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'Managing values' in health economics modelling: Philosophical and practical considerations

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ABSTRACT

Stakeholder involvement has been proposed as a key strategy for appropriately managing value-laden decisions or 'value judgments' in health economics modelling. Philosophers of science, however, conceive of stakeholder involvement in research in conflicting ways, and also propose alternative strategies for 'managing values' in science. Furthermore, all proposed strategies for managing values in science raise philosophical questions and practical challenges that are difficult to resolve. As a result, health economists who seek to appropriately inform value judgments in modelling must currently go without straightforward guidance. There is a need to further explore how health economists should manage value judgments in modelling, taking into account philosophical debates and contextual constraints. This paper discusses core proposals for managing values in science and identifies philosophical questions and practical challenges these proposals leave unresolved. It further considers how this could potentially inform processes to manage value judgments in health economics modelling, using examples from an ongoing modelling project called LEAP (Lifetime Exposures and Asthma Outcomes Projection). We conclude that all strategies to 'manage values' in health economics modelling have strengths and weaknesses, but are generally compatible with one another, suggesting that health economists may use a combination of strategies. Further research is needed to explore the effects of strategies to 'manage values' in health economics modelling.

1. Introduction

The influence of values in modelling—and how to manage that influence— is a topic of debate in health economics and adjoining fields, including epidemiology and climate science. This topic invites increasing attention, particularly as health economists use models to study interventions that might offset the health impacts of climate change, but present significant uncertainty and come at considerable cost (Adibi et al., 2024). Many suggest that stakeholder involvement is a key strategy for appropriately managing "value judgments" in health economics modelling (Harvard, 2024; Harvard and Winsberg, 2023), which Harvard et al. (2020) define as decisions where scientists agree there is more than one legitimate way of doing things, and there could be social or ethical consequences following the decision, whether these consequences are immediate or delayed. Philosophers of science, however, conceive of stakeholder involvement in research in conflicting ways, and also propose alternative strategies for "managing values" in science (Elliott, 2022), which have not received equal attention in the health economics literature. Furthermore, all proposed strategies for managing values in science raise philosophical questions and practical challenges that are difficult to resolve. As a result, health economists who seek to appropriately inform value judgments in modelling must go without straightforward guidance. Although many initiatives have involved stakeholders in modelling, including in health economics (Bunka et al., 2022; Gibbs et al., 2023; Xie et al., 2021), few have centred the task of managing values or addressed the difficulties that philosophers of science emphasize. There is a need to further explore how health economists should manage values in modelling, taking into account philosophical debates and contextual constraints. The aims of this paper, therefore, are to: a) discuss core proposals for 'managing values'

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in science and identify philosophical questions and practical challenges these proposals leave unresolved; b) consider how this can inform processes to manage value judgments in health economics modelling.

The paper proceeds as follows: in Section 2, we define and illustrate value judgments in health economics modelling, drawing on literature from philosophy of science and examples from an ongoing modelling project called LEAP (Lifetime Exposures and Asthma Outcomes Projection). In Section 3, we discuss philosophical proposals for managing values in science and consider how they could be applied to the LEAP project. Section 4 concludes, suggesting that health economists may combine multiple strategies to 'manage values' in modelling.

2. 'Value judgments' in modelling: definition and illustration using the LEAP model

