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**The Politics of Scientific Consensus? Political Divergence and Partisanship in
Unconventional Energy Development in the United States**

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Abstract

Risk communication scholars have examined public perception of scientific consensus on a variety of politically controversial risk topics; social-psychological factors that shape such views (i.e., political ideology); and effects on issue attitudes. Few studies, however, have combined these antecedents and outcomes within a single framework – one that describes how politically polarized attitudes emerge via ideologically-divergent perceptions of scientific agreement. We address this shortcoming in the context of an emerging risk topic - unconventional oil and natural gas development (UOGD) in the United States – that is politically controversial and where scientific agreement on specific impacts along with value-laden assessments of benefit and risk are subjects of scholarly and public debate. Using a quota survey of United States adults (n = 700), we find that political conservatism heightened support indirectly via: (1) perceived scientific consensus that benefits outweigh the risks and, in turn, the belief that UOGD's health, economic, and environmental impacts in the United States have been positive and (2) lower perception of scientific consensus that risks outweigh benefits, which likewise heightened beliefs that aforementioned impacts have been positive. We discuss implications for risk communication research related to energy development.

Keywords: Hydraulic fracturing; shale oil and gas development; risk communication; political ideology; scientific consensus

1. Introduction

From vaccine safety to climate change, risk communication scholars have examined public perceptions of scientific agreement (or lack thereof) on a variety of politically controversial risk topics along with social-psychological antecedents and attitudinal outcomes of such views [1-7]. In this article, we contribute to this research in the context of unconventional oil and natural gas development (UOGD)¹: a risk issue that is politically divisive and where scientific discourse on specific impacts along with value-laden assessments of benefit and risk have garnered scholarly and public attention. In particular, we examine antecedents and outcomes within an integrative framework. Given that political ideology influences how people view information through partisan lenses [8], we suggest that it informs perceptions of scientific consensus (or lack thereof) pertaining to whether UOGD's risks outweigh benefits or vice-versa. Also, with scientists as a trusted information source for UOGD [9], we expect that perceiving a scientific consensus one way or the other would, in turn, exert commensurate effects on perceived impacts and issue support. These relationships provide insight into how polarized attitudes emerge via ideologically-divergent beliefs about scientific agreement – a premise that studies in other risk domains have implicitly suggested but not directly examined [3-5]. More broadly, we further contribute to social science research on factors that drive public acceptance of energy development - research that has been central to the mission of this journal [10].

We put our relationships to the test using a national quota sample (n=700) of adults in the United States. Home to one of the world's largest reserves of unconventional oil and natural gas and the world's largest producer of both [11], communities throughout the country have experienced various impacts associated with this novel type of energy extraction. Also, in few places in this topic more politically divisive [12-13] and scientific discourse on its potential

impacts, benefits, and risks more a central figure in scholarly and public debate [12, 14].

Therefore, despite our reliance on a single case study, our work has implications for social science research in other locations where UOGD and the debate surrounding it are still emerging.

2.0. UOGD background

“Unconventional” fossil fuel sources such as shale gas and oil require additional well-drilling and stimulation techniques that differ from conventional energy development - specifically, a combination of horizontal drilling that allows access to a greater proportion of resource-bearing rock along with hydraulic fracturing or “fracking,” in which pumping water, sand, and chemicals underground at high pressure allows oil or natural gas “to move more freely from the rock pores to production wells...to the surface” [15]. This combined process uses greater amounts of water, sand, and chemicals and at greater pressures and depths than conventional oil and gas wells [15].

Technically recoverable unconventional natural gas and oil reserves that can be developed using current technology irrespective of profitability are found in numerous geological formations across dozens of countries. Greater natural gas and oil production from these sources as well as greater consumption of the former for electricity generation represents major shifts in global energy policy, and these trends are expected to continue over the next few decades [17]. These macro patterns, however, belie variation across countries in terms of the existence/size of unconventional energy reserves, potential for commercial production, and current levels of commercial exploitation, all due to geological, technological, economic, political, and policy factors [18-20]. Countries span a wide gamut. The U.S, in particular, has one of the largest technically recoverable unconventional reserves in the world and is the leading commercial producer of unconventional oil and natural gas [11, 21]. The result has been increases in

domestic oil and natural gas production, the export of both fuels for the first time in decades [22], and increased natural gas consumption, in particular, for electricity generation at the expense of coal [20].

Others countries such as China and Canada have large reserves and much smaller levels of commercial production, while several nations in Europe, Africa, and South America possess the former and the potential for future commercialization [23-26]. Still others like the United Kingdom possess much smaller reserves, no current commercial development, and little potential for it going forward [21, 23]. Within these categories, moreover, are countries have adopted anti-UGD bans or moratoria on the national level (i.e., Germany and France, [27, 28]) or state/regional level, including the United States [29]. Pro/anti-UOGD movements and the policies they seek to promote speak to the role of public perception in shaping UOGD's long-term trajectory. Such perception reflects individual attitudes as well as broader social discourse among stakeholder groups, with psychological and social factors influencing both [9, 30-43].

3. Overview of proposed framework

3.1. Conceptualizing (perceived) scientific discourse on UOGD

We define scientific consensus as shared agreement on the evidence base surrounding a topic (i.e., the clarity or completeness of available data) as well as the conclusions drawn from that evidence. Scientific consensus in the context of UOGD can be analyzed across two broad dimensions consistent with this conceptual definition. The first involves agreement on evidence pertaining to the likelihood and magnitude of specific impacts, drawing on relevant studies [44-47]. Consensus appears more robust for

some impacts than others. For example, studies have documented various potential pathways for surface and ground water contamination tied to various UOGD-related processes [44] – phenomena that affect both the environment as well as public health [47]. Moreover, a variety of economic impacts have also been documented, energy-related jobs in local communities, higher household wealth among private landowners who lease their land for energy development, and higher levels of economic activity both outcomes may elicit. Each of these effects, in turn, contains inherent assumptions about how many jobs are created, the extent local people fill those jobs, how individuals and companies spent any additional wealth, and the extent energy development crowds out other sources of economic growth such as tourism [48]. At the other end of the spectrum, UOGD's carbon emissions and associated climate impacts are less clear and depend on factors like how much methane escapes as natural gas is extracted, the extent natural consumption for electricity generation displaces coal, and whether such consumption complements or displaces wind and solar [45, 49]. These climate ramifications likewise affect the environment and public health depending on the extent UOGD mitigates or amplifies climate change [49].

A second dimension of scientific consensus, and the subject of our focus, involves agreement on more subjective, value-laden conclusions pertaining to whether certain impacts are risky or beneficial, whether benefits outweigh the risks or vice-versa, and (perhaps ultimately) whether UOGD should take place and (if so) under what conditions. While in theory, this dimension of consensus derives from its counterpart above - that is, agreement on the evidence pertaining to specific impacts can help inform agreement on the conclusions that such evidence would support – in practice, it involves normative considerations that arguably go beyond what any scientific assessment can answer.

