PARTISANSHIP, INFORMATION, AND PUBLIC OPINION ABOUT YUCCA MOUNTAIN

Matthew C. Nowlin
College of Charleston, Department of Political Science, nowlinmc@cofc.edu

The knowledge deficit model posits that differences in opinions between experts and the mass public about scientifically and technically complex issues can be overcome by providing information to the public. Using a nationwide sample of the US population from March 2002, this paper examines the knowledge deficit model as a Bayesian learning model. I find that, contrary to the standard knowledge deficit model, respondents did not update their priors or process information in an unbiased way, but rather that Democrats and Republicans varied in the weight they attached to the information and in their overall support for Yucca Mountain. I conclude with a discussion of the continued utility offered by the knowledge deficit, particularly when expressed as a Bayesian learning model.

I. INTRODUCTION

In the United States, policy choices are made within and across political institutions that rest on a foundation of public support[1]. As a result, public support–or at least the lack of sustained public opposition–is an important component of successful policy development. The planned used nuclear fuel (UNF) repository in Yucca Mountain became steeped in political and social controversy from the moment it was selected to be the only repository site considered. Much of this controversy focused on the selection process of Yucca Mountain, which was seen by many in the state of Nevada to be a political, and not a scientific, consideration. As a result, the public and elected officials in Nevada were, in large part, opposed to Yucca Mountain. The opposition to Yucca Mountain arose despite consensus about its safety and efficacy among the scientists and engineers involved with its development[2]. This disconnect represents a familiar pattern where expert and public opinion diverge on technical and controversial issues (e.g., climate change, stem cells) and is certainly prevalent within the issue of used nuclear fuel[3–5].

Among the scientific and technical community, this disconnect is often seen as resulting from a lack of understanding about the science underlying the issue or a lack of overall scientific literacy among the public. The assumption of public ignorance regarding science is the basis of the *knowledge deficit model* and, according to this model, the way to close the gap between science and public opinion is to educate the public by providing information about the basic science from which scientists draw in forming their opinions. In keeping with the knowledge deficit model, many saw the opposition to Yucca Mountain as based in ignorance of the facts surrounding the safety of the proposed repository and once these mis-perceptions were corrected, support for the facility would rise. This paper uses public opinion data collected in 2002, when Yucca Mountain approval was being considered in Congress and by the president, to examine the knowledge deficit model and its predictions about support for the Yucca Mountain facility.

II. THE KNOWLEDGE DEFICIT MODEL

The knowledge deficit model posits that disagreements between scientists and the public results from information asymmetries, therefore reducing disagreement entails reducing the information asymmetry between scientists and the public. Implied in this approach is the assumption that individuals are rational and update their beliefs or opinions in a way that is proportional to the information. Given this assumption, the standard knowledge deficit model can be expressed as a Bayesian learning (or updating) model, based on Bayes' theorem. In brief, Bayes theorem states that a conditional probability $P(Y|X)$ represents the odds of Y conditioned on X and it is expressed as:

$$P(Y|X) = \frac{P(X|Y)P(Y)}{P(X)}$$

Bayesian learning states that $P(Y)$ represents the belief about Y *prior* to the introduction of some information X and $P(Y|X)$ represents the *posterior probability* or the beliefs about Y following the introduction of X. In addition, $P(X|Y)$ represents the likelihood function that is assigned to the information X. Finally, the posterior probability is updated according to Bayes' Rules that states that the posterior is proportional to the prior times the likelihood[6]. In terms of the knowledge deficit model, Bayes learning would state that the public has some prior opinion $P(Y)$ about a science based policy issue, is presented with information I, and updates their prior opinion in light of the information $P(Y|I)$, shown below:

$$\text{Prior Opinion} \rightarrow \text{Information} \rightarrow \text{Post Opinion}$$

Under the assumptions of the standard knowledge deficit model, the public's updated opinion would more closely

reflect scientific opinion because, under Bayes' rule, the posterior probability results from the prior multiplied by the likelihood function of the information. In the knowledge deficit model, this likelihood function would be in proportion to the weight of the evidence. Therefore, even strong priors should be overcome in light of heavily weighted information. For example, under this model those least likely to think that humans have contributed to climate change would update that belief given the weight of scientific consensus.