2.1. Values and value judgments

There is considerable heterogeneity in how authors define 'values' and 'value judgments', both within and across the disciplines (Fischhoff, 1991). This includes health economics (Drummond et al., 2015; Shiell et al., 1997) and philosophy of science, where an area of concentration is the role of values in science (Korf and Elliott, 2024). A common, broad definition of 'values' is "anything desirable or worthy of pursuit" (Elliott, 2017, p.11). However, Winsberg (2024) has argued that scholars focused on the influence of values in scientific *decision-making*, including modelling, should define 'values' according to basic decision theory, wherein all decisions are understood to be determined by an agent's values and beliefs.[1] On this view, the term 'values' means the same thing as 'utilities': desired outcomes to which decision-makers attach numerical weights in theory, i.e., what Jeffrey (1965, p.531) called "numerical desirabilities". Winsberg (2024) suggests that conceiving of values according to basic decision theory will help keep sight of three things: 1) modelling decisions involve both values and beliefs; 2) modelling decisions necessitate trade-offs; 3) modelling decisions have social and ethical (as well as epistemological) significance, given their potential for real-world implications. Winsberg (2024) argues for conceptualizing values this way even though the values of scientists (i.e., decision-makers in science) will seldom be possible to measure. Indeed, Winsberg (2024) emphasizes that articulating the values and beliefs that drive a given modelling decision will generally be impossible in practice, given the number of concurrent, inter-dependent decisions, the complexity and unpredictability of downstream events, and modellers' own cognitive limitations (see also Parker and Winsberg, 2018; Winsberg and Harvard, 2024).

Here, we follow Winsberg (2024) in assuming that all modelling decisions involve values in the sense defined by basic decision theory, though knowing precisely what values and beliefs drive modelling decisions will seldom be possible. Following Harvard et al. (2020), we refer to modelling decisions as 'value judgments' when our intent is to emphasize that those decisions are flexible from a scientific perspective and have social and ethical significance.[2] Where relevant, we distinguish between 'inferential decisions' and 'representational decisions', which Harvard and Winsberg (2022) argue are two importantly different types of value-laden decisions in science, i.e., decisions concerning the truth of hypotheses versus decisions concerning the adequacy-for-purpose of scientific representations, respectively (see also Harvard et al., 2021; Winsberg and Harvard, 2024). As Harvard and Winsberg (2022) describe, inferential decisions pose 'inductive risk' (the risk of endorsing a hypothesis whose objective truth value is false) while representational decisions pose 'representational risk' (the risk of using a scientific representation that is inadequate for purpose). Philosophers of science point to these 'epistemic risks' to emphasize the real-world implications, and hence social and ethical significance, of scientific decisions (Douglas, 2000; Elliott and Richards, 2017; Winsberg and Harvard, 2024).

2.2. The LEAP model: illustration of value judgments in modelling

The LEAP model is an open-population microsimulation model that aims to inform asthma policy and resource allocation decisions in Canada, including those relating to climate change. Following the tradition of 'Whole Disease' modelling (Tappenden et al., 2012), the long-term goal is for the LEAP model to include all relevant risk factors for asthma, asthma-related outcomes (e.g., asthma onset, exacerbations, hospitalizations), and a range of asthma prevention and treatment strategies alongside their societal- and health system-level costs. Currently, those involved in building the LEAP model (hereafter, 'the LEAP team'[3]) are working on incorporating a specific asthma risk factor (air quality) and evaluating a specific asthma intervention (the use of high efficiency particulate air (HEPA) filter machines, which reduce exposure to fine particulate matter or 'PM2.5'). Their short-term research objectives are to i) incorporate projections of air quality over a 16-year time horizon, taking climate change into account, to evaluate its impact on the number of Canadians with asthma, days with asthma symptoms, asthma exacerbations, and healthcare costs; ii) estimate the cost-effectiveness of HEPA filter machines for asthma prevention and management, while exploring differences in cost-effectiveness based on age, sex, asthma severity, and socioeconomic factors.