Although there is no shortage of studies that gauge public attitudes about the likelihood and magnitude of specific impacts [33-34, 37] and whether those impacts are beneficial or detrimental [9], research on *public perception of scientific agreement* on these dimensions is far less developed. To our knowledge, no studies have examined perceived consensus on the likelihood or magnitude of specific impacts, which would allow for a comparison with actual levels of consensus where available to identify gaps between the two. Such is the case for other topics like anthropogenic climate change and the debunked link between vaccines and autism [50-52]. Moreover, only one study has assessed perceived scientific consensus as to whether UOGD “risks” are high or low [12, 14] and without any examination of psychological antecedents (in particular, political ideology) and subsequent effects on how people view UOGD’s impacts as well as overall issue support.

3.2. Antecedents of perceived scientific consensus on UOGD: The role of political ideology

Political ideology, defined as “a set of beliefs about the role of government that shapes responses to a wide range of specific policy issues” [53, p. 177], has long been associated with support for a variety of energy-related issues in the United States including UOGD [13, 54, 55-59]. Such polarization occurs when psychological, social, cultural, and identity-based antecedents of political ideology [60-63] interact with specific features of an issue such that issue-specific views become closely tied to – and, in essence, a indicative of - one’s ideological leanings. For example, UOGD has arguably become connected with debates surrounding fossil-fuel driven economic development, environmental protection, and government regulation of private industry [64-65] that have long divided political liberals and conservatives. Conservatives who tend to value order, stability, and respect for tradition arguably see in UOGD the sanctity of energy markets unencumbered by government regulation and a status-quo economic system

build on fossil fuels – all reasons to support it. Conversely, liberals who tend to be especially concerned about the environment arguably see in UOGD the potential for health and environmental risk – reasons to oppose it. Moreover, issue polarization on the part of “elites” in positions of influence and authority (such as elected officials) can filter down to the broader public and further amplify ideological schisms [66-67], although the potency of this effect is debated [68]. Nonetheless, Republican elected officials tend to be more uniformly supportive of UOGD than their Democratic counterparts [54].

People’s ideological dispositions not only influence attitudes toward energy issues but also bias how issue-related information and scientific discourse is evaluated, with people often inclined to accept ideologically favorable information while ignoring or counter-arguing unfavorable information [8, 69]. Notions of what UOGD impacts are beneficial or risky; whether those risks outweigh benefits (or vice-versa); and whether there is scientific agreement on these points are inherently value-laden because they involve normative considerations that arguably go beyond what any scientific assessment can provide – not simply what the impacts are but whether they are good/bad and what the implications of those decisions are for UOGD’s trajectory in a given area. Moreover, these notions involve the same politically value-laden questions about economic development, environmental protection, and the role of fossil fuels in society that help drive partisan gaps in UOGD support. For these reasons, while there not may be “objective” scientific consensus for political partisans to accept or reject if it runs counter to their ideological dispositions (as is the case for topics like climate change; [51]), partisans would nonetheless be inclined perceive a scientific consensus related to UOGD’s putative benefits and risks that reflects their own ideologically-informed views [70]. Specifically, concern over protecting the sanctity of energy markets from government regulation along with a fossil fuel-

based economy may lead conservatives to believe in a scientific consensus that UOGD's *benefits* outweigh the *risks*.

Conversely, concern about environmental protection may lead liberals to perceive a consensus that the *risks* outweigh the *benefits*. Stated formally:

- H1: The greater one's political conservatism (on a conservative-liberal continuum), (a) the more likely one will perceive a scientific consensus that UOGD's benefits outweigh risks and (b) the less likely one will perceive a scientific consensus that risks outweigh benefits.

3.3. Outcomes of perceived scientific discourse on UOGD

Studies have examined how perceptions of scientific consensus influence attitudes toward a variety of risk topics. For example, the more one endorses the medical consensus that vaccines are safe and that parents should be required to immunize their children, the lower their perception of vaccine risk and, in turn, the higher their support for mandatory vaccine policies [6]. Also, endorsing the scientific consensus that vaccines do not cause autism is associated with greater belief that there is no connection, which in turn heightens favorable vaccine attitudes [2, 71]. Finally, recognizing the scientific consensus that climate change is happening/human-caused is linked to heightened beliefs about its existence/human causality and, in turn, amplified risk perception and climate policy support [1, 3]. Although our conceptualization of perceived scientific consensus as it applies to UOGD's benefits and risks differs from these other studies, we believe that the same premise applies. By serving as a decision-making cue, especially with scientists a trusted source for UOGD information [9], we suggest that perceptions of a scientific consensus that UOGD's benefits outweigh the risks (or vice-versa) exerts commensurate changes

in how people view its potential impacts as well as overall support. We discuss these relationships in greater detail below.

As noted earlier, various studies have gauged the extent people view specific impacts as likely to happen and positive or negative if they occur [9, 33-34, 37]. Of course, there can be considerable variation in such perceptions based on external factors like the intensity of energy development nearby [37], and people may understandably be undecided on the likelihood, magnitude, and valence of these impacts (or feel that things haven't changed) in the absence of direct personal experiences [40, 72]. Nonetheless, in situations where people have formed opinions, several broad trends emerge. For instance, economic impacts are seen as likely to occur and generally (but not always) positive. People expect jobs in local communities, economic activity, and other effects to increase and be beneficial [33, 40, 72], albeit with some concern over the potential for energy development to crowd-out other local industries such as tourism or recreation [73]. Environmental and public health impacts, furthermore, are viewed as likely to occur and generally (but not always) negative. People expect water and air pollution to get worse and be a potential risk to both the environment and public health [33, 40, 73]. Also, although some believe that UOGD and greater levels of natural gas consumption will can reduce carbon emissions and mitigate climate change, there seems to be far greater belief (and concern) over higher emissions and exacerbated climate change [72-73].

Considering how people view UOGD's health, economic, and environmental impacts, it stands to reason that perceived scientific consensus on its risks/benefits serves a cue that influences how positive/negative people consider these impacts to be, in our case within the United States. That same reasoning would also apply to issue support, with people drawing on

perceived consensus in deciding how acceptable they find unconventional energy development. Therefore, we hypothesize that the more people perceive a scientific consensus that UOGD's benefits outweigh the risks,

- H2a: The more they will view UOGD's health, economic, and environmental impacts in the United States in more positive (or at least less negative) terms.
- H2b: The more supportive they will be.

