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Risk and benefits in a fracking boom: Evidence from Colorado

Adam Mayer

Colorado State University, United States

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ABSTRACT

Unconventional oil and gas technology such as hydraulic fracturing ("fracking") has created a boom in production in the United States. In this paper we add to the growing literature on public perceptions of risk and benefits related to fracking using data from Colorado. We find that trust in the oil and gas industry is powerful predictor of a range of risk and benefit perceptions while other ostensibly important variables—such as the extent of local drilling or the perceived economic significance of the oil and gas industry—have little role in risk and benefit perceptions. The effect of trust is robust across several different types of risk and benefits perceptions and survives the inclusion of an array of control variables. Moving forward, we suggest researchers work to understand the factors which create public trust in the oil and gas industry.

1. Introduction

Hydraulic fracturing ("fracking") is increasingly coupled with horizontal drilling as a means to extract oil and gas from "tight" shale formations located in previously unreachable underground deposits. The deployment of these technologies has ushered in a new era of onshore, unconventional oil and gas production in the U.S. (Krupnick et al., 2014; Yergin, 2011). By providing and abundant source of readily available natural gas fracking can reduce the overall carbon footprint of the U.S. economy while simultaneously providing jobs and tax revenue to economically marginalized parts of the country (Sovacool, 2014; Munasib and Rickman, 2015; Newell and Raimi, 2015; Lee, 2015). On the other hand, the rapid spread of fracking has also been associated with adverse environmental impacts, negative effects on public health, and strains on public infrastructure (Finkel and Law, 2011; Colborn et al., 2011; Hill, 2014; Holzman, 2011; Graham et al., 2015). States and local governments are still struggling to foment a policy regime for unconventional oil and gas extraction (Rabe, 2014; Warner and Shapiro, 2013; Davis, 2014; Fisk, 2013; Zirogiannis et al., 2016). Thus, it is imperative for social scientists to understand public perceptions of risks and benefits regarding fracking[1] to inform better policy-making and risk governance strategies.

The purpose of this paper is to understand the complex array of risk and benefit perceptions held by the general public using data from state-wide survey of Colorado residents. Colorado is at the epicenter of the fracking boom with roughly 55,000 active oil and gas wells (COGCC, 2015) yet researchers have given it much less attention than other areas. Pennsylvania, for instance, has been the focus of much social science literature (e.g. Malin, 2013; Malin Stephanie and DeMaster, 2016; Jacquet and Stedman, 2013; Jacquet, 2012; Brasier et al., 2013) while others have national survey data (e.g. Boudet et al., 2013; Davis and Fisk, 2014; Clarke et al., 2015). In this paper we argue that variables like unwanted proximity, trust in regulators and the oil and gas industry, and the perceived importance of the oil and gas industry are important predictors of risk and benefit perceptions. Typically, prior research has aggregated risk and benefit perceptions into additive scales (e.g. Jacquet, 2012; Schafft et al., 2013); here we consider risk and benefit perceptions individually to reveal overlooked nuances into the contribution of different predictors of risk and benefit

[1] The term "fracking" is used throughout this paper to refer to the entire process of unconventional oil and gas development from exploration to drilling to the storage of waste and by-productions. While fracking is technically only used for a short time to stimulate an oil or gas well it has become a catch-all term in the public mind for the entire process of unconventional, onshore oil and gas development. We also ask that the reader bear in mind that, as of the writing of this article, onshore oil and gas production in the United States is in decline and the fracking boom may be nearing an end.

E-mail address: apmayer@rams.colostate.edu (A. Mayer).

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perceptions. In the next section we review the relevant social science literature on fracking, risk and benefit perceptions, and trust.[2]

2. Literature review

2.1. Public views on fracking risks and benefits

Nationally, a large portion of the public is unaware of or has little information about fracking (Boudet et al., 2013; Clarke et al., 2015). Populations that are more familiar with the issue perceive a number of risks and benefits related to the fracking boom. Many note economic benefits like jobs, increased tax revenue, and improved public services (Theodori, 2009; Silva and Crowe, 2015; Ceresola and Crowe, 2015; Willow, 2015; Jacquet and Stedman, 2013; Jacquet, 2012; Brasier et al., 2013) though these benefit perceptions are far from uniform. Theodori (2009) found inconsistent perceptions of local natural gas development; some informants pointed to economic benefits and others suggested that these benefits are minimal. These findings are echoed in two related studies by Schafft et al. (2013) and Schafft et al. (2014) who reported that many school administrators in the Marcellus Shale region point to economic gains from local drilling while others view the direct economic benefits as rather small and transitory. Residents of areas experiencing intense drilling percieve positive multiplier effects for their local economy, such as increased sales at restaurants, alongside negative economic effects like inflated wages and rents (Schafft et al., 2014; Brasier et al., 2013). Some view the economic windfall of fracking as short-lived while others feel that it will be a motor for long-term economic revitalization (Larson et al., 2014). Other research has shown that fracking is often viewed as environmentally beneficial because it burns cheaper than coal (Ladd, 2013).

