

Figure 2: Measures of - from left to right - (a) state political ideology and (b) share of a state's GDP in 1963 that was made up of the energy extraction industry.

historical strength, N_i. This is an imperfect measure for a wide range of reasons. First of all, it is one year of data, which does not take into account the role of the industry over the course of time. Second, while 1963 was half a century ago, it does not take into account pre-world war II data, or information on the construction of a state's social relationship with resource extraction over the development of the state. However, it should be a good indication regarding the general presence of absence of resource extraction early in the state's history.

Interest Group Strength

The level of involvement and power of the relevant groups should impact regulatory stringency. Both the energy industry and the environmental movement have powerful voices in this process. Perhaps the best anecdotal example of this in the hydraulic fracturing discussion is the role of comment periods in the New York process, where interest groups as well as regular citizens were allowed to read a draft of the policy and propose changes, voice concerns, and talk with politicians and policymakers to address particular issues that came up. The result of one of these periods was a complete reworking of the entire process in response to complaints about environmental protection. Clearly, interest groups can have an effect on the evolution of policy, shown as IG_i.

Using information gathered from the website followthemoney.org, combined with a form of factor analysis called Principle Component Analysis (PCA)[5] I created four different variables to measure the strength of different interest groups.[6]

[5]PCA is a tool that allows you view and understand the patterns within a set of variables, and compress the variables without losing those patterns, and was used in this scenario to combine several different variables (see below) to create a cohesive measure of interest group strength. (STATA, 2013).

[6]In essence, the website "followthemoney.org" allows for classification of contributions to politicians and political parties by sector and sub-sector categories. I first created two groups to represent the "energy" and "environmental" categories. The energy category is a combination of the *Miscellaneous Energy & Natural Resources, Miscellaneous Energy, Oil & Gas, Mining, and Waste Management* categories, while the environmental categories is a combination of *fisheries and wildlife, hunting, and pro-environmental policy* categories.

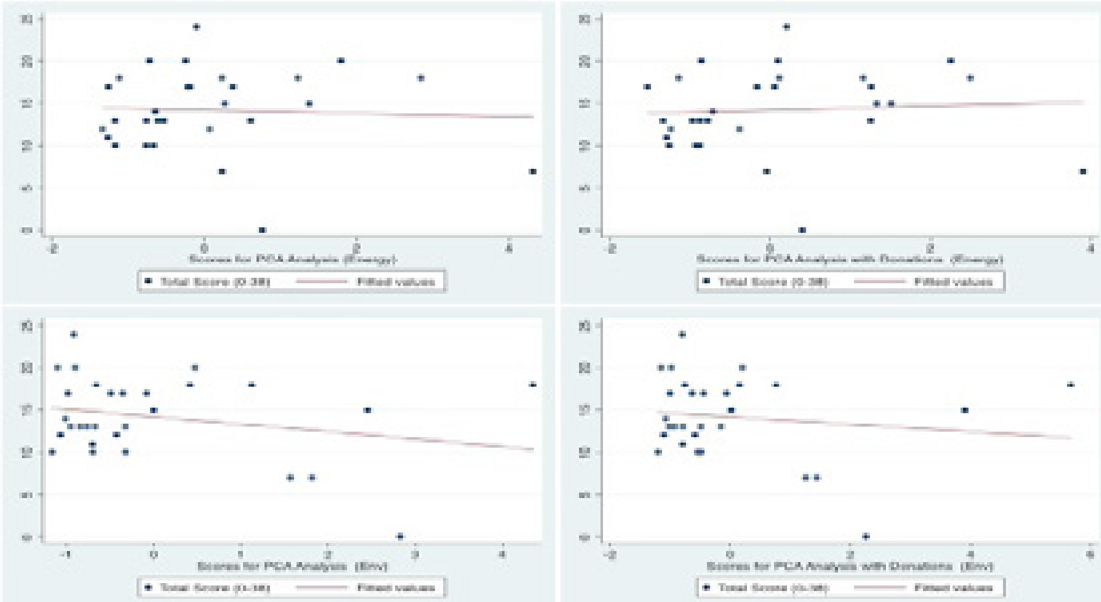

Figure 3: Four scatterplots of the different measures of interest group strength. From top left: (a) energy industry interest group measure without donations, (b) energy industry interest group measure with donations, (c) environmental industry interest group measure without donations, (b) environmental industry interest group measure with donations.