Conversely, the more people perceive a scientific consensus that UOGD's risks outweigh the benefits,

- H3a: The more they will view UOGD's health, economic, and environmental impacts in the United States in more negative (or at least less positive) terms.
- H3b: The less supportive they will be.

3.4. *An integrative model (see Figure 1)*

In this study, we consider an integrative framework whereby (1) political ideology informs perceptions of scientific consensus about whether UOGD's risks outweigh benefits or vice-versa, and (2) these perceptions (in turn) influence beliefs about its various impacts (i.e., the extent they are seen as positive or negative) and overall support. The last sequence is based on research suggesting that beliefs about the likelihood, magnitude, and positive/negative nature of specific impacts predict issue support [34; 74]. For the latter, unsurprisingly, impacts seen as positive are associated with support, while those seen as negative are associated with opposition. Overall, this framework provides insight into how polarized UOGD attitudes emerge via ideologically-

divergent beliefs about scientific consensus and is consistent with principles of motivated reasoning described in earlier sections. Moreover, social scientists have examined mechanisms driving political polarization for a variety of contentious social issues [60-63], with some hinting of indirect effects involving perceptions of risk-related scientific agreement [3-5]. However, such effects have largely not been directly tested especially in reference to UOGD specifically.

Therefore, we hypothesize the following:

- H4: Greater political conservatism will be associated with higher support via perceived scientific consensus that benefits outweigh risks and, in turn, heightened belief that impacts have been positive.
- H5: Greater political conservatism will be associated with higher support via a lower likelihood of perceiving a scientific consensus that risks outweigh benefits and, in turn, heightened belief that impacts have been positive. (The latter relationship is simply the mirror image of H3a).

4. Methods

4.1. Sample

To test our hypotheses, we conducted a survey of United States adults - an approach well-suited to examining potential associations outlined in our proposed model (see Figure 1). Specifically, we obtained a national quota sample of United States adults 18 years or older (n=700) from the survey vendor Qualtrics in January 2016. Subjects elected to participate in exchange for monetarily equivalent compensation redeemable on the Qualtrics platform. Also, Qualtrics incorporated a number of attention filters (i.e., asking people to select certain responses

for certain questions) to exclude people who were not paying sufficient attention, thus further ensuring high-quality data. The project received human subjects research approval from [AFFILIATION REMOVED FOR PEER REVIEW].

Under a quota-based sampling approach, Qualtrics used e-mail invitations from market research panels and survey research companies as well as self-enrollment through advertisements on web banners and social media to select a sample with demographic and regional quotas designed to mirror corresponding Census-based values. Our two demographic quotas were for gender (a 50-50 split for males and females) and education (roughly a third of the sample with a 4-year college degree or greater), and our regional quota involved the percentage of respondents located in Northeastern, Western, Midwestern, and Southern states. These two demographic variables, especially gender, have emerged as predictors of UOGD support in past studies (13, 43, 74), and while region has tended not be a significant factor likely due to its broad categorization that combines states with/without ongoing UOGD [13], it does provide for a geographically diverse sample. As shown in Table 1, moreover, our quotas largely succeeded in comparison to relevant Census-derived population values. We acknowledge, though, that our sample deviated on other metrics, including self-identified ethnic and racial groups. Racially and ethnically-divergent levels of risk perception reflect levels of societal power and status (i.e., discrimination) that in turn lead to disproportional levels of risk exposure especially among minority communities [75]. Few studies of UOGD-related public opinion, however, incorporate these factors, and null effects have emerged within studies that have done so [13].

Finally, while quota sampling is not probability-based and thus limits our ability to generalize findings to the United States population, it is very useful for testing theory-informed

relationships with a diverse sample that mirrors the population on a number of key demographic fronts. We discuss specific strengths and weaknesses in section 6.3.

4.2. Procedure and measures

After giving informed consent, participants read a short introductory statement on UOGD: “We’d like to ask you a few questions about shale oil and gas development via hydraulic fracturing (or “fracking”). This issue refers to extracting oil and natural gas from shale rock underground. In the United States, a number of states have either begun - or are considering - doing so. Based on this information, please answer the following questions.” Participants then answered questions on political ideology³), perceived scientific consensus that UOGD’s risks outweigh benefits and vice-versa; beliefs about its health, economic, and environmental impacts; and issue support. In addition, several covariates were included as observed exogenous/control variables, including political party affiliation⁴, gender, education, and UOGD familiarity. These covariates have emerged as significant predictors of UOGD-related support in the United States [13, 64].

Table 2 provides all question wordings and response scales, and Table 3 lists the correlations among the main variables in the model minus the covariates.

4.3. Data analysis

Using Mplus [76], we ran a structural regression model (SEM) with confirmatory factor analysis and maximum likelihood (ML) estimation. An SEM approach allowed us to test the various pathways in our hypothesized model, although we acknowledge that cross-sectional data limits us to identifying potential *associations* among variables that may be causal per our model.

However, such data can serve as a foundation for future research that draws on longitudinal sampling techniques.

We first ran the model with all covariates included to minimize biased parameter estimates [77], followed by second (“reduced”) model with non-significant covariates omitted in the interest of parsimony. We calculated both point estimates and 95% bootstrapped and bias-corrected confidence intervals for all hypothesized direct and indirect effects. As shown in Table 4, while model fit was similar across models, it was best for the more parsimonious version. Furthermore, model coefficients (see Table 5) were similar in direction and magnitude of association, with only modest differences in statistical significance. Therefore, we elected to go with the more parsimonious, “reduced” model, $X^2(54) = 115.805, p < 0.001; X^2/df = 2.144$; RMSEA = 0.057 (95% CI: 0.043, 0.072); CFI = 0.973). (NOTE: If the manuscript is accepted, we will include a link to the archived dataset).

5. Results

5.1. Convergent validity

The confirmatory factor analysis revealed strong convergent validity for our latent variables:

- Political ideology toward economic issues ($b = 0.93, p < 0.001$; 95% CI: 0.82, 1.03) and social issues ($b = 1.06, p < 0.001$; 95% CI: 0.96, 1.15) strongly loaded onto the same factor.
- The belief that scientific opinion ($b = 0.77, p < 0.001$; 95% CI: 0.66, 0.8773) and scientific evidence ($b = 0.873, p < 0.001$; 95% CI: 0.77, 1.01) points to UOGD’s risks outweighing benefits strongly loaded onto the same factor.

- The belief that scientific opinion ($b = 0.79, p < 0.001$; 95% CI: 0.69, 0.89) and scientific evidence ($b = 0.92, p < 0.001$; 95% CI: 0.83, 1.03) points to UOGD's benefits outweighing risks strongly loaded onto the same factor.
- Beliefs about the positive/negative nature of UOGD's economic ($b = 0.74, p < 0.001$; 95% CI: 0.64, 0.87), environmental ($b = 0.95, p < 0.001$; 95% CI: 0.85, 1.074), and health impacts in the United States ($b = 0.92, p < 0.001$; 95% CI: 0.81, 1.07) strongly loaded onto the same factor.

