The role of better information in discrete choice experiment: a mining focus

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Abstract

In a discrete choice study, I challenge the common hypothesis of Bayesian updating in the face of new information. To this end, a large-scale on-line experiment is designed to elicit the social desirability of mining for gold, uranium and rare earths in the Canadian province of Quebec. In this experiment, I compare how individuals with opposite priors update their risk beliefs in response to more useful information. As a result, I find mixed evidences of Bayesian updating in varying valuation contexts. Despite of useful information, prior beliefs matter for valuation purpose in preference analysis.

Key words: useful information, Bayesian updating, belief distortions, discrete choice experiment

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1. Introduction

Many industrial projects pose a social dilemma under uncertainty and risks. Information plays here a huge role as it gives ground to decisions-taking relating to public projects. People must understand how well the proponents will maintain and monitor an oil-pipeline project, a gold pit expansion or a nuclear central plant. When information is missing or false, people are likely to make wrong inference on the balance between risks, costs and benefits (Fischhoff, 2015). Put another way, information influences belief formation which in turn will affect preferences on how to implement and regulate large-scale projects.

Under free information provision, discrete choice studies used to elicit changes in preference on a bundle of goods unavailable on the market. Subjects commonly receive additional information about risk reduction to policies, projects or environmental public goods (Norden et al., 2017; Torres and Faccioli, 2017; Byun, Shin and Lee, 2018; Faccioli, Kuchfuss and Czajkowski, 2018). It is typically assumed that people process new information towards the Bayesian updating system (Rabin, 2002). In this neoclassical framework, rational individuals update prior beliefs in an unbiased way after receiving imperfect information on the state of the world. This leads to the following question under preference analysis and risks: do people update additional information in their choices such as in the lens of Bayesian updaters?

This paper studies this question when people share different prior beliefs about large-scale projects. A mining focus is suitable to this purpose and a discrete choice experiment is applied to test the hypothesis of Bayesian updating. In the mining context, people shall learn on how well the technology is appropriate to control a hazard at the lowest bound of risk. From this perspective, how do people with opposite priors about mining assimilate new information? The goal of this paper is to provide an answer.

If people fail to update additional information in a "Bayesian" fashion, a vast literature in psychology and behavioral economics pays attention on distorted belief attitudes. Under the so-called confirmation bias, people overweight information in support of their initial beliefs, but denigrate the quality of conflicting information (Golman, Hagmann and Loewenstein, 2017). Beliefs are closely connected with information when it relates to personal abilities (Eil and Rao, 2011), prior knowledge (LaRiviere et *al*., 2014) or opinions on public issues (Lord, Ross and Lepper, 1979).

As for the context of climate change, people used to have different priors about man's responsibility (Sustein et *al*., 2017). People with stronger beliefs are more likely to overvalue unfavourable predictions while undervaluing favourable predictions. After having heard a non-catastrophic nuclear breakdown, people with different views react in the opposite direction (Plous, 1991). Opponents emphasis on the failure of public hazard control whereas supporters stress on the success of mitigation measures. Belief divergence appears even to balanced information about food contamination (Morgan et *al*., 2009) and hormone-treated food (Alfnes and Rickertsen, 2003). These pieces of evidences together suggest an unexpected outcome in preference analysis. The same information could result after belief revision in increasing the dispersion of preferences across individuals.

With this major concern in mind, I perform a test of Bayesian updating in a discrete choice experiment framework. To this end, a simple way is to examine the interaction between beliefs and preferences. In particular, I clearly identify belief attitudes about the good under valuation and I provide additional information more or less relevant to valuation context.

Beliefs are highly dependent to the context (Alekseeva, Charnessb and Gneezy, 2017). For this reason, I apply exogeneous contexts where exposure to risks varies across individuals. In split samples, I systematically elicit prior beliefs about mining gold, uranium and rare earths when the mine is located in (*i*) less than 20 km, (*ii*) 20 to 100 km, (*iii*) more than 100 km.

On the basis of experts' advices, I construct information treatments more or less relevant to the context. In doing so, people should gradually increase their understanding on the valuation context. Consistent with "Bayesian updating" predictions, more relevant risk information improves the quality of data (Roberts, Boyer, and Lusk 2008; Shaw and Baker 2010) with lower variance and higher convergence in choice-based preferences.

For the testing of Bayesian updating, the experiment proceeds as followed. At the time of reading the mining context, subjects state whether they are pro, neutral or con the desirability of the new mine. On an 8-point Likert scale, individuals with opposite priors indicate how sure they are to be opponents or supporters. Next, subjects are randomly exposed to three possible information treatments: (*i*) missing information, (*ii*) useless information and (*iii*) useful information. Finally, subjects after processing information make choices on the social desirability of mining among alternatives of improved projects.

Our results produce clear insights for preference analysis. First, beliefs influence the pattern of choice-based preferences as highlighted by a growing body of the literature in non-market valuation (Meldrum, 2015; Kragt et al., 2016; Meyerhoff and Liebe, 2009). I find that subjects with opposite priors are more likely to choose an alternative in support of their initial beliefs. Put another way, opponents are more convinced to choose the statu quo option whereas supporters are more likely to accept at least one option of improved projects.

Second, subjects with opposite priors reflect an asymmetry in the predictability of their choices. Setting neutral groups as the baseline, supporters have a higher scale (lower variance) in contrast to opponents.

Third, additional information interacting with prior beliefs affects preferences. In the experiment of gold, both opponents and supporters display convergent preferences in line with the Bayes' rule, while belief divergence appears for uranium and rare earths mining.

Fourth, I do not find any evidences of belief attitude polarization once additional information is revealed. For example, opponents reinforce their beliefs about disproportional costs of a uranium mine in the face of more relevant information whereas supporters revise their beliefs suggesting partial processing of Bayesian updating.

Aggregated welfare results could mask the importance in prior beliefs. This paper provides mixed evidences of Bayesian updating under free information provision in discrete choice surveys. Incorrectly assuming Bayesian subjects, if in fact individuals have distorted beliefs, would lead to biased aggregated welfare results. I suspect that parts of information relating to risks and uncertainty could interact with prior beliefs. Belief distortions are one potential explanation among other psychological factors. More research is needed to test the potential for belief distortions under free information provision over a broader range of goods.

The remainder of the paper proceeds as follows. Section 2 presents a brief literature about the role of information in the valuation of goods. Section 3 discusses the data collect about multiple non-renewable resources. Section 4 explains the identification strategy to capture the effects of information processing on preferences. Section 5 presents the results and section 6 concludes.

Testing the model of Bayesian updating

In a discrete choice experiment, I provide a formal test of Bayesian updating in response to new information. This paper is related to a large body of the non-market valuation literature questioning the impacts of new information on preferences (***). In an attempt of setting up the valuation context, discrete choice studies used to provide large amounts of free information (***).

