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Information, Values and Expert Decision-Making: The Case of Soil Decontamination

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Abstract

Building on insights from cognitive psychology and scholarship on decision-making, this article examines the respective role of values and information, and the interaction between them, in the formation of expert judgment. We analyze data from an original expert survey on soil decontamination practices, and test several hypotheses found in the literature. While it is common to assume that experts rely primarily on factual information when making decisions, we find that values may also orient the judgment of experts when such information is lacking. In such cases, experts may be influenced by their value predispositions, leading to a wider range of expert assessments. Conversely, the judgment of experts who possess the relevant information tends to converge on the best known outcomes. We thus find that relevant knowledge mediates the role of values in expert judgment. While suggesting that some caution should always be taken when deferring to experts, our findings suggest that governments and the public are justified in taking experts' judgment seriously.

Keywords

Expert; decision-making; cognitive psychology; values; soil contamination.

Introduction

In various domains, policy-making is so technical that governments delegate authority to experts, while members of the public and media routinely defer to experts' judgment when considering issues. The justification for such trust in experts rests on assumptions about their specialized knowledge and skills, which are commonly thought to produce more rational, well-founded decisions. Numerous studies have challenged these assumptions, however, with evidence suggesting that values also play a role in expert decision-making (Sabatier and Zafonte 2001; Barke and Jenkins-Smith 1993; Jenkins-Smith, Silva, and Murray 2009; Rimkutė 2015; Haas 2004; Gottweis 1998). Despite this well-documented observation, calls for more deference toward experts continue, justified by the idea that policy decisions should be protected against the biases of activists, politicians and a relatively un-informed public (Weber and Stern 2011; Henderson 2012; Paarlberg 2008; Blinder 1997; Margolis 1996).

Why the insistence on the delegation of decision-making authority to experts? One explanation is that most of the empirical research on collective decision-making rests on one-dimensional models of thinking. Indeed, existing models usually emphasize either technical knowledge/skills or biases, and rarely examine the role of both, simultaneously.[1] In this article, we draw on scholarship from cognitive psychology and decision-making to put forth a model of expert thinking that allows for complex interactions in the making of judgments between information short cuts and knowledge-based analysis. We are interested in ascertaining whether and under what conditions experts are more likely to make valid judgments in their area of competence.[2] This builds on previous research, which finds that experts are able to learn from science, in the sense that they are able to integrate newly acquired information (Montpetit and Lachapelle 2015). In this paper, we explore whether expert decision-making is enhanced when experts are more informed.

We formulate three hypotheses from our reading of the literature, and test them in the context of an elite survey of experts working in the area of soil decontamination. Specifically, we asked soil decontamination experts to evaluate two proposals for decontaminating a particular (fictitious) site, just as they would in the context of their day-to-day activities. The first solution they were asked to evaluate represents the conventional way of decontaminating soil, but in the context of the scenario presented, is inefficient.[3] We

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[1] There are exceptions : (Tetlock 2005; Weiss 1979).

[2] By valid judgment, we refer to an expert's ability to propose the best known solution to a specific problem. In the context of the present study, decontamination professionals are hired to advise their clients on the most appropriate means of decontaminating their land. The best known solutions in this case are those that are efficient in the sense of maximizing the output/input ratio, ensuring a maximum of efficacy with a minimum of resources.

[3] While conventional excavation is efficacious, it is also very expensive. Phytoremediation for certain pollutants offers an efficacious way to decontaminate land over a longer time period but at much lower cost. For projects that are not time-sensitive, phytoremediation may offer the most efficient solution in terms of maximizing the output-to-input ratio.

then asked experts to evaluate a second proposal, this time referring to a newer, less well known, but in the context of our scenario, more efficient technology. Comparing expert evaluation across the two proposals, we find that, at high levels of relevant knowledge, expert judgments converge around the most efficient solution. That is, information enhances expert decision-making. At low levels of knowledge, however, we find that experts are more influenced by their values. In such cases, expert decisions are more variable, increasing the likelihood of error. Together, this suggests that relevant knowledge mediates the role of values in expert decision-making. If these results justify some degree of deference to expert judgment, they also call for some caution. Indeed, the validity of expert judgments may vary a great deal, depending on values and knowledge.

The paper is divided in five sections. First, we develop a theoretical model of how experts make judgments. Second, we discuss the problem of soil contamination before specifying three hypotheses drawn from the literature. Third, we present the details of our expert survey and fourth the results of our analysis. Lastly, we elaborate on the theoretical and normative implications of our findings.

System 1, System 2 and Expert Judgment

This article examines the respective roles of what decision-making scholars call system 1 and system 2 reasoning, applied to the case of expert judgment. According to this theory, the human mind in fact enables at least two modes of reasoning: system 1, which is spontaneous, effortless, affective and associative; and system 2, which is information intensive, rule-governed and demanding in terms of analysis, computation and calculation (Kahneman 2003). Researchers in cognitive psychology refer to heuristic versus systematic processing to denote the key role of information shortcuts (or heuristics) in system 1 and of rational information processing in system 2 (Chaiken, Liberman, and Eagly 1989). Heuristics are always used to reduce demands on information, but they take on various forms, including positive or negative affects toward an object, experiences with high emotional salience and value orientations that can be confirmed or violated by an event (Slovic et al. 2004). Likewise, rational information processing can take on many forms, from statistical analysis to formal logic, but it always assumes factual knowledge that is not easily accessible.

The limitations of system 2 reasoning have been known since at least Herbert Simon (1945). These limitations rest in imperfections in the information to be processed by objective-driven decision-makers, as well as in human's insufficient cognitive capacities to process large quantities of information. Despite his severe criticism of rationality as used in economics, Simon (1985) considered that individuals, driven by subjective objectives, adopt attitudes that are internally rational. In other words, individuals value system 2, but imperfection in information and limits in cognitive capacities frequently make them adopt attitudes more commonly associated with system 1 and which, from the outside, appear irrational. In a similar vein, research in cognitive psychology assumes that individuals are motivated by the desire to "hold valid attitudes", that is, make judgments that are "perceived to be congruent with relevant facts" (Chaiken, Liberman, and Eagly 1989, 214).

However, individuals are also "economy-minded" (Chen, Duckworth, and Chaiken 1999, 44). They consciously or intuitively know that system 2 increases the validity of judgments, but they nonetheless resort to less demanding system 1 reasoning when confident that heuristics provide "sufficient" validity. System 1 reasoning thus prevails over system 2.