5.2. *Direct effects (see Table 5)*

Many of the hypothesized direct effects were supported. First, greater political conservatism was associated with a stronger likelihood of perceiving a scientific consensus that UOGD's benefits outweigh risks ($b = 0.33, p < 0.001$; 95% CI: 0.18, 0.48) and a lower likelihood of perceiving a consensus that risks outweigh benefits ($b = -0.3, p < 0.001$; 95% CI: -0.45, -0.15). Both H1a and H1b were supported. Tables 6 and 7 displays these findings in visual terms, and although we collapsed the continuous measure of political ideology into a nominal liberal/moderate/conservative variable in the interest of simplicity, the main finding mirrors the SEM results. Of particular note, the average partisan gap between liberals and conservatives when it came to perceived scientific consensus on whether UOGD's risks outweigh the benefits across all response levels was nearly 10 percentage points – nearly the same gap as for perceived consensus on whether the benefits outweighed the risks. More specifically, only 24% of liberals felt that “most” or “virtually” all of scientists/scientific evidence pointed to the benefits outweighed risks versus nearly 40% of conservatives. Conversely, nearly 47% of liberals felt that

“most” or virtually” all of scientists/scientific evidence showed than the risks outweighed the benefits versus less than 23% of conservatives.

As an aside, greater political conservatism was not associated with heightened UOGD support ($b = 0.08, p = 0.313$; 95% CI: -0.06, 0.23).

Second, the more respondents perceived scientific consensus that UOGD’s benefits outweigh the risks, the more likely they were to say that its health, economic, and environmental impacts have been positive ($b = 0.67, p < 0.001$; 95% CI: 0.5, 0.9), and the more supportive they were ($b = 0.45, p < 0.001$; 95% CI: 0.3, 0.61). H2a and H2b were both supported. Conversely, the more respondents perceived a scientific consensus that UOGD’s risks outweigh the benefits, the less likely they were to believe that its health, economic, and environmental impacts are positive ($b = -0.19, p = 0.009$; 95% CI: -0.32, -0.04), and the less supportive they were ($b = -0.28, p < 0.001$; 95% CI: -0.39, -0.17). H3a and H3b were both supported.

Third, although not hypothesized, the more respondents believed that UOGD’s health, economic, and environmental impacts have been positive, the more supportive they were ($b = 0.71, p < 0.001$; 95% CI: 0.56, 0.86).

5.3. *Indirect effects (see Table 5)*

To examine indirect effects of political ideology on issue support, we first estimated the total indirect effect ($b = 0.22, p < 0.001$; 95% CI: 0.12, 0.29) followed by the two hypothesized sequential indirect effects. These were both supported. First, greater political conservatism was associated with heightened support via higher likelihood of perceiving scientific consensus that

benefits outweigh risks and, in turn, stronger belief that these impacts have been positive ($b = 0.16$ $p < 0.001$; 95% CI: 0.09, 0.24). H4 was supported.

Second, greater political conservatism was associated with heightened support via lower likelihood of perceiving scientific consensus that risks outweigh benefits and, in turn, a heightened belief that these impacts have been positive ($b = 0.04$, $p = 0.049$; 95% CI: 0.01, 0.09). H5 was supported.

6. Discussion

Scholars have increasingly examined public perception of scientific consensus (or lack thereof) surrounding politically divisive issues along with psychological antecedents (i.e., political ideology) and effects on issue attitudes. In this study, we extend this research by combining antecedents and outcomes within a single framework that we then apply to UOGD.

6.1. Review of key findings – Political ideology and perceived scientific consensus

The first part of our framework examined political ideology as an antecedent to perceived scientific consensus on UOGD's risks versus benefits. The more conservative respondents were, the more likely there were to perceive a scientific consensus that UOGD's benefits outweigh risks and, conversely, the less likely they were to perceive a scientific consensus in the opposite direction. This finding is consistent with motivated reasoning [8] – that given the political polarization surrounding UOGD acceptance [13, 54] and the politically value-laden ramifications of notions of UOGD “risk” and “benefit,” liberals and conservatives are inclined to perceive a scientific consensus that reflects their own ideologically-informed views [70].

6.2. Review of key findings – Political ideology and perceived UOGD impacts, support

The second part of our framework focused on attitudinal outcomes associated with beliefs regarding scientific consensus. We found that perceived scientific consensus that UOGD's benefits outweigh risks was associated with a heightened belief that its health, economic, and environmental impacts in the U.S have been positive (or at least less negative) as well as heightened overall support. Conversely, perceived consensus that risks outweigh benefits was associated with a lower likelihood of believing these impacts to be positive (i.e., more negative) as well as reduced support. These findings reinforce our contention that because scientists remain a trusted source of information about UOGD [9], perceptions of scientific consensus can act as a decision-making cue and exert commensurate effects on beliefs about these impacts as well as issue acceptance.

6.3. Review of key findings – Indirect effect of political ideology on UOGD support

Examining antecedents and outcomes of perceived scientific consensus *simultaneously*, furthermore, allowed us to identify two indirect effects linking political conservatism to UOGD support. In the first, political conservatism heightened support via perceived scientific consensus that benefits outweigh risks and, in turn, beliefs that its health, economic, and environmental impacts have been positive. In the second, conservatism also increased support via a *lower* likelihood of recognizing scientific consensus that risks outweigh benefits, which likewise *heightened* the perception of positive impacts. There is no shortage of research on psychological mechanisms driving political polarization [60-63], and while a few studies have hinted at ideologically-divergent perceptions of risk-related scientific consensus as one such mechanism [3-5], our study is the first to directly examine this premise in general and in regard to UOGD specifically.

Although not hypothesized, we feel compelled to comment on the null *direct* effect of political ideology on UOGD support especially given its emergence in other studies on this topic and other forms of energy development [13, 54, 55-59]. This finding was surprising; the association was trending in the anticipated direction, political ideology was a significant predictor of other model components (including perceived scientific consensus on UOGD's risk/benefits and beliefs about its various impacts), and political ideology was moderated correlated with support (see Table 3). The answer, we believe, is methodological in nature. One possibility is that although we had an ideologically diverse sample, the *distribution* of liberals, moderates, and conservative differed from population estimates of political ideology (see Table 1) – in particular, we had fewer conservatives – may have led to lose crucial variance on the political ideology variable leading to a null effect. We were, unfortunately, not able to obtain quotas according for respondents' political ideology. However, in light of the significant effects found on other model components, this explanation seems less plausible. Instead, another possibility is that controlling for the effect of perceived scientific consensus and beliefs about impacts on UOGD support was enough to weaken the direct effect of political ideology so that it became non-significant. At any rate, our core finding related to the indirect effect of political ideology on issue support remains unchanged, and a direct effect is not needed to demonstrate the former [78].

Our findings also raise a number of interesting questions, some of which future research can address. First, we focused on perceived scientific consensus on more subjective, value-laden conclusions pertaining to whether benefits outweigh the risks or vice-versa. We believe, though, that our framework could also be used to study perceived scientific consensus on *specific* impacts with or without these value-laden elements. The evidence base and associated expert

consensus appears more robust for some UOGD impacts like water contamination pathways [44] and various potential economic effects [48] than others, including potential climate impacts ramifications [45]. Therefore, future research could compare public perception of scientific agreement on these impacts compared to actual consensus based on available evidence in order to identify gaps that could be remedied, as has been the case for topics like anthropogenic climate change and the debunked link between vaccines and autism [50-52]. Moreover, scholars could also examine whether politically polarized issue support emerges via ideologically-divergent perceptions of scientific consensus regarding specific impacts - a likely premise in light of the political polarization surrounding UOGD more broadly along with people's inclination to question scientific evidence that runs counter to their ideologically-driven views while accepting that which supports those views [70].

Second, to what extent do our findings apply outside the United States in light of our reliance on a single-country case study? Large number of countries have unconventional fossil fuel reserves and current (or planned) commercial development, and by virtue of its role as a leading producer of unconventional oil and natural gas [11], the United States' experience with UOGD – including large-scale development as well as public and political polarization surrounding its potential impacts, scientific evidence on these impacts, and overall support [12-13, 14, 54] – arguably serves as useful model for understanding public discourse in other countries where this issue has likewise captured public attention and political controversy. Thus, the pathways we identified through which political ideology drives polarized issue support via partisan gaps in perceived scientific consensus on UOGD's risk/benefits seem applicable in these other contexts. We also acknowledge, however, the value of comparative work with other countries to further explore these areas, given that a variety of psychological and social factors can shape public

perception across (and even within) countries and, by extension, UGD's long-term trajectory in those places [9, 35, 42, 79]. Also, as O'Connor and Fredericks [72, p. 61] observed, public perception toward UGD in one country "do not easily translate into different places due to disparate histories, cultures, and economies" (p. 61). Opportunities exist to test the applicability of our framework in places where, for instance, UOGD is politically divisive or where such polarization may be less intense. We therefore echo calls for intra-national and international comparative studies that "can more rigorously generate and test hypotheses across multiple areas, resulting in stronger evidence through a convergence of findings and a wider applicability of results" [10, p. 13; for examples, see 72, 79].

Third, while our study is grounded in UOGD, the underlying premise seems applicable to any risk topic where scientific discourse on the likelihood/magnitude of potential impacts as well whether they are positive or negative are subjects of scientific attention and political controversy. In the domain of energy development, additional examples include nuclear power, renewable energy, and energy infrastructure such as oil/natural gas pipelines [55-59].

6.2. Risk communication implications

With public opinion playing an important role in UOGD policy, especially in light of individual or collective/group-based efforts to restrict or prohibit it (with some degree of success; 27-29; 80-81], persuasion and engagement-oriented risk communication take on added importance. We believe that claims about scientific consensus pertaining to specific impacts or broader questions of risk/benefit are an important part of both communication approaches.

In a more persuasion-oriented context, numerous studies have focused on closing a “gap” between public perception of scientific disagreement on a particular risk topic (such as anthropogenic climate change) and quantified levels of consensus among scientists [52]. It hoped that heightened perceptions of scientific agreement among the former will facilitate more favorable issue attitudes in line with scientific evidence – a fact borne out in the case of climate change and other topics [1, 2, 6, 50-52]. For UOGD, attempting to convey broad scientific agreement on potential economic and water quality impacts to help better inform public discourse has clear value, although such efforts are more complicated for impacts with a more heterogeneous evidence base as well as normative questions involving risk/benefit. Nonetheless, such claims about scientific consensus can be a potentially powerful persuasive tool for issue advocates. For instance, UOGD supporters may claim that scientific consensus points to low potential for some impacts seen as undesirable (such as water contamination), high potential for others viewed as beneficial (such as local jobs), and an overall sense that benefits outweigh the risks. Conversely, UOGD opponents may emphasize perceived scientific consensus in the opposite direction - high potential for some impacts seen as undesirable (such as water contamination), low potential for others considered beneficial (such as local jobs), and an overall sense that risks outweigh the benefits. Moreover, for engagement-based risk communication that focuses on maximizing public input into UOGD-related decision-making [82], summarizing the state of scientific agreement on specific impacts helps provide important background information for citizens as they participate in the policy-making process [83].

However, in light of how political ideology influences perceptions of scientific consensus regarding the likelihood/magnitude of specific impacts as well as risks versus benefits (not to mention overall support), we suspect that audience acceptance or rejection of the aforementioned

scientific consensus claims would likewise diverge along ideological lines. While there are no message testing studies in this area of which we are aware, scholars examining scientific consensus messages on anthropogenic climate change have found mixed evidence related to politically polarized message effects [84-87]. We call for similar research specific to UOGD.

6.3. *Limitations*

This study has several limitations that present opportunities for future research.

First, although the framework we tested is based on – and consistent with – research on motivated reasoning and the influence of perceived scientific discourse on attitudes towards contentious risk topics [1-7], we cannot show causality with cross-sectional data alone. We hope that future research using longitudinal panel data will examine causal relationships among our framework elements as well as the potential for reverse/mutually reinforcing pathways. For example, although political ideology is arguably antecedent to opinions we form about topics with political connotations, these attitudes (such as UOGD support) may also reinforce one's ideological affiliation. Also, people's existing levels of UOGD support may influence their beliefs about potential impacts [88].

Second, many of our response scales did not contain an unsure or undecided option. Whether to do so is a seemingly endless debate in survey research [89], and some scholars contend that with their absence, those unsure or undecided may be forced to choose a response that does not necessarily reflect their view [90] or about which they may not feel strongly. However, omitting these options reduces “satisficing,” in which people choose these options in order to avoid “doing the cognitive work necessary to report the true options they do have” [91, p. 371]. Also,

the frequency with which respondents in the United States select these options in UOGD surveys has declined as people become more familiar with it [92] and more willing to state an opinion. Similarly, our use of “slightly” options (i.e., slightly support or oppose) may provide respondents hitherto uncertain of their views with an outlet to express them, especially if they merely lean in one direction.