Two variables were created looking at both "energy" and "environmental" interest groups. All variables incorporated information on the number of lobbyists and "lobbyist clients", or those who hired and use lobbyists. One variable in each interest group also incorporated actual donation from each interest group category (See Figure 3). [7]

Natural Gas Industry

Another important factor to control for is the current presence of natural gas in the state. It is easy to see that an active natural gas industry would lead to a change in policy awareness that could affect the development of regulation and perhaps lead to a different level of regulatory stringency. It is common in the literature to control for the activity of the industry in question, whether that means looking and electricity prices or industry activity in the policy studies of renewable portfolio standards. I used data gathered by the Energy Information Agency on both the number of natural gas wells and the total amount of natural gas extracted for each state from 2007 to 2010, shown in the model as W_i. Given the consequence of the wells themselves – in terms of jobs and environmental impact – I focus there. I created two different measures based on natural gas wells. The first was a mean of the number of wells during the first two years, lagged to consider the effect on policy development; the second was a growth rate for each state over the course of the four years.

Controls

Finally, I use data from the US Census and Bureau of Labor Statistics on a state's urban population and per capita income (C_i). It is possible that wealth could correlate with stronger regulations, especially if we treat environmental quality as a normal good. Wealthier states might have a preference for stronger regulations that restrict potential contamination. In addition, the size

[7] I decided to create this second group because of some small data problems; namely, there was a reported 0 donations for Virginia, which seemed inaccurate, and reflective not of an actual absence of donations but a gap in the data.

of the urban population in a state might be worth considering. Rural communities are exposed to most environmental risk of hydraulic fracturing, but at the same time large urban centers might exert political force to limit the potential contamination of water sources. For example, New York City has raised fears that its aquifers in upstate New York might be at risk of contamination, a threat that could increase regulatory strength.

IV. Methodology

To address the effect these different state level factors might have on natural gas regulation; I first consider a Poisson Model. This model examines count data, in this case the regulatory stringency score. To make sure the results of this model were robust, I also used negative binomial. The results did not differ in major ways from the results of the Poisson regressions, so only the Poisson results are reported below.

Given the existence of several outliers in the data, I also chose to use a Probit model to measure what factors affect the classification of regulations into the categories of "strong" and "weak". A Probit model examines dichotomous outcomes in the dependent variable, in this case, whether a state has strong (dependent variable = 1) or weak (dependent variable = 0) regulation. To measure strong and weak regulations, I found the median regulation score, and the states with higher scores were marked as "strong", while those below were marked as "weak".

V. Results

The results from the analysis outlined above show a lack of statistical significance for almost all variables in this regression, with the exception being both the current and historic resource extraction variables. Columns 1 – 4 (see following page for table) correspond with the usage of different measures of interest group strength, and in each specification, the results stay constant. There were several other variations of different variables explored. First, both the growth in natural gas wells and the mean number of wells was used to examine the current natural gas market in each state. Second, regressions were run both with and without the two controls – urban population and per capita income. Third, Washington was excluded from some regressions. In total, 64 regressions were run for this paper, each with slightly different specifications to account for potential alterations in the model. There were 32 regressions for each of the modeling techniques – Probit and Poisson. I viewed this methodological variation as a series of robustness checks. (Leamer, 1983)[8]

With the potential exception of the resource extraction variables, the results for the different regressions are varied and inconsistent. There are regressions where other variables are statistically significant. However, viewing each regression alternative, I see that the model is very susceptible to changes in variables and functional forms. Even the resource extraction variables have a weaker significance when the Probit model is used. As a result, we can only tentatively conclude from these regressions that the presence of the natural gas industry causes regulation to emerge or to strengthen. Given data and model restrictions – mainly due to the limited sample size – I cannot draw any strong conclusions from any regression.

[8] For the do-files, data and full results from the regressions, please contact the author at jiselin@reed.edu.