Unsurprisingly then, research inspired by cognitive psychology has largely focused on system 1, even in studies of experts, and has been particularly interested in the distortions it induces into system 2, the commonly held ideal for collective decision-making (Atkinson 2013). Tetlock (2005), for example, shows that experts who base their predictions on their preferred theory are more error-prone than those whose prudence encourages them to consider conflicting perspectives and information. In one of the few studies of experts that uses survey data, Silva et al. (2007) observe a distance between scientists' evaluation of the risks of radiation and their judgments of appropriate safety norms. In the case of several scientists, this distance reflects a precautionary bias, which in turn is statistically related to their values. In their words: "The results indicate a strong presence of extra-scientific considerations in the judgments that scientists make about the characterization of risk and their tendency toward caution in setting safety standards" (Silva, Jenkins-Smith, and Barke 2007, 767. See also Silva and Jenkins-Smith 2007; Mitchell et al. 2007). As one might expect, similar demonstrations showing the influence of system 1 heuristics are numerous in the public opinion literature (e.g. Druckman and Bolsen 2011; Kahan et al. 2012; Nisbet 2004; Nisbet 2005). While departures from system 2's standards of reasoning might be more surprising among experts, these deficiencies in experts' reasoning have been observed nonetheless.

At this point, two precisions are in order. First, research has shown that it would be misleading to treat system 2 as inherently superior to system 1. Not only does system 1 frequently enable one to make relatively good decisions more efficiently, research by Slovic and colleagues (e.g. Slovic et al. 2004) have shown that system 1 can play a role in bringing individuals to reason along the line of system 2. For example, individuals have been found to wrongly consider risks and benefits to be inversely related. That is, individuals who fear that a regulation or a technology is risky are likely to discount or ignore the benefits in the making of their judgment and vice versa. In actual fact, systematic analyses of regulations or technologies often show that risks and benefits are positively correlated: high-risk technologies/policy are normally associated with a high probability of benefits. But it was shown in a laboratory setting that making available a positive emotion in the repertoire of heuristics of risk-averse individuals encourages them to better account for benefits, along risks, in making judgments (Finucane et al. 2000). Likewise, scholars who want to induce more rationality in collective decision-making prescribe message framings, which appeal to system 1, to nudge individuals toward attitudes more in line with system 2's standards (Kahan, Jenkins-Smith, and Braman 2011; Kahan et al. 2012; Druckman and Bolsen 2011; Weber and Stern 2011; Atkinson 2013). In other words, system 1 can interact with system 2 in ways that increase the prevalence of the latter in decision- making.

Second, individuals differ in their capacity to make judgments along the expectations of system 2, even when system 1 heuristics encourages them to do so. By nature or by their own choosing, individuals are not equal in their ability to collect, process and compute all

relevant factual information necessary to maximize the validity of their judgment on all complex issues. Rather, in modern societies, individuals develop specialized skills adapted for different domains. On any given issue, a minority of individuals will acquire the large quantity of specialized knowledge, as well as the analytical skills, that grant them the status of experts. Relative to non-experts, making valid probability assessments on a policy or a technological solution is relatively easier, sometimes even instinctive, for trained and experienced experts (Kahneman 2003, 1453; Considine, Alexander, and Lewis 2014). Of course, information levels and skills also differ among experts, making them variously capable of making valid judgment through calculation or instinctively. This said, if any instinctive thinking affects expert judgment, the expectation is that it will only accentuate the importance of factual knowledge, probability reasoning or formal logic, to name just a few of the possibilities when reasoning under system 2. Therefore, individuals who cannot or choose not to develop their own analytical skills, but who nevertheless count on system 2 to validate their judgment, defer to experts. Chaiken, Liberman, and Eagly (1989, 216) argue that individuals sometimes resort to the simple heuristic "experts' statements can be trusted". Not only is the heuristic economical, it also helps in the making of valid judgments when the trusted experts have the necessary skills to process relevant factual information through system 2.

Although system 1 and system 2 cannot be disentangled and hierarchized as neatly as it was initially believed, any form of deference to experts assumes that these experts are less likely to rely on misleading cognitive shortcuts. Expert judgments made from system 2 standards are thus more likely to converge around the best options, while the judgments based on system 1 heuristics are likely to be more variable. Though some information shortcuts may haphazardly lead toward to the making of better decisions, the likelihood of error will be greater where decisions are not based on careful calculation of relevant information. Therefore, individuals resorting to system 1 are more likely to disagree among themselves than individuals who adhere strictly to system 2.

List (2002) conducted a quasi natural experiment among baseball card traders that speaks to the validity of the assumption about expert's reasoning.[4] During a sports card trade show, he asked participants to bid on two distinct sets of cards, one with an inferior value and one with a superior value, objectively asserted by the fact that the latter bundle included the exact same cards as the former one, plus three, which were however marked to cue an inferior quality. In their assessment, participants were found to rely on heuristic thinking, reacting to the quality cue and therefore biding less on the bundle of superior value. More interestingly, the pattern was similar between lay and expert dealers, although the difference between the two bids were smaller among the expert dealers. Demonstrating how misleading information shortcuts can interfere with system 2 among both experts and the lay public, the experiment nevertheless suggests that System 1 distortions might be less severe among experts.

[4] Baseball cards are a type of collectible trading card related to baseball. Common in countries where baseball is a popular sport (i.e. North America, some parts of Latin America and Japan), baseball cards can be highly sought after and be of significant monetary value.

Early studies of risk perception comparing the lay public with experts suggested significant differences in judgment (Flynn, Slovic, and Mertz 1993; Margolis 1996), but the literature does not unequivocally infirm List's (2002) conclusion. In fact, Rowe and Wright (2001) argue that empirical studies are inconclusive on whether or not experts and the lay public assess risks differently, although the few studies published since Rowe and Wright show that expert judgment is affected by system 1 heuristics in much of the same way as lay-public judgments (Jenkins-Smith, Silva, and Murray 2009; Mitchell et al. 2007; Silva, Jenkins-Smith, and Barke 2007; Silva and Jenkins-Smith 2007). However, these studies mostly show that expert evaluations are influenced by value predispositions and unlike List's (2002) experiment, fail to explore the details of the interaction between system 1 and system 2 in the capacity of experts to make valid judgments. In the study of experts in soil decontamination presented here, we examine the role of information and values, and the interaction between them, in a real policy context.

Expectations about Experts' Judgment of Phytoremediation

To better understand the relative importance of system 1 and system 2 parameters in expert judgment, we developed a study based on expert assessments of a new soil decontamination technology known as phytoremediation. A few characteristics of this technology make it an excellent candidate for testing ideas about how experts produce judgments.

In practical terms, soil contamination is an important policy problem, worldwide. In Europe, for instance, the number of contaminated sites, known for presenting unacceptable risks to humans, water and ecosystems, is estimated at 160, 000, while another 1, 470, 000 sites are suspected of presenting similar risks from contamination (Panagos et al. 2013). Similar estimates are not available for North America, although indicators point to a problem of similar magnitude (e.g. Van Metre and Mahler 2005). In addition to the scale of the problem, the vast majority of contaminated sites are left abandoned, with no attempt of stabilization or remediation. As a result, contaminants migrate and sometimes reach the food chain (Ikem and Egiebor 2005). Despite its severity, however, the problem of soil contamination has received little press and public attention, perhaps owing to its diffuse and unspectacular nature. This low level of attention is a distinct advantage for this research on experts as it provides some assurance that the issue has not been too heavily politicized.