Finally, we recognize that quota sampling, although becoming more popular in public opinion studies on UOGD [79] and other contentious risk issues [93], is still less common than probability-based sampling and involves (like any method) advantages and disadvantages. We believe, though, that survey quality depends on the match between specific goals and the type of data available to achieve them [94]. While the non-probability nature of quota sampling limits our ability to generalize our findings to the broader United States population [94-96], it does provide a diverse sample with which to test a theory-informed model – one that approximated the United States population on a number of demographic fronts. We view ourselves as “describers” [94] whose goal is to “seek data with measures that fully capture the concepts needed to test their theories” (p. 99) in order to “assess whether two variables were related to each other along the lines that theory anticipated” [96, p. 737]. Also, the fact that our findings supported relevant theory by and large gives us confidence that we are describing phenomena occurring in the broader United States population. Future research with probability samples can provide even more robust tests of our framework.

7. Conclusions

This article contributed to research on public perception of risk-related scientific consensus in the context of UOGD. In combining antecedents and outcomes in an integrative framework,

we sought greater insight into how polarized attitudes emerge via ideologically-divergent perceptions of scientific consensus regarding whether risks outweigh benefits (or vice-versa) – a premise not directly tested in previous research in other risk domains. We identified pathways, consistent with this reasoning, through which partisan gaps in UOGD support were amplified. This insight is crucial to risk communication efforts on energy topics that, like UOGD, are scientifically complex and politically divisive.

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Notes

¹ Several recent studies have explored appropriate terminology with which to describe unconventional energy extraction and associated impacts [54, 97-98]. UOGD supporters and opponents alike tend to use “fracking” – a practice that can shape public opinion, with people holding more negative attitudes toward “fracking” compared to other terms like “shale oil or gas development” [54]. This study elected to use “unconventional oil or gas development” (UOGD) as a means to avoid undue negativity attached to “fracking”, although no label is likely devoid of positive or negative connotations.

² A number of multi-item political ideology measures have used economic and social-themed items [60-61], and there is some debate about whether they tap into univariate or multivariate dimensions of political ideology. We agree with those who argue that they share the same psychological antecedents of political ideology (i.e., the need for order, certainty, and security) and that people desire to maintain ideological consistency across economic and social domains [65, 71]. Data from the present study also supports this premise, especially given the high correlation between the economic and social dimensions ($r = 0.81, p < 0.001$) as well as the fact that both indicators loaded strongly onto the same factor.

³ Both political party affiliation and political ideology reflect, at least in part, social identities tied to affiliation with political parties and/or ideological movements [53, 99]. There is increasing evidence that the two are increasingly correlated in the United States [100] – a finding reinforced in this study ($r = 0.81, p < 0.001$). However, because political ideology has conceptual roots beyond social identities [61], we opted to keep these two concepts distinct.

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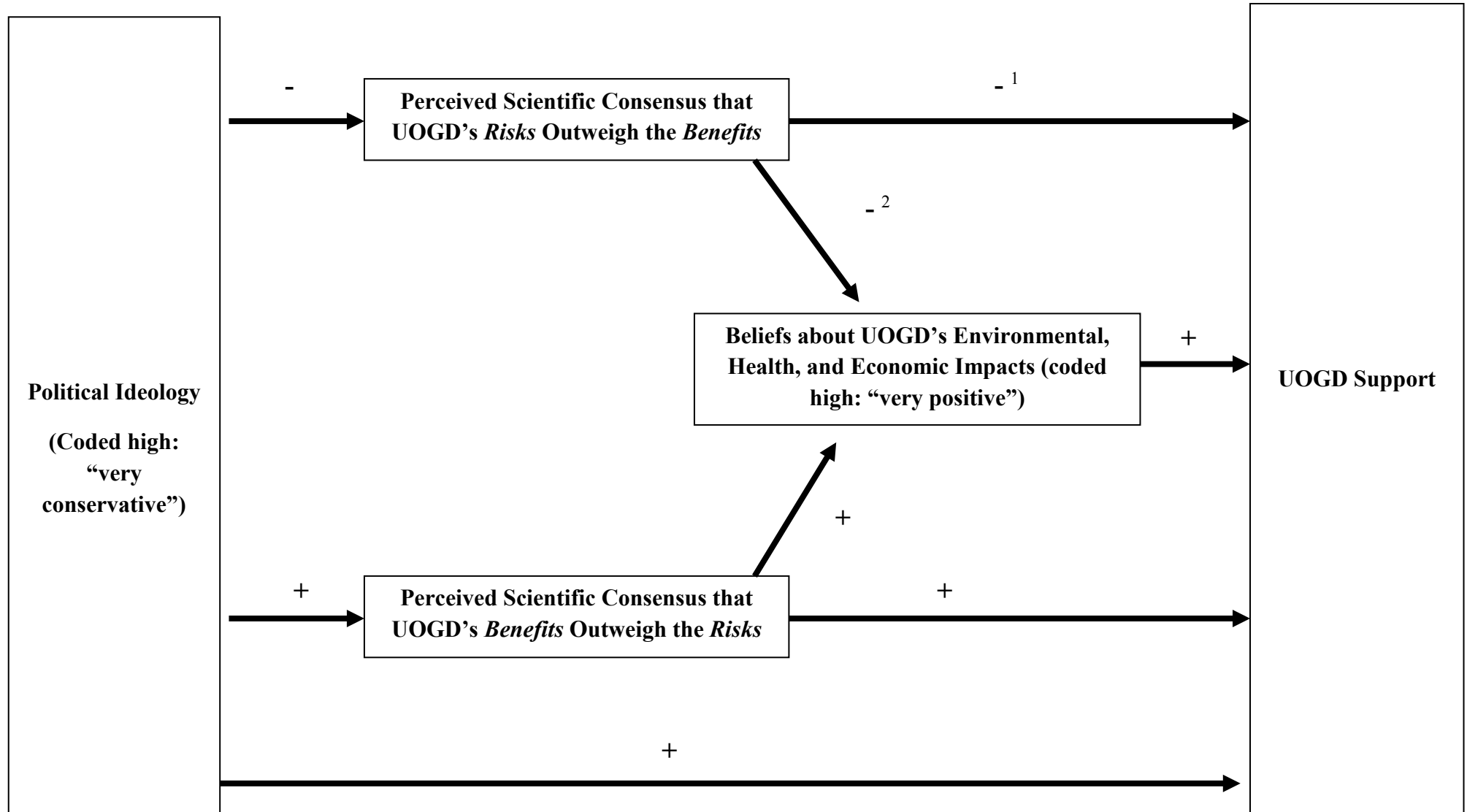
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Figure 1: Proposed Model



¹ Although we expect that perceived scientific consensus that UOGD's risks outweigh benefits will dampen issue support, we are more interested in the *reverse* relationship (*lower* levels of perceived consensus will be associated with *heightened* support) because we expect that political conservatism is associated with decreased perceptions of consensus.