Developing the LEAP model will involve numerous representational decisions, some of which have especially salient social and ethical significance. This follows from the fact that these decisions not only have predictable effects on model results, but link to downstream social outcomes that people are likely to value differently. Consider three examples:

First, the choice to represent the cost-effectiveness of HEPA filters rather than other potential interventions for asthma (e.g., programs to increase breastfeeding, optimize gut microbiome, or reduce unnecessary antibiotic use) has the effect of directing attention toward HEPA filters and away from those other potential interventions; it also amounts to endorsing HEPA filters as a *prima facie* socially- and ethically-acceptable intervention worthy of further investigation (Harvard et al., 2021). This representational decision, which equates to the choice of research topic, is an example of a value judgment in the so-called 'external' phases of science, i.e., value judgments long considered unproblematic from an epistemological perspective (Elliott and McKaughan, 2009). Nonetheless, the decision remains value-laden and has the potential to spark ethical debate. For example, stakeholders who prioritize addressing the root causes of climate change may object to an intervention that aims to help people adapt to worsening air quality (cf. Winsberg, 2021). Therefore, some stakeholders may disagree that HEPA filters are *prima facie* a socially and ethically acceptable intervention worthy of further investigation.

Second, to estimate the cost-effectiveness of HEPA filters, modellers will have to choose among different available estimates to represent the intervention's effectiveness in improving indoor air quality, as well as

[1] For example, according to basic decision theory, one's decision whether or not to carry an umbrella is determined by one's beliefs about the weather (e.g., one's degree of belief that it will be sunny and dry out, or start raining) and the value one places on various outcomes (e.g., carrying an umbrella around while it is sunny and dry out, not having an umbrella when it rains, etc.). For more on the distinction between values and beliefs, see Steele & Stefánsson (2020).

[2] The practice of referring to scientific decisions as 'value judgments' is subject to important criticisms (e.g., it is redundant, if one takes values to be part of all decisions; it downplays the part of the decision rooted in beliefs; it makes the contested assumption that values are uncovered through a cognitive process). However, we believe the rhetorical benefits of the term outweigh these considerations here.

[3] Please see Acknowledgments.

decide on the extensiveness of sensitivity analyses around this parameter. Decisions like these are routine in health economics modelling, but are not fully constrained by evidence and have a predictable effect on model results (Harvard et al., 2020). This means modellers are put in a position to judge the acceptability of potential errors from an ethical perspective, i.e., of representing HEPA filters as more effective or less effective (by various degrees) than they really are (Harvard et al., 2021; Winsberg and Harvard, 2024).

Third, to estimate the cost-effectiveness of HEPA filters over a 16-year time horizon, modellers must choose how to represent the intensity of future wildfires in Canada. Importantly, climate scientists suggest that current climate models are not adequate for predicting wildfires, which are the result of complex interactions between fuel accumulation, vegetation dynamics, CO2 concentrations, environmental management and human ignitions (Kloster and Lasslop, 2017; Sanderson and Fisher, 2020). While modelling studies have attempted to project wildfires under a variety of CO2 emissions scenarios, significant uncertainty surrounds their results (e.g., Xie et al., 2022). Consequently, health economics modellers must again judge the ethical significance of potential errors, i.e., representing future wildfires in Canada as being more severe or less severe (by various degrees) than they really will be. Currently, many sources emphasize that wildfires are expected to increase due to climate change, implying a preference not to underestimate future wildfire severity (e.g., United Nations Environment Program, 2022). However, some might worry that this does not adequately capture uncertainty and could signal to policymakers that wildfires are outside their control, when in fact policymakers have a non-trivial influence on wildfire through environmental management policies. Thus, the representation of future wildfire is a modelling decision with social and ethical implications, the kind of value judgment in science that philosophers argue should be carefully managed.

In addition to representational decisions in model development, interpreting the LEAP model will require making inferential decisions, i.e., decisions regarding which truth-apt claims to endorse on the basis of model results (Harvard et al., 2021). For example, a key inferential decision to be made in interpreting the LEAP model will be whether to conclude that HEPA filters are a cost-effective intervention for asthma. The social and ethical implications of inferential decisions are well-appreciated in health economics, given the presence of uncertainty and the potential for a wrong decision to negatively affect resource allocation and downstream health outcomes (Claxton, 2008). The question of how to manage the 'inductive risk' involved in making inferential decisions is central to the philosophical proposals discussed in the next section.