To make clear the predictions of Bayes' rule in preference analysis, useful information is a mean to improve decisions while useless information does not have any impacts (Golman, Hagmann and Loewenstein, 2017). Missing information about an unfamiliar good lead people to make more erroneous choices (***). New information relevant to the valuation context pushes welfare estimates in the direction of the "true" social values (***). It is expected that the variance in choices decrease in the face of more informative signals (***). New information beyond the valuation context should not affect both preferences and the predictability of choices.

While a growing body of the literature recognize how important are beliefs in preference analysis (Meldrum, 2015; Kragt et al., 2016; Meyerhoff and Liebe, 2009), it is still unclear how prior beliefs interact with free information provision.

To date, two field studies empirically test the model of Bayesian updating in the discrete choice experiment framework (LaRiviere et *al*., 2014; Czajkowski et *al*., 2015; Czajkowski, Hanley and LaRiviere, 2016). In particular, LaRiviere et *al*. (2014) test the impacts of information about the familiarity relative to the good under consideration. Their findings suggest that familiar individuals display higher willingness-to-pay a public good after receiving new information. Czajkowski et *al*. (2015) propose a theoretical foundation of Bayesian updating process in which individuals update their experience resulting from the public environmental good after completing a survey on the same field.

Holt and Smith (2009) find that individuals seem to not deviate from the Bayes' rule at the aggregate levels. But when looking closely extreme prior beliefs, they find systematic evidences of non-Bayesian updating. In a contingent study, Czakowski et al. (2017) evaluate three competing models of information updating process. Their findings suggest the presence of confirmation bias such when individuals display biased assimilation of objective scientific information.

Discrete choice survey

In the last twenty years, worldwide demand encouraged the extraction of non-renewable resources (e.g. rare earths), which were in turn combined with larger external effects in producer countries. Values of these externalities are rarely reflected in international market prices as unavailable in the market but could be source of social conflicts in mineral-rich economies. While some project attributes appeared to be not aligned with public preference, few data exist on the social desirability of mining. The Government in the Canadian province of Quebec indicated their willingness to obtain more complete information on how people want to regulate and monitor mining projects.

In August 2017, a field survey is conducted in the Canadian province of Quebec to determine the social desirability of mining three resources: gold, uranium and rare earths. Mining sectors are well-developed in Quebec representing around thirty minerals under operation. At the time of the study, uranium and rare earths recently demonstrated a huge potential for extraction, whilst gold mining served the development of the province from 1800 until today. Data were collected on-line by a Canadian polling agency. We obtain 3004 completed questionnaires including 1017 respondents for gold, 1046 respondents for uranium and 941 respondents for rare earths.

The field survey included five parts. The first part collects information about social perceptions to energy and individual trust towards stakeholders. The second part tests the general knowledge of the subject in the form of a an 8-question multiple choice quiz. The third part is the discrete choice experiment with a series of follow-up questions. The fourth part collects information about the sociodemographic characteristics of the respondent.

Experimental procedure

To do the testing of the hypothesis of Bayesian updating, four stages are implemented in this experiment: (I) variations in the valuation context, (II) belief elicitation specific to the context, (III) provision of additional information, (IV) a discrete choice experiment.

1. Stage I: Exogeneous variations of the mining context

A typical discrete choice survey gives many details about the good under consideration, the valuation context and also describe the nature of changes in a useful form. One key feature of this experiment is to elicit different prior beliefs in the valuation context of mining. I randomly assign a series of nine mining contexts across respondents in a manner that ideally enable testing the Bayesian updating assumption.

All subjects receive a script depicting a context of a twenty-year mining project providing substantial economic benefits in the surroundings in harmony with the current environmental norms (see one possible example of a script in Annex). What is different across the mining contexts are the type of resource and risk exposures. The type of resources includes gold, uranium and rare earths. Risk exposures are expressed in terms of distance between the hypothetical mine and the subject's house.

2. Stage II: Elicitation of prior beliefs

After the respondents reading the valuation context, I employed two questions to elicit prior beliefs on the costs and benefits of the planned mine. The first question "*Is the opening of the new mine preferable to the current situation with no planned mine?*" presents three possible statements in order:

- "*I am certain that costs would overcome the benefits of the new mine.*"
- "*I am not certain that benefits and costs would be more or less.*"
- "*I am certain that benefits would overcome the costs of the new mine.*"

I treated as opponents (*supporters*) respondents who chose the first (*third*) statement. Other respondents who chose the second statement have neutral attitudes towards the planned mine and therefore belong to the neutral groups. Second, opponents and supporters were asked the magnitude of their beliefs using the wording "*Please indicate how sure you are on a scale from 1 to 8, where 1 means weakly certain and 8 means strongly certain.*" Neutral groups do not answer this question and directly access to the next screen on details about the project attributes.

On the basis of the results collected with the two questions of belief elicitation, the table 1 reports the proportions of subgroups ranked by belief status. Belief-based groups display extreme beliefs when they stated a score of belief above the average. Either opponents or supporters who share moderate beliefs have stated belief score below the average. The last two lines report the average score of beliefs across sub-groups.

Table 1 - Initial beliefs on planned mining projects

	Gold			**Uranium**			**Rare earths**		
	0-20km	20-100km	>100km	0-20km	20-100km	>100km	0-20km	20-100km	>100km
Extreme opponents	11%	9%	8%	20%	16%	15%	12%	9%	6%
Moderate opponents	8%	11%	8%	15%	16%	24%	12%	12%	13%
Indifferents	47%	46%	45%	39%	40%	37%	46%	48%	44%
Moderate supporters	19%	21%	22%	17%	18%	14%	19%	18%	26%
Extreme supporters	15%	13%	16%	9%	11%	10%	11%	14%	10%
Avg belief score									
– opponents	6.5	6.27	6.19	6.44	6.18	6.05	6.12	6.21	6.05
	(1.59)	(1.4)	(1.54)	(1.59)	1.69	(1.44)	(1.64)	(1.51)	(1.11)
– supporters	6.30	6.32	6.26	5.95	6.24	6.15	6.18	6.21	5.90
	(1.11)	(1.09)	(1.02)	(1.44)	(0.97)	(1.44)	1	(1.10)	(1.26)

Note: In the first panel proportions of belief-based groups are reported. We indicated in the second panel mean values and standard deviations in parenthesis.

3. Stage III: The design of better information

Subjects are randomly exposed to three information treatments: missing information, useless information and useful information. The structure of information is designed in line with advices from experts in the mining industry. Information with larger quality requires that respondents enhance their understanding of valuation scenarios. By doing so, we distinguished information beyond the scope of mining (useless information) and information relevant to the valuation scenario (useful information). Importantly, the structure of information is constructed with respect to specific features of each resource (see table 2).

The three versions of information reminded respondents information on the geological characteristics of the resource. The treatment 1 (T1) did not provide any information in addition to those displayed in the survey (missing information). T2 was similar to T1 except that additional information was given on three uses of complement goods relative to the resource. T3 provided additional information on the technology risks on the environment. Either T1 or T2 is expected to not increase the understanding of valuation scenarios, while T3 contributes to underline the associated risks of mining one resource.

Table 2 - Information treatments with varying quality

	Gold	Uranium	Rare earths
T1: Characteristics of mineral	Gold is a precious yellow metallic element, highly malleable and ductile, and not subject to oxidation or corrosion.	Uranium is a white, metallic element which exists in the nature and is found in varying low quantities in rock, land, water, air, plants, animals and human beings.	Rare earths are any of a group of similar oxides of metal or a mixture of such oxides occurring together in widely distributed but relatively scarce minerals.
T2: Resource's uses	Gold is used to manufacture electronic circuit and luxury item such as jewels. Dentists use gold for filling and crown.	Uranium is used in medical and nuclear medicine for the cancer treatment. Uranium contributes to generate nuclear energy by decreasing the emissions of greenhouse gas.	Rare earth elements are used to produce wind turbines, battery for electric car as well as smartphones.
T3: Technology of extraction	Gold extraction needs to use chemical products such as arsenic and cyanide. During the process, the current technology is able to control and monitor mining wastes.	Uranium extraction may lead to reject radioactive gas called radon. The current technology is able to control and monitor the mining wastes.	In certain circumstances, extraction of rare earth elements could release important quantity of radioactive elements. A new technology is developed to limit at the minimum the environmental damages.

In particular, T1 is uninformative for the decision-making situation because this information type describes basic characteristics of the resource without consequences on the valuation scenarios. T2 is a mixed quality information. On one hand, T2 is a less reliable information for the decision-making situations as the sequence of valuation scenarios excluded an opportunity for processing minerals across the province. On the other hand, T2 reminded three positive uses of the resource which helped ensure that individuals perceived the resource as a more desirable good for the society.

T3 is an information with larger quality as a balanced view is depicted on how adapted technologies succeeded in minimizing adverse consequences of extraction.

Preferences on mining projects would be incomplete without properly understanding the associated risks of mining on the environment.

4. Stage IV: Discrete choice experiment

On a sequence of six valuation scenarios, respondents were asked to choose among three alternatives: two multi-attribute project alternatives (acceptance choice) and a statu quo alternative (reject choice). The choice of statu quo mentioned explicitly representing the preference for the current situation without a planned mining project. By doing so, we avoid forcing respondents to choose a project alternative inconsistent with their preference, (Dissanayake and Ando, 2015; Blaej et *al.*, 2007) especially when belief updating is embodied by the reject choice.

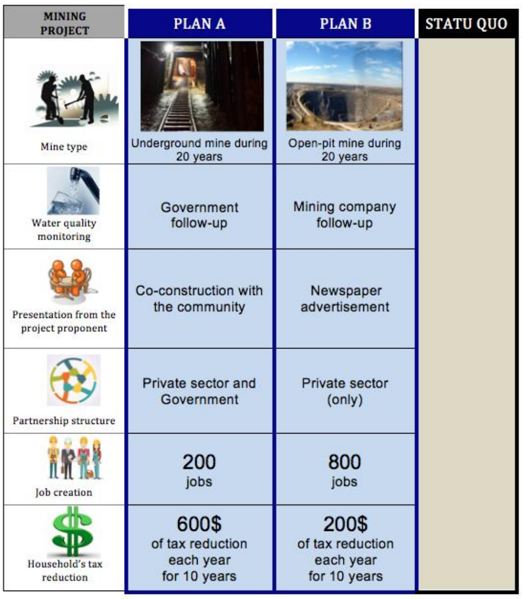
Table 3 – Attributes and levels

Attributes	Description	Levels
Mine types	Low-quality mineral requires open-pit mining and high-quality mineral involves underground mining.	Open-pit mine (baseline) - Underground mine
Water quality monitoring	Mining impacts affect the water quality for which frequent monitoring is required. Different stakeholder can conduct water quality monitoring.	Mining company (baseline) - Government - Independent committee
Presentation by the proponent	Mining proponents may adopt different approach to present their own project to the general public.	Newspaper advertisement (baseline) - Information session with a mediator - Co-construction with the community
Partnership structure	Project funding of mining can be shared by multiple shareholders.	Private sector (baseline) - Private sector and Government - Private sector and Region
Job creation	The mining project offers job opportunities.	200 jobs (baseline) - 500 jobs - 800 jobs
Household's tax rebate for the next ten years	The Government, which received mineral revenues from this large-scale mine, employ a tax decrease for the whole population.	\$100, \$200, \$300, \$400, \$500, \$600 each year for 10 years

The description of project attributes and levels are given in the table 3. Valuation scenarios were constructed on the basis of extensive information collected among 63 stakeholders in the mining industry. In line with expert's advices, the list of attributes was refined to include the key social, economic and environmental aspects in the proposal of a project.

The final hypothetical scenario described in attribute order two environmental aspects, one social aspect and three economic aspects: (*1*) mine types, (*2*) water quality monitoring, (*3*) presentation by the proponent, (*4*) partnership structure, (*5*) job creation and (*6*) tax rebate. Importantly, the willingness-to-accept (WTA) in the form of tax reduction covers both affected people in the surroundings of the planned mine and those located far away.

Figure 1 – Example of choice card



Note: The choice card in French is translated.

I do not include any attribute of distance in the valuation scenarios because large-scale mining projects are located where the mineral deposits are discovered. As shown in stage I, we adopt a split-sample approach to investigate the effect of distance relative to mining projects on changes to people's preference and prior beliefs. The provision of distance intervals [20;100[were oversampled in the big cities of Montreal and Quebec City because during the pre-test, the concern of hypothetical bias appeared to be stronger whether a planned project opened within a 20-km radius in a great city.

We applied the D-efficiency criteria procedure to obtain the final design of 36 choice tasks for which six blocks of six choice sets were randomly distributed across respondents.

5. Randomization of the sample

One major issue is the representativeness of stated preference data relative to the general population. Table 4 compares sociodemographic characteristics between informed groups under better information and the whole population across the province. Each column represents the mean values from T1 to T3 for one of the three resources. The last column reports the mean values for the general population based on the Census 2016. We obtained similar characteristics between the treated groups and the general population.

