

## Legitimizing Values in Regulatory Science

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**BACKGROUND:** Over the last several decades, scientists and social groups have frequently raised concerns about politicization or political interference in regulatory science. Public actors (environmentalists and industry advocates, politically aligned public figures, scientists and political commentators, in the United States as well as in other countries) across major political-regulatory controversies have expressed concerns about the inappropriate politicization of science. Although we share concerns about the politicization of science, they are frequently framed in terms of an ideal of value-free science, according to which political and economic values have no legitimate role to play in science. For several decades, work in philosophy of science has identified serious conceptual and practical problems with the value-free ideal.

**OBJECTIVES:** Our objectives are to discuss the literature regarding the conceptual and practical problems with the value-free ideal and offer a constructive alternative to the value-free ideal.

**DISCUSSION:** We first discuss the prevalence of the value-free ideal in regulatory science, then argue that this ideal is self-undermining and has been exploited to delay protective regulation. To offer a constructive alternative, we analyze the relationship between the goals of regulatory science and the standards of good scientific activity. This analysis raises questions about the relationship between methodological and practical standards for good science, tensions among various important social goods, and tensions among various social interests. We argue that the aims of regulatory science help to legitimize value-laden choices regarding research methods and study designs. Finally, we discuss how public deliberation, adaptive management, and community-based participatory research can be used to improve the legitimacy of scientists as representatives of the general public on issues of environmental knowledge.

**CONCLUSIONS:** Reflecting on the aims of regulatory science—such as protecting human health and the environment, informing democratic deliberation, and promoting the capacities of environmental justice and Indigenous communities—can clarify when values have legitimate roles in regulatory science. <https://doi.org/10.1289/EHP3317>

### Introduction

Over the last several decades, scientists and social groups have frequently raised concerns about politicization or political interference in regulatory science. A 2015 survey of U.S. government scientists by the Union of Concerned Scientists found that “Political influence on [four U.S. government] agencies is perceived as too high by many federal scientists” (Union of Concerned Scientists 2015, 18; see also Nisbet and Markowitz 2015). These kinds of concerns motivated many participants in the March for Science on Earth Day 2017 (Ross et al. 2018), and such concerns have also been raised in other political contexts, in the United States (Gough 2003) as well as in other countries (Death of Evidence 2012; Political Priorities 2016). Although we share many of these concerns, they are frequently framed in terms of an ideal of value-free science, according to which political and economic values have no legitimate role to play in science. Work in philosophy of science has identified serious conceptual and practical problems with the value-free ideal.

In this commentary, we first discuss the prevalence of the value-free ideal in regulatory science and conceptual and methodological problems with this ideal. Next, we discuss how reflecting on the goals, aims, or purposes of regulatory science can help

articulate legitimate roles for values in scientific research. Finally, we discuss how public deliberation, adaptive management, and community-based participatory research can be used to support the legitimacy of scientists as representatives of the public in the production of scientific knowledge.

Our arguments make heavy use of the concepts of “regulatory science” and “legitimacy.” In many cases regulatory science is formally distinct from regulatory decision making and other kinds of policy making. However, regulatory science provides the stock of knowledge used by policy makers to promote goals such as protecting human health and the environment, and we argue that this relationship has implications for the standards of good regulatory science. We define regulatory science broadly, to include original scientific research as well as literature reviews and meta-analyses performed as part of broader risk assessments. We use the term “legitimacy” to refer to a normative notion that characterizes the way things should be done, which will differ among different social groups and contexts.

### Discussion

#### *The Ideal of Value-Free Science*

Social, economic, and ethical considerations play a variety of uncontroversially legitimate roles in shaping scientific research. Scientists may choose to investigate certain topics because of their potential negative impact on human health and society, and they may choose projects based on the availability of funding. Similarly, ethical requirements for informed consent or humane treatment of animals place legitimate constraints on research design.

In contrast, it is a common view that social, economic, and ethical considerations have no legitimate role within the core of scientific reasoning, i.e., when gathering data or evaluating a hypothesis, model, or theory. Actual scientists necessarily fall short of this value-free ideal, but it is still widely seen as an important standard that scientists should strive to reach.

The ideal of value-free science operates in a variety of ways at environmental and other regulatory agencies, such as the U.S.