3. Philosophical proposals for 'managing values' in science

Most contemporary philosophers of science agree that values influence all stages of scientific inquiry and the 'Value Free Ideal' for science is untenable (Holman and Wilholt, 2022). Consequently, many philosophers have turned their focus to preventing values from having problematic effects, sometimes also promoting "responsible roles" for values and/or conceiving of their beneficial effects in science (Elliott, 2022; Brown, 2020). Two possible problematic effects include damage to scientific objectivity (e.g., damage that would result if scientists endorsed only the claims they want to be true) and damage to democratic decision-making (e.g., damage that would result if political decisions informed by science were more influenced by scientists' values than the public's) (Anderson, 2004; Betz, 2013; Bright, 2018). Related worries include damage to science as an institution and to public trust in science, should the public's values conflict with those guiding scientific inquiry (DiMarco, 2023; Douglas, 2009). The goal of preventing problems like these (with or without the goal of encouraging responsible or beneficial influences for values in science beyond this) is often discussed in terms of how to "manage values" in science (Elliott, 2022). Where we refer to 'managing values' in modelling, we mean the goal of making modelling decisions in a way that at least helps avoid the specific problematic effects listed above.[4]

Philosophical proposals for how to manage values in science have been recently reviewed by Elliott (2022). Here, we draw on Elliott's (2022) review, but categorize proposals somewhat differently, on the basis of *whose* values are suggested as being the right ones to inform scientific decisions: 1) Scientists'; 2) Philosophers'; 3) the General Public's; 4) Science Users'. Within each category, we discuss two or more proposed processes for managing values in science and consider how they might be applied in health economics, using examples from the LEAP project.

3.1. Scientists' values

One group of proposals for how to manage value-laden science assumes that scientists will continue to make decisions using their own values. Some focus on what scientists can do independently during the initial decision-making process (Douglas, 2009; Steel, 2010), while others focus on what scientists can do at a group level later on (Longino, 1990, 2002).

A much-discussed proposal by Douglas (2009) emphasizes the need for scientists to ensure their values play an appropriate *role*. Specifically, Douglas (2009) draws a distinction between a 'direct' role for values and an 'indirect' role, arguing that the direct role is unacceptable at the core of scientific reasoning. According to Douglas (2009, p.96), values play a direct role if they provide "direct motivation for the adoption of a theory", but an indirect role if they "act to weigh the importance of uncertainty about the claim, helping to decide what should count as sufficient evidence for the claim". Thus, Douglas argues that values may play a direct role in some decisions (e.g., picking a topic to study), but not in establishing empirical claims. Nonetheless, many argue that, upon scrutiny, the distinction between direct and indirect roles for values is ambiguous: Douglas' (2009) proposal does not always amount to instructions that scientists can easily follow, nor does it prevent values from having problematic effects (Elliott, 2013; Steel and Whyte, 2012).

The difficulty with Douglas' (2009) proposal can be demonstrated using an example from the LEAP model. In this context, an ethically-significant representational decision is how to model the severity of future wildfires in Canada (Section 2). According to Douglas (2009), it is acceptable for scientists' values to inform this decision indirectly (by determining how to manage potential error) but not directly (by driving the model to a pre-determined conclusion). However, it seems that modellers could arrive at the same final representational decision with values operating in either purported 'role'. To illustrate, imagine that modellers choose to represent the severity of wildfire over the next 16 years as a range of possible values, one that shows future wildfire as being potentially more severe or less severe than the historical average. One could argue that this decision reflects values working appropriately in an indirect role, guiding modellers to manage the risk of error by demonstrating the full extent of uncertainty. Conversely, one could argue that this decision reflects values working inappropriately in a direct role, with modellers purposely driving to the conclusion that HEPA filters would not be cost-effective in many scenarios. Alternatively, modellers might choose to represent future wildfire as inevitably increasing from levels observed to-date and potentially reaching catastrophic heights, in line with the results of certain models and expectations. Again, one interpretation is that this is an acceptable

[4] We define 'managing values' in this minimal way in order to avoid debating what it means for values to have a 'beneficial' effect in science beyond preventing the specific problems listed above and whether ensuring such a beneficial effect is a coherent or achievable goal, which is outside the scope of this paper. What is widely-agreed is that the influence of values in science is unavoidable: whether their influence is ultimately good or bad in a given instance is itself a value-laden question.

strategy for managing the risk of error: to assume the worst-case scenario and thereby err on the side of having model results support mitigation efforts. However, a competing interpretation is that such a decision amounts to manipulating the model's outcomes, an inappropriate influence of values in Douglas' (2009) view. This type of interpretation might be more likely if, for example, the model were sponsored by a manufacturer of HEPA filters (cf. Steel and Whyte, 2012).

Like Douglas (2009), other philosophers have assumed that managing the influence of values starts with scientists. In a proposal dubbed the *epistemic priority thesis*, Steel (2010, 2017) argues that scientists should privilege epistemic considerations throughout their decision-making. That is, values should influence decisions when designing, interpreting, or disseminating scientific research only when epistemic considerations fail to determine the best option (Steel and Whyte, 2012, p.170). Similarly, John (2015) argues that scientists should adopt "fixed, high epistemic standards" when making public-facing scientific claims. One unique feature of John's (John, 2015) proposal is the emphasis he places on the role of scientific institutions: he asserts that high epistemic standards for scientific communication to the public should be set and enforced through institutional norms and mechanisms.

In health economics, modellers are expected to follow good practice guidelines, which take into account a variety of epistemic considerations (e.g., Caro et al., 2012). It is well-recognized that certain modelling techniques can be used to purposely produce favourable model results (i.e., to lower incremental cost-effectiveness ratios) and such practices are the object of reproach (Beca et al., 2018). In our interpretation, Steel's (2010, 2017) epistemic priority thesis is not in conflict with Beca et al.'s (2018) advice to health economists to favour "good practices" and "rigorous conduct", with which few scientists would disagree. However, interpreting what counts as good practices and rigorous conduct in science is an ongoing process. Furthermore, although it is widely agreed that scientists should carefully consider scientific criteria throughout decision-making, the epistemic priority thesis is challenged by accounts that show that scientific decisions are *always* underdetermined or 'unconstrained' by epistemic criteria alone (Douglas, 2009; Rudner, 1953; Winsberg, 2024; Winsberg and Harvard, 2024). These accounts emphasize that scientific evidence never affords certainty and scientists must always make decisions. And while it might seem possible in principle for scientists to make decisions by suspending their individual judgment and deferring to scientific norms with "high epistemic standards", proposals like John's (2015) face two difficulties. First, it is improbable that scientific norms and standards could ever be articulated at a level of detail adequate to inform every unique decision that modellers come to face. As it stands, good practice guidelines are a valued source of advice, but insufficient to resolve all representational decisions in the LEAP project. Second, the choice to suspend individual judgment and defer to scientific norms is itself a value-laden decision: the fact remains that modellers have power over decisions and the responsibility to look out for potential cases where deferring to norms might, for whatever reason, have unacceptable consequences. These difficulties show that institutional norms and standards cannot be expected to 'manage values' in modelling.

A distinct possibility is that scientists have the prerogative to make value judgments as needed, but a responsibility to be *transparent* about those judgments. Elliott and McKaughan (2014), for example, suggest that scientists should be explicit about what assessments they make and how values influence those assessments. They argue that if scientists are explicit about their goals and the criteria they are using, this will enable the users of science to "backtrack" to any points of disagreement and make their own assessments and conclusions (see also McKaughan and Elliott, 2013). This general idea is consistent with good practice guidelines in health economics, which emphasize that "there are no unambiguous criteria to apply to judgments about a model or its application" (Eddy et al., 2012, p.846), