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Discourse over a contested technology on Twitter: A case study of hydraulic fracturing

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Abstract

High-volume hydraulic fracturing, a drilling simulation technique commonly referred to as "fracking," is a contested technology. In this article, we explore discourse over hydraulic fracturing and the shale industry on the social media platform Twitter during a period of heightened public contention regarding the application of the technology. We study the relative prominence of negative messaging about shale development in relation to pro-shale messaging on Twitter across five hashtags (#fracking, #globalfrackdown, #natgas, #shale, and #shalegas). We analyze the top actors tweeting using the #fracking hashtag and receiving @ mentions with the hashtag. Results show statistically significant differences in the sentiment about hydraulic fracturing and shale development across the five hashtags. In addition, results show that the discourse on the main contested hashtag #fracking is dominated by activists, both individual activists and organizations. The highest proportion of tweeters, those posting messages using the hashtag #fracking, were individual activists, while the highest proportion of @mention references went to activist organizations.

Keywords

hydraulic fracturing, shale gas, shale oil, social media, Twitter

1. Introduction

Hydraulic fracturing, a drilling simulation technique commonly referred to as "fracking," is a contested technology. There is not scientific consensus regarding its environmental, health, and social impacts, which are debated by competing stakeholders in the public sphere and regulatory areas. Thus, fracking is an exemplar of a controversial technology (Mazur, 2014). Hydrofracking sits at the juncture of democratic decision-making over the application of science and technology in societies around the world, with implications for global energy policy and environmental

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governance. It is often framed as an economic boom, with shale gas as a bridge fuel in the transition to cleaner energy (Engelder, 2011), or as the source of serious environmental and health concerns (Howarth and Ingraffea, 2011). Major areas of concern include greenhouse gas emissions, a lack of baseline data, seismic activity, water contamination, and public health issues, as well as policy and regulatory considerations such as disclosure of chemicals (United Nations Environment Programme (UNEP), 2012). Other issues are social in nature, including noise pollution, increased transient populations, and demand for social services (Christopherson and Rightor, 2012; Ferrar et al., 2013).

The energy industry is investing into the development of "unconventional" shale fossil fuels at an unprecedented rate. The US shale boom has sparked international interest. The technology's reception globally has been mixed, with governments of countries such as Poland and Argentina favoring development, while others including France and South Africa have instituted moratoria or bans (Krauss, 2013). Within this context, social movements can serve as challengers to the dominant paradigms within science and technology by contesting official notions of safety and risk to emerging technologies (Hess et al., 2008). At the end of 2014 in the United States, New York State became the first with major shale deposits to ban the practice, widely viewed by anti-fracking activists as a significant victory for the movement (Steingraber, 2014).

Despite the controversy, there has been little social science research on fracking (Jaspal and Nerlich, 2014). Recent research on the technology has examined state-level framing and agenda change (Davis and Hoffer, 2012), legislative framing in the western United States (Kear, 2011), and public acceptance at the state level (White, 2012). Research by Jaspal and Nerlich (2014) on the representations of shale gas in the UK press indicated competing positive and negative social representations of the issue. Another study by Mazur (2014) examined fracking news coverage in relation to public opinion. While these studies highlight the importance of social science research into the social meanings associated with fracking, our research is unique in its focus on the dynamics of discourse about the issue on social media.

In this study, we explore discourse over the shale industry on the social media platform Twitter during a period of heightened contention regarding the application of fracking. Our goal is to gauge the valence of sentiment and degree of certainty across five social movement, industry, and contested hashtags (#fracking, #globalfrackdown, #natgas, #shale, and #shalegas). The data come from 1 week prior to and 1 week following an international day of action against fracking and the shale industry held on 19 October 2013, the Global Frackdown, with more than 200 events planned in 27 countries (Food and Water Watch, 2013). The Global Frackdown (n.d.) mission includes, "We stand united as a global movement in calling on governmental officials at all levels to pursue a renewable energy future and not allow fracking or any of the associated infrastructure in our communities or any communities." Furthermore, we analyze the top actors who posted with the main hashtag in the dataset, #fracking, as well as the top @mentioned actors for this hashtag. Through natural observation of social data, this study contributes to responsible research and innovation theory by providing empirical evidence of segmentation in networked conversation on a contested emerging technology.

Innovation and social media

Science and technology have increasingly higher uncertainty and higher decision stakes, which calls for more democratic process of development (Funtowicz and Ravetz, 1993). Responsible research and innovation, which is broadly caring for the future through present "collective stewardship of science and innovation," is one response to addressing developments in an age of science and technology with both high decision stakes and high uncertainty (Stilgoe et al., 2013: 1570).

Responsible innovation is a systems-wide approach to developing technologies that is ideally anticipatory, inclusive, reflexive, and responsive (Stilgoe et al., 2013). Recent research on responsible innovation calls for the inclusion of public values relevant to technological development into public debate about contested technologies (Taebi et al., 2014).