Table 4 – Summary statistics

	Gold			Uranium			Rare earths			Census
	T1	T2	T3	T1	T2	T3	T1	T2	T3	**2016**
Percent female	0.46 (0.50)	0.47 (0.50)	0.50 (0.50)	0.47 (0.50)	0.51 (0.50)	0.44 (0.50)	0.49 (0.50)	0.49 (0.50)	0.49 (0.50)	0.50
Age (mean)	53.4 (14.2)	53.17 (14.31)	53.63 (13.24)	53.09 13.89	52.99 (13.94)	53.61 (13.80)	54.04 (13.23)	52 (13.95)	52.69 (14.11)	49.2
Education years (mean)	14.54 (3.13)	14.37 (3.26)	14.74 (2.90)	14.55 2.86	14.44 (2.95)	14.36 (3.08)	14.38 2.83	14.57 (2.98)	14.67 (3.06)	13.2
Income (mean)	$64,406 (38,414)	$68,754 (39,722)	$67,694 (38,885)	$63,478 (39,066)	$62,226 (40,084)	$63,147 (39,304)	$64,663 (38,150)	$67,278 (37,544)	$62,777 (38,120)	$63,744
Owner (percent)	0.67 (0.47)	0.67 (0.47)	0.68 (0.47)	0.64 0.47	0.63 (0.49)	0.64 (0.48)	0.67 0.47	0.65 (0.48)	0.67 (0.47)	0.61
Years of residency (mean)	4.85 (1.88)	4.90 (1.81)	4.86 (1.91)	4.92 1.81	4.91 (1.87)	4.95 (1.84)	4.99 1.75	4.65 (1.99)	4.89 (1.86)	
Number of respondents	501	259	257	539	256	251	461	237	243	

Note: Statistics are mean and below standard deviations appeared in parenthesis.

Model and estimation

Model of Bayesian updating

I assess the desirability of extracting a non-renewable resource using the Random utility theory (McFadden, 1974). Assume that a proponent hesitates on J alternatives of improved mining projects for which an individual derives a utility U by choosing an alternative j in choice set t. The choice context is characterized under uncertainty and risks. The expected utility from an additional project is $E(U_{ijt}) = E\{V_{ijt} + e_{ijt}\}$. The deterministic component of the utility V_{ijt} is the observed project attributes relative to the social, environmental and economic aspects. The random component of the utility e_{ijt} captures unknown characteristics from the perspective of the researcher including both attributes of choice and individual-specific characteristics (Czajkowski et *al*., 2015).

Assume two possible states of the world: (*i*) state A at low risk and (*ii*) state B at high risk. The state of the world defines the project type with different risk exposures. Individuals with same unbiased priors consider equiprobable the probability of either being in the states A or B: $P(x = A) = P(x = B) = 0.5$. At time t, information sets i_t are independently and identically distributed across individuals. Information differs in terms of relevance for the context such as $i_t = \{a, b, \emptyset\}$. Useful information (a, b) is given with p while useless information $(\emptyset)$ is provided with $1 - p$. Individuals receive information relevant to the project type with $P(i_t = a/A) = P(i_t = b/B) = \eta \in (0.5,1)$. Either new information a or b is clear to inform on the state A or the state B. In contrast, the signal Ø appears to be a noisy signal unrelated to the states of the world.

People do not know the true social value of the large-scale project. A planned project procured the expected utility $E(V_{ijt}/\eta)$ conditional to the signal received: $E(V_{ijt}/\eta) = \eta\, V_{ijt}^{A} + (1 - \eta)V_{ijt}^{B}$. When the signal is informative about the state A, additional information of $\eta > \frac{1}{2}$ indicates that the project is at low risk. At the opposite in state B, additional information of $\eta > \frac{1}{2}$ informs on a project at high risk. When the signal is uninformative at the probability $1 - p$, Bayesian individuals ignore information as useless information is flawed in state A or state B.

Better information on the state of the world impacts both preferences and variance relating to any choices. In state A, the project procured a lower preference V^A for changes in the project while the project requires more improvements to mitigate risks in state B. When information reminding higher risks ($i_t = b$), Bayesian updaters move upward their preferences for improvement of the project in state B. Otherwise, additional information a argues lower risks justifying less improvements of the project. Useless information (Ø) is equivalent to no additional information relevant to the choice context and is simply ignored with no changes in the preference.

$$Var(V/\eta) = \eta\ (1-\eta)V_a V_b$$

The quality of information also affects the variance associated to any choices. When Bayesian updaters improves their understanding of the choice context, η rises to one or falls to zero. If so, Bayesian updaters know better the risk type of the project consistent which results by the decrease of the variance at the aggregate level. Information unrelated to the state of the world (imperfect signal) triggers a delay in belief updating because individuals need more time to converge towards the true state of the world. In this case, the variance in the choices

Model specification

On the basis of the predictions derived from the theoretical model, I assess people's preference on mining projects. To this end, I applied the estimator General-Multinomial Logit type II (G-MNL II) which provides several advantages for preference elicitation. First, this specification allows to simultaneously account for preference heterogeneity and scale heterogeneity (Fiebig et *al.*, 2010). In this specification, the error term is assumed to be independently and identically distributed (i.i.d.) from Extreme value of type 1 with constant variance. Under the assumption of Independent and Irrelevant Alternatives (IIA), the error term is distributed on a Gumbel distribution of extreme value Type I. Typically, the mean scale parameter is normalized to one.
The component of the deterministic utility is E(V_ijt)= E(Beta X_ijt + alpha ASC_it). X_ijt is a vector of the key attributes of the project relative to the social, economic and environmental aspects. *B* is the estimated preference parameter indicating the marginal utilities of the attributes. The variable Alternative Specific Constant (ASC) defines the individual preference

for a return to the statu quo situation without a new mine. The scale parameter stands for the deterministic portion of the utility relative to the random portion of the utility.

Empirical testing of Bayes' rule

In a discrete choice model, I develop testable assumptions of belief updating in response to new information. In previous discrete choice studies, prior beliefs are cofounding across respondents when testing the impacts of information. The common approach is to test the impact of varying information at the aggregate level. Instead, I consider the belief status across individuals. Once beliefs enter in the utility function, one major concern is that information type could distort belief updating in respect with initial beliefs. Under varying information provision, we adopted a between-subject comparison to compare individuals with unbiased priors (neutral groups) and individuals with biased priors (belief-based groups). If individuals were correctly Bayesian updaters, either opponents or supporters should interpret better information in a similar vein than neutral individuals.

Given the large amount of information provided in discrete choice surveys, it is reasonable to expect that varying information sets affect both estimated preference parameters and the estimated scale parameter. Under Bayesian updating assumption, Czajkowski, Hanley and LaRiviere (2016) assess how the impacts of newly information influences the scale parameter. As an extension of discrete choice models, the role of the scale parameter is to account for the common effects of varying information on the decision-making for individuals.

Table 5 – Predictions on belief updating

	Opponents (relative to neutral individuals)	Supporters (relative to neutral individuals)
Parallel updating	$\theta_3 = 0$ Mean sale parameter unchanged	$\theta_3 = 0$ Mean scale parameter unchanged
Convergent updating	$\theta_3 > 0$ Mean scale parameter rises	$\theta_3 > 0$ Mean scale parameter rises
Divergent updating	$\theta_3 < 0$ Mean scale parameter falls	$\theta_3 < 0$ Mean scale parameter falls

Neutral groups are the baseline for testing the assumption of Bayesian updating. Parallel updating of better information means that better information has common effects on belief-based groups and neutral groups. When individuals with opposite priors display convergent updating, better information improves their understanding on the valuation scenarios. If some belief-based groups adopt divergent updating of better information, this implies that they have biased interpretation of information.

Results

In this section, we present the results of the information effects on the predictability of preferences and taste preferences. We verify whether neoclassical predictions of Bayesian updating can fit well with stated preference data as explained by the table 5. Information processing is incorporated in the scale parameter using an index of beliefs and information treatments. The interpretation of information is discretized between groups with different beliefs in terms of belief direction and intensity.

Information effects on the predictability of preferences

Quality signals and belief direction

We focus on the convergence of the interpretation of information between opponents and indifferents as well as between supporters and indifferents. The different information treatments control for any change of the quality of information. Using the same baseline "no additional information", table 6 illustrates the information effects of varying quality.

Across minerals, interpretation of low-quality information is globally convergent between the groups with different beliefs and the neutral groups. There are almost no effects on the predictability of preference using the information of uses. Surprisingly, information of rare earths uses has a positive effect on the predictability of preferences. Opponents in response of low-quality information make less random choices, while supporters do not respond it differently. In the end, opponents seem to deviate from the Bayes' rule as low-quality information improves the predictability of preference instead of having no effects.

Beliefs have an effect on the predictability of preferences. From the econometrician's perspective, we find that supporters have more convergent choices than opponents in comparison with the choices of indifferents.

Differences of scale can result from a trust gap between opponents and supporters. In addition, supporters may become more optimistic than opponents considering strongly that advantages would overcome drawbacks.

Table 6 – Prior belief effects (direction) on the interpretation of information

	Gold		Uranium		Rare earths	
	Mean	S.d.	Mean	S.d.	Mean	S.d.
ASC	1.630***	0	2.216***	0	1.472***	0
	(9.30)	—	(11.95)	—	(7.89)	—
ASC X Distance	-0.14	0	−0.190*	0	0.0779	0
	(-1.78)	—	(−2.30)	—	(0.90)	—
Underground mine	0.773***	-1.346***	0.810***	1.638***	0.477**	1.493***
	(5.27)	(-13.95)	(4.58)	(14.95)	(2.83)	(14.33)
Underground mine X Distance	-0.142**	0.0984	0.000643	-0.351***	0.0209	0.202*
	(-2.06)	(0.88)	(0.01)	(-3.54)	(0.24)	(2.11)
Government monitoring	0.837***	1.083***	1.134***	0.959***	0.880***	1.208***
	(11.33)	(10.52)	(11.92)	(8.35)	(10.48)	(10.85)
Independent committee	0.827***	0.929***	1.045***	1.044***	0.887***	0.984***
	(12.13)	(7.69)	(11.93)	(8.62)	(11.37)	(8.20)
Information session	0.311***	0.425***	0.471***	-0.269*	0.364***	-0.401**
	(6.37)	(3.37)	(7.90)	(-2.12)	(6.24)	(-2.58)
Co-construction	0.52***	0.611***	0.595***	-0.689***	0.688***	-0.526**
	(7.79)	(4.71)	(7.28)	(-5.28)	(8.56)	(-3.15)
Public-private partnership	0.395***	0.279	0.647***	-0.725***	0.483***	-0.897***
	(6.75)	(1.67)	(8.40)	(-5.82)	(6.79)	(-6.90)
Regional partnership	0.43***	0.535***	0.513***	-0.341*	0.420***	0.508**
	(7.11)	(3.44)	(7.16)	(-2.20)	(6.14)	(3.11)
500 new jobs	0.504***	0.110	0.523***	-0.655***	0.638***	0.504**
	(8.99)	(0.56)	(7.20)	(-5.47)	(8.94)	(2.94)
800 new jobs	0.924***	1.111***	0.960***	1.065***	0.937***	1.103***
	(12.06)	(9.98)	(10.58)	(7.35)	(11.45)	(9.10)
Tax rebate	0.0018***	0	0.00289***	0	0.00224***	0
	(11.19)	—	(12.77)	—	(11.52)	—
Covariates of scale						
Information	-0.0701		0.0272		0.0659	
	(-1.05)		(0.36)		(1.08)	
Opponents (direction)	-0.348***		-0.421***		-0.623***	
	(-3.43)		(-4.97)		(-5.85)	
Information X Opponents	0.285**		-0.24**		-0.133	
	(2.04)		(-2.02)		(-0.95)	
Supporters (direction)	0.515***		0.436***		0.529***	
	(6.82)		(5.24)		(6.44)	
Information X Supporters	0.0706		-0.248**		-0.287***	
	(0.72)		(-2.15)		(-2.87)	
τ	0.824***		0.924***		0.826***	
	(14.42)		(14.91)		(14.18)	
Log-likelihood	-2771.53		-2564.57		-2514.20	
Pseudo-R^2	0.145		0.1534		0.1505	
AIC/n	0.60		0.57		0.59	
Observations	18306		18828		16938	
Number of respondents	1017		1046		941	

Note: * $p \leq 0.10$; ** $p \leq 0.5$; *** $p \leq 0.01$. S.d. refers to standard deviations.

Across the sub-groups of belief, interpretation of high-quality information is convergent for gold and rare earths. However, there is a negative asymmetric interpretation of uranium technology. Both opponents and supporters have divergent interpretation of information in comparison with indifferents. In this case, high-quality of information distorts the predictability of preferences for uranium mining. These mixed results of Bayesian updating may not be explained by unexperienced goods or high-level of toxicity. Uranium and rare earths are both unexperienced by communities in Quebec. Mining of these two minerals release radioactive particles. Nevertheless, interpretation of high-quality information is divergent for uranium and convergent for rare earths.

Quality signals and belief intensity

The above results show that the direction of beliefs could distort the interpretation of information in asymmetric way. In addition, we want to test whether the intensity of beliefs strengthen the divergent interpretation of information. With this aim, we consider sub-groups divided into moderate beliefs and extreme beliefs and compare the predictability of preferences with neutral groups.

Table 8 – Interpretation of information based on the intensity of prior beliefs.

	Covariates (θ_3)	Information Mineral uses			Information Extraction technology		
		Gold	Uranium	Rare earths	Gold	Uranium	Rare earths
Moderate beliefs	Moderate opponents	0.14 (0.33)	0.18 (0.64)	0.02 (0.10)	0.89*** (2.99)	-0.18 (-0.72)	-0.13 (-0.52)
	Moderate supporters	0.16 (0.86)	-0.27 (-1.15)	0.16 (0.78)	0.25 (1.17)	-0.48*** (-2.03)	-0.03 (-0.18)
Extreme beliefs	Extreme opponents	0.26 (0.92)	-0.14 (-0.62)	0.39 (0.27)	0.67*** (2.26)	-0.39*** (-2.94)	-0.52 (-1.28)
	Extreme supporters	-0.70*** (-3.20)	-0.007 (-0.03)	0.08 (0.34)	0.12 (0.60)	-0.63*** (-3.01)	-0.10 (-0.37)

Note: Here are reported the coefficient of the interacted term between moderate/extreme beliefs and information of uses/technology. The standard errors are below the coefficient in parenthesis.

In table 8 we only report the third covariate of the interacted term between the intensity of beliefs and information treatments. We obtain the binary variable "moderate beliefs" (extreme beliefs) that includes opponents and supporters by assigning the value of one if the individual score of beliefs is lower (higher) than the belief average. The neutral groups are the baseline to determine subjects with moderate/extreme beliefs. Results of the two covariates “prior beliefs” and “information treatments” are not reported here (see Annex 2) but are in line with the findings presented in table 6 and 7.

Extreme opponents and supporters who received the information of uranium technology make more random choices than subjects sharing moderate beliefs. Groups with extreme beliefs have a lower scale coefficient in particular for the group of extreme supporters. Information of uranium technology does not affect the scale for moderate opponents as shown by no significant changes of interpretation compared to the neutral groups.

Information of gold technology improves the accuracy of choices both for moderate and extreme opponents. Once again, extreme opponents have a lower scale coefficient than moderate opponents. Information of rare earths technology does not affect the scale regardless of the intensity of beliefs.

Information of mineral uses has no effects on the mean scale across minerals excepting for gold. Extreme opponents respond to the information of gold uses with higher random choices.

In line with Johnston et *al*. (2017), this result may come from the interpretation of low-valuable information in discrete choice models. Extreme supporters could be more likely to exhibit random choices when they received perceived irrelevant information about the new project.

Controlling for the direction of prior beliefs for several minerals, we find mixed results of Bayesian updating. In general, there are no changes in the interpretation of information which is consistent with the neoclassical predictions. But we find significant shifts of scale mean when groups with different priors received the low-quality signal of rare earths and the high-quality signal of uranium. Together, these results indicate that subjects with biased beliefs could misread the signal for certain goods.

Information effects on the preferences for the opening of the new mine

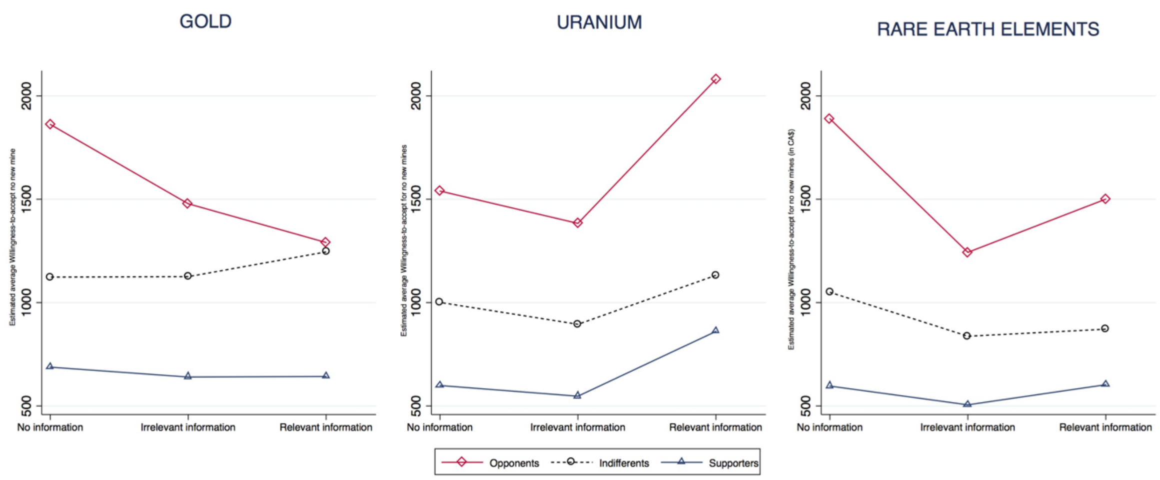
We test the effects of prior belief directions and intensity on the scale of preferences for multiple resources. Most of our findings are in line with the neoclassical predictions of

Bayesian updating; however, we find some evidences of non-Bayesian updating for uranium and rare earths. Shifts in scale of the utility do not explain why we may observe non-Bayesian updating for certain minerals and certain signals at different quality levels.

One potential explanation for non-Bayesian updating is the confirmation bias (Rabin and Schrag, 1999) particularly for subjects with extreme beliefs (Lord, Ross and Lepper, 1979). Some of the mining projects were highly controverted with a favorable climate of social polarization. Accordingly, we test in the next sections the effects of information at different quality levels on the resource preferences. Anomalies in preference patterns may be reflected by wide variations of WTA compensation between information treatments.

As shown in figure 2 we find that information at different quality levels result in changes for the preferences of statu quo (SQ), i.e. the current situation without a new mine. Consistent with prior beliefs, supporters (opponents) have lower (higher) preferences for the SQ. The neutral groups which we called the "indifferents" show intermediate SQ preferences between the results of supporters and those of opponents.

Figure 2 – Information effects on the resource preferences for statu quo

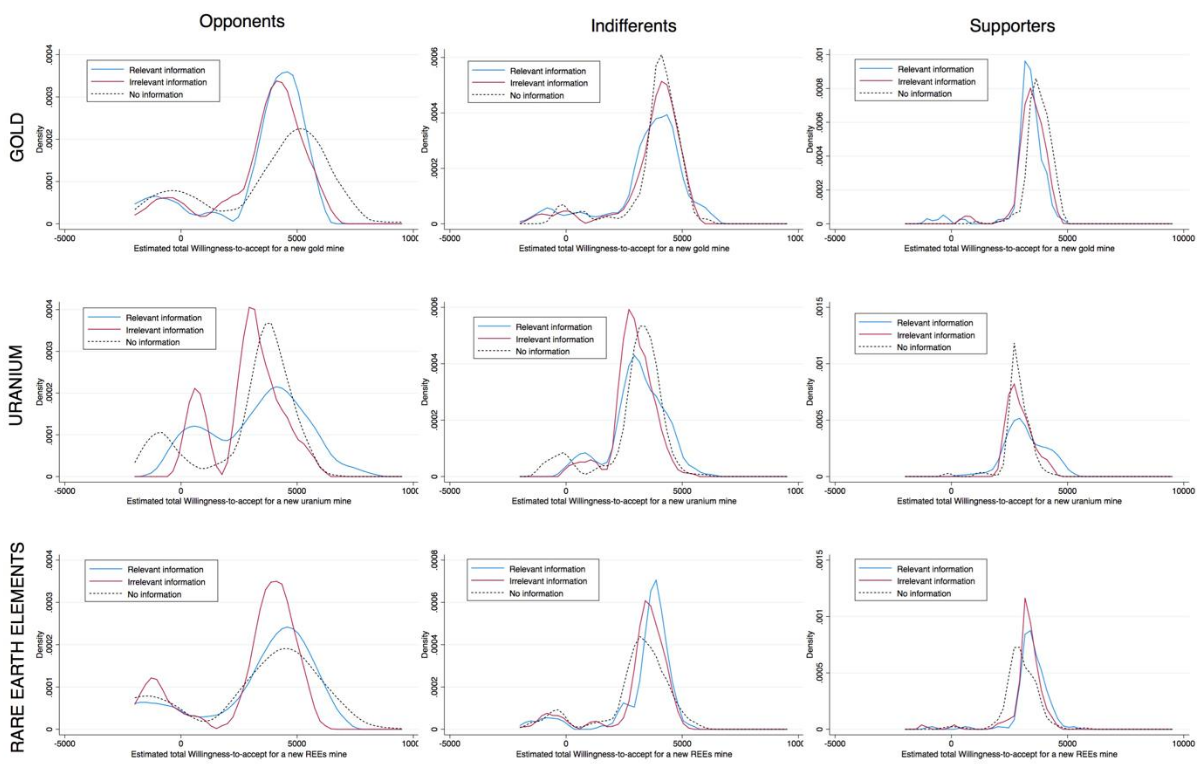


The type of minerals matters despite the quality of information. More important information (technology) does not imply lower preferences for the SQ across minerals, while less important information (uses) lead the subjects to a decrease of their SQ preferences. Uranium is obviously a specific individual case among minerals because information of technology result in systematic higher SQ preferences for opponents, supporters and indifferents. Opponents who received information of technology show a sharp increase of SQ preference even higher than uniformed opponents.

Confronted with balanced information of technology, citizens should credit more confirming evidences that support their initial beliefs and disregard disconfirming evidences. We show that this pattern of information updating does not hold for all resources. Opponents are likely to polarize their view about uranium mining while revising their view about gold and rare earths mining. On the contrary, supporters are likely to polarize their view in gold and rare earths projects, but they revise their beliefs in uranium project.

Information suggesting positive uses of the three minerals may interact with initial view about the resource project. Groups with different priors do not ignore this information about uranium and rare earths diverging from Bayesian updating. Opponents may interpret this disconfirming information as good news and be less likely to protest against the resource projects. Supporters perceiving it as confirming evidences are less likely to protest as well.

Figure 3 – Total WTA distribution by information provision and beliefs (including ASC)



In figure 3 we examine the distribution of marginal willingness-to-accept (WTA) estimates for the opening of the new mine across groups with different priors. We test if the stated preference data is skewed to the left or the right in order to highlight significant differences across sub-samples in the interpretation of information. As we are interested in agents sharing beliefs, we focus only on the behavioral anomalies for supporters and opponents. Preferences of neutral groups serve as a benchmark.

We find asymmetric interpretations of the information between opponents and supporters for uranium and rare earths, but not for gold. Overall, the distribution of total WTA estimates for uranium and rare earths shifts to the left after opponents received information of uses. There is exactly the opposite pattern of WTA distribution in the case of gold which moves to the right after opponents and supporters interpret irrelevant information.

In the experiments of uranium and rare earths, the distribution of WTA for opponents shows more asymmetric tendency than supporters when interpreting information of technology. We suggest that subjects interpret information in accordance with their beliefs and therefore overreact faced to perceived unreliable information. This results in a flatter WTA curve of opponents and also a shift of their curve on the right.

Discussion

Our novel approach deals information effects with individual perceptions on several goods and different quality signals. We find that the type of mineral matters in the interpretation of information. A low-valuable information in the mind of proponents may have higher value than expected because of prior beliefs.

Relevant information presents both confirming signal and disconfirming signal, thus we cannot isolate the alone effect of confirming/disconfirming signals. However, ambiguity may be an important factor contributing both to confirmation bias and overconfidence (Griffen and Tversky, 1992).

The non-market valuation of controverted goods could be sensitive to strong biased estimates of willingness-to-accept. In the end, we question the role of information in refining the preferences of unfamiliar agents. Information could hold an opposite meaning depending on prior beliefs. In this paper, we confront some limitations in providing information faced to the potential interaction with prior beliefs.

We only identify one form of beliefs when an agent is weighting costs and advantages of mining projects. But there is a multitude of beliefs relating the opening of a new mine especially with unpredictable mining impacts.

These findings suggest we obtain partial evidences of confirmation bias. Eil and Rao (2011) find results of asymmetric reactions between agents by stressing on the importance of beliefs directions as main result, confirming signal alone do not have effect. Under ambiguous signals, we find emergence of social polarization with asymmetric reactions between agents (resulting by a gap of welfare estimates). If the researcher does not control for the priors in the case of complex goods, results could be misleading with different provision of pack information.

Schulze, McClelland and Lazo (1994) note that respondents may have more sophisticated view than the researchers assume. For instance, respondents consider not only the specific species for the valuation of species protection but also this includes the ecosystem to which it belongs.

Conclusion

There is a common understanding that agents need information to get more familiar with complex goods and make more accurate choices. If agents are perfectly Bayesian to support full rationality, they should efficiently update new information related to the good. In order to verify that agents are Bayesian, we investigate a field experiment to evaluate the preferences of multiple non-renewable resources (i.e. *gold, uranium and rare earth elements*). To this end, we provide two types of objective information to agents: (i) one about the collective intermediate goods (IG) and (ii) one related to the use of IG as collective final goods (FG). The former signal helps the agents to better know one specific consequence of the mining project that we call "relevant" information. The latter signal is beyond the scope of the mining project by informing on potential uses of the mineral in the daily life and could be perceived as "irrelevant" by researchers as well as mining proponents.

We show that heterogeneous social preferences for multiple minerals may interact both with relevant and irrelevant contents of information. We find some evidences of confirmation bias in the process of Bayesian updating for uranium and rare earth elements. Biased estimates of welfare for collective goods are mainly driven by beliefs direction and strength. Opponents to mining projects exhibit more random choices compared to supporters when expressing their preferences. Surprisingly, opponents strongly express WTA more consistent for uranium and rare earth element, but inconsistent for gold. Similar results for supporters are less convincing, as they are only more consistent for uranium. Additionally, we find that supporters overweight economic advantages and underweight environmental monitoring, and conversely for opponents.

These findings suggest that on average we could not reject Bayesian updating process for agents. Researchers should design experimental studies of collective goods with cautious at the light of potential interactions between piece of information and the set of information from the agents. In the same vein, proponents of collective goods have to keep in mind that the public need for information may go beyond the frame of their own project.

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References

Acemoglu, D., Chernozhukov, V., & Yildiz, M. (2016). Fragility of asymptotic agreement under Bayesian learning. Theoretical Economics, 11(1), 187-225.

Ackerberg, D. A. (2003). Advertising, learning, and consumer choice in experience good markets: an empirical examination. International Economic Review, 44(3), 1007-1040.

Ajzen, I., Brown, T. C., & Rosenthal, L. H. (1996). Information bias in contingent valuation: effects of personal relevance, quality of information, and motivational orientation. Journal of environmental economics and management, 30(1), 43-57.