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Environmental Protection Agency (EPA). First, there are institutional and cultural distinctions between science and policy, with EPA's Office of Research and Development (ORD) having primary responsibility for conducting intramural research, including aspects of formal risk assessment, whereas EPA's program offices are responsible for writing and enforcing regulations. The institutional division between value-laden policy making and (ideally) value-free science is further exemplified by EPA's Framework for Human Health Risk Assessment, which assumes a strict distinction between the scientific activity of risk assessment and the policy activity of risk management (U.S. EPA 2014, 5; NRC 1983). In addition, EPA's Scientific Integrity Policy states that all EPA employees are expected to "ensure that the Agency's scientific work is . . . free from political interference or personal motivations," and "recognizes the distinction between scientific information . . . [and] the policy decisions made based on that scientific information" (U.S. EPA 2012). This policy allows epistemic or truth-promoting values—such as empirical adequacy or coherence between multiple kinds of evidence (Steel 2010; Hill 1965)—to play an essential role in the core of EPA's science activities, whereas ethical, social, and economic considerations belong to the policy side of the agency. Thus, this notion of scientific integrity is consistent with the ideal of value-free science.

Regulators are faced with different, conflicting goods and interests: human health, environmental quality, industrial development, cost to consumers. (In ethics, the term "goods" refers generally to objects or states of affairs that are desirable, promote well-being, or are otherwise valuable. This use of the term is broader than the economic use, such as objects that are bought and sold on the market.) According to the ideal of neutrality (Lacey 1999, 75), science should provide assessments of evidence and different policy options that will be universally acceptable to all interest groups (Beck 1992; Havstad and Brown 2017b; Jasanoff 1987; Jasanoff and Simmet 2017; Porter 1993, 1995, 2003). However, universal acceptability requires that scientific findings do not depend on controversial (not universally acceptable) ethical, social, or economic considerations. Thus, neutrality is another form of the value-free ideal.

Nevertheless, the ideal of value-free science has caused serious problems for regulatory science. In the context of policy, it has made science an easy target for industry and industry-aligned political actors. According to the ideal, science should be an impartial and politically neutral source of facts. However, actual science always falls short of this ideal, leaving it vulnerable to accusations of bias and never-ending demands for further research, higher standards of evidence, or increased transparency, all in the name of "sound science" (McGarity 2003; Ceccarelli 2011; Elliott and Resnik 2014; Trasande et al. 2016).

The tobacco industry used this strategy to undermine scientific research on the health hazards of smoking (Proctor 2012). Manufacturing doubt by questioning the strength of the scientific evidence tying tobacco use to cancer and cardiovascular disease became one of the leading mechanisms to avoid regulation of cigarettes. The industry claimed that the evidence was not good enough, that the science was not objective, and that further research was always needed. Through clever manipulation of the value-free ideal, the tobacco industry was able to maintain social uncertainty, not losing any court cases until the 1990s, and slowing down the regulation of nicotine as an addictive substance (Oreskes and Conway 2010). Moreover, the chemical, pharmaceutical, and lead industries have used similar strategies to favor commercial interests over public health (Markowitz and Rosner 2013; McGarity and Wagner 2008; Michaels 2008). By holding other scientists and regulators accountable to the value-free ideal,

industry groups such as tobacco, lead, fossil fuels, and pesticide manufacturers have obstructed and obscured the production of critical scientific knowledge, while funding and supporting industry-friendly research. In this way, the value-free ideal undermines its own goal of neutrality.

Given that scientific hypotheses are never completely certain, scientists must judge whether the evidence is strong enough to accept a hypothesis or not. For instance, when considering the hypothesis that a certain drug or chemical does not have harmful effects, scientists must value the risk of falsely accepting it—e.g., unknown harmful effects or even death—and then establish a threshold to endorse the hypothesis or not (Douglas 2009). Conventional standards of evidence imply value judgments: A type I error rate of 5% and test power of 80% implies that type I errors are four times as bad as type II errors. In this way, scientists inevitably use or assume values concerning the risk of erring when accepting or rejecting a hypothesis, a judgment at the core of the scientific process.

Ethical, political, or economic considerations also influence other decisions throughout the research process. Consider the measurement of water or air quality. Different instruments are needed to detect different pollutants, with different levels of sensitivity and specificity. Should we look for many chemicals using several less sensitive tests, or spend our resources on a few highly sensitive tests for a few key chemicals? Given that the available evidence does not determine such methodological decisions, other considerations—ethical, political, or economic considerations—should be taken into account (Elliott 2017; Longino 1990). These decisions will have a strong influence on the hypotheses and evidence available for further research and policymaking (Okruhlik 1994; Elliott 2012). These gaps between evidence and research decisions also appear at other stages of the research process, e.g., when collecting and interpreting data, where scientists appeal to other considerations for decision making. In this way, scientists use value judgments at different stages of the research process.

The goals, aims, or purposes of scientific inquiry play an important role in the rules and standards that define legitimate scientific activity (Shrader-Frechette 1991, Kitcher 2001, Longino 2002, Brown 2012, Intemann 2015, Elliott 2017, Fernández Pinto 2018): Research methods are legitimate insofar as they tend to promote the goals of inquiry. For environmental and biomedical science, the goals of research can be described in terms of broad social goods: promoting human health, alleviating the burden of disease and injury, or protecting human health and the environment. Scientists rarely produce these goods directly; more typically, they produce knowledge that is used by others—regulators, local government, community organizations, industry—to accomplish these goals. The ultimate goal of regulatory science is to promote broad social goods, but the immediate goal is to produce knowledge that can be used by other people to do so.

For fields such as environmental and biomedical science, the standards of good scientific activity are not only about the production of knowledge. They are about the production of useful knowledge (Cartwright 2006), and specifically knowledge that is useful for the fields' goals, such as protecting human health and the environment. In this sense, we argue that researchers have good reasons to develop or choose research methods and study designs that tend to promote these goals. However, goals such as protecting the environment or promoting human health are too vague. For these goals to inform their research, scientists will often need to consider the relationship between methodological standards and practical standards, the tensions among various important social goods, and the tensions among various social interests. In the next section, we consider these three issues.

## Specifying the Goals of Inquiry

If we recognize that the goal of environmental science is to protect human health and the environment, this recognition may already tell us something about, e.g., how environmental scientists should balance type I and type II errors. (Namely, that false negative errors are often much worse than false positive errors; Hicks 2018.) However, more complicated cases raise complex questions about the specific goals of research and how they relate to the goals and interests of people outside the lab.

**What are the goals of scientific research?** On a traditional view, science has a single goal: to produce evidence for or against a hypothesis, according to “fixed, high epistemic standards” such that “scientists assert claims only when those claims are extremely unlikely to be false” (John 2015; c.f. Aschner et al. 2016). We refer to this as the *conclusive evidence standard*. This standard provides a key rationalization for the “sound science” movement, and fuels debate over whether climate science is settled. It has also played a prominent role in delaying or preventing regulation. For example, in April 2017, U.S. EPA rejected a petition to revoke all tolerances for the organophosphate pesticide chlorpyrifos (U.S. EPA 2017). (Revoking these tolerances would have effectively banned the use of the pesticide.) A key argument to reject the petition relied on the conclusive evidence standard: “The science addressing neurodevelopmental effects remains unresolved and . . . further evaluation of the science . . . is warranted to achieve greater certainty as to whether the potential exists for adverse neurodevelopmental effects to occur from current human exposures to chlorpyrifos” (U.S. EPA 2017). That is, because research on the neurotoxicity of chlorpyrifos has not (yet) arrived at claims that are extremely unlikely to be false, it does not (yet) provide a reason to revoke the tolerances for this pesticide.

However, regulatory science is policy-oriented: Its primary goal is not to produce conclusive evidence, but to support policy decisions; its goals are both *epistemic* (knowledge-related) and *practical*. Therefore, when the goal of conclusive evidence conflicts with the practical requirements of regulatory science, regulatory science could legitimately abandon the conclusive evidence standard. In fact, in the context of regulatory science, the conclusive evidence standard can direct researchers away from producing evidence that is relevant to policy. For example, experiments that expose cell cultures to bisphenol A alone might produce conclusive causal evidence of an *in vitro* effect but would not provide information about the effects of chemical mixtures that include bisphenol A (Ribeiro 2017), effects in whole animals (Gore et al. 2015), or social or economic determinants of human exposure and susceptibility (Liévanos 2015). More generally, experiments designed to produce conclusive evidence of causal effects under carefully controlled circumstances may have little relevance to the real-world cases that policy needs to address; producing more relevant knowledge may require observational studies that cannot satisfy the conclusive evidence standard (Cartwright and Hardie 2012; Intemann and de Melo-Martín 2010; Steel 2008, 2010). Thus, the inability to meet the conclusive evidence standard may be used to delay or prevent regulation until “the science is settled” (Hicks 2018; Lerner 2017; Steel 2016).

To some extent, regulatory scientists recognize the importance of matching methods and goals for regulatory science, under headings such as “problem formulation” and “fit for purpose” (U.S. NRC 2009; U.S. EPA 2014). However, in practice it seems that “fit for purpose” refers to the conclusive evidence standard, not the value of research for policy. Consider EPA’s September 2016 issue paper on glyphosate (U.S. EPA 2016). In the issue paper’s systematic review of the epidemiology literature, cohort studies are ranked higher than case–control studies

because the former can “avoid and/or adjust for potential biases”; this ranking is despite the fact that “Cohort studies are particularly inefficient for evaluating associations with rare outcomes and diseases with long induction or latency periods” (U.S. EPA 2016). Thus, although some case–control studies may be more informative about certain policy-relevant effects, and thus might be more fit for purpose than a cohort study, the glyphosate issue paper gives more weight to cohort studies by default because they provide more conclusive evidence.

When the goals of research are laden with social values—such as protecting human health—then it is legitimate for those values to influence every stage of research. Indeed, ignoring those values in favor of ideals of neutrality, impartiality, or conclusive evidence produces research that is less fit for purpose and therefore decreases legitimacy. However, this means rejecting the conclusive evidence standard and the value-free ideal.

**What goods are at stake?** Although human health and environmental well-being are the primary goals for regulatory environmental science, and preventing and treating injury and disease are the primary goals for biomedical science, other goods will also be relevant to scientific decisions, because they will be affected as a result of those decisions. (Recall that we are using the term goods broadly to refer generally to anything that is valuable.) It is obvious that, in environmental policy, a regulated industry’s profits will often be reduced as a result of decisions that tend to protect human health and the environment. For individuals and communities who are economically dependent on a regulated industry, new regulations may threaten their well-being (Ottinger 2013, Hicks 2017b). In addition, opponents of regulation often argue that regulations will increase costs for consumers and result in economic inefficiencies. These economic impacts are not only the result of policy decisions, but also scientific decisions that influence the quality and quantity of knowledge used by policymakers.

Deeper disagreement over the meaning of human and environmental well-being is also possible. Human well-being might be quantified in terms of willingness to pay (McGartland et al. 2017); or it might reflect aesthetic and cultural values that cannot be monetized (Whyte 2017). Similarly, environmental well-being might be quantified based on the economic value of ecosystem services (Simpson 2016), or might be defined by broader concepts or ideals, such as “interdependence” (Millstein 2018). Different concepts and beliefs regarding the scope and nature of human and environmental well-being can make a fundamental difference in the research questions posed by environmental scientists.

In some cases, the policy context can provide guidance on how to handle these tensions. For example, the Lautenberg Act—a major 2016 revision to the Toxic Substances Control Act—requires U.S. EPA to determine whether chemicals “present [. . .] an unreasonable risk of injury to health or the environment, without consideration of costs or other non risk factors” (U.S. Congress 2019). Scientists who are working to produce evidence to inform policy decisions under the Lautenberg Act thus have a good reason to not take economic considerations into account in their research.

The preceding paragraph does not mean that scientists must regard the policy context as a fixed constraint. Science also informs policy by producing knowledge about environmental or human health hazards that are not addressed by policy as it stands (Kwiatkowski et al. 2016). In both kinds of cases—where science works within the given policy context, and where science challenges policy—scientists can legitimately argue that they need policymakers to accept the findings of their research for both parties to pursue the common goal of protecting human health and

the environment. This argument assumes, of course, that all parties understand this common goal in the same way.

In addition to policy guidelines, in some cases scientists work collaboratively with a community to produce knowledge that community members can use to pursue broader social goals. For example, researchers might work with a community to develop evidence of tap water contamination that the community can then use to argue for legal or policy remedies (Hanna-Attisha 2018). In these cases, scientists have good reasons to shape their work according to the specific strategy and broader concerns and interests of the community members, as long as the concerns of the community include the ultimate goals of the scientific community (e.g., protecting human health and the environment).

Therefore, legitimacy is typically improved when natural scientists work with social scientists, humanists, lawyers, policymakers, and in participatory research settings with members of particular communities or the general public. Because tensions and trade-offs between different kinds of goods are encountered in every stage of scientific research, engaging in this kind of collaboration throughout the research process can promote legitimacy.

**Whose interests should be promoted?** The suggestion that scientists should work with other stakeholders—policy makers, community members, and industry representatives, as well as people with expertise in other disciplines—does not yet resolve the kinds of tensions and trade-offs between different kinds of goods that we identified in the last section. Different stakeholder groups—and different individual members of those groups—will have different ways of understanding goals such as protecting the environment, reflecting different interests, disciplinary training, and social location. Working with certain stakeholders, rather than others, means that certain values, but not others, will shape the research that is produced. How can scientists navigate these tensions in their knowledge production, especially when stakeholders have deeply conflicting and incompatible interests? How can they choose which stakeholders to work with—whose interests to promote?

In ethics, theories of distributive justice describe how benefits and burdens should be distributed across society. Furthermore, the methods of fields such as environmental science, toxicology, and public health are especially well-suited for studying the distribution of environmental burdens. These scientific fields can provide the factual basis for claims of distributive environmental injustice.

This factual basis is especially important for promoting the interests of environmental justice communities. Since the publication of the watershed report “Toxic Wastes and Race” (Commission for Racial Justice 1987), a large body of literature has examined the relationship between environmental hazards and other forms of systematic inequality, including race, ethnicity, class, and gender (Taylor 2014). Schlosberg points out that, although environmental injustice is not limited to distributive injustice, distributive issues are a key part of “a broad and multifaceted approach to [environmental] justice” (Schlosberg 2007; see also Young 1990). We adopt a simplified definition of environmental justice communities here as communities where distributive environmental injustice is causally related to other forms of distributive injustice, especially along the lines of race, ethnicity, class, or gender.

Although serious theoretical disagreements exist between major theories of distributive justice (Holtug and Lippert-Rasmussen 2007), they provide convergent arguments that the interests of environmental justice communities should often take priority over other, competing concerns (Shrader-Frechette 2002). Because they suffer from other forms of injustice, environmental

justice communities typically have limited political and economic power and so may be burdened with environmental hazards without their consent (Shrader-Frechette 2002, ch 4). In the U.S. policy context, these philosophical arguments are bolstered by Executive Order 12898, which directs federal agencies to “make achieving environmental justice part of [their] mission[s]” (The President of the United States of America 1994).

The value of environmental justice can provide substantive guidance when scientists navigate tensions between different kinds of goods and competing groups of stakeholders, legitimizing the choice to produce knowledge that can help understand and respond to the burden of environmental injustice over the production of knowledge that will be useful to a particular privileged group.

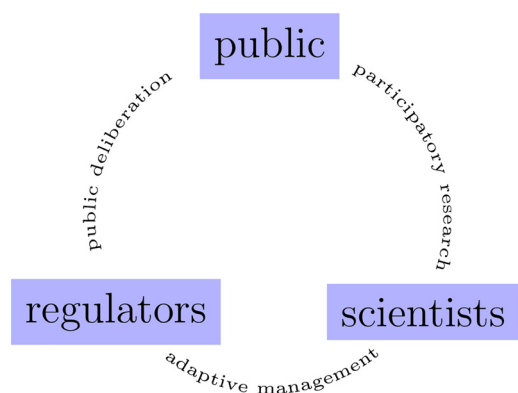
In the face of controversies over environmental justice, scientists may be tempted to take a more neutral role, presenting themselves as an “honest broker of policy alternatives” (Pielke 2007). However, because of the sheer size of the space of scientific-policy alternatives, true neutrality is practically impossible (Havstad and Brown 2017a); scientists must make substantive decisions (or assumptions) about which alternatives are more or less feasible and attractive. We argue that it is better for scientists to be thoughtful and explicit about how their research is designed to promote substantive values, especially when those values are controversial.

### **Strategies to Improve Legitimacy**

Regulatory scientists inevitably make value judgments throughout their research, even in its most technical aspects. However, some defenders of the value-free ideal argue that value judgments should be made by citizens and their representatives, not scientists, and that allowing scientists to exercise their own judgment about values may lead to technocratic, antidemocratic forms of governance (Betz 2013; John 2015; Mitchell 2004), or may foster a science charade, where scientists present value-laden decisions as though they were value-free (Dudley and Peacock 2017; Wagner 1995).

To ensure that scientists’ value judgments do not contribute to antidemocratic forms of governance, their judgments should remain accountable to citizens. In other words, scientists ought to make sure their judgments are democratically legitimate (Intemann 2015). To achieve this, we suggest that environmental scientists could be thought of as epistemic representatives, in much the same way that legislators or executive branch regulators are political representatives. Just as duly elected members of Congress may legitimately make value-laden decisions on behalf of citizens in certain policy processes, scientific experts may—through certain democratic processes of authorization and accountability—legitimately make value-laden decisions on behalf of a particular public in certain knowledge-production processes. Just as with political representation, legitimate epistemic representation requires that representatives understand the interests of the public they represent and be accountable to that public (Young 2000). The performance of scientists as epistemic representatives might be assessed through various formal or informal systems of authorization, accountability, public participation, opportunities for deliberation and remonstrance, and certain kinds of resemblance to the public they represent (Brown 2009).

We propose three strategies to increase the legitimacy of scientists as epistemic representatives (Figure 1). Each strategy concerns a process to strengthen connections, accountability, and mutual understanding between scientists, policymakers, and the public, to help ensure that science and policy are informed by citizens’ concerns and interests.



**Figure 1.** Strategies for legitimacy. Public deliberation, participatory research, and adaptive management support the legitimacy of political and epistemic representation by connecting representatives to each other and to the public.

**1. Public deliberation.** For policymakers in a democratic society, perhaps the most important source of values and basis for legitimacy is democratic accountability—accountability to the public in whose name policymakers act. Political theorist Mark Brown contrasts two different conceptions of accountability. Managerial accountability is a matter of producing evidence that resources have been spent efficiently to achieve fixed goals (Brown 2009). This way of thinking about accountability appears to be common in regulatory agencies today, as exemplified by cost–benefit analysis (CBA) (Ackerman and Heinzerling 2002).

In contrast, political theorists and philosophers in the deliberative democracy tradition understand accountability as “giving an account” (Brown 2009), or exchanging reasons for or against various policies. This kind of accountability requires robust, participatory institutions. Citizens must have not only “effective opportunities to present [their] views, [and] question or challenge the views of others,” but also “have [their] questions or challenges answered” by policymakers (Hicks 2017a).

The National Academies report titled *Understanding Risk*—sometimes called the Orange Book—argues that “deliberation is necessary and appropriate at every step in the [risk assessment] process” and “agencies (and other organizations) [should] begin by asking *how* to involve the parties in the steps leading up to risk characterization and *what* to deliberate, rather than asking *whether* to involve them” (emphasis in original) (U.S. NRC 1996). Specifically, the Orange Book argues that deliberation can help ensure that risk assessment is both informed by the local or specialized knowledge of affected communities and is relevant to the concerns and interests of these communities. That is, deliberation can improve the quality of risk assessment by incorporating both relevant knowledge and relevant values (U.S. NRC 1996; U.S. NRC 2008).

Public hearings—in which any member of the public can explain their views on a policy proposal to representatives from a regulatory agency—are sometimes considered a form of public deliberation. In addition, community-based environmental justice organizations have used presentations at public hearings effectively to challenge regulatory science and policy (Corburn 2005). However, public hearings are often regarded as, at best, a limited approximation to deliberative governance. Environmental justice scholars have observed that public hearings are often noninteractive forums in which agency representatives listen but do not answer questions or otherwise respond to public comments in real time (Kojola 2018). Furthermore, both environmental justice scholars and theorists of deliberative democracy have noted that rhetorical constraints of public hearings can effectively

exclude marginalized communities (Ottinger 2013). For example, members of the public who offer emotional appeals or speak from personal experience, rather than presenting technical scientific evidence, are often effectively ignored (Corburn 2005; Young 2000). The Orange Book considers a number of other, more robustly deliberative forms of public–agency interaction, including citizen advisory committees, citizen juries, focus groups, and surveys (U.S. NRC 1996). Although we acknowledge that public deliberation of policy development and implementation is frequently time-consuming and not always efficient at reaching consensus, the democratic accountability that deliberation warrants, when feasible, makes this public deliberation a significant procedural strategy to legitimize value judgments in regulatory science.