The cost of site rehabilitation is the key explanation for inaction on contaminated sites. The most commonly used decontamination method involves the excavation of the soil and its transportation to treatment facilities or landfills, in which the risks of migration of the contaminants into water or to populated areas are lower than on the original site. The method is highly effective in removing contaminants, but its high cost does not always make it efficient, the market value of several sites being simply insufficient to justify investing in such a costly solution. To make matters worse, a large number of the known contaminated sites are under the responsibility of local governments, whose fiscal capacity is generally limited. Owing to their responsibilities for waste collection, municipal governments have polluted a large number of sites, but they have also seized large amounts of contaminated

land from private owners who could no longer meet their obligations after the decline of their industrial activity. In other words, several of the organizations responsible for contaminated sites today simply cannot afford effective decontamination methods, hence the absence of any rehabilitation activity on a large number of these sites (Salt et al. 1995).

For more than 20 years, researchers have been working on new technologies that, if not as effective as conventional methods, are more efficient in a wide range of contaminated sites. Phytoremediation is one of these new technologies (McIntyre 2003). Phytoremediation employs plants and trees to stabilize contaminants, to degrade them on-site or to extract them from the soil for a treatment off-site. Trees, plants and their root areas can act as barriers containing contaminants on their respective sites. They can also stimulate microbial activities capable of degrading organic contaminants, including polycyclic aromatic hydrocarbons found in oil products (Barac et al. 2004; Reichenauer and Germida 2008). Lastly, plants and trees are capable of absorbing trace elements, including zinc and cadmium, in their biomass, which can be harvested at the end of the growing season and treated off-site (Bissonnette, St-Arnaud, and Labrecque 2010). It goes without saying that transporting branches and leafs to treatment facilities is significantly less onerous than transporting large quantities of soil. In fact, planting, maintaining and even harvesting plants comes at a cost that just cannot be matched by conventional solutions, hence the efficiency of phytoremediation.

On most contaminated sites, the efficacy of phytoremediation is undeniably lower than that of conventional methods. For example, on a site whose soil contains a moderate quantity of zinc and copper at the surface, phytoremediation may take up to twenty years before contamination reaches an acceptable level (Batty and Dolan 2013), while excavation can fully decontaminate the site in a matter of days, if the site is of reasonable size. Of course, time is not always a factor, all sites are not of reasonable size, nor contaminated with trace elements and phytoremediation has produced excellent results with organic contaminants (Campos et al. 2008). Moreover, environmental protection and public health sometimes do not require the extraction of trace elements, their stabilization sufficing to prevent leaching, and phytoremediation does in fact stabilize several trace elements in the soil (Vamerali, Bandiera, and Mosca 2010). The factual knowledge published in scientific journals is clear: phytoremediation may produce smaller benefits in absolute terms than conventional methods, but it produces these smaller benefits at such a low cost that the technology is more efficient than conventional methods in a wide range of contaminated sites. It certainly offers a better alternative to the simple abandonment of polluted land. We thus expect that the more an expert has knowledge of phytoremediation, the more likely the expert is to offer a favorable evaluation of the technology for suitable sites.

We also expect that knowledge of phytoremediation will vary, with a large number of experts knowing little about the technology. Specialized factual information on this relatively new technology is not yet available in accessible format and therefore identifying site conditions under which it works adequately still requires reading through numerous scientific articles that are not readily accessible. In addition, casual knowledge that the efficacy of phytoremediation is low discourages efforts by rational experts to obtain additional factual information on the technology. And anyone who believes that experts

reason through system 2 should expect those admitting having little knowledge of phytoremediation to refrain from approving the technology. Indeed, as Kahneman (2003, 1457–1458) explains, a choice situation usually involves a reference, an option with which the decider has experience, putting new options at a disadvantage and inducing a status quo bias. Most experts in soil decontamination have significant experience and knowledge of the costs and benefits of excavation. If in addition they admit having little knowledge of phytoremediation, it will be even easier for them to obey the simple heuristic "without factual information, I cannot approve." Such a bias works against phytoremediation, which on several sites is the most efficient option.

Equally important to our analysis is the framing of phytoremdiation. As should already be obvious, phytoremediation was developed to make decontamination more affordable and widely available. In fact, the technology is most useful to organizations, governments in particular, responsible for sites of low market value. Without low cost technologies such as phytoremediation, these sites would remain polluted, exposing to harmful contaminants populations that cannot afford moving to richer neighborhoods (see McIntyre 2003; Campos et al. 2008). In light of this framing, it is not difficult to see how phytoremediation might be appealing to individuals who value social equality. Indeed, several respondents wrote about this method's economic and social advantages in open-ended comment boxes included in our survey. For instance, one expert remarked, "If there are few time constraints on the length of treatment, this method is no doubt the cheapest and most environmentally friendly." Such social and economic advantages should resonate with egalitarian values, which refer to a predisposition toward equitable social outcomes, and that have been found to influence the judgment of individuals, as well as those of experts (Jenkins-Smith, Silva, and Murray 2009; Kahan, Jenkins-Smith, and Braman 2011; Druckman and Bolsen 2011; Lachapelle, Montpetit, and Gauvin 2014). The framing of phytoremediation thus enables an effective test of the importance of political values in the making of technical judgments.

To sum up, the case of soil decontamination provides us with an ideal case to test the role of information and values in the making of expert decisions. Experts in this area vary widely in their familiarity with phytoremediation as they do in their values. Moreover, the case provides a clear idea of what constitutes valid expert judgment given the characteristics of a particular contaminated site, allowing us to measure the extent to which information and values facilitate or hinder making the most appropriate recommendations. We expect experts that are relatively less familiar with phytoremediation, but who nevertheless place a premium on factual information, to display a status quo bias, preferring excavation, the solution that they know best. By the same logic, experts with greater knowledge of phytoremediation are expected to be more informed of the efficiency of the technology and therefore be more favorable to its application in suitable contexts. In both cases, experts abide by system 2 standards, which put a premium on knowledge. In the first case, however, this premium on knowledge, combined with an admission of having little of it, induces an error that has been classically treated by Simon (1945) as the effect of imperfect information on judgment. An alternative line of thinking suggests that experts are not so different from members of the lay public. For instance, experts whose judgments on phytoremediation are biased by their gut reaction, whose values fill in for their lack of

suitable information, may violate the widespread assumption that their reasoning is more consistent with system 2. Given the framing of phytoremediation as a cost-effective, widely applicable technology, we might expect that experts with egalitarian values are more likely than non-egalitarians to be predisposed to phytoremediation.

We thus formulate three hypotheses, which we test based on data generated by our elite survey. The first two hypotheses are consistent with the widespread expectation that experts abide by the standards of system 2. The third hypothesis is more consistent with findings indicating that expert judgment, like that of the general public, is influenced by values (e.g. Jenkins-Smith, Silva, and Murray 2009). It goes without saying that these three hypotheses do not exhaust all the possibilities arising from the theory of experts that we have presented above. They simply are the hypotheses that the case of soil decontamination allows us to test best.

H1: The less experts know about phytoremediation, the more likely they are to display a clear preference for conventional decontamination methods over phytoremediation.

H2: The more experts know about phytoremediation, the more likely they are to approve the technology in a suitable context.

H3: The more an expert values social equality, the more likely they are to be favorably predisposed to phytoremediation.

In the next section, we present a survey of experts that we conducted to test these three hypotheses.

Presentation of an Expert Survey on Solutions to Soil Contamination

To test these hypotheses, we designed and administered an on-line survey to a population of 193 soil decontamination experts currently working in Quebec, Canada. These experts play key roles in the preparation of decontamination plans, in the selection of decontamination technologies and in policy-making. In fact, private owners and local governments responsible for contaminated sites generally sub-contract land characterization and the preparation of adequate rehabilitation plans to firms providing engineering and environmental consultation or services. In Quebec, these firms employ experts with university training in engineering, chemistry, geology and biology. The firms, however, prioritize experts who, in addition to their university training, are accredited by the province's ministry of the environment and/or by the provincial association of environmental evaluators (AQVE). In addition to authorizing experts to perform tasks required by law, the accreditation guarantees a high level of experience and qualification.[5] These experts therefore occupy senior positions in the consulting and environmental services firms and their approval is essential before any new decontamination technology becomes used on a regular basis in the province.

[5] However, only experts accredited by the province's environment ministry are authorized to certify decontamination plans and evaluations as required by law.

The two organizations that grant accreditation provide the full list of names and coordinates of their members on their respective web sites. The list on the web site of the ministry of the environment contains 109 names while the AQVE list has 122 names. Thirty-eight experts are on both lists, therefore our population of interest totals 193 experts. A professional polling firm, CROP, administered the web-survey between November 18 and December 12, 2013. One hundred and thirteen experts filled out the survey at least partially (of which 60 have a ministry accreditation and 53 an accreditation from the AQVE). Of these, 94 experts completed the survey entirely. Respondents who have filled out the questionnaire entirely thus represent 49 percent of the expert population.

The survey included regular socio-demographic questions in addition to questions on expert's work experience, values and knowledge of phytoremediation. Specifically, we measured the extent to which experts value social equality, as well as their environmental values, which might also influence their judgment. Indeed, as noted above, the social and environmental advantages of this new technology are likely to resonate with environmental and egalitarian values. These values were measured with questions commonly used by public opinion scholars (Kahan, Jenkins-Smith, and Braman 2011; Lachapelle, Montpetit, and Gauvin 2014). For example, we measured egalitarian values on a six point Likert scale asking respondents to indicate the extent to which they agreed with a statement suggesting that inequalities between rich and poor should be radically reduced. Response options ranged from completely disagree (1) to strongly agree (6), yielding a mean score of 4.3, which is closer to somewhat agree (4) than to agree (5). The standard deviation for this variable is 1.3. We also included an environmental values measure, using the same scale, that asked respondents the extent to which they agree that it is acceptable to slow economic growth if it can help solve environmental problems. The mean score on this variable was 4.1 with a standard deviation of 1.2.

For knowledge of phytoremediation, we rely on respondents' self-evaluation, ranging from 0 to 10, on which it was specified that 5 corresponds to an average level of knowledge. In the regression models, we use self-identified levels of knowledge rather than an objective measure (with which it is highly correlated). We use the self-reported measure because it is more consistent with our assumption (underlying H2) that, when experts are consciously aware of the fact that they do not have the technical knowledge to properly assess a given proposal, they will privilege the status quo with which they are more familiar, and refrain from accepting a new, unfamiliar technology. As expected, a majority of respondents we surveyed acknowledge having little knowledge of phytoremediation, situating themselves below a score of 5, which was clearly demarcated as the average level of knowledge for this technology. The mean for the knowledge variable is 4 and the standard deviation, 1.9.

Descriptive statistics also indicate that respondents have an average of 16 years of experience in soil decontamination and a large majority of them are male (73.4 percent). Forty-two percent have a degree in engineering, 26 percent in biology, 24 percent in geology and 8 percent in chemistry. These numbers are consistent with information we gleaned on our total population of interest (193 experts) from the Internet, and therefore give us confidence in the representativeness of our sample.

The survey measures experts' acceptance of phytoremediation using a description of a fictitious site, loosely based on a successful case of phytoremediation found in the literature, which also resembles the types of plans experts are encountered with on a daily basis. Following a description of the scenario, respondents were asked to provide an evaluation of two decontamination plans on a seven-point Likert scale. The first plan proposed using conventional methods, involving excavation and off-site treatment. The second plan recommended the use of phytoremediation. The vignette also contained a comment box in which respondents were invited to comment on their responses. While most comments reflected an effort by experts to justify the score they attributed to either plan, some respondents (a total of 4) specified that they did not know how to respond. These respondents were subsequently removed from the empirical analysis. The site description, remediation plans and response options are presented in Figure 1.

[Figure 1 about here]

Three elements of the site description and associated remediation plans contribute to the validity of the measure. First, respondents were not informed at the outset that the survey was largely on phytoremediation. They were simply informed that the researchers were exploring solutions to soil contamination. If questions could have eventually cued respondents about our particular interest in phytoremediation, it was not the case of this particular question, which appeared on the first page of our survey and used to assess baseline acceptance levels of different remediation technology. The entire content of this page is presented in Figure 1.

Second, the description is of a site similar to sites successfully decontaminated with phytoremediation (Doyle 2008). In fact, the site has all the characteristics making it suitable for phytoremediation. The contamination is shallow and concentrations are low. Moreover, the description cues experts that the site owner, a local government, is not seeking any increase in market value or after any kind of use for which contamination might be problem. The decontamination is voluntary and nothing in the description justifies a speedy process. In other words, phytoremediation on such a site is a more efficient solution than costly conventional excavation methods.

Third, experts were asked to assess two remediation plans: one recommending conventional methods, and the other, phytoremediation. The first plan, recommending excavation methods – by far the most commonly used decontamination practice in Quebec – represented the status quo, or the decontamination practice with which the experts are most familiar. In the scenario presented, however, the conventional method is an inferior option given the site's characteristics. We placed the phytoremediation plan directly beside (on the same page) the conventional method, and asked respondents to evaluate both. As argued in the literature, placing both options together increases the validity of our measure. For instance, List (2002) shows that evaluation in a choice situation is more accurate when subjects are given two rather than a single option.

Figure 2 presents Kernel distributions, indicating the density of respondents at different acceptability levels for conventional excavation and off-site treatment, and for phytoremediation. As shown in the Figure, a large number of experts assigned a higher score to the proposal recommending conventional methods, relative to that recommending the use of phytoremediation. Specifically, the average acceptance of the conventional method is 4.4, with a standard deviation of 1.3, compared to an average of 2.9, and a standard deviation of 1.5, for phytoremediation. A majority of respondents thus refused to endorse phytoremediation as an acceptable method to use in this situation, despite the scenario's suitability for this method. In demonstrating a clear preference for conventional methods, experts also opted for an inferior technology, at least in terms of efficiency.

[Figure 2 about here]

Results

To further analyze the factors contributing to expert decisions on suitable remediation technology, we ran a series statistical models to test our specific hypotheses. Table 1 presents results from two of our models. The first model seeks to answer the fundamental question of whether or not experts, who lack suitable knowledge, demonstrate a bias for the status quo. To test this, we run a logistic model where the dependent variable is conceptualized as a net preference for conventional excavation methods (i.e. a dummy variable identifying respondents who assigned excavation a larger score than phytoremediation).

[Table 1 about here]

As shown in the first column of Table 1, experts with more experience are more likely to prefer conventional excavation methods over phytoremediation. While in this case a less efficient option, experts have years of accumulated factual knowledge about the results obtained with excavation and therefore are likely to prefer it over a technology on which they know relatively little about. Given that excavation has been applied for decades, while phytoremediation, as an alternative, is relatively new, the length of the respondent's experience unsurprisingly correlates positively with a relatively unreflective inclination toward the status quo. This result is entirely consistent with the assumption that system 2 dominates expert thinking – when in doubt, experts will go with the status quo with which they are more familiar. Results with the variable "knowledge" are also consistent with this hypothesis, as knowledge of phytoremediation reduces the probability that experts prefer the status quo option.

Other significant variables include experts that are accredited by government, women and egalitarian values. Being female and accredited by the government reduces the likelihood that experts prefer conventional decontamination methods. Consistent with our expectations, egalitarian values are also associated with a reduced probability of preferring excavation over phytoremediation, suggesting that experts may reason along system 1 and system 2 simultaneously. Other variables, including environmental values and professional

training, appear unassociated with the probability of preferring conventional methods to phytoremediation in the scenario presented.

The second model in Table 1 provides additional insight into H2 and H3. To test these hypotheses, we regresses knowledge, egalitarian values and other control variables on the experts' evaluation of phytoremediation (the solid line in Figure 2), using OLS. As shown in Table 1, self-reported levels of knowledge about phytoremediation is positively associated with higher approval ratings for this technology. This is consistent with H2, or the idea that the more experts know about phytoremediation, the more likely they are to approve the technology.

The number of years of experience has a small negative effect on the acceptance of phytoremediation, women are more likely to accept the technology than men and experts accredited by the ministry of the environment have a higher degree of acceptance than experts accredited by the AQVE. The discipline in which experts are trained, however, as well as environmental values, have no significant effect on expert assessments of phytoremediation technology. These results are consistent across both models.

Interestingly, we also find support for H3. Indeed, both models show that in addition to knowledge, egalitarian values are also positively associated with increased approval of phytoremediation, even when controlling for level of knowledge. This latter finding suggests that the division between system 1 and system 2 may not be as clear cut as one-dimensional models of expert thinking suggest. The support found for hypotheses H2 and H3 raise the question of how, if at all, knowledge and egalitarian values might interact. To explore this possibility, we re-ran model 2, but included an interactive term. The results are presented in graphic format to better visualize the effect of knowledge on the acceptability of phytoremediation for experts holding different levels of egalitarian values (Brambor, Clark, and Golder 2006).

[Figure 3 about here]

Figure 3 offers considerable nuance to hypotheses 2 and 3, and to ideas about the role of facts and values in expert decision-making more generally. At low levels of factual knowledge, expert assessments of phytoremediation vary significantly between those with stronger and weaker predispositions toward egalitarian values. This is consistent with the idea that values may play some role in expert judgment. As information about phytoremediation increases, however, expert assessments converge around relatively higher levels of acceptability. In this sense, information neutralizes the role of values in expert decision-making. Thus, experts appear to reason along the lines of system 1 and system 2 in a more complex manner than is sometimes assumed. In the particular context of phytoremediation, the framing of this technology as an accessible decontamination technology appears to suffice to generate acceptance among experts who value social equality. Though additional knowledge does not increase support further among experts with strong egalitarian values, knowledge of the technology clearly mitigates the reticence among experts whose values are not necessarily predisposed to this efficient, socially beneficial solution.

Conclusion

Governments and the public frequently defer to experts' judgment to guide individual and policy decision-making. Whether or not such deference leads to socially better choices, however, depends to some extent on whether or not experts are able to think differently. In fact, the public and government often justify their deference to experts on the grounds that experts provide sophisticated judgments based solely on factual information. The public and government expect that expert assessments are objective, and that their reasoning process is guided more by formal logic and empirical evidence than by potentially misleading informational shortcuts.

In this article, we show that experts do think differently, but not under all conditions. When possessing the relevant factual information, we find that specialized knowledge encourages the acceptance of superior alternatives, independent of any prior value predispositions. This is consistent with system 2. Experts, however, cannot be expected to be fully informed about everything relevant to their work. Lacking information, experts are more likely to be influenced by their values, which vary widely among individuals, and may substitute for making rational, informed and well-calculated decisions. As a result, reasoning along system 1 processes, expert opinion where relevant information is absent is more likely to produce divergent outcomes. Concretely, we find that, at low levels of knowledge, experts' perceptions vary, and that this variance is conditioned by underlying values. At high levels of knowledge, experts' perceptions converge, and the role of values matters much less. Factual information thus matters a great deal. Though experts may occasionally be influenced by system 1's potentially misleading information shortcuts, such system 1 processing is conditional upon level of relevant factual information.

What are the implications of these findings? An important stream of public policy research asks how experts associate with different coalitions of actors in policy-making processes (e.g. Weible, Sabatier, and Pattison. 2010; Sabatier and Zafonte 1995; Montpetit 2011; Weible, Siddiki, and Pierce 2011; Weiss 1979). The model of expert thinking provided here hints at answers. On soil decontamination, for example, experts who are informed about phytoremediation might call for regulatory adjustments that better accommodate the particular decontamination timeline associated with the technology. And their policy-making efforts stand a better chance of finding support among other experts who value social equality. In contrast, experts with no particular inclination toward social equality are more likely to find themselves in a competing coalition, resisting any investment in phytoremediation knowledge and therefore having more of an inclination to prefer the status quo.

Other studies of experts adopt more of a critical approach, underlining the normative biases in experts' judgment and thereby questioning the authority that they sometime enjoy within government, in regulatory processes and among the public (Brunner and Ascher 1992; Rietig 2014; Jasanoff 1990; Schneider and Ingram 1997). Our findings encourage caution in deferring to experts' judgment. We have shown that experts sometimes use information shortcuts and that such information shortcuts are associated with a wider range of judgments, which may contribute to error. Future research might explore further

the different heuristics that may influence expert decisions, which may lead to both valid and invalid judgments. However, this should not be interpreted as a type of decisional relativism. Indeed, we have shown that there are limits to the questioning of experts' authority. As Jasanoff (2003) indicates, to admit that values matter in expert judgment does not necessarily imply that they bring no value added to complex problems. Experts are frequently used by policy-makers to improve policy decisions (Rimkutė and Haverland 2015), and there are good reasons for doing so. In fact, we have shown here that specialized knowledge can mitigate the effect of values, increasing the likelihood of valid judgments. Although caution is warranted in surrendering authority to experts, governments and the public are justified in taking experts' judgment seriously.

References

Atkinson, Michael M. 2013. "Policy, Politics and Political Science." *Canadian Journal of Political Science* 46 (04): 751–72.

Barac, Tanja, Safiyh Taghavi, Brigitte Borremans, Ann Provoost, Licy Oeyen, Jan V Colpaert, Jaco Vangronsveld, and Daniel van der Lelie. 2004. "Engineered Endophytic Bacteria Improve Phytoremediation of Water-Soluble, Volatile, Organic Pollutants." *Nature Biotechnology* 22 (5): 583–88.

Barke, Richard P., and Hank C. Jenkins-Smith. 1993. "Politics and Scientific Expertise: Scientists, Risk Perception, and Nuclear Waste Policy." *Risk Analysis* 13: 425–39.

Batty, Lesley C., and Colette Dolan. 2013. "The Potential Use of Phytoremediation for Sites With Mixed Organic and Inorganic Contamination." *Critical Reviews in Environmental Science and Technology* 43 (3): 217–59.

Bissonnette, Laurence, Marc St-Arnaud, and Michel Labrecque. 2010. "Phytoextraction of Heavy Metals by Two Salicaceae Clones in Symbiosis with Arbuscular Mycorrhizal Fungi During the Second Year of a Field Trial." *Plant and Soil* 332 (1-2): 55–67.

Blinder, Alan S. 1997. "Is Government Too Political?" *Foreign Affairs* 76: 115–26.

Brambor, Thomas, William Robert Clark, and Matt Golder. 2006. "Understanding Interaction Models: Improving Empirical Analyses." *Political Analysis* 14: 63–82.

Brunner, Ronald D., and William Ascher. 1992. "Science and Social Responsibility." *Policy Sciences* 25 (3): 295–331.

Campos, V.M., I. Merino, R. Casado, L.F. Pacios, and L. Gomez. 2008. "Review: Phytoremediation of Organic Pollutants." *Spanish Journal of Agricultural Research* 6: 38–47.

Chaiken, Shelly, Akiva Liberman, and Alice H. Eagly. 1989. "Heuristic and Systematic Information Processing within and beyond the Persuasion Context." In *Unintended Thought*, edited by James S. Uleman and John A. Bargh, Guilford Press, 212–52. New York.

Chen, Serena, Kimberly Duckworth, and Shelly Chaiken. 1999. "Motivated Heuristic and Systematic Processing." *Psychological Inquiry* 10 (1): 44–49.

Considine, Mark, Damon Alexander, and Jenny M. Lewis. 2014. "Policy Design as Craft: Teasing Out Policy Design Expertise Using a Semi-Experimental Approach." *Policy Sciences* 47 (3): 209–25.

Doyle, Christian. 2008. "La Phytoremédiation: Une Solution À La Contamination Des Sites de

Traitement Du Bois?" Université de Sherbrooke.
Druckman, James N., and Toby Bolsen. 2011. "Framing, Motivated Reasoning, and Opinions About Emergent Technologies." *Journal of Communication* 61 (4): 659–88.
Finucane, Melissa L., Ali Alhakami, Paul Slovic, and Stephen M. Johnson. 2000. "The Affect Heuristic in Judgments of Risks and Benefits." *Journal of Behavioral Decision Making* 13 (1): 1–17.
Flynn, James, Paul Slovic, and C. K. Mertz. 1993. "Decidedly Different: Expert and Public Views of Risks from a Radioactive Waste Repository." *Risk Analysis* 13 (6): 643–48.
Gottweis, Herbert. 1998. *Governing Molecules. The Discursive Politics of Genetic Engineering in Europe and in the United States*. Cambridge: MIT Press.
Haas, Peter M. 2004. "When Does Power Listen to Truth? A Constructivist Approach to the Policy Process." *Journal of European Public Policy* 11: 569–92.
Henderson, Mark. 2012. *The Geek Manifesto : Why Science Matters*. London: Bantam.
Ikem, Abua, and Nosa O. Egiebor. 2005. "Assessment of Trace Elements in Canned Fishes (Mackerel, Tuna, Salmon, Sardines and Herrings) Marketed in Georgia and Alabama (United States of America)." *Journal of Food Composition and Analysis* 18 (8): 771–87.
Jasanoff, Sheila. 1990. *The Fifth Branch: Science Advisers as Policymakers*. Cambridge: Harvard University Press.
———. 2003. "(No?) Accounting for Expertise." *Science and Public Policy* 30 (3): 157–62.
Jenkins-Smith, Hank C., Carol L. Silva, and Christopher Murray. 2009. "Beliefs Aabout Radiation: Scientists, the Public and Public Policy." *Health Physics* 97 (5): 519–27.
Kahan, Dan M., Hank Jenkins-Smith, and Donald Braman. 2011. "Cultural Cognition of Scientific Consensus." *Journal of Risk Research* 14 (2): 147–74.
Kahan, Dan M., Ellen Peters, Maggie Wittlin, Paul Slovic, Lisa Larrimore Ouellette, Donald Braman, and Gregory Mandel. 2012. "The Polarizing Impact of Science Literacy and Numeracy on Perceived Climate Change Risks." *Nature Climate Change*, May.
Kahneman, Daniel. 2003. "Maps of Bounded Rationality: Psychology for Behavioral Economics." *American Economic Review* 93 (5): 1449–75.
Lachapelle, Erick, Éric Montpetit, and Jean-Philippe Gauvin. 2014. "Public Perceptions of Expert Credibility on Policy Issues: The Role of Expert Framing and Political Worldviews." *Policy Studies Journal* 42 (4): 674–97.
List, John A. 2002. "Preference Reversals of a Different Kind: The 'More Is Less' Phenomenon." *American Economic Review* 92 (5): 1636–43.
Margolis, Howard. 1996. *Dealing with Risk: Why the Public and the Experts Disagree on Environmental Issues*. Chicago [u.a.]: Univ. of Chicago Press.
McIntyre, Terry. 2003. "Phytoremediation of Heavy Metals from Soils." In *Phytoremediation*, edited by DavidT. Tsao, 78:97–123. Advances in Biochemical Engineering/Biotechnology. Springer Berlin Heidelberg.
Mitchell, Neil J., Kerry G. Herron, Hank C. Jenkins-Smith, and Guy D. Whitten. 2007. "Elite Beliefs, Epistemic Communities and the Atlantic Divide: Scientists' Nuclear Policy Preferences in the United States and European Union." *British Journal of Political Science* 37 (04): 753–64.
Montpetit, Éric. 2011. "Scientific Credibility, Disagreement, and Error Costs in 17 Biotechnology Subsystems." *Policy Studies Journal* 39 (3): 513–33.
Montpetit, Éric, and Erick Lachapelle. 2015. "Can Policy Actors Learn from Academic Scientists?" *Environmental Politics*.

Nisbet, Matthew C. 2004. “Public Opinion About Stem Cell Research and Human Cloning.” *Public Opinion Quarterly* 68: 131–54.

———. 2005. “The Competition for Workdviews: Values, Information, and Public Support for Stem Cell Research.” *International Journal of Public Opinion Research* 17: 90–112.

Paarlberg, Robert L. 2008. *Starved for Science: How Biotechnology Is Being Kept Out of Africa*. Cambridge, MA: Harvard University Press.

Panagos, Panos, Marc Van Liedekerke, Yusuf Yigini, and Luca Montanarella. 2013. “Contaminated Sites in Europe: Review of the Current Situation Based on Data Collected through a European Network.” *Journal of Environmental and Public Health* 2013: 1–11.

Reichenauer, Thomas G., and James J. Germida. 2008. “Phytoremediation of Organic Contaminants in Soil and Groundwater.” *ChemSusChem* 1 (8-9): 708–17.

Rietig, Katharina. 2014. “‘Neutral’ Experts? How Input of Scientific Expertise Matters in International Environmental Negotiations.” *Policy Sciences* 47 (2): 141–60.

Rimkutė, Dovilė. 2015. “Explaining Differences in Scientific Expertise Use: The Politics of Pesticides.” *Politics and Governance* 3 (1): 114.

Rimkutė, Dovilė, and Markus Haverland. 2015. “How Does the European Commission Use Scientific Expertise? Results from a Survey of Scientific Members of the Commission’s Expert Committees.” *Comparative European Politics* 13 (4): 430–49.

Rowe, Gene, and George Wright. 2001. “Differences in Expert and Lay Judgments of Risk: Myth or Reality?” *Risk Analysis* 21 (2): 341–56.

Sabatier, Paul A., and Matthew Zafonte. 1995. “The Views of Bay/Delta Water Policy Activists on Endangered Species Issues.” *West/Northwest Journal of Environmental Law and Policy* 2: 131–46.

———. 2001. “Policy Knowledge: Advocacy Organizations.” In *International Encyclopedia of the Social & Behavioral Sciences*, edited by Neil J. Smelser and Paul B. Baltes, 17:11563–68. Amsterdam: Elsevier.

Salt, David E., Michael Blaylock, Nanda P.B.A. Kumar, Viatcheslav Dushenkov, Burt D. Ensley, Ilan Chet, and Ilya Raskin. 1995. “Phytoremediation: A Novel Strategy for the Removal of Toxic Metals from the Environment Using Plants.” *Nature Biotechnology* 13 (5): 468–74.

Schneider, Ann L., and Helen Ingram. 1997. *Policy Design for Democracy*. Lawrence: University of Kansas Press.

Silva, Carol L., and Hank C. Jenkins-Smith. 2007. “The Precautionary Principle in Context: U.S. and E.U. Scientists’ Prescriptions for Policy in the Face of Uncertainty.” *Social Science Quarterly* 88 (3): 640–64.

Silva, Carol L., Hank C. Jenkins-Smith, and Richard P. Barke. 2007. “Reconciling Scientists’ Beliefs about Radiation Risks and Social Norms: Explaining Preferred Radiation Protection Standards.” *Risk Analysis* 27 (3): 755–73.

Simon, Herbert A. 1945. *Administrative Behavior*. New York: McMillan.

———. 1985. “Human Nature in Politics: The Dialogue of Psychology with Political Science.” *American Political Science Review* 79: 293–304.

Slovic, Paul, Melissa L. Finucane, Ellen Peters, and Donald G. MacGregor. 2004. “Risk as Analysis and Risk as Feelings: Some Thoughts about Affect, Reason, Risk, and Rationality.” *Risk Analysis* 24 (2): 311–22.

Tetlock, Philip E. 2005. *Expert Political Judgment: How Good Is It? How Can We Know?*. Princeton, N.J.: Princeton University Press.

Vamerali, Teofilo, Marianna Bandiera, and Giuliano Mosca. 2010. "Field Crops for Phytoremediation of Metal-Contaminated Land: A Review." *Environmental Chemistry Letters* 8 (1): 1–17.

Van Metre, Peter C., and Barbara J. Mahler. 2005. "Trends in Hydrophobic Organic Contaminants in Urban and Reference Lake Sediments across the United States, 1970–2001." *Environmental Science & Technology* 39 (15): 5567–74.

Weber, Elke U., and Paul C. Stern. 2011. "Public Understanding of Climate Change in the United States." *American Psychologist* 66 (4): 315–28.

Weible, Christopher M., Paul A. Sabatier, and Andrew Pattison. 2010. "Harnessing Expert-Based Information for Learning and the Sustainable Management of Complex Socio-Ecological Systems." *Environmental Science and Policy* 13: 522–34.

Weible, Christopher M., Saba N. Siddiki, and Jonathan J. Pierce. 2011. "Foes to Friends: Changing Contexts and Changing Intergroup Perceptions." *Journal of Comparative Policy Analysis* 13: 499–526.

Weiss, Carol H. 1979. "The Many Meanings of Research Utilization." *Public Administration Review* 39: 426–31.

Figure 1: Description of a Contaminated Site and Presentation of a Decontamination Plan Involving Phytoremediation

Site Description:
Located in the periphery of a large city, this building-free 2.7 hectare site has been abandoned by its owner. It is zoned industrial and commercial. In the 1980s and the 1990s, a wood treatment facility operated on the site, where creosote, copper, zinc, lead, chrome VI and arsenic was used. The soil is sandy silt and the contaminants are at less than a meter deep. The contamination is generally in the B-C zones of the criteria of the province's policy, but they occasionally reach above the C level. Based on documents and a site visit, it was decided that underground water contamination was nevertheless a risk. Abandoned several years ago, the site was seized by the municipality that now wants it rehabilitated, although it has no specific project for it.

Decontamination Plan # 1:
The excavation of the contaminated soil and their off-site treatment will prevent leaching. Risks to underground water will be further minimized though pumps that will limit the dispersion plume. Once extracted, the organic contaminants will be treated with activated charcoal and the inorganic pollutants with reverse osmosis. An authorized agent will manage the contaminants.

In your opinion this rehabilitation scenario is:

0. Completely unacceptable
1. Unacceptable
2. Moderately unacceptable
3. Neither acceptable nor unacceptable
4. Moderately acceptable
5. Acceptable
6. Completely acceptable

Decontamination Plan # 2:
Trees with roots deep enough to reach underground water will stabilize contaminants, preventing leaching. Among the species authorized by the municipality, hybrid willows and poplars will form a barrier limiting the dispersion plume. The contaminants will thus be attracted to the root area and immobilized. The microbial activities in this root area will degrade the organic contaminants. Some of these contaminants will also be evaporated in the atmosphere by the plants. Inorganic contaminants will be removed from the soil by the trees, which will accumulate them in their tissues and be treated off-site by an authorized agent after their harvesting.

In your opinion this rehabilitation scenario is:

0. Completely unacceptable
1. Unacceptable
2. Moderately unacceptable
3. Neither acceptable nor unacceptable
4. Moderately acceptable
5. Acceptable
6. Completely acceptable

Figure 2: Distributions of the Acceptability of the Two Plans

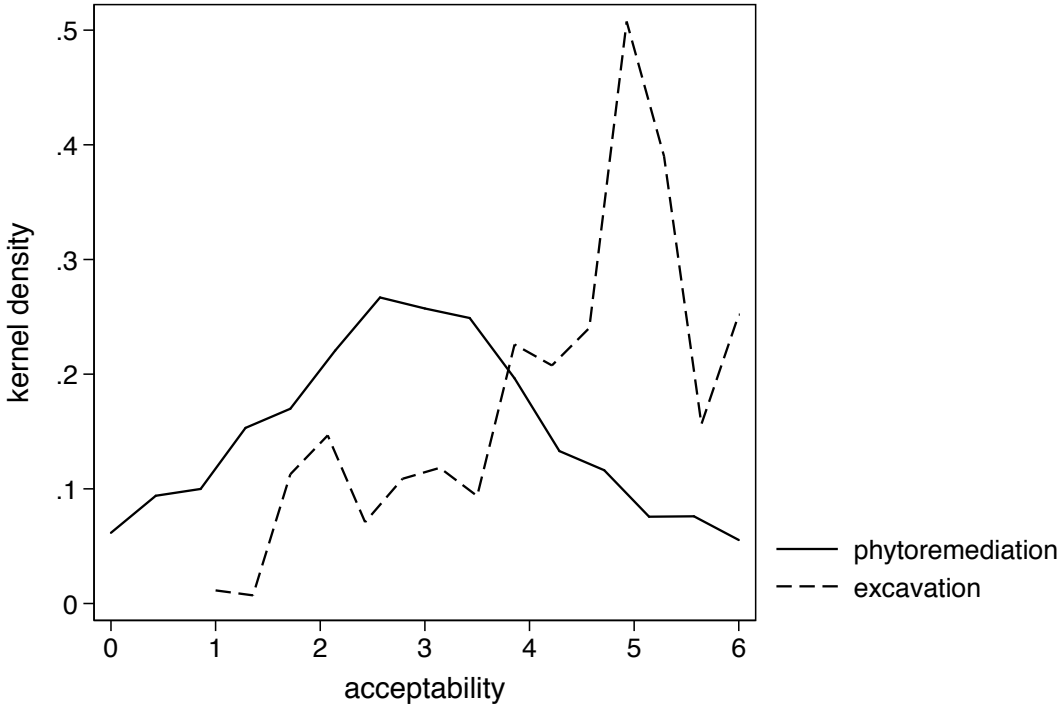
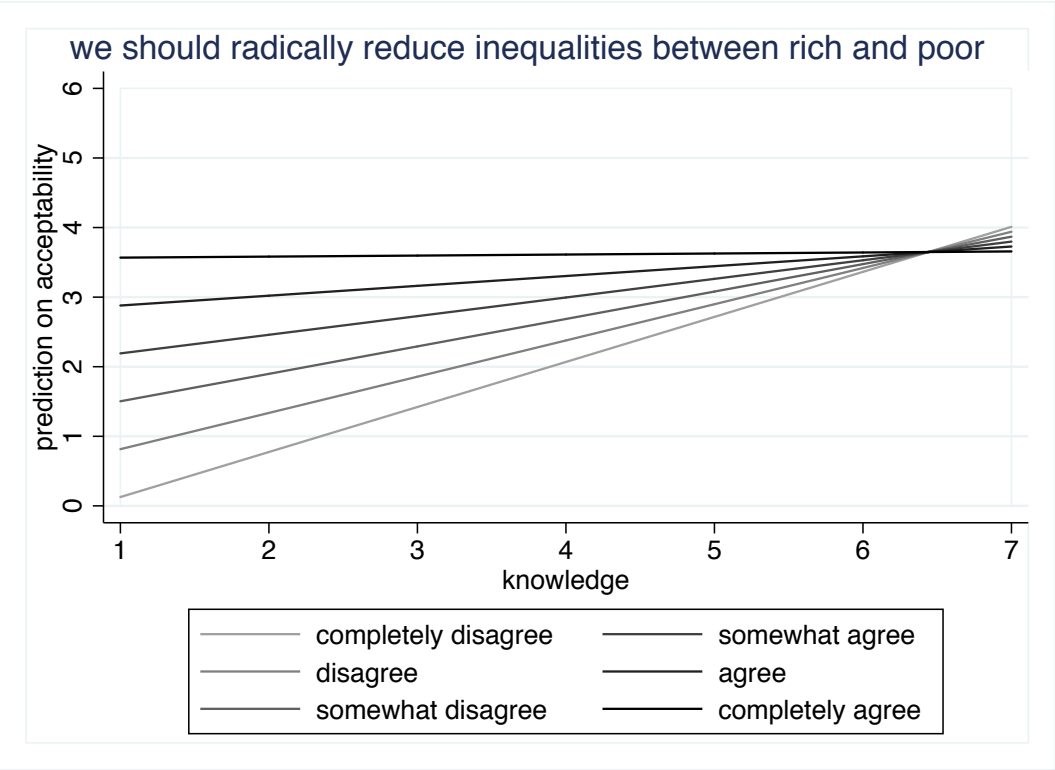


Table 1 : Basic Regression Models

	(1) preference for excavation	(2) degree of acceptation of phytoremediation
knowledge	-0.40* (0.20)	0.22* (0.09)
egalitarian values	-0.73* (0.37)	0.40* (0.13)
environ. values	0.23 (0.31)	-0.17 (0.14)
experience	0.13* (0.06)	-0.05* (0.02)
gvt. accred.	-1.87* (0.93)	0.86* (0.37)
women	-2.21* (0.81)	0.86* (0.37)
engineering	ref.	ref.
geology	1.10 (0.88)	-0.59 (0.42)
biology	0.44 (0.91)	-0.25 (0.42)
chemistry	2.10 (1.47)	-0.96 (0.66)
_cons	7.05* (2.61)	0.52 (1.08)
N	82	90
adj. R^2		0.13
pseudo R^2	0.25	

Standard errors in parentheses; * $p < 0.05$
Log odds are reported for model 1. Partial regression coefficients in model 2.
In regression 1, missing values were attributed to the 8 respondents who indicated equal acceptance of phytoremediation and excavation.

Figure 3: Marginal Prediction of the Interaction between Knowledge and Egalitarian Values



Confidence intervals are not included in the graph to better visualize the effect. At low levels of knowledge, the confidence intervals of each line overlap with those of the closest line. They do not overlap with those of the second closest line, indicating a 95% confidence in statistical difference.