² Although we expect that perceived scientific consensus that UOGD's risks outweigh benefits will dampen the belief that its environmental, health, and economic impacts are positive, we are more interested in the *reverse* relationship (*lower* levels of perceived consensus will be associated with a *heightened* belief that these impacts are positive) because we expect that political conservatism is associated with decreased perceptions of consensus.

Table 1 | Sample Demographics Compared to the United States Population

Variable	Sample Demographics	United States population
Gender ¹	50% female	50.8% female ¹
% White	85.6%	76.6% ¹
% Hispanic	7.4%	18.1% ¹
% ≥ 4 year college degree (age 25 +) ^a	28.9%	30.3% (2012-2016 estimate) ¹
% Democrat/leaning Democrat	42%	47% ²
% Republican/leaning Republican	33%	44% ²
% Liberal (economic issues) ^c	25%	20% ³
% Liberal (social issues)	33.1%	30% ⁴
% Conservative (economic issues)	29.3%	41% ³
% Conservative (social issues)	27.6%	34% ⁴
% Northeast ⁵	20%	17.7% ^a
% South ⁶	35%	37.5% ^a
% Midwest ⁷	25%	21% ^a
% West ⁸	20%	23.8% ^a

¹ Data courtesy of the United States Census Bureau Quick Facts estimates as of July 1st, 2017 (<https://www.census.gov/quickfacts/fact/table/US/PST045217>)

² Data courtesy of Gallup (<https://news.gallup.com/poll/15370/party-affiliation.aspx>), September 4-12, 2018 survey wave.

³ Data courtesy of Gallup as of May 20th, 2016 (<https://news.gallup.com/poll/191741/democrats-liberal-social-issues-economic-ones.aspx>)

⁴ Data courtesy of Gallup as of July 28th, 2017 (https://news.gallup.com/poll/214598/social-liberals-nearly-tie-social-conservatives.aspx?g_source=link_NEWSV9&g_medium=TOPIC&g_campaign=item_&g_cont)

[ent=Social%2520Liberals%2520Nearly%2520Tie%2520Social%2520Conservatives%2520in%2520U.S.\)](#)

⁵ Includes the following states: Pennsylvania, New York, New Jersey, Delaware, Rhode Island, Connecticut, Massachusetts, New Hampshire, Vermont, and Maine.

⁶ Includes the following states: Maryland, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, Tennessee, Kentucky, Alabama, Mississippi, Louisiana, Arkansas, Oklahoma, and Texas.

⁷ Includes the following states: Kansas, Nebraska, South Dakota, North Dakota, Minnesota, Iowa, Missouri, Illinois, Indiana, Ohio, Michigan, and Wisconsin

⁸ Includes the following states: Colorado, Wyoming, Montana, Idaho, Washington, Oregon, California, Arizona, Nevada, Utah, New Mexico, Hawaii, and Alaska.

^a Data courtesy of the Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2017 (NST-EST2017-01) (https://www.census.gov/data/datasets/2017/demo/popest/state-total.html#par_textimage_500989927)

Table 2 | Variable Measures and Response Scales

Variable	Question	Response Scale	M (SD)
Political ideology <i>(Exogenous)</i>	When it comes to economic issues, do you think of yourself as... When it comes to social issues, do you think of yourself as...	1 = very liberal 2 = somewhat liberal 3 = moderate 4 = somewhat conservative 5 = very conservative	3.07 (1.08) 2.92 (1.14)
UOGD familiarity <i>(Exogenous)</i>	Overall, how familiar are you with shale oil and gas development via “fracking”?	1 = not at all familiar 2 = not very familiar 3 = somewhat familiar 4 = moderately familiar 5 = very familiar	3.18 (1.15)
Gender <i>(Exogenous)</i>	Are you (male/female)?	0 = male (50%) 1 = female (50%)	--
Education <i>(Exogenous)</i>	What is your highest level of formal education?	0 = < 4-year/Bachelor degree – 72.9% 1 = ≥ 4-year/Bachelor degree – 27.1%	--

<p>Political party affiliation</p> <p><i>(Exogenous)</i></p>	<p>Which of the following best describes your political party affiliation?</p>	<p>1 = Strong Democratic</p> <p>2 = Democrat</p> <p>3 = Independent/leaning Democratic</p> <p>4 = Independent</p> <p>5 = Independent/leaning Republican</p> <p>6 = Republican</p> <p>7 = Strong Republican</p>	<p>3.84 (1.74)</p>
<p>Perceived scientific consensus that UOGD's benefits outweigh risks</p> <p><i>(Endogenous)</i></p>	<p>In your view, how many scientists believe that the benefits of shale oil and gas development via fracking outweigh the risks?</p> <p>In your view, how much scientific evidence shows that the benefits of shale oil and gas development via fracking outweigh the risks?</p>	<p>1 = virtually none</p> <p>2 = some</p> <p>3 = a moderate amount</p> <p>4 = most</p> <p>5 = virtually all</p>	<p>2.64 (1.06)</p> <p>2.57 (1.17)</p>
<p>Perceived scientific consensus that UOGD's risks outweigh benefits</p> <p><i>(Endogenous)</i></p>	<p>In your view, how many scientists believe that the risks of shale oil and gas development via fracking outweigh the benefits?</p> <p>In your view, how much scientific evidence shows that the risks of shale oil and gas development via fracking outweigh the benefits?</p>	<p>1 = virtually none</p> <p>2 = some</p> <p>3 = a moderate amount</p> <p>4 = most</p> <p>5 = virtually all</p>	<p>2.85 (1.09)</p> <p>2.86 (1.17)</p>

Perceived impacts <i>(Endogenous)</i>	<p>How positive or negative of an impact do you think shale oil and gas development via fracking is having on the following?</p> <p>The environment in the United States in general</p> <p>Human health in the United States in general</p> <p>The United States economy in general</p>	<p>1 = very negative</p> <p>2 = moderately negative</p> <p>3 = slightly negative</p> <p>4 = slightly positive</p> <p>5 = moderately positive</p> <p>6 = very positive</p>	<p>3.15 (1.45)</p> <p>3.22 (1.37)</p> <p>4.04 (1.33)</p>
Issue support (DV) <i>(Endogenous)</i>	Overall, to what extent do you support or oppose shale oil and gas development via fracking in the United States in general?	<p>1 = strongly oppose</p> <p>2 = moderately oppose</p> <p>3 = slightly oppose</p> <p>4 = slightly support</p> <p>5 = moderately support</p> <p>6 = strongly support</p>	3.56 (1.69)

Table 3 | Correlations among Key Model Components

	2	3	4	5	6	7	8	9	10
(1) When it comes to economic issues, do you think of yourself as [very liberal→very conservative]	0.81***	0.13**	0.18***	-0.2***	-0.24***	0.23***	0.19***	0.19***	0.35***
(2) When it comes to social issues, do you think of yourself as [very liberal→very conservative]	--	0.15***	0.21***	-0.21***	-0.25***	0.31***	0.25***	0.2***	0.38***
(3) In your view, how many scientists believe that the benefits of shale oil and gas development via fracking outweigh the risks? [virtually none → virtually all]	--	--	0.74***	0.03	-0.01	0.45***	0.44***	0.36***	0.51***
(4) In your view, how much scientific evidence shows that the benefits of shale oil and gas development via fracking outweigh the risks? [virtually none → virtually all]	--	--	--	-0.003	-0.07	0.51***	0.49***	0.44***	0.6***
(5) In your view, how many scientists believe that the risks of shale oil and gas development via fracking outweigh the benefits? [virtually none → virtually all]	--	--	--	--	0.73***	0.14***	-0.09*	-0.09*	-0.22***
(6) In your view, how much scientific evidence shows that the risks of shale oil and gas development via fracking outweigh the benefits? [virtually none → virtually all]	--	--	--	--	--	-0.19***	-0.14***	-0.16***	-0.31***

(7) How positive or negative of an impact do you think shale oil and gas development via fracking is having on the following? [very negative → very positive] The environment in the United States in general	--	--	--	--	--	--	0.84***	0.59***	0.69***
(8) How positive or negative of an impact do you think shale oil and gas development via fracking is having on the following? [very negative → very positive] Human health in the United States in general	--	--	--	--	--	--	--	0.61***	0.68***
(9) How positive or negative of an impact do you think shale oil and gas development via fracking is having on the following? [very negative → very positive] The United States economy in general	--	--	--	--	--	--	--	--	0.63***
(10) Overall, to what extent do you support or oppose shale oil and gas development via fracking in the United States in general? [Strongly oppose → strongly support]	--	--	--	--	--	--	--	--	--

Notes: Statistically significant correlations are **bolded**.

N = 700

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 4 | SEM Fit Statistics – Model Comparison

Fit Statistics	Full	Reduced
Model X^2 (df)	112.5 (53)***	115.8 (54)***
Model X^2 / df ratio	2.12	2.14
RMSEA	0.061	0.057
95% CI - RMSEA	0.047, 0.075	0.043, 0.072
CFI	0.97	0.97

Notes: “Full” model includes all covariates, while the “Reduced” model only includes statistically significant covariates identified from the Full version.

N = 700 for all analyses

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 5 | Unstandardized SEM Coefficients – Model Comparison

		Full	Reduced
Independent variable	Dependent variable	b	b
Political ideology (“very conservative” coded high)	Perceived scientific consensus that UOGD’s risks > benefits	-0.3**	-0.3***
Perceived scientific consensus risks > benefits		--	--
Perceived scientific consensus benefits > risks		--	--
Perceived health, economic, and environmental impacts (“very positive” coded high)		--	--
Political party affiliation (“strong Republican” coded high)		0.01	--
Education (0 = < 4-year degree; 1 = ≥ 4-year degree)		0.03	--
Issue familiarity (“a lot” coded high)		0.33***	0.32***
Gender (0 = Male; 1 = Female)		-0.15	--
Political ideology (“very conservative” coded high)	Perceived scientific consensus that UOGD’s benefits > risks	0.3**	0.33***
Perceived scientific consensus risks > benefits		--	--
Perceived scientific consensus benefits > risks		--	--
Perceived health, economic, and environmental impacts (“very positive” coded high)		--	--
Political party affiliation (“strong Republican” coded high)		0.02	--

Education (0 = < 4-year degree; 1 = ≥ 4-year degree)		0.002	--
Issue familiarity (“a lot” coded high)		0.17**	0.17**
Gender (0 = Male; 1 = Female)		0.11	--
Political ideology (“very conservative” coded high)	Perceived health, economic, and environmental impacts (“very positive” coded high)	0.31**	0.21**
Perceived scientific consensus risks > benefits		-0.14	-0.19**
Perceived scientific consensus benefits > risks		0.71***	0.67***
Perceived health, economic, and environmental impacts (“very positive” coded high)		--	--
Political party affiliation (“strong Republican” coded high)		-0.08	--
Education (0 = < 4-year degree; 1 = ≥ 4-year degree)		-0.06	--
Issue familiarity (“a lot” coded high)		-0.11	--
Gender (0 = Male; 1 = Female)		-0.06	--
Political ideology (“very conservative” coded high)	UOGD support (“strongly support” coded high)	0.08	0.08
Perceived scientific consensus risks > benefits		-0.29***	-0.28***
Perceived scientific consensus benefits > risks		0.45***	0.45***
Perceived health, economic, and environmental impacts (“very positive” coded high)		0.69***	0.71***
Political party affiliation (“strong Republican” coded high)		0.09*	0.09*
Education (0 = < 4-year degree; 1 = ≥ 4-year degree)		0.1*	0.1*

Issue familiarity (“a lot” coded high)		0.02	--
Gender (0 = Male; 1 = Female)		-0.02	--

Notes: “Full” model includes all covariates, while the “Reduced” model only includes statistically significant covariates identified in the Full version. In each cell, significant coefficients are **bolded**.

N = 700 for all analyses

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 6 | Perceptions of Scientific Consensus regarding whether UOGD's Benefits outweigh Risks, by Political Ideology

Perceived scientific consensus that UOGD's benefits > risks	Very/somewhat liberal	Moderate	Very/somewhat conservative
Virtually none	69 (30.1%)	50 (19.4%)	31 (14.7%)
Some	77 (33.6%)	96 (37.2%)	53 (24.9%)
A moderate amount	28 (12.2%)	60 (23.3%)	45 (21.1%)
Most	38 (16.6%)	40 (15.5%)	68 (31.9%)
Virtually all	17 (7.4%)	12 (4.7%)	16 (7.5%)

Table 7 | Perceptions of Scientific Consensus regarding whether UOGD's Risks outweigh Benefits, by Political Ideology

Perceived scientific consensus that UOGD's risks > benefits	Very/somewhat liberal	Moderate	Very/somewhat conservative
Virtually none	23 (10%)	27 (10.5%)	29 (13.6%)
Some	62 (27.1)	94 (36.4%)	97 (45.5%)
A moderate amount	37 (16.2%)	69 (26.7%)	39 (18.3%)
Most	69 (30.1%)	48 (18.6%)	34 (16%)
Virtually all	38 (16.6%)	20 (7.8%)	14 (6.6%)