**2. Adaptive management.** A second strategy to strengthen collaboration and improve the legitimacy of the values in regulatory science is adaptive management. Originally articulated in conservation biology and natural resources management, adaptive management is a flexible learning strategy for policymaking in the face of uncertain or complex scenarios (Mitchell 2009). “Adaptive management aims to create policies that can help organizations, managers, and other stakeholders respond to, and even take advantage of, unanticipated events. . . Management policies are designed to be flexible and are subject to adjustment in an iterative, social learning process” (U.S. NRC 2004).

Adaptive management starts with the available scientific knowledge and encourages the timely incorporation of new research outcomes in the regulatory process. The strategy encourages collaboration between scientists and policymakers, who then learn from each other’s advances. Adaptive management promotes policy-relevant research by encouraging scientists to design research projects that address the information needs and value frameworks of policymakers. Adaptive management also encourages policymakers to account for new scientific knowledge (Fischman and Ruhl 2015; Westgate et al. 2013). For example, policymakers might issue a temporary moratorium and accelerate reregistration review of a common pesticide in light of provisional evidence suggesting that it is much more hazardous than previously thought (*c.f.* Cressey 2017). Similarly, adaptive management encourages climate-change researchers to consider multiple possible scenarios and complex socioeconomic and environmental systems when designing research, while also encouraging policymakers to accept uncertainties embedded in climate models and projections when developing policy responses (Tompkins and Adger 2004).

**3. Community-based participatory research.** For scientists concerned with the social impact of their work and with using legitimate values to guide their research process, community-based participatory research (CBPR) is also a relevant strategy. CBPR emerged as an alternative to traditional research, which is commonly indifferent to or exploitative of the communities who will be affected by research outcomes (Gust and Seifer 2011). Driven by a social commitment to the needs and interests of the communities involved and by a general commitment to social justice and community empowerment (Petras and Porpora 1993), CBPR aims at collaboration with community members in all aspects of the research process, so that research outcomes improve the health and well-being of the communities affected by the issue being studied (Blumenthal 2011; Faridi et al. 2007; Israel et al. 1998). CBPR is thus a methodological approach to inquiry, not just a deliberative process to understand communal needs and interests.

In contrast with traditional research—where scientists choose and control topic selection, study design, data collection and interpretation, and the dissemination of results—CBPR encourages the

participation of community members at every stage of the research process. In this way, CBPR ensures that the values and interests of the communities affected are considered and that research outcomes are relevant to their needs. Because community members are included in every stage of research, CBPR goes beyond citizen science, which often includes nonscientists only in the data-collection process (Wilderman 2007).

CBPR has also been a successful methodology for addressing environmental and public health issues (O'Fallon and Deary 2002). For instance, the partnership between the Environmental Health Coalition (EHC) (a not-for-profit organization that trains members of the general public from marginalized communities in San Diego and Tijuana to address environmental health issues) and the Southern California Environmental Health Sciences Center at the University of Southern California, that seeks to help address concerns over asthma rates and its potential links to industry in Old Town National City, California. Through a CBPR initiative called the Toxic Free Neighborhoods Campaign, the EHC partnership was successful in gathering quantitative and qualitative data showing a disproportionate exposure to air pollutants, which in turn helped bring about environmental health policy change (Minkler et al. 2010). CBPR is thus a third strategy for legitimizing value judgments in regulatory science, fostering a close relation between scientists and the public, and encouraging scientists to better understand the needs and interests of the community and incorporate them in the research process.

## Conclusions

Although the value-free ideal is deeply embedded in the institutions and culture of regulatory science, there are serious conceptual and methodological problems with this ideal. Critics of the value-free ideal argue that there are legitimate roles for ethical, political, and economic considerations even in the core of the scientific process. Values are not necessarily sources of bias and error; values can, do, and should help set standards of evidence, inform methodological decisions, and characterize the proper relationship between science and democratic policy-making. Accordingly, we recommend that regulatory science incorporate values that reflect the goals of protecting human health and the environment, informing democratic deliberation, and promoting the capacities of environmental justice and Indigenous communities. Public deliberation, adaptive management, and community-based participatory research are three strategies that can help scientists achieve such goals.

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