There is an ongoing dialogue among scholars interested in responsible innovation that calls for increased reflection and responsiveness of bodies governing innovations to public interests and values (e.g. Stilgoe et al., 2013; Sykes and Macnaghten, 2013). Legitimizing knowledge and values of lay audiences is not enough, according to Callon et al. (2010). The core challenge is to include lay audiences in the decision-making process before and during the innovative process, without issues or publics pre-existing each other, but rather emerging concurrently (Callon et al., 2010). In the case of fracking, political contexts influence whether input from publics has been or will be formally taken into account (Sovacool, 2014). With social media, we have the opportunity to monitor a global public dialogue on fracking that comprises "spontaneous and unsolicited" expressions by stakeholders (Runge et al., 2013, p. 2).

Twitter reports 316 million monthly active users, 77% of which are accounts outside of the United States (Twitter Inc., 2015). Users send a daily average of 500 million tweets (Twitter Inc., 2015), making it an important sphere for discourse on contemporary issues. Twitter is a broadcast-like microblogging service, similar to older broadcast technologies, as public, multicast (many-to-many), interactive, and networked (Murthy, 2013: 16). Users can tweet to people they do not know offline, for example US President Barack Obama (@BarackObama), in the hopes of getting their attention. Hashtags and retweeting enable conversations (boyd et al., 2010; Honeycutt and Herring, 2009). Retweeting is a practice in which users forward or share messages originating from other users, allowing frames to potentially gain momentum in the Twitter-sphere (Murthy, 2013). Hashtags, marked by the "#" symbol, allow for indexing of content, what Zappavigna (2012) calls "searchable talk," so that users can monitor discourse about specific topics and see what other users they do not follow are saying (p. 95).

As science communication scholars Brossard and Scheufele (2013) write, a paradox of new media is that while the Internet makes information on scientific topics more accessible to broader publics, these tools could also limit knowledge gain through algorithms and self-reinforcing search results. In the United States, 40% of adults say that they turn to the Internet first when they need science and technology information (National Science Board, 2014). Given that in the United States 74% of adults use social networking sites (Pew Research Internet Project, 2014), it becomes crucial to study the representations of science and technology on social platforms. A rigorous understanding of the dynamics of communication about science and technology in online-networked environments is necessary to understand the factors that contribute to making a technology contested. Communications scholarship does not yet fully address the evolving dynamics of exposure to scientific information in social media environments (Runge et al., 2013). In this study, we adapt the dimensions studied by Runge et al. (2013) to research Twitter discourse on fracking.

Past research has examined the mediation of political issues on Twitter and shown evidence of segmentation and varying degrees of discourse across political groups (Colleoni et al., 2014; Yardi and boyd, 2010). There has been little research to date on what differences may exist between related hashtags for an issue and whether or not hashtags for a given topic represent a cohesive networked public or sets of distinct publics, and counter-publics, as theorized by Fraser (1992). A homogeneous discourse across hashtags would have strikingly different implications in terms of who is represented in the dialogue than a discourse voiced by distinct publics. Therefore, in addition to examining overall sentiment across hashtags, we investigated the potential for differences in the proportions of pro-shale and anti-shale sentiment and levels of certainty across hashtags.

Given the level of heightened contention over hydraulic fracturing and shale development, we predicted there would be statistically significant differences between hashtags:

H1a. The social movement hashtag #globalfrackdown will display a greater degree of anti-shale sentiment.

H1b. The industry hashtag #natgas will display a greater degree of pro-shale sentiment.

H1c. The industry hashtag #shalegas will display a greater degree of pro-shale sentiment.

Given the general, contested nature of the other two hashtags included in this study, #fracking and #shale, we ask the following question:

RQ1. What is the opinion valence in #fracking and #shale tweets about hydraulic fracturing?

Because certainty expressed in tweets could have mobilizing effects, it is reasonable to expect that discourse around social movements will be more certain than other hashtags. Thus, we predicted the following hypothesis:

H2. The social movement hashtag #globalfrackdown will display a greater degree of certainty.

As stated above, given the contested nature of the other two hashtags included in this study, #fracking and #shale, we ask the following research question:

RQ2. What is the level of certainty in tweets about fracking for the #fracking, #natgas, #shalegas, and #shale hashtags?

Public perceptions of contested technologies

Contextualizing fracking among other contested technologies, like nanotechnology and agricultural biotechnology, is helpful to understanding how people make sense of emerging technologies. Nanotechnology and agricultural biotechnology differ from fracking in many obvious ways. However, several key elements that make them all prime examples of contested technologies are controversies over (a) who the decision makers are, (b) the extent of regulation, and (c) the environmental and health impacts. Public perceptions of them are not formed through knowledge of the technology, but rather through value predispositions as heuristics (e.g. Brossard and Nisbet, 2007; Kahan et al., 2009; Scheufele et al., 2007). For example, in the context of agricultural biotechnology in the United States, deference to scientific authority is a major driver of attitudes toward agricultural biotechnology in the United States (Brossard and Nisbet, 2007). Another example is that US publics with hierarchical–individualistic worldviews accessed and interpreted information related to nanotechnology differently than publics with egalitarian–communitarian worldviews (Kahan et al., 2009).

In US public opinion research on fracking, Boudet et al. (2014) find a low level of familiarity with the technology and mixed support, with 58% of survey respondents not knowing or being undecided, 20% being somewhat/strongly opposed, and 22% being somewhat/strongly supportive. They find that women, individuals with "egalitarian worldviews," newspaper readers, and those concerned about environmental impacts were more likely to oppose fracking (p. 57). On the other hand, for older, more conservative individuals, higher educational levels, watching TV news more

than once a week, and concern for economic impacts were factors correlated with support (Boudet et al., 2014). Research from the Pew Research Center for the People and the Press (2012) found partisan differences in levels of support for fracking, with conservatives more likely to be supportive and liberals more likely to oppose the technology. In Europe, public opinion research has shown that among the 27 member states of the European Union, 74% of survey respondents would be concerned about shale gas development in their neighborhood (Flash Eurobarometer 360, 2013).

Given the differences that underlie support, we hypothesize a disjuncture between competing claims of pro- and anti-shale actors, which increases contention over risk and controversy over technological development. We assume that all associations are social, with controversies being defined by actors in interaction with each other (Latour, 2005). We conceptualize *networked public sphere* as the mediated deliberative public space between formal governmental institutions and the private life of citizens in which the social and political processes of complex societies are legitimatized (see Friedland et al., 2006).

We study four types of actors: citizens, industry, science, and governmental. According to Wasserman and Faust (1994), "Actors are discrete individual, corporate, or collective social units" (p. 17). To purposefully allow for a broad conceptualization of key actors who may participate in the discourse about hydraulic fracturing and shale development on Twitter, we define *citizen actors*, in terms of organizations and other groups working together for a collective goal, as formally and informally organized sets of individuals and civil society representatives engaging in collective actions to raise public concern surrounding the health and environmental impacts of hydraulic fracturing. This definition conflates the nonspecialist with the specialist. We house the individuals in the same category as the civil society representatives because "in the digital age, all perspectives can get equal airtime" (Luers and Kroodsma, 2014: 203).

We define *industry actors*, in terms of organizations and other sets of individuals, as formally and informally organized sets of corporations, trade groups, and individuals promoting the use of hydraulic fracturing in the oil and gas industry, either on a nation-state or on international scale.

We conceptualize *scientific actors* as organizations and sets of individual scientists, which comprise an internationally recognized academy, with technical expertise in the area of environmental, geoscience, and related scientific fields.

Finally, we define *governmental actors* as the internationally recognized representatives of sovereign populations, whose vested interests may include, but not be limited to, economic development, as well as the protection of human health and the environment within a given territory.

For the final part of this study, we examine the top actors for the main hashtag in the dataset, #fracking, in order to gain a greater understanding as to who is driving the discourse on the issue during a period of heightened contention. Thus, we ask the following question:

RQ3. What types of actors are driving the #fracking hashtag conversation?

RQ4. What types of actors are the #fracking hashtag conversation directed toward?

Methods

Data collection

The data were collected using the cloud-based textual analytic software DiscoverText. This enabled us to collect a full corpus of all tweets from 13 October to 27 October 2013. The date range was selected to cover 1 week prior to and 1 week following the Global Frackdown. Data were collected for five hashtags: #fracking, #globalfrackdown, #natgas, #shale, and #shalegas. The first of these, #fracking, is a general term used to refer to the technology, which has been employed by
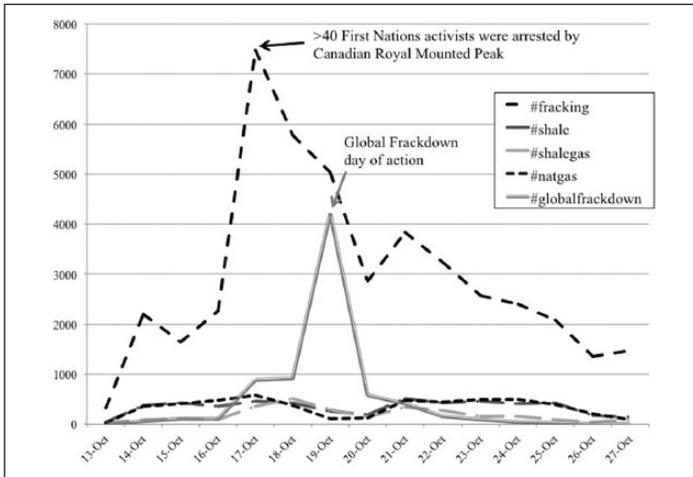
Figure 1. Tweets with fracking-related hashtags from 13 October to 27 October 2013.

both supporters and opponents. The second, #globalfrackdown, is a hashtag of the name of the anti-fracking movement and one promoted by organizers to share information about events affiliated with the day of action. The third, #natgas, is a hashtag associated with the oil and natural gas industry. The last two, #shale and #shalegas, are more general terms used to refer to the industry and the shale gas resources. A total of 72,195 tweets were collected. The sample was narrowed to the English language tweets ($n = 64,973$) for further analysis (see Figure 1).

As Figure 1 shows, #fracking had the highest number of tweets (44,548), followed by #globalfrackdown (7565), #natgas (5040), #shale (5063), and #shalegas (2757). In terms of the tweet frequency, the largest spike in tweet volume for the #fracking hashtag is on 17 October 2013, 2 days prior to the Global Frackdown day of action. On this date in New Brunswick (NB), Canada, the Royal Canadian Mounted Police (RCMP) enforced an injunction by SouthWestern Natural Resources, a company conducting seismic testing in the area, against a blockade by members of the Elsipogtog Mi'kmaq First Nations tribe, who were protesting the project through litigation and direct action. More than 40 people were arrested. There is a jump in the tweet volume for the #globalfrackdown hashtag on the official day of action, 19 October 2013, followed by a steep drop-off on the subsequent day and in the week that followed.

Data analysis

The goal of this analysis was to measure the relative frequency of tweets across hashtags along two dimensions. Modeled on the analytical frame developed by Runge et al. (2013), the first dimension identified support or opposition to the shale industry as pro-shale–neutral–anti-shale. The second dimension captured certainty and uncertainty (see Table 1).

"Pro-shale" is conceptualized as language indicating a positive or beneficial outcome related to the shale industry and hydraulic fracturing technology, or positive commentary on the technology and industry. "Neutral" is conceptualized as language indicating no judgment relative to a positive or negative outcome or judgment on the industry or technology (e.g. informational or event reporting). "Anti-shale" is conceptualized as language indicating a negative or harmful outcome related to the shale industry or hydraulic fracturing technology, or negative commentary on the technology and industry. This code also includes language that is positive toward and/or indicates support for

Table 1. Examples of coded fracking and shale-related tweets expressing opinion on Twitter from 13 to 27 October 2013.

	Certain	Uncertain
Pro-shale	@ShaleMarkets: Increased Shale Development Is Good For Ohio Workers—TY @EnergyInDepth for Article http://buff.ly/19Gc3Yz #Shale #Fracking @ XXXX (8:25 a.m.—14 October 2013)	RT @TheFrackingTrap: Will Europe pass on a shale gas revolution? http://t.co/ JD79txVR8x #fracking #shale
Neutral	@Osmich: NB judge rules #SWN injunction against anti #fracking protests will not be extended, ending today. (12:06 p.m.—21 October 2013)	@BloombergNRG: South Africa may see legal battle over #fracking regulations http://bloom.bg/1bxLO5P by @ pburkhardt (9:10 a.m.—16 October 2013)
Anti-shale	@XXXX: Wow. After watching the two Gasland documentaries, I'm pretty disappointed with our government #fracking #Gasland #sacj100 (9:57 p.m.—21 October 2013)	@SierraClubRMC: Where is the $ Going? Home Buyers Kept in Dark as Builders Retain Mineral Rights w/ Eye on #Fracking Revenue @AllGov http://bit.ly/H1JLwG (1:41 p.m.—15 October 2013)

the anti-shale industry social movement. "Certainty" is conceptualized as language indicating clear or known consequences and/or the firm conviction in the positive or negative aspects of the technology and shale industry. "Uncertainty" is conceptualized as language indicating unclear or unknown consequences and/or doubt about the positive or negative aspects of hydraulic fracturing technology and the industry. A final code of "N/A" was used for tweets that did not reference fracking and/or the shale industry.

The DiscoverText program includes a computer-aided content analysis function to combine human-coding with machine-classification (Grimmer and Stewart, 2013; Hopkins and King, 2010). We randomly generated a training set ($n = 650$) equal to approximately 1% of the total number of tweets. Each tweet could be assigned only one of the seven mutually exclusive codes.

Two coders independently coded the training set (the authors). Two measures of intercoder reliability were used to assess agreement. Scores for both were within acceptable ranges, Krippendorff's Alpha (.87) and Fleiss' Kappa (.86). For the two individual categories with low reliability scores, measured in Krippendorff's Alpha, neutral and uncertain (.494) and pro-shale and uncertain (.686), after supplementary discussion and training both coders coded additional items within a second random sample training set of $n = 200$. With the additional coding, the Krippendorff's Alpha intercoder reliability scores for these two categories, neutral and uncertain, and pro-shale and uncertain, reached acceptable levels (.75 and .73, respectively).

We conducted two chi-square tests for independence using the statistical software package SPSS version 20. First, we compared the independent variable of "hashtag" with the dependent variable of "valence of opinion." Second, we compared the independent variable of "hashtag" with the dependent variable of "certainty of opinion about shale." The data were weighted by count. To test the strength of the relationships, we examined Cramer's V test statistics. A higher value signifies a stronger association between the two variables (Hayes, 2005).

Top tweeters and @mentioned users

We selected the hashtag #fracking for analysis of what actor types tweeted the most, as well as those who were retweeted and @mentioned in posts most frequently. The hashtag #fracking comprised the highest volume of tweets (69%). Given that fracking has become a widely used

colloquial term to refer to high-volume hydraulic fracturing, we hypothesized it was likely that both pro and anti-shale development actors may use the hashtag #fracking to influence the wider Twitter discourse on the issue. We selected the top 200 tweeters and @mentioned users for further analysis.

Using an iterative process, adapting the coding frame used by Lotan et al. (2011) and Vis (2013), two coders (the authors) independently coded all the data. In cases of disagreement, the coders discussed discrepancies until agreement was reached. We used the Twitter users' profile bios, recent tweets, and any linked websites to classify the data. The categories are as follows: mainstream median (MSM), MSM (online only), alternative media, alternative media (online only), journalists (mainstream), journalists (alternative), activists (organization/group), activists (individual), activists (bloggers), celebrities, political actors (organization), political actors (individual), industry (organization/ company), industry (individual supporter), researchers/scientists, members of the public, fake/spoof account, and bots. Codes were also included for "unclear" accounts, as well as "defunct/suspended" accounts and "other" for spam accounts that did not fit within any of the above categories.

3. Results

Opinion valence and level of certainty

For the #fracking hashtag, 13% of tweets were pro-shale, 11% were neutral, and 76% were anti-shale. For #globalfrackdown, 0% of tweets were pro-shale, 2% were neutral, and 98% were anti-shale. For #natgas, 61% of tweets were pro-shale, 19% were neutral, and 20% were anti-shale. For #shale, 69% of tweets were pro-shale, 10% were neutral, and 20% were anti-shale. For the #shalegas hashtag, 24% of tweets were pro-shale, 17% were neutral, and 59% were anti-shale.

Across all hashtags, the majority of tweets expressed certainty. For the #fracking hashtag, 82% of tweets expressed certainty and 18% expressed uncertainty. For #globalfrackdown, 99% of tweets expressed certainty and 1% of tweets expressed uncertainty. For #natgas, 78% of tweets expressed certainty and 22% expressed uncertainty. For #shale, 74% of tweets expressed certainty and 25% expressed uncertainty. Finally, for #shalegas, 87% of tweets expressed certainty and 13% expressed uncertainty.

Chi-square tests for independence

A chi-square test was conducted and a significant relationship was found between hashtag and valence of opinion about shale, $\chi^2(df = 8, N = 64,417) = 18,632.95$, $p = .000$.[1] For the hashtags #fracking and #globalfrackdown, the observed values of pro-shale tweets were lower than would be expected by chance and the proportions of anti-shale tweets are higher than would be expected by chance. In contrast, for the hashtags #natgas, #shale, and #shalegas, the proportions of pro-shale tweets were higher than would be expected by chance and the observed values of anti-shale tweets lower than would be expected by chance alone. The hashtags included in this study were chosen on the expectation they would represent varied perspectives on shale extraction. This expectation is supported by the data.

The relationship between hashtag and valence of opinion about shale development is fairly strong, indicating statistically significant differences in the proportions of pro-shale, neutral, and anti-shale tweets across the five hashtags (Cramer's $V = .380$, $p = .000$). Hypotheses 1a and 1b are supported, while hypothesis 1c is not (see Table 2).

Second, we hypothesized that there would be a statistically significant difference in the degree of certainty in opinion about shale development between hashtags. A chi-square test was conducted

Table 2. Valence of shale-related tweets by hashtag.

Hashtag	Valence of shale-related tweets			Total
	Pro-shale	Neutral	Anti-shale	
#fracking	13.1%	11.4%	75.5%	44,165
#globalfrackdown	0.3%	1.8%	97.9%	7502
#natgas	61.9%	18.9%	19.2%	5030
#shale	69.7%	10.4%	19.9%	4977
#shalegas	23.8%	17.2%	59.1%	2743
Total	13,049 (20.3%)	7107 (11%)	44,261 (68.7%)	64,417 (100%)

$\chi^2(df=8, N=64,417)=18,632.95, p=.000.$
Cramer's $V=.380, p=.000.$

Table 3. Certainty of shale-related tweets by hashtag.

Hashtag	Certainty of shale-related tweets		Total
	Certain	Uncertain	
#fracking	81.6%	18.4%	44,165
#globalfrackdown	99.5%	0.5%	7502
#natgas	77.8%	22.2%	5030
#shale	74.4%	25.6%	4977
#shalegas	86.6%	13.4%	2743
Total	53,477 (83.0%)	10,940 (17.0%)	64,417 (100%)

$\chi^2(df=4, N=64,417)=1888.29, p=.000.$
Cramer's $V=.171, p=.000.$

and a significant relationship was found between hashtag and degree of certainty about shale development, $\chi^2(df=4, N=64,417)=1888.29, p=.000$. In terms of explaining the variance of observed proportions of certainty compared to uncertainty, only the activist hashtag #globalfrackdown showed a higher degree of certainty than expected by random chance. In contrast, the rest of the hashtags, #fracking, #natgas, #shale, and #shalegas, had a lower proportion of certainty than expected by chance.

In addition, the association between hashtag and certainty of opinion about shale development is significant, indicating statistically significant differences in the proportions of certain and uncertain tweets across the five hashtags (Cramer's $V=.171, p=.000$). Thus, hypothesis 2 is supported (see Table 3).

Top 200 #fracking tweeters and @mentioned users

Unlike past research examining top Twitter users for specific issue publics (Lotan et al., 2011; Vis, 2013), using the DiscoverText platform we were able to separate out the users who posted the most tweets using the #fracking hashtag from the users who were @mentioned the most using the hashtag. We will first address the top actors in terms of the 200 users who posted the most tweets within the dataset using the #fracking hashtag. In total, the top 200 users posted 13,608 tweets, comprising 31% of the total. The distribution of Twitter users followed a power law distribution, with only 17 users tweeting more than 100 times. As Figure 2 shows, tweets
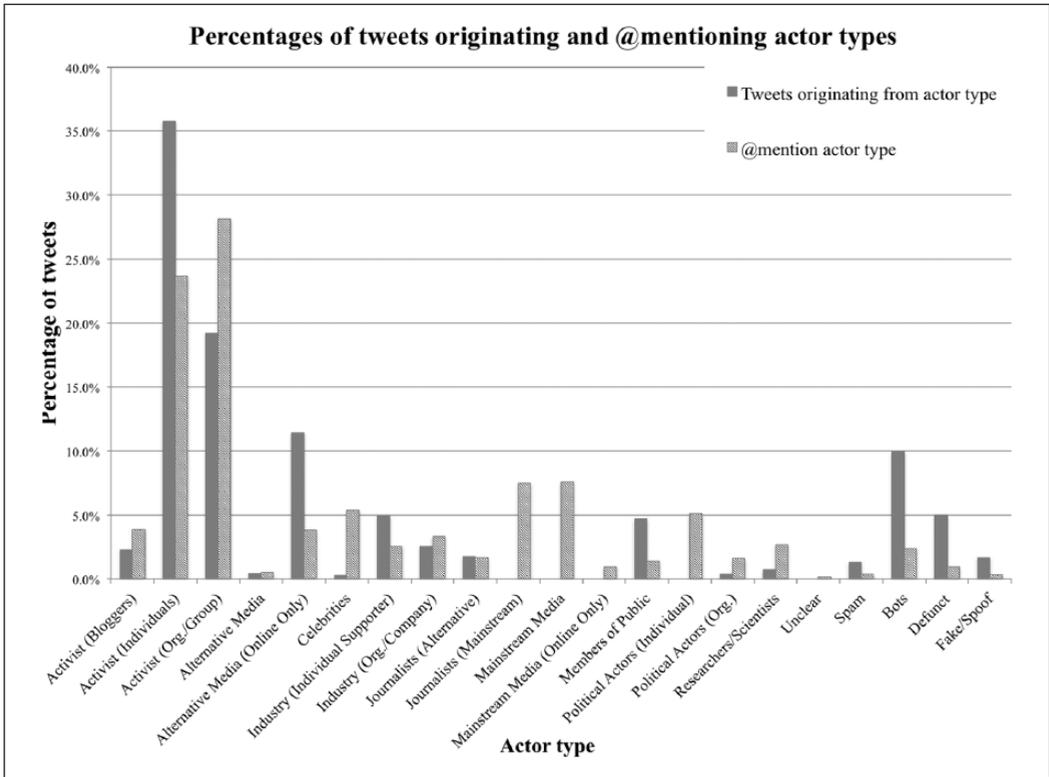
Figure 2. Percentages of tweets originating and @mentioning actor types.

from activists comprised the majority of the top actor tweets, with 35% coming from individual activists and another 19% coming from activist organizations and groups. In contrast, individual supporters of the shale industry posted only 5% of the tweets and industry organizations another 3%. Other categories that warrant mention are alternative media (online only), which made up 11% of tweets, bots (10%), and defunct or suspended accounts (5%). It is notable that the categories for mainstream media journalists, both mainstream media and online mainstream media, as well as individual political actors had no tweets among the top 200 tweeters. There are several possible explanations for this finding. It could be that media actors are tweeting about fracking, but without using hashtags. This would indicate that they could be using the microblogging platform as a new broadcast channel, rather than one in which to engage actively with audiences.

Of the top 10 accounts, 6 are activist accounts including @marcellus_SWPA, an anti-fracking alliance based in Pennsylvania, as well as three individuals.[2] In addition, the top 10 tweeters include one individual industry supporter and a bot. The highest ranking organizational industry supporters were @ShaleMarkets (#14), a news and advertising group, and @EnergyfromShale (#23), a project of Energy Tomorrow, which is affiliated with the American Petroleum Institute (API), a national trade group in the United States representing the oil and natural gas industry. The top 200 @mentioned accounts had 31,247 mentions (56% of the total).[3] The most @mentioned categories were activist organizations and groups (27%) and individual activists (23%). Activists' blogs about fracking and shale-related issues comprised another 4% of the @mentions (see Figure 2).

Taken together, the top actor results indicate that the #fracking agenda is largely driven by activists, as well as directed at and in response to other activists. What is striking about these results is the way in which they diverge from related research on top Twitter actors for large-scale breaking news events, Arab Spring in the case of research by Lotan et al. (2011), and on the 2011 riots in the United Kingdom (Vis, 2013). In both of those cases, the agenda was largely driven by and directed to mainstream media, journalists, and bloggers. In the case of this dataset, an anti-shale protest that took place in NB and the resulting crackdown by RCMP in Rexton, NB, on Elsipogtog First Nation activists was a key topic. It coincided with the pre-planned Global Frackdown day of action against the shale industry. Global Frackdown activists, along with First Nations activists in Canada, tried to break into the mainstream agenda and bring heightened attention to the arrests of activists in NB and Global Frackdown events.

While mainstream media outlets and journalists do not appear in the top user results, they do appear among the top @mentioned users, meaning that as a category media accounts are among those targeted with directed interactions by anti-fracking activists. The mainstream media category accounted for 7% of the @mentioned tweets, mainstream media (online only) accounted for another 1%, and journalists (mainstream) for 7%. A video journalist for the Canadian network APTN (@Osmich) ranked second in terms of @mentions. Mainstream news organizations in the top @mentioned Twitter users included: @nprnews (#12), @NPR (#15), @APTNNews (#27), @RT_com (#38), @guardian (#39), and @CBCAlerts (#71). The categories of industry (organization/company) and industry (individual supporter) combined accounted for 5% of the @mentions, making them less of a target for activist attention than media accounts. The highest ranked industry actor in terms of @mentions was the trade group America's Natural Gas Alliance (@ANGAus), which ranked 11th. The lack of industry actors among top @mentioned accounts could be due to the extent of overall polarization on shale development, in its more advanced stage, in the United States. Believing they have been shut out of decision-making processes, activists may not feel agency to target messages toward industry actors.

Finally, individual elected officials and a few governmental agencies appeared within the top @mentioned users. The category for organizational political actors made up 1.5% of the @mentions, while individual political actors (e.g. @barackobama) made up 5%. Individual political actors did not make up any of the top actors sending tweets using the #fracking hashtag. Among politicians, New York Governor Andrew Cuomo (@NYGovCuomo) ranked 6th for @mentions, followed by US President Barack Obama (@BarackObama), ranked 33; Canadian Prime Minister Stephen Harper (@pmharper), ranked 51; and a Green Party member of the British Parliament, Caroline Lucas (@CarolineLucas), ranked 52. Several governmental agencies also received @mentions, including the US Environmental Protection Agency (@EPA), ranked 32, and the Obama Administration's White House account (@WhiteHouse), ranked 193. The results indicate that while individual elected officials are not actively participating in the #fracking twitter discourse, they are passively receiving tweets about the issue. This indicates an emerging form of political engagement directed toward traditional powerbrokers, as well as appeals to media outlets for attention to a contested scientific issue as an indirect means to reach seemingly undecided publics.

4. Discussion

We have examined the valence of Twitter discourse about fracking across five hashtags: #fracking, #globalfrackdown, #natgas, #shale, and #shalegas. The results indicate differences across hashtags, with some being more anti-shale than expected by chance (#fracking and #globalfrackdown), while others (#natgas, #shale, and #shalegas) were more pro-shale in overall sentiment than would be expected by chance. The results suggest that, as the general public increasingly gets news about

science and technology from social platforms, discourse is segmented such that the valence of pro-shale, neutral, and anti-shale opinion audiences is exposed to vary significantly across hashtags related to the same issue. Furthermore, the level of certainty of opinion varied significantly across hashtags, with the activist hashtag #globalfrackdown having a higher level of certainty than would be expected by chance. The results show segmentation on the part of those opposed to the shale industry, with potential implications for the incidental informational exposure of nonactivist audiences, agenda setting within social media environments, and constructive dialogue between stakeholders as to possible energy futures.

Contrary to our expectations, industry actors appeared within the top 200 tweeters and @mentioned Twitter users for the #fracking hashtag to a low degree. There are several possible explications for this finding. First, given that the hashtags #natgas and #shale were more pro-shale in sentiment, it is possible that industry actors are using other more neutral terminology to index their Twitter posts. The fact that industry actors may be opting out of contested hashtags is striking, given that the #fracking hashtag comprised the majority of the overall sample and that tweet volume can be considered a measure of attention. The #fracking discourse was driven by activists and directed primarily to other activist accounts, in terms of @mentions. This provides empirical evidence that anti-fracking activists dominated Twitter discourse on the #fracking hashtag, during the time period under study, as part of a global social movement that is connecting about this contested technology, while industry actors were largely absent from this networked conversation, with implications for effective public deliberation on fracking. Our research findings indicate that discourse is largely driven by activists, which challenges our conflation of specialist and nonspecialist actors into a single "citizen actor" category. Prior to the data collection used in this analysis, there was no reason to suggest that specialist and nonspecialist actors would participate disproportionately in the fracking discourse. Hence, when we approached the investigation of what sentiment and players constitute #fracking discourse, we proposed an exploratory research question rather than a particular set of hypotheses. Our findings suggest that future research would do well to parse out specialist and nonspecialist citizen actors.

There did not appear to be a widespread coordinated effort on the part of activists to target specific elected officials, governmental agencies, or companies. The one notable exception is New York Governor Andrew Cuomo who, when the data were collected, had been under intense pressure from anti-fracking activists to ban fracking in New York State. For example, CREDO Action (n.d.), ran a comment campaign targeted at Cuomo, "Tell Governor Cuomo: Don't encourage fracking by lifting New York's ban on liquefied natural gas infrastructure," that was promoted through Twitter during the period of time under study. Observations of these messages on Twitter and subsequent action suggest that social media dialogue could serve as evidence of increased reflection and responsiveness of governing bodies to self-expressed public values and interests, as called for by researchers like Stilgoe et al. (2013) and Sykes and Macnaghten (2013).

The results suggest hashtags can act as cohesive spheres within, and of, themselves. Hashtags can be thought of as reflective of, and formative of, distinct *hashtag publics*. Take, for example, the contrast between the two hashtags #natgas and #shalegas. Based on background research, we hypothesized that the two would function similarly as industry hashtags. However, the results indicate contrasting, almost exactly opposite, valence in their sentiment about shale. While both hashtags have similar levels of certainty and neutral tweets, the results for the #natgas hashtag are in line with our expectations, being in their majority pro-shale (61%). However, the #shalegas hashtag was opposite of our expectation, with a similar degree but opposing sentiment, weighted to the anti-shale side (59%). In fact, the definition of #natgas in the online database #TagDef.com reads, "*Shale* gas is natural gas produced from shale" (emphasis added).[4] So, these two hashtags, with similar meanings, function as markedly distinct networked conversational spheres.

The significance of these findings comes with the challenge to the notion of networked public spheres as deliberative spaces. As hashtags form distinct publics, future research should examine the extent of the overlap between them and the interactions that take place at their intersections. We must also consider the ways in which publics enacted through hashtags are not equal in terms of political, economic, and social resources. Our results show that the least segmented hashtags in terms of anti-, neutral, and pro-shale sentiment are the #natgas and #shalegas hashtags, which means they have the most potential for cross-cutting discourse to occur, yet their overall volume is markedly lower than the hashtag we expected to be most contested, #fracking. Future research should examine the quality of interactions that take place within networked social platforms. Whether they constitute spaces for deliberative dialogue and are supportive of democratic processes, or rather if they polarize and mobilize a particular set of stakeholders's base, such as anti-fracking activists, as the results of this study suggest, requires further study. Additionally, our analysis did not delineate tweets by topic, which could have allowed for examination of how certain topics played out across hashtags. An interesting next research step is to examine which topics cross-cut hashtag publics discourse and which topics are siloed within each hashtag public.

The social media platform Twitter fuses media broadcast-like and gatekeeping functions embedded within, and generative of, social ties and networks. The affordances and constraints of each platform affect the interactions taking place within them and shape identities and audiences in complex ways (Baym and boyd, 2012). The information shared within hashtag publics is often personalized. In the context of a movement hashtag, a high degree of certainty expressed in tweets could have mobilizing effects and amplify or reinforce movement diffusion processes, yet have negative effects on cross-cutting deliberation. On the other hand, uncertainty could have demobilizing effects. High certainty within a hashtag public could reinforce a sense of moral authority or of being "correct" about contested issues, in this case either in favor of shale development or opposed to it.

While the results of this study are significant in charting new areas for Twitter research, specifically on the use of hashtags, there are several limitations. First, Twitter users are not representative of overall public opinion. As of November 2013, only 16% of US adults used the platform (Mitchell and Guskin, 2013). Individuals who report getting news from Twitter are younger, more educated, and use mobile devices to a greater degree than the general US public (Mitchell and Guskin, 2013). While Twitter is a platform conducive to discourse on current events and breaking news, past research has shown that opinion on Twitter is not a reliable indicator of broader public opinion (Matsa and Mitchell, 2014). The period of time during which the data used in this study was collected was one of heightened contention. Our research shows that voices on Twitter for the #fracking hashtag are reflective of a particularly engaged subset of specialist actors. Disinterested individuals likely hold a wide range of opinions on this issue and our research indicates are not publicly expressing them using the #fracking hashtag. Thus, the findings of this study are not generalizable as, in anyway, reflective of overall public opinion on fracking. However, this research provides insight into the synergistic effects of activists' use of Twitter to share information about pre-planned events on a transnational scale, in combination with responses to breaking news events, such as the arrests of First Nations anti-shale demonstrators in NB, Canada.

5. Conclusion

Social media platforms provide new potential modes of networked public participation around contested technology and science. In this article, we show statistically significant differences in the sentiment about fracking across the five hashtags. In addition, results show that the discourse on the main contested hashtag #fracking is dominated by activists, both individual activists and organizations. The highest proportion of tweeters, those posting messages using the hashtag

#fracking, were individual activists, while the highest proportion of @mention references went to activist organizations. This research contributes to responsible research and innovation theory by contributing to understanding the dynamics of networked, social media conversation within public engagement on a contested technology. Platforms like Twitter offer a space to naturally observe the discourse of interested publics around a scientific issue. Finding segmentation among the interested publics involved in the discourse—hashtag publics—has significant implications for both policymakers and the idea of online deliberation. Policymakers turning to new media platforms to gauge temperature of public are going to get very different views depending on what logically synonymous hashtags they follow.

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Notes

1. The 555 tweets coded as "not applicable," less than 1% of the total number of English tweets, are excluded from the chi-square analyses.
2. In accordance with the university institutional review board (IRB) approval for this research, we are not identifying individual Twitter users who are not public figures (e.g. elected officials or journalists).
3. Between the top tweeters and @mentioned accounts, there is an overlap of 70 accounts (35%).
4. #TagDef can be accessed at https://tagdef.com/.

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