In addition to opportunities fracking is often simultaneously perceived as a threat on a number of fronts. The classic "boomtown" literature documents adverse social impacts, such as increased crime or strain on infrastructure, resulting from rapid natural resource development (Kohrs 1974; Cortese and Jones, 1977; Albrecht, 1980). Though foundational, this literature suffers from a range of methodological pIroblems (Wilkinson et al., 1984) and Jacquet and Kay (2014) argued that the model presented in the boomtown literature is not fully applicable to the case of hydraulic fracturing. Still, residents of areas experiencing rapid deployment of fracking raise concerns about crime and other unwelcome social changes (Theodori, 2009; Israel et al., 2015). But perhaps the most significant potential risk of fracking is its environmental impacts. These may relate to nuisances like noise, traffic and dust (Jacquet, 2012; Stedman et al., 2013; Willow, 2015) to more grave problems like water contamination or air pollution (Theodori, 2009; Ladd, 2013; Jacquet and Stedman, 2013; Brasier et al., 2013). Public health concerns are also routinely mentioned (Kriesky et al., 2012; Poole and Hudgins, 2014; Jalbert et al., 2014).

As Ladd (2014) noted, public perceptions of fracking are a paradox, or perhaps a double-edge sword (Ladd (2014), p. 296). Residents of communities impacted by fracking welcome potential economic gains in the form of job or tax revenue yet also express concerns about health, the environment and strains on local infrastructure. To varying degrees public perception is corroborated by empirical analyses. For instance, it is likely that fracking does pose some degree of threat to public health (Hill, 2014; Rabinowitz et al., 2015; Colburn et al., 2011; Kassotis et al., 2014; Kassotis et al., 2016) and the environment (Paulik et al., 2015; Holzman, 2011; Rozell and Reaven, 2012; Ferrar et al., 2013; Howarth et al., 2011) and causes traffic problems (Graham et al., 2015). Alternatively, there is evidence of job growth (Weber, 2012; Munasib and Rickman, 2015; Hastings et al., 2015) and a boost in tax revenue (Newell and Raimi, 2015; Kelsey et al., 2012). The next section describes that factors that drive risk perception.

2.2. What causes risk perception?

The literature cited in the last section indicates that, to some degree, public risk and benefit perceptions track the actual risks and benefits generated by the rapid expansion of hydraulic fracturing. Among risk scholars there is a consensus that risk perception is "socially constructed" but there is still some controversy about how much risk perceptions are socially constructed versus the result of real, actual experience with risk. In this regard, Lupton (1999a) explained that risk theory is gradational—some theorists present risks as purely socially constructed while others adopt a more realist perspective in which actual environmental conditions interact with social forces to create risk perceptions. Further, individual risk theorists often drift between a more constructionist and a more realist approach (Lupton, 1999b).

Numerous survey-based studies have connected actual exposure to risk, typically measured as a contextual level variable, to different types of risk perception. These studies have produced extremely mixed results. Zahran et al. (2006) and Brody et al. (2008) found that proximity to a coast has a small *negative* effect on climate change risk perception while Park and Vedlitz (2013) detected no effect. Some studies show that climate change risk perceptions are increased by temperature anomalies (Egan and Mullin, 2012; Hamilton and Keim, 2009; Hamilton and Stampone, 2013; Shao et al., 2014; Zahran et al., 2006; Brooks et al., 2014; Cutler, 2015) while others observed the opposite (Brody et al., 2008; Goebbert et al., 2012; Shum, 2012; Marquart-Pyatt et al., 2014). Perceptions of air quality do not appear to be impacted by actual air quality (Brody et al., 2004; Kirkby, 1981; Dworkin and Pijawka, 1982; Bickerstaff and Walker, 2002). Conversely, Howel et al. (2002) found that pollution-related risk perceptions were higher for individuals who live in close proximity to industrial facilities. Both Marquart-Pyatt et al. (2014) and McCright et al. (2013) pointed out that some of the research on the risk exposure-risk perception interface has not included adequate individual-level controls for known predictors of risk perception, such as political ideology. Overall, the literature on the interface between risk perception and proximity to risk suggests that exposure to actual risk does not consistently impact risk perceptions.

More specific to fracking, Budgen (2014) used nationally representative survey data to show that respondents who lived in a shale play were more supportive of fracking while Boudet et al. (2016) report that local employment in mining is positively associated with fracking support. Schafft et al. (2013) find that, among school administrators in the Marcellus Shale, perceptions of both risks and benefits rise with the proximity of local drilling. Kriesky et al. (2012) compared two Pennsylvania counties—one with very little drilling and another with a great deal of drilling—and observed only small differences in support for fracking between the two areas. Hence, proximity to fracking may be positively associated with both risk and benefit perceptions.

Case study research points to the specific mechanisms by which exposure to a risk become socially constructed into risk perceptions. In particular, media and local leaders can frame an objective risk as more or less harmful, potentially heightening or attenuating risk perceptions (Kasperson et al., 1988; Renn, 1992;

[2] For general reviews on the social, environmental economic and health dimensions of onshore, unconventional oil and gas development we recommend Short et al. (2015), Jacquet (2014), Jacquet and Stedman (2014), Jackson et al. (2014), Kinnaman (2011) and Lave and Lutz (2014).

Masuda and Garvin, 2006; Zavestoski et al., 2002, 2004). People can become desensitized to living in a toxic environment (Auyero and Swistun, 2007, 2008, 2009). At times, economic dependence upon potentially harmful industrial or extractive industries—whether real or perceived—may reduce risk perceptions related to said industries (Malin, 2013; Malin, 2014, 2015; Ladd, 2014; Bell and York, 2010).

Trust is also a factor in risk perception. For instance, individuals who are more trusting of the nuclear power industry and government are more supportive of nuclear power (Whitfield et al., 2009; Ansolabehere and Konisky, 2009) and trust in the pharmaceutical industry increases support for nanotechnology (Siegrist et al., 2000). Regarding trust in the oil and gas industry, Ladd (2014) argued that Louisianans have historically trusted the industry to operate safely while simultaneously providing jobs and economic development. The primarily regulator of oil and gas activity in Colorado—The Colorado Oil and Gas Conservation Commission (COGCC)—may not be trusted to effectively regulate the industry. Opsal and Shelley (2014) conducted an exhaustive study of COGCC complaint documents and interviewed several people who had filed formal complaints against the oil and gas industry with the agency. They conclude that the COGCC regularly "dilutes" the extent of citizen complaints and has created a de facto regulatory environment which privileges the industry; one informant referred to the COGCC as "The fox guarding the henhouse" (Opsal and Shelley, 2014 p. 575).

Risk perceptions also vary by socio-demographics; whites and males typically perceive lower risks than other groups (Finucane et al., 2000; Kahan et al., 2007; Palmer, 2003). Political ideology is a strong predictor of a range of environmental and technological attitudes (Leiserowitz, 2006; Saleh Safi et al., 2012; Yeo and Cacciotore, 2014) and public opinion about some environmental issues, such as climate change, has become sharply partisan in recent years (McCright and Dunlap, 2011a; McCright and Dunlap, 2011b; McCright and Dunlap, 2013). Conservatives are more supportive of fracking than liberals (Boudet et al., 2013; Clarke et al., 2015; Crowe et al., 2015; Veenstra et al., 2016) but to date political ideology has not been a central variable of interest for social scientists studying fracking.

The present paper bridges these gaps by examining an array of fracking risk and benefit perceptions using trust and the perceived importance of industry while also accounting for actual and unwanted proximity to drilling and relevant ideological and socio-demographic control variables. The next section describes the data, measures, and methods.

3. Data, variables and methods

3.1. Data

Data is provided by a novel state-wide survey data of Colorado residents collected in Fall 2014 by a team of undergraduate and graduate research assistants using an RDD sample which included both land-lines and cell phones. The Colorado population has a very unequal spatial distribution—most of the population is concentrated in the metropolitan Denver area and neighboring cities like Boulder and Colorado Springs. These areas have relatively little drilling. To insure that the views of people who live in close proximity to fracking were represented high-drilling, rural areas were purposefully over-sampled by ranking counties by the number of active wells and dividing this ranking into strata. Households were then sampled at random within strata.

The survey instrument was exhaustively pre-tested using cognitive pretesting procedures and interviews were conducted

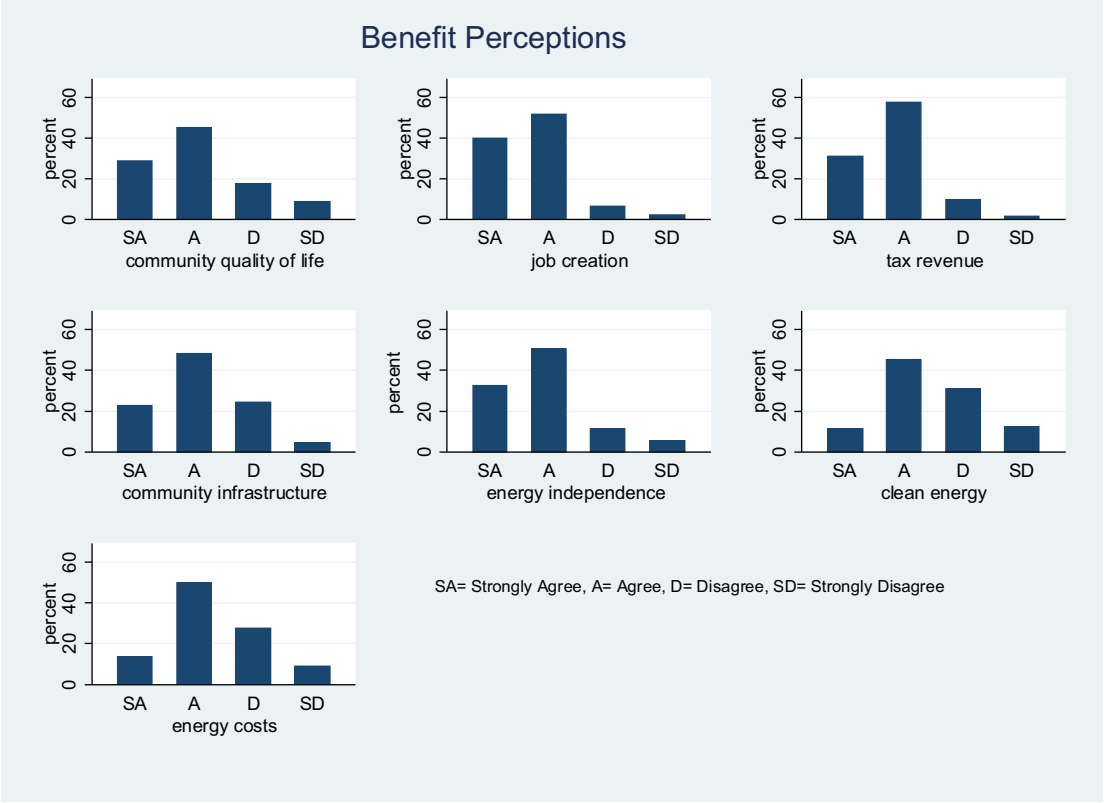

Fig. 1. Benefit Perceptions.

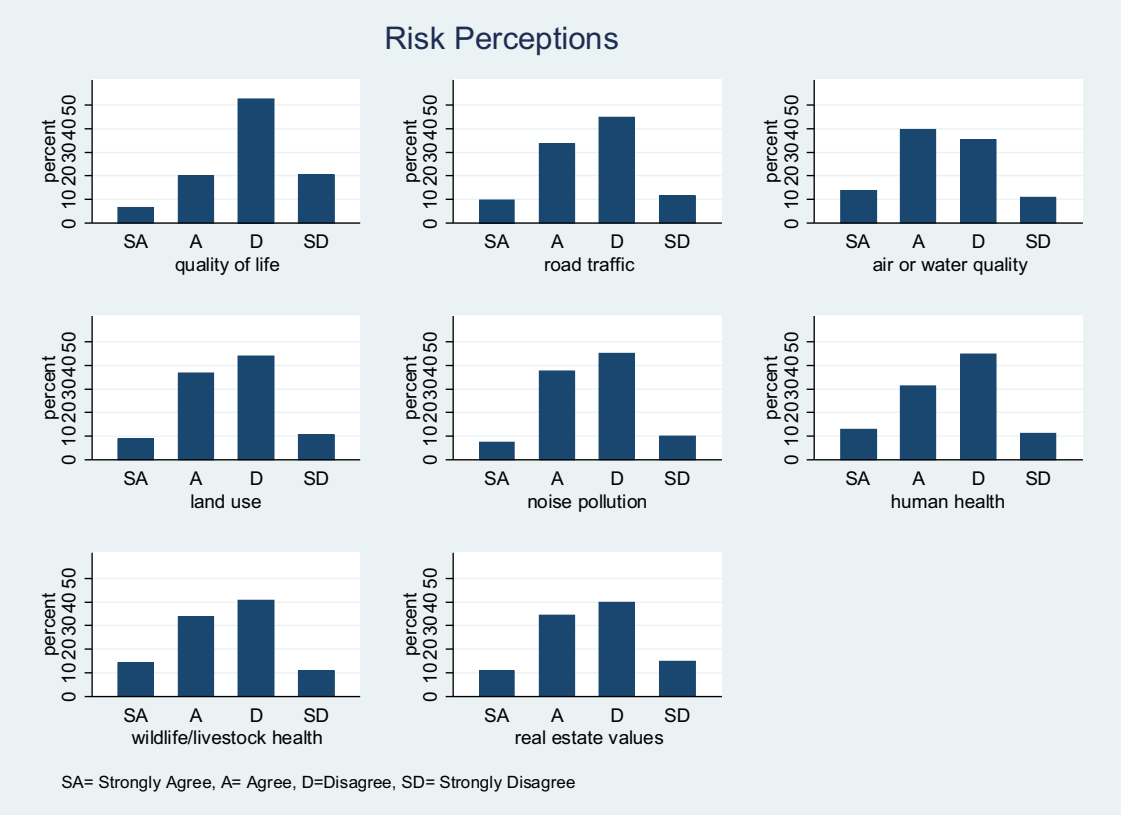

Fig. 2. Risk Perceptions.

in both English and Spanish using an 8 call-back rule. The response rate was 9%, similar to other studies of energy attitudes (e.g. Clarke et al., 2015; Pew, 2014a; Pew, 2014b).

Evensen et al. (2014) found that question wording might bias survey respondents. Specifically, the term "fracking" was found to elicit greater negative reactions while the term "shale gas development" was more neutral. To avoid this type of bias the survey instrument primarily used the term "oil and gas activity". Before respondents were asked any specific questions, interviewers explained that "oil and gas activity" referred to the entire process of oil and gas development from exploration to drilling to processing using a standardized prompt.

3.2. Dependent variable: benefit perceptions

Benefit perceptions were assessed using likert type items in which respondents could "strongly agree" to "strongly disagree" that oil and gas activity in their area has had a positive impact on: community quality of life, job creation, tax revenue, investment in infrastructure, energy costs, energy independence, and clean energy. The distribution of these questions is shown in Fig. 1.

Fig. 1 demonstrates that Coloradoans perceive a number of benefits. In particular, a strong majority of respondents believe that oil and gas development creates jobs (92% "strongly agree" or "agree") and generates tax revenue (89% "strongly agree" or "agree"). Results for the other benefits are less starkly skewed but, overall, fracking is seen as beneficial on a number of fronts. Most of these variables have a rather sparse distribution—data sparseness of this type is known to induce bias regression coefficients unless the sample size is unusually large (Heinze and Schemper, 2002; Albert and Anderson, 1984; Peduzzi et al., 1996). To reduce bias in the coefficients the benefit indicators were dichotomized (0 = strongly disagree and disagree, 1 = agree and strongly agree).

3.3. Dependent Variable: Risk Perceptions

In addition to benefits fracking is also believed to cause a number of problems. To understand risk perceptions a series of likert-type items were used. Respondents were queried about negative impacts in the following areas: real estate values, wildlife/livestock health, human health, noise pollution, land use, air or water quality, road traffic, and quality of life. The distribution of these variables is shown in Fig. 2.

Air and water quality concerns lead the risk perception items (53% "strongly agree" or "agree"). None of the remaining risk perceptions items reach a majority of agreement. Because of the data sparseness concerns discussed above these items are also dichotomized for the purposes of analysis (0 = strongly disagree or disagree, 1 = agree or strongly agree).

3.4. Predictor variables

3.4.1. Proximity

Because we do not have street addresses for the anonymous respondents each respondent was assigned to the latitude and longitude of their zip code's population centroid. Then, a shapefile of all active wells in Colorado was scrapped to attain latitude and longitude for each well. In the next step miles to the nearest well was calculated for each respondent.[3] In addition, the participants were asked to report if they felt oil and gas operations were too close to where they live (0 = no, 1 = yes). Thus, we measure both actual and unwanted proximity to oil and gas operations.

[3] In Stata 14, the user-written *shp2dta* command was employed to scrape the COGCC shapefile and another user-written command, *geonear*, was used to calculate distances in miles.

3.4.2. Importance of the oil and gas industry

As explained above, the perceived importance of an industry to an area may reduce risk perceptions and increase benefit perceptions. The survey instrument included a question which asked respondents to assess the importance of the oil and gas industry to their local area—because of data sparseness this item was recoded so that 0 = oil and gas is not at all important or has very little importance and 1 = oil and gas is somewhat or very important.

3.4.3. Trust

Trust in the oil and gas industry was captured via a survey question worded as follows: "How much do you trust the oil and gas industry to operate safety?" (1 = no trust, 4 = a great deal of trust). Trust in the COGCC was assessed via a survey question which asked how much respondents trusted the COGCC to provide neutral oversight of the oil and gas industry (1 = no trust, 4 = a great deal of trust). The second question was recoded so that 0 = no to very little trust and 1 = some to a great deal of trust.

3.4.4. Political Ideology and socio-demographics

Political ideology was captured with an ordinal scale (1 = liberal, 2 = moderate, 3 = conservative) while sex is binary (1 = male, 2 = female), education is ordinal (1 = less than high school, 6 = graduate degree) and age is in years (Table 1).

3.5. Analytic strategy

In the first step of the analysis we present bivariate correlations between the dependent variables and the predictors; we calculate polychoric correlations because most of the variables are categorical (Olsson, 1979; Holgado-Tello et al., 2010). Next, binary logistic regression models are used to understand the predictors of benefit and risk perceptions. The correlational analysis informs variable selection for the regression models; predictors which have little to no correlation with the dependent variables are excluded from the binary logistic regression models. Both the correlational analysis and logistic regression models use probability weights to adjust for respondent selection and the regression models also adjust for the complex sampling design.

3.6. Correlational analysis: benefit perceptions

Table 2 provides polychoric correlations between the benefit perceptions items and the predictor variables. Proximity to the nearest well has little correlation with any of the benefit perceptions and benefit perceptions are generally slightly lower for respondents who live close to drilling. Unwanted proximity has a relatively strong and consistently negative relationship with benefit perceptions; for instance, it correlates at −0.692 with community quality of life and −0.636 with infrastructure investment. Regarding trust, people with more trust in the oil and gas industry perceive more benefits while trust in the COGCC is also associated with benefit perception, albeit more weakly. The perceived importance of the oil and gas industry has relatively mild correlation with perceived benefits while many of the socio-demographic variables appear to be relatively unimportant. For instance, sex has essentially no correlation (with the lone exception of energy cost benefits were the coefficient is −0.249) and the findings for age, education and income are nearly null. Politically conservative persons have greater benefit perceptions; in particular, conservatives perceive more benefits in terms of infrastructure investment (rho = 0.581) and believe that fracking produces cleaner energy (rho = 0.446).

Table 1
Descriptive Statistics for Predictor Variables.

Variable Name	Question Wording	mean	sd
Unwanted Proximity	Do you feel oil and gas activity is too close to where you live? (0 = no, 1 = yes)	0.109	0.312
Distance to nearest well	Author's calculation from COGCC data	3.449	4.124
Trust-Oil and Gas Industry	How much do you trust the oil and gas industry to operate safely? (1 = No trust, 4 = A Great Deal of Trust)	2.777	0.979
Trust-COGCC	How much do you trust the COGCC to provide neutral oversight of oil and gas activity? (0 = very little to no trust, 1 = A great deal to some trust)	0.763	0.426
Importance- Oil and Gas	How important is oil and gas activity to your local area? (0 = not at all important	0.503	0.501
Sex	0 = male, 1 = female	1.478	0.500
Political Ideology	How would you describe your political beliefs? (1 = very liberal, 5 = very conservative)	3.107	1.206
Education	What is the highest level of education you have received?	4.453	1.368
Income	What is your total household income before taxes? (0 = less than $25,000, 6 = greater than $150,000)	3.609	1.634
Age	Age in years (author's calculation)	51.652	16.250
White	What is your race or ethnicity? (0 = non-white, 1 = white)	0.825	0.381

Table 2
Polychoric correlations for benefit perception items and predictor variables.

	Community Quality of Life	Jobs	Tax Revenue	Infrastructure Investment	Energy Independence	Clean Energy	Energy Bills
Unwanted Proximity	−0.692	−0.583	−0.447	−0.636	−0.498	−0.394	−0.341
Distance to nearest well	−0.196	0.109	−0.075	−0.100	−0.067	−0.131	−0.086
Trust-Oil and Gas Industry	0.755	0.654	0.647	0.745	0.599	0.561	0.410
Trust-COGCC	0.356	0.566	0.432	0.369	0.430	0.297	0.320
Importance- Oil and Gas	0.396	0.473	0.511	0.479	0.289	0.284	0.146
Sex	−0.046	−0.196	−0.171	−0.031	−0.072	0.087	−0.249
Political Ideology	0.379	0.316	0.386	0.581	0.267	0.446	0.358
Education	−0.114	−0.112	0.048	−0.190	−0.020	−0.287	−0.141
Income	0.091	0.177	0.189	−0.006	0.140	−0.153	−0.101
Age	−0.192	−0.018	−0.044	−0.028	0.036	−0.047	−0.083
White	0.025	−0.009	−0.100	−0.152	−0.115	−0.294	−0.146

Bivariate polychoric correlations between the risk items and the predictors are displayed in Table 3. Here, actual proximity to oil and gas drilling have little correlation with risk perceptions—with the exception of wildlife or livestock risks (rho = 0.254). Unwanted proximity correlates moderately to strongly with risk perceptions while trust in the oil and gas industry is negatively associated with risk perception; there are especially strong associations between lack of trust in the industry and the perception of air or water quality risks (rho = −0.782) and human health risk (rho = −0.709). Also, respondents who believe that the oil and gas industry is important to their area have lower risk perceptions and trust in regulators has a milder inverse relationship. Political conservativism is associated with less risk perception. On the other hand, sex, age and education have very little association with the risk perception variables and income is mostly weakly correlated.

3.7. Statistical models

Because the outcome variables are binary we use a series of binary logistic regression models for the risk and benefit items. To simplify the models and preserve statistical power the socio-demographic variables—age, sex, income and education—which correlated very weakly with risk and benefit perceptions—are excluded. The *logit* command in Stata 14/IC was used to estimate the models (StataCorp 2014). All models include probability weights to adjust for non-response. Standard multi-collinearity diagnostics indicate no troublesome multicollinearity. Due to the large number of models our discussion of the modelling results focusses on finding patterns across models.

3.7.1. Benefit models

Results for the benefit perception model are reported in Table 4. Political ideology has relatively little influence in all of the models; there is no statistically significant difference between moderates and liberals or even conservatives and liberals in any of the models with the lone exception of infrastructure investment (b = 1.200, $p < 0.01$). Perceived importance of the oil and gas industry only predicts infrastructure support though the coefficients for jobs, tax revenue and community quality of life are practically significant. Trust in the oil and gas industry is a strong and statistically significant predictor of benefit perceptions; individuals with greater trust in the industry perceive greater benefits in most models. Trust in the COGCC has little to no impact on benefit perceptions in any of the models while unwanted proximity only

Table 3
Polychoric correlations for risk perception items and predictor variables.

	Traffic	Air and Water Quality	Land Use	Noise	Human Health	Livestock/Wildlife Health	Real Estate Values	Quality of life
Unwanted Proximity	0.741	0.760	0.641	0.609	0.641	0.521	0.480	0.619
Distance to nearest well	0.183	0.160	0.127	0.124	0.144	0.254	0.092	0.093
Trust-Oil and Gas Industry	−0.613	−0.782	−0.701	−0.612	−0.709	−0.726	−0.563	−0.426
Trust-COGCC	−0.238	−0.252	−0.273	−0.243	−0.328	−0.317	−0.336	−0.498
Importance- Oil and Gas	−0.145	−0.305	−0.340	−0.249	−0.341	−0.379	−0.320	−0.410
Sex	−0.032	0.029	0.098	−0.002	0.083	0.167	0.048	0.008
Political Ideology	−0.336	−0.586	−0.529	−0.571	−0.599	−0.591	−0.542	−0.447
Education	0.114	0.080	0.011	0.126	0.034	0.106	0.117	0.066
Income	−0.015	−0.167	−0.276	−0.200	−0.107	−0.243	−0.163	−0.101
Age	0.036	−0.186	−0.026	−0.105	−0.022	−0.119	−0.034	−0.056
White	0.094	−0.136	−0.108	0.034	−0.106	−0.205	0.007	−0.043

Table 4
Binary Logistic Regression for Benefit Perceptions.

	Community Quality of Life	Jobs	Tax Revenue	Infrastructure Investment	Energy Independence	Clean Energy	Community Quality of Life
Political Ideology *(ref liberal)*							
Moderate	0.135	0.399	−0.066	0.764	−0.316	−0.463	0.537
	(0.453)	(0.573)	(0.451)	(0.422)	(0.443)	(0.374)	(0.341)
Conservative	0.635	0.701	0.479	1.200**	0.143	0.500	0.680
	(0.505)	(0.623)	(0.538)	(0.448)	(0.547)	(0.389)	(0.392)
Importance(Oil &Gas)	0.672	0.801	0.774	0.710*	0.292	0.226	−0.141
	(0.399)	(0.579)	(0.431)	(0.342)	(0.396)	(0.316)	(0.296)
Trust-Oil and Gas Industry *(ref no trust)*							
Very little trust	0.886	1.007	0.496	0.535	1.235*	0.225	1.004
	(0.608)	(0.576)	(0.564)	(0.670)	(0.560)	(0.600)	(0.553)
Some trust	2.488**	1.998**	2.031**	2.161**	1.993**	1.484*	1.598**
	(0.632)	(0.732)	(0.644)	(0.680)	(0.587)	(0.616)	(0.550)
A great deal of trust	3.828**	3.139l**	2.719**	3.019**	3.206**	2.258**	2.269**
	(1.105)	(0.963)	(0.854)	(0.822)	(0.770)	(0.701)	(0.625)
Unwanted Proximity	−1.249*	−0.407	−0.336	−0.933	−0.786	−0.095	−0.310
	(0.555)	(0.590)	(0.602)	(0.675)	(0.547)	(0.563)	(0.517)
Distance	−0.085	0.044	0.090	−0.046	0.032	−0.052	−0.011
	(0.053)	(0.061)	(0.067)	(0.047)	(0.050)	(0.042)	(0.041)
Trust-COGCC	−0.287	0.929	−0.413	0.185	0.595	0.494	0.136
	(0.508)	(0.493)	(0.476)	(0.480)	(0.418)	(0.363)	(0.380)
Constant	−1.547	−1.178	−0.987	−2.714	−0.906	−1.531	−1.199
–							
N	320	322	321	322	321	321	321

** $p < 0.01$. Standard errors reported in parentheses.

reaches statistical significance for community quality of life. Here, individuals who believe that oil and gas drilling is too close to where they live perceive lower quality of life benefits ($b = -1.249$, $p < 0.05$). On the other hand, actual proximity to oil and gas operations had a very little explanatory power in any of the models.

3.7.2. Risk models

Table 5 provides the results of the binary logistic regression models for the risk perception items. Compared to benefit perceptions political ideology does predict some types of risk perceptions; conservatives believe fracking produces less noise-related problems and lower risk to human health and livestock. Still, political ideology has a null effect in many of the other models. The perceived importance of the oil and gas industry does not reach statistical significance in any of the models though the coefficients for quality of life, livestock/wildlife health and human health may have some practical significance; here, risk perceptions decline as the perceived importance of the oil and gas industry increases (e.g $b = -0.670$ in the quality of life model). Trust in the oil and gas industry is an especially relevant predictor of fracking risk perceptions. Individuals who trust the industry perceive less of every type of risk; the effect of "A great deal of trust" on air and water risks is especially strong ($b = -4.178$, $p < 0.01$). Unwelcome proximity of oil and gas operations predicts risk perceptions in the area of traffic, air or water quality, noise and human health while actual distance in general has almost no effect. Trust in the COGCC is again non-significant and its coefficient appears practically small across all risk perceptions.

4. Discussion and conclusion

The purpose of this paper was to understand fracking risk and benefit perceptions in an understudied area—the state of Colorado—using novel survey data and indicators for a range of possible benefits and risk perceptions. This section discusses the modelling results and situates this analysis in the existing research.

Unlike prior studies, we did not combine the risk and benefit perceptions items into an additive scale. By not doing so the analysis reported here reveals several important nuances. In particular, there are few consistent predictors of all types of risk or benefit perceptions.

Compared to other variables, trust in the oil and gas industry is an important variable across all of the risk and benefit perceptions models. Ladd (2014) suggested that many people who live in areas that have a history of extractive activity implicitly trust the industry to provide jobs and operate safely; as such, trust be reflective of a type of informal social contract between the oil and gas industry and the public. Trust in the oil and gas industry is a uniquely important variable, at least in Colorado, because it is associated with greater benefit perception and lower risk perception. Following Ladd (2014), the importance of trust is likely rooted in the historical economic and cultural importance of extractive industries in Colorado.

The inconsistent and often null results for political ideology deserve discussion. As noted earlier political ideology has emerged as an especially powerful explanatory variable for some environmental issues—particularly climate change (e.g. McCright and Dunlap, 2013; McCright and Dunlap, 2011a; McCright and Dunlap, 2011b)—and other analyses have observed that political conservatives are more supportive of fracking (Clarke et al., 2015; Crowe et al., 2015). Political ideology can be understood as a type of social identity in which people rely on information from other members of their social group to formulate their own views about complex, abstract issues (Cohen, 2003; Jost et al., 2009; Malka and Lelkes, 2010). It is possible that political ideology may have an inconsistent role in fracking perceptions in Colorado because oil and gas drilling is so proximate to where people live and work. That is, fracking is unlike climate change in that it is not abstract or distant but rather an issue that many engage with in some way on a regular basis. Perhaps because of this personal salience Coloradoans may lean less heavily on political ideology as a heuristic to inform their opinions.

On the other hand, the perceived importance of the oil and gas industry has almost no effect as a predictor of either risk or benefit perceptions. This finding is especially important given that other research has shown that real or perceived economic dependence on extractive industries may blunt risk perceptions and lead to

Table 5
Binary Logistic Regression for Risk Perceptions.

	Quality of Life	Traffic	Air or Water	Land Use	Noise	Wild Life/Livestock	Real Estate	Health
Political Ideology (*ref. liberal*)								
Moderate	0.240	0.338	−0.022	−0.475	−0.445	−0.467	−0.630	−1.028**
	(0.467)	(0.362)	(0.446)	(0.373)	(0.364)	(0.408)	(0.350)	(0.385)
Conservative	−0.549	−0.336	−0.840	−0.575	−1.711**	−0.917*	−0.724	−1.134**
	(0.515)	(0.408)	(0.431)	(0.432)	(0.383)	(0.421)	(0.383)	(0.430)
Importance(Oil &Gas)	−0.670	0.214	−0.387	−0.208	−0.011	−0.633	−0.193	−0.426
	(0.452)	(0.301)	(0.342)	(0.315)	(0.313)	(0.327)	(0.293)	(0.335)
Trust-Oil and Gas Industry *(ref no trust)*								
Very little trust	−1.415*	−1.011	−0.297	−1.059	−1.456**	−0.648	−0.155	−1.108
	(0.604)	(0.543)	(0.847)	(0.620)	(0.557)	(0.727)	(0.548)	(0.684)
Some Trust	−2.974**	−1.167*	−2.688**	−2.544**	−1.171*	−2.296**	−0.922	−2.419**
	(0.659)	(0.543)	(0.870)	(0.653)	(0.577)	(0.746)	(0.546)	(0.687)
A great deal of trust	−3.367**	−1.748**	−4.178**	−3.195**	−2.534**	−3.159**	−1.477*	−2.947**
	(0.881)	(0.617)	(0.964)	(0.765)	(0.707)	(0.848)	(0.606)	(0.749)
Unwanted Proximity	1.158	1.655**	3.162**	0.907	1.692**	0.622	0.928	1.613*
	(0.605)	(0.601)	(1.148)	(0.642)	(0.561)	(0.564)	(0.499)	(0.659)
Distance	0.031	0.076	0.095	0.035	0.042	0.173**	−0.007	0.028
	(0.046)	(0.042)	(0.053)	(0.046)	(0.045)	(0.058)	(0.043)	(0.046)
Trust-COGCC	−0.029	−0.038	0.980	0.751	0.274	0.332	−0.050	−0.095
	(0.474)	(0.380)	(0.515)	(0.521)	(0.429)	(0.477)	(0.405)	(0.486)
Constant	1.817	−0.005	2.052	1.458	1.134	2.374	1.143	2.888
–								
N	303	322	322	322	321	322	321	318

* $p < 0.05$.
** $p < 0.01$. Standard errors reported in parentheses.

exaggerated benefit perceptions (e.g. Bell and York, 2010; Blaacker et al., 2012; Cabrejas, 2012). Our results suggest that risk and benefit perceptions, at least in the case of fracking, are relatively independent of economic dependency. Bell and York (Bell and York, 2010) explain that the coal industry "constructs" an economic identity around coal extraction in West Virginia via intense PR efforts. It is possible that the oil and gas industry has not engaged in such intense PR efforts in Colorado, leading to a null finding for the perceived importance of the industry.

Surprisingly, trust in the COGCC has a negligible effect in any of the models—other research has shown that trust in government regulators helps explain risk or benefit perceptions (Whitfield et al., 2009). There are a few reasons for this null finding. For one, some individuals, especially politically conservative individuals, may hold a general distrust for government (Cook and Gronke, 2005). Secondly, the COGCC is seen by many Coloradoans, including those who have had interactions with the agency, as too closely aligned with the oil and gas industry (Opsal and Shelley, 2014). Thus, there may be opposing dynamics of trust captured within that single variable, leading to a null effect.

Gender, long recognized as a significant factor in risk perception and environmental attitudes more generally (e.g. Gustafsod, 1998; Finucane et al., 2000; Xiao and McCright, 2015; Strapko et al., 2016), has almost no correlation with any of the risk perception or benefit perception items. Resistance to extractive industries in other parts of the U.S., such as Appalachia, is largely driven by women (Bell and Braun, 2010; Smith, 2014) and other research has found that women are somewhat less supportive of fracking than men (e.g. Jacquet, 2012). On the other hand, Smith's (Smith, 2008; Smith, 2010; Smith, 2014) research on Wyoming coal miners indicates that extractive industries in the American West are likely more gender egalitarian than in other regions. Hence, it is possible that the effect of gender on energy or environmental attitudes is contextual—it varies from place to place and across industries.

There are several limitations to this research. The sample size, while adequate for the models presented, does not lend itself to complex models with more control variables and endogenous predictors. Secondly, the cross-sectional nature of this data does not facilitate strong causal inference. Thirdly, and perhaps most importantly, this paper has identified trust in industry as a key explanatory variable for both risk and benefit perceptions but the estimated models do not explain why some individuals trust in industry more than others.

We suggest that more research is needed to understand what drives specific fracking risk perceptions, particularly in areas outside of Pennsylvania. In particular, unpacking the forces which shape trust in industry and regulators is an important endeavor for further scholarship. We also suggest that future research should attend carefully to benefit perceptions as the fracking boom is associated with both risks and benefits. There is a critical mass of cross-sectional scholarship on fracking opinions (e.g. Jacquet, 2012; Jacquet and Stedman, 2013; Boudet et al., 2014; the present paper) but, to the best of our knowledge, there is little scholarship that has examined how attitudes towards fracking evolve over time using longitudinal data (Willits et al., 2013 provide a notable exception by using two waves of data). This is a key limitation because public attitudes towards a natural resource boom are hypothesized to change as the boom progresses (e.g. Brown et al., 2005). Further, we suspect that communities affected by the fracking boom weigh the risks and benefits associated with the process. Moving forward we suggest that future scholarship should work to understand the calculus of risk and benefits that inform public acceptance and resistance to the expansion of fracking.

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