Attanasio, O. P. (2009). Expectations and perceptions in developing countries: their measurement and their use. The American Economic Review, 99(2), 87-92.

Arrow, K. J. (1952). Social Choice and Individual Values.

Berman, Nicolas, Mathieu Couttenier, Dominic Rohner, and Mathias Thoenig. 2017. "This Mine Is Mine! How Minerals Fuel Conflicts in Africa." American Economic Review, 107(6): 1564-1610.

Blackwell, D., & Dubins, L. (1962). Merging of opinions with increasing information. The Annals of Mathematical Statistics, 33(3), 882-886.

Brennan, N., & Van Rensburg, T. M. (2016). Wind farm externalities and public preferences for community consultation in Ireland: A discrete choice experiments approach. Energy Policy, 94, 355-365.

Chapman, L. J., & Chapman, J. P. (1975). The basis of illusory correlation.

Czajkowski, M., Hanley, N., & LaRiviere, J. (2016). Controlling for the effects of information in a public goods discrete choice model. Environmental and resource economics, 63(3), 523-544.

Contu, D., Strazzera, E., & Mourato, S. (2016). Modeling individual preferences for energy sources: The case of IV generation nuclear energy in Italy. Ecological Economics, 127, 37-58.

DellaVigna, S. (2009). Psychology and economics: Evidence from the field. Journal of Economic Literature, 47(2), 315-372.

Duflo, E., & Saez, E. (2003). The role of information and social interactions in retirement plan decisions: Evidence from a randomized experiment. The Quarterly journal of economics, 118(3), 815-842.

Jensen, R. (2007). The digital provide: Information (technology), market performance, and welfare in the South Indian fisheries sector. The quarterly journal of economics, 122(3), 879-924.

Eil, D., & Rao, J. M. (2011). The good news-bad news effect: asymmetric processing of objective information about yourself. American Economic Journal: Microeconomics, 3(2), 114-138.

Farrer, B., Holahan, R., & Shvetsova, O. (2017). Accounting for heterogeneous private risks in the provision of collective goods: Controversial compulsory contracting institutions in horizontal hydrofracturing. Journal of Economic Behavior & Organization, 133, 138-150.

Fryer, R. G., Harms, P., & Jackson, M. O. (2017). Updating Beliefs when Evidence is Open to Interpretation: Implications for Bias and Polarization.

Golman, R., Hagmann, D., & Loewenstein, G. (2017). Information avoidance. Journal of Economic Literature, 55(1), 96-135.

Grossman, Z., & Owens, D. (2012). An unlucky feeling: Overconfidence and noisy feedback. Journal of Economic Behavior & Organization, 84(2), 510-524.

Hoehn, J. P., Lupi, F., & Kaplowitz, M. D. (2010). Stated choice experiments with complex ecosystem changes: the effect of information formats on estimated variances and choice parameters. Journal of Agricultural and Resource Economics, 568-590.

Hoffman, M. (2016). How is Information Valued? Evidence from Framed Field Experiments. The Economic Journal, 126(595), 1884-1911.

Johnston, R. J., Schultz, E. T., Segerson, K., Besedin, E. Y., & Ramachandran, M. (2016). Biophysical Causality and Environmental Preference Elicitation: Evaluating the Validity of Welfare Analysis over Intermediate Outcomes. American Journal of Agricultural Economics, aaw073.

Johnston, R. J., Boyle, K. J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T. A., ... & Tourangeau, R. (2017). Contemporary guidance for stated preference studies. Journal of the Association of Environmental and Resource Economists, 4(2), 319-405.

Kolstad, C. D., & Krautkraemer, J. A. (1993). Natural resource use and the environment. Handbook of Natural Resource and Energy Economics, 3, 1219-1265.

LaRiviere, J., Czajkowski, M., Hanley, N., Aanesen, M., Falk-Petersen, J., & Tinch, D. (2014). The value of familiarity: effects of knowledge and objective signals on willingness to pay for a public good. Journal of Environmental Economics and Management, 68(2), 376-389.

LaRiviere, J., Czajkowski, M., Hanley, N., & Simpson, K. (2016). What is the Causal Impact of Knowledge on Preferences in Stated Preference Studies? (No. 2016-12).

Lord, C. G., Ross, L., & Lepper, M. R. (1979). Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. Journal of personality and social psychology, 37(11), 2098.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior.

McFadden, D. (1976). The revealed preferences of a government bureaucracy: Empirical evidence. The Bell Journal of Economics, 55-72.

Morgan, O. A., Martin, G. S., & Huth, W. L. (2009). Oyster demand adjustments to counter-information and source treatments in response to Vibrio vulnificus. Journal of Agricultural and Applied Economics, 41(3), 683-696.

Ostrom, E. (1965). Public entrepreneurship: a case study in ground water basin management (Doctoral dissertation, University of California, Los Angeles.).

Ostrom, E. (2014). Collective action and the evolution of social norms. Journal of Natural Resources Policy Research, 6(4), 235-252.

Ostrom, E. (2016). The comparative study of public economies. The American Economist, 61(1), 91-107.

Rabin, M., & Schrag, J. L. (1999). First impressions matter: A model of confirmatory bias. The Quarterly Journal of Economics, 114(1), 37-82.

Read, D., & Van Leeuwen, B. (1998). Predicting hunger: The effects of appetite and delay on choice. Organizational behavior and human decision processes, 76(2), 189-205.

Rogers, A. A. (2013). Public and expert preference divergence: evidence from a choice experiment of marine reserves in Australia. Land Economics, 89(2), 346-370.

Throsby, C. D., & Withers, G. A. (1986). Strategic bias and demand for public goods: Theory and an application to the arts. Journal of Public Economics, 31(3), 307-327.

Sunstein, C. R. (2009). Going to extremes: How like minds unite and divide. Oxford University Press.

Sunstein, C. R., Bobadilla-Suarez, S., Lazzaro, S. C., & Sharot, T. (2016). How people update beliefs about climate change: Good news and bad news.

Tversky, A., & Kahneman, D. (1974). Heuristics and biases: Judgement under uncertainty. Science, 185, 1124-113

Vatn, A. (2004). Environmental valuation and rationality. Land economics, 80(1), 1-18.

ANNEX A – Introductory script

A proponent proposes to launch a new mining project of GOLD/URANINUM/RARE EARTHS located BETWEEN 0-20KM/ BETWEEN 20-100KM and FAR AWAY THAN 100KM from your house. The planned project will last 20 years. The mining proponent is aware that his own project aligns with the satisfaction of the population. Discovered mineral deposits can be operated … From the perspective of the proponent, this project will contribute largely to the local and regional economies such as priority contracts for local firms, priority hiring from local employees, construction of arena and schools. From the perspective of the government, each proposal of the different mining projects is consistent with the environmental standard on the fauna and flora, air quality and water quality. The proponent includes in the proposals of rehabilitation plan after the closure of the mine.