Table 1: Results of the Poisson Regression

Variables	(1) Model with Environmental and Energy Interest Group Measure	(2) Model with Energy Interest Group Measure	(3) Model with Environmental and Energy Interest Group Measure Including Donations	(4) Model with Energy Interest Group Measure Including Donations
Measure of State Political Ideology (Log)	0.921 [1.19]	1.002 [1.34]	1.021 [1.38]	0.961 [1.28]
Energy Extraction as a Percentage of State GDP (1963)	2.141*** [2.59]	2.013*** [2.61]	2.053** [2.51]	2.289** [2.55]
Measure of Energy Interest Group Strength	-0.043 [-0.50]	-0.013 [-0.27]		
Measure of Environmental Interest Group Strength	0.034 [0.43]			
Growth of Natural Gas Wells (2007-2010)	0.763*** [3.15]	0.718*** [3.28]	0.721*** [3.31]	0.754*** [3.36]
Urban Percentage of State Population (Log)	0.051 [0.15]	0.102 [0.33]	0.109 [0.35]	0.078 [0.25]
Per Capita Income (Log)	-0.206 [-0.36]	-0.286 [-0.54]	-0.306 [-0.60]	-0.262 [-0.51]
Measure of Energy Interest Group Strength with Donations			-0.011 [-0.26]	-0.037 [-0.62]
Measure of Environmental Interest Group Strength with Donations				0.030 [0.63]
Constant	3.453 [0.58]	4.316 [0.77]	4.516 [0.84]	4.028 [0.74]
Observations[9]	29	29	29	29

Even the seemingly robust results for energy extraction and natural gas wells are no longer satisfying.

To summarize, I ran 64 variations of my theoretical model. Given these variations, and the need to make certain simplifying assumptions, I feel that these results – while useful in pointing out areas of future work – are not strong enough to draw many meaningful conclusions.

VI. Discussion and Conclusion

Hydraulic fracturing sits at the well-worn intersection of energy and environmental policy. On the one hand, it speaks to the apparent need for increased amounts of domestic energy.

[9] Z-statistics in brackets, *** p<0.01, ** p<0.05, * p<0.1

At the same time, it poses a complex set of questions for environmental activists who are stuck between a desire to move away from coal and the risk of water pollution that comes with fracturing fluids. (Lowry, 2008) This paper was an attempt to judge how "on paper" regulations lived up to that standard, and see what state-level factors helped or hindered that development. I looked at seven different explanatory variables, each of which accounts for a different factor that the literature indicates should effect policy stringency. Out of the claims made – concerning political culture, interest group strengths, and energy resource extraction - I would hesitantly support only the latter. A different research methodology is necessary to investigate the questions posed in this project. For future work on this project, I would recommend creating a time series panel dataset, taking into account how regulations have changed over time in any of the 25 categories laid out in this project. I would also consider how state regulations changed after the passage of the energy policy act of 2005, a potential natural experiment that is complicated by the technological growth over the similar period. That year would be an obvious starting point as it is the moment most states' gained primacy over water protection. However, some states have always – through compacts with the EPA – had primacy over their own water protection. Primacy is a complex notion requiring compliance with certain minimal standards, but it would be interesting to observe the differences post 2005 in states with and without primacy. States with primacy already had programs in place, while states without would have to construct programs that would react to current state level factors. I would encourage future researchers to create a more complex measure of regulatory strength, incorporating aspects of enforcement and detection of violations. I have so far measured what a state is willing to designate a violation of law, but the next step should incorporate how the state finds and reacts to such violations. In addition, the permitting process should be ranked based on stringency, and taken into account.

As with many projects, the main obstacle to a more rigorous analysis of natural gas regulations and the factors that affected it over time is the availability of data. The project I have outlined above not only calls for a much deeper reading of regulations over the span of decades, but also demands similar rigor in the construction of independent variables over that same span of time (or before, in the case of historical natural gas use). The question of how natural gas regulation will evolve in the future based on state level factors is relevant in a number of ways, given the role that hydraulic fracturing in posed to play for the foreseeable future.

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