Despite the intuitive appeal of the knowledge deficit model, little empirical evidence has been found to support it or, more broadly, the notion of Bayesian updating by the mass public. There are several reasons that the public may fail to be "good Bayesians." One is that people tend to be susceptible to "cognitive conservatism"–the over-weighting of prior beliefs[7]–or "confirmatory bias" where individuals interpret ambiguous evidence as supporting their prior beliefs[8]. Given that, under Bayes' rule, the posterior is proportional to the prior times the likelihood, over-weighting the prior would mean that the posterior would not fully reflect the new information. The implication is that individuals are not likely to update their beliefs in a manner sufficient to reflect learning.

In addition to over-weighting priors, individuals may be *motivated reasoners*. These motivations include a motivation for accuracy or a motivation for "directional goals" where individuals only seek information that confirms their prior beliefs and opinions[9]. Updating as a result of this type of information would either not cause a shift from prior beliefs or lead to a polarization of opinions[10].

Apart from a failure to move significantly from their priors, individuals are limited in the ways that they process information. As noted, the knowledge deficit model assumes that information will be weighted through the likelihood function and posterior beliefs are updated in proportion to the weight of the information. However, information is typically not weighted in that way given that individuals have cognitive limitations in the amount of information that they can consider[11]. Therefore, individuals are not able to effectively process all of the relevant information when trying to update their beliefs or opinions. In addition, individuals may weight information differently. For example, they may weight information that confirms their prior beliefs more than other pieces of information. Finally, individuals may also weight information differently based on how it is framed[12]. Views on policy issues can be shaped, in part, by how the media and political elites present information about the issue[13].

Even given its shortcomings, the knowledge deficit model (expressed in Bayesian terms) is still quite useful as a baseline or benchmark with which to examine the ways in which individuals fail to update their beliefs[14]. The standard knowledge deficit model posits that divergent views between scientists and the public on policy issues are overcome through the provision of information. This model, expressed in Bayesian terms, posits that the public's prior opinion is updated after receiving some information about the policy issue. However, individuals tend to overweight their priors and process (or weight) information differently and this results in a failure to update in a consistent and additive manner across individuals. Even so, the model is useful for simplifying the knowledge updating process and for highlighting the key components, namely the prior and the weighting of new information. Based on the model, hypotheses can be drawn that examine the nature of prior beliefs and who might hold them and how individuals might weight information differently. The next section examines the knowledge deficit model and public opinion regarding Yucca Mountain.

III. PUBLIC OPINION ABOUT USED NUCLEAR FUEL STORAGE

Public support, or the lack of public opposition, is a vital piece of policy success. However, the engagement of the public on specific policy issues tend to vary by issue type. For example, "hard" policy issues that are scientifically and technologically complex, like used nuclear fuel management, and require effort on the part of the public to become informed tend to be less salient to the general public. These types of issues can be contrasted with "easy" policy issues where the issue has become "so ingrained over a long period that it structures voters' 'gut responses' to candidates and political parties"[15]. One of the things that separate hard issues from easy issues is the attention they have received from political elites and the media. Issues that are more salient–have received widespread and sustained attention–are considered easy for the mass public to develop consistent opinions about, whereas complex issues that receive sporadic elite attention are more difficult for the public to form opinions. However, when provided with information the general public can form systematic and consistent views about hard issues like Yucca Mountain[16].

The distinction between hard and easy issues applies well to the general public and leads to the expectation that, overall, the mass public is not likely to have strong opinions regarding Yucca Mountain. However, Yucca Mountain does have a strong and vocal *issue public*. An issue public is a subset of the mass public that finds a particular issue highly salient and is more likely to be informed about the issue and involved in the political process that deals with the issue. Issue publics are motivated by self-interest, identification with a reference group, and relevance of basic values[17]. The issue public that engaged in the Yucca Mountain issue is largely in opposition to the facility and consists of residents of Nevada, environmentalists, and opponents of nuclear energy. Nevada residents are motivated to oppose Yucca Mountain through self-interest due to the perceptions of risk associated with the facility[18,19] and the potential for stigma for the state

of Nevada, due to the negative images associated with nuclear waste[20,21]. Finally, opposition is related to basic values such as cultural worldview, political ideology, and political party attachments[22,23]. The next section explores the knowledge deficit model and support for Yucca Mountain.

III.A. Knowledge Deficit and Yucca Mountain

This paper examines the utility of the knowledge deficit model for understanding the nature of support and opposition to the Yucca Mountain facility among the mass public in the United States. The standard knowledge deficit model, expressed in Bayesian terms, posits that citizens have some opinion about a policy issue, receive some information regarding that issue, and update their opinions based on the information. Empirical work has shown that in general individuals do not update information in this way but rather act as imperfect Bayesians. However, this model can still provide useful insight into how individuals process information. In addition, this model can be used to derive some expectations about support for Yucca Mountain both prior to and after receiving information about Yucca Mountain.

To examine the knowledge deficit model, I explore prior support for Yucca Mountain, the weighting of information about Yucca Mountain, and the post support. In terms of prior support, given the low salience of Yucca Mountain for the mass public, I expect low levels of support overall. In addition, I expect support among Republicans to be higher than Democrats.

For information processing, I expect that information with a negative frame will be weighted negatively and information with a positive frame weighted positively. In addition, I expect that Republicans will place a more positive weight on the information than Democrats.

Finally, for post-information support I expect that prior support and the weight given to the information to be significant predictors of support. In addition, I expect Republicans to have a higher level of post support than Democrats.

IV. DATA, ANALYSIS, AND RESULTS

To examine the impact of information on public support for the Yucca Mountain facility, I used survey data collected by Ipsos-Reid in March of 2002.[a] This data comes from a phone survey administered to a nationally representative sample of 1,000 adults living in the United States. The survey asked respondents several demographic questions, questions about political attitudes, and questions about the Yucca Mountain facility. Specifically, respondents were asked about their level of support for the facility. Respondents were then given six facts about Yucca Mountain–three framed in a positive way and three framed in a negative way–and they were asked whether each fact made them more likely to support or more likely to oppose the facility. Following the introduction of these facts, respondents were again asked about their level of support for the Yucca Mountain facility.[b] This data allows for a pre and post test to examine the influence of information on support for Yucca Mountain. In addition, it allows for an understanding of how information is weighted and its impacts on views about Yucca Mountain. In total, the data is useful for analyzing the knowledge deficit model as a Bayesian updating model.[c] The next section examines how each of the variables used in the subsequent analysis were measured and prior support for Yucca Mountain.

IV.A. Prior Support for Yucca Mountain

The first step in the analysis is to examine support for Yucca Mountain prior to the introduction of information. Survey respondents were asked their level of support for the Yucca Mountain facility:

> Recently, the Department of Energy and the Bush Administration recommended that the Yucca Mountain site in Nevada be developed as the nation's first long-term geologic repository for high-level radioactive waste. This means that all of the nation's nuclear waste would eventually be moved to and stored at Yucca Mountain. From what you know or have heard, would you say that you strongly support, somewhat support, somewhat oppose, or strongly oppose a nuclear waste storage facility at Yucca Mountain, or do you not know enough to say at this time?

The above question measures the prior level of support for Yucca Mountain. Prior to the introduction of information, 24.8% of respondents indicated that they either strongly or somewhat supported Yucca Mountain. However, the majority of respondents, 51.7%, indicated that they did not know enough to say. This result speaks to the overall lack of salience of Yucca Mountain *for the general public.*

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[a] This dataset in available through the Roper Center for Public Opinion Research, USIPSOSREID2002-093.

[b] Full question wording is available from the author by request.

[c] Note that this is observational data and not an experimental design where information can be randomly assigned to a treatment group that is compared to a control group that did not receive information. In this case each respondent received the same information, therefore statistical controls will be used in place of random assignment.

I used logistic regression to predict support for Yucca Mountain, both pre and post information. The dependent variable, prior support for Yucca Mountain, is a dichotomous variable with 1 being strongly/somewhat support and 0 being strongly/somewhat oppose and don't know enough to say.[d] Several independent variables were used including demographic variables–age, race, gender, education, income, and location of residence which included dummy variables for the northeast and rural areas–and political variables including approval of President George W. Bush, a 1 to 7 scale with 1 being strongly disapprove and 7 being strongly approve, and political party attachment with 1 indicating strongly Republican and 5 strongly Democratic.

With each variable at its mean, the predicted prior level of support for Yucca Mountain was 0.251. In terms of the demographic variables, **age**, **gender**, and **education** were significant predictors of support. Older respondents were, on average, more supportive, men were more supportive than women, and higher levels of education led to more support. In addition, income was positive and significant at the $p < .10$ level. For the political variables, **approval of President Bush** was significant at the $p < .10$ level and **political party** was highly statistically significant at the $p < 0.0001$. For strong Democrats the predicted probability of support, holding all else constant, was 0.162, whereas for Republicans it was 0.337.[e] This was as expected given the partisan divide over nuclear energy and technology.

IV.B. Information

As noted, prior support for Yucca Mountain was divided between Democrats and Republicans. The next step is to determine the degree to which the provision of information about Yucca Mountain can both a) increase overall support among survey respondents and b) reduce differences in support along partisan lines. In its purest form, the knowledge deficit model argues that closing the information deficit between scientists and the public would lead to agreement on scientific and technically complex policy issues such as Yucca Mountain. This model, expressed as a Bayesian updating model, states the degree to which opinions are updated are a reflection of the strength of the prior opinion and the weight given to the information presented. This section examines the different weights given to the various pieces of information that were provided to the respondents. Overall, six facts–three with a negative frame and three with a positive frame–about Yucca Mountain were given to respondents and respondents were then asked to state whether that fact made them much more likely/somewhat more likely to support or oppose. I recoded these responses such that -2 means much likely to oppose, 0 means no difference, and 2 means much more likely to support. These scores were used to determine the weight that respondents gave to each piece of information with scores closer to a -2 indicating a strong negative weight and scores closer to 2 indicating a strong positive weight. Table I presents each fact given to respondents, the frame (negative or positive), and the mean $\bar{X}$ weight assigned to each fact.

TABLE I. Information about Yucca Mountain

Frame	Fact	X Weight
Negative	The Yucca Mountain is located just 90 miles from Las Vegas	-0.443
Negative	Nuclear waste would be transported to Yucca Mountain from storage sites all over the United States, which could mean that nuclear waste would be transported through your state	-0.483
Negative	Storage of nuclear waste at Yucca Mountain could lead to groundwater contamination	-1.152
Positive	Scientists say the rock will keep the waste sufficiently isolated for thousands of years so that the radioactive material will pose about the same risk or less risk of health effects to the public as that of unmined uranium ore	0.517
Positive	Scientists say that Yucca Mountain's very dry climate, less than 6 inches of rainfall a year, and its extremely deep water table make Yucca Mountain a good choice for a national storage facility	0.512
Positive	Some people say that it is better to have one central storage facility for nuclear waste rather than storing it in numerous facilities as is currently the case	0.449

As can be seen the strongest weight, -1.152, was given to the possibility of groundwater contamination. The other negative facts also have negative weights, whereas the positively framed facts had positive weights. I added the scales together and divided by six to measure the overall weight given to the information. Therefore, the scale for the overall weight given to the information ranged from -2 to 2. The overall mean was -0.094, which is close 1 (a slight negative overall weight). The slight negative is likely a result of the strong negative weight given to the groundwater contamination item.

Despite the overall mean being near 1, it is likely that respondents varied systematically in the weights they assigned to the information. For example, given the lower levels of prior support I expect that Democrats will weight the negative information more, whereas Republicans will weight the positive information more. To examine this proposition, I performed an OLS regres-

[d] The variables were coded as dichotomous to allow for the most straightforward estimation of the influences of support. Other modeling approaches such as OLS regression and multi-nominal regression produced the same results, therefore Logit regression is used for ease of presentation and discussion.

[e] Full model results are available from the author by request.

sion with the overall scale of information weights as the dependent variable and the same demographic and political predictors as the prior support model. For the demographic variables **age**, **male**, **white**, and **education** were all positive and significant predictors of information weights. In terms of the political variables, both **presidential approval** and **political party** were significant predictors.[f] As expected Democrats placed a more negative weight on the information than Republicans. On average, strong Democrats have a predicted weight of -0.382, whereas strong Republicans have a predicted weight of 0.218. These results indicate that, as expected, political values affect not only the initial level of support for Yucca Mountain, but they also affect the way that information about Yucca Mountain is weighted and processed.

IV.C. Post Support for Yucca Mountain

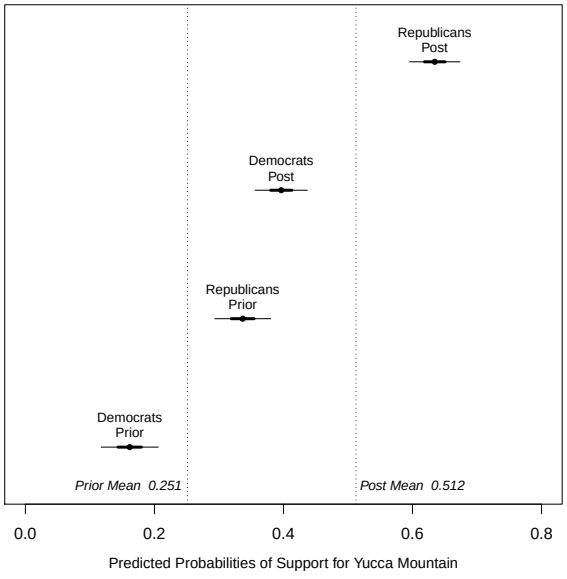
The final step in this analysis is to measure the support for Yucca Mountain accounting for both the prior level of support and the weight given to the information about Yucca Mountain provided to the respondents. The model for post support contains the same demographic and political variables, but it also includes the prior support variable and the information weights variable. I expect that those respondents that supported Yucca Mountain previously and those that placed a positive weight on the information will be more supportive of Yucca Mountain. The results show precisely this, those that supported Yucca Mountain previously were more likely than those that opposed or didn't know enough to support Yucca Mountain in the post model. Also, as expected, those that placed a more positive weight on the information were more likely to support Yucca Mountain. Finally, only the approval of President Bush remained significant once controlling for prior support and information weights. This result indicates that only presidential approval and not demographics or political party had an independent impact on Yucca Mountain approval after controlling for prior support and information.

V. DISCUSSION AND CONCLUSION

This paper used survey data collected in March 2002 to examine the support for Yucca Mountain using the knowledge deficit model expressed as a Bayesian learning model. As expected, respondents did not follow the standard knowledge deficit model, where prior beliefs are updated based on new information in an additive way but rather the information was weighted differently based on demographics and political values. However, this paper does demonstrate the utility of a Bayesian approach to the knowledge deficit model when the differences in prior support and differences in the way information is weighted are taken into account.

Figure 1 represents the results of the analysis for prior and post support for strong Democrats and strong Republicans, with 90% and 95% confidence intervals.[g]

FIG. 1. Predicted Probabilities of Support for Yucca Mountain Pre and Post Information by Political Party



As can be seen; the predicted probability of support for Democrats *prior* to the information was 0.162, whereas the predicted *post* level of support was 0.397. These results indicate, as the knowledge deficit model would expect, an increase in support among Democrats following the introduction of information. However, that increase remains below 50% and does not reflect complete updating because of the low prior level of support and the overall negative weight given to the information. For Republicans, the prior predicted level of support was 0.337, and the post predicted level of support was 0.634.

The results presented offer some insights to consider in terms of public support for a future UNF repository. First, information provision is not enough to convince the public, particularly an issue public. While the mass public is likely not to hold strong views, an issue public will

[f] The full model results are available from the author.

[g] The results show the predicted probabilities based on the models with control variables held constant at their mean for the prior model. For the post model control variables are held at their mean, but prior support and information weights are based on their model predictions for Democrats and Republicans respectively.

likely over-weight their prior opposition and weight the information presented in a more negative fashion, making agreement much more difficult. In addition, the standard knowledge deficit model overestimates the degree to which consensus can be achieved through providing information, regardless of the type of information or how it is framed. However, understanding the knowledge deficit model as a Bayesian learning model illustrates the ways in which it is not effective. Its effectiveness is questionable because of how individuals over-weight priors and how they process information. While the results indicate that overall support increased in the general public, they also indicate that the issue public–those for whom the issue is extremely salient–are not likely to see a shift in opinion toward support. Note that the issue public was represented in this analysis by strong Democrats in the overall public, however resistance from the public in the state that is being considered to host a repository will likely be much stronger. The most effective strategy for dealing with an issue public is to design a site-selection process that is open and consensus-based from the beginning. Strategies that are decide-announce-defend are likely to create strong and vocal issue publics, which in turn make successful policy development much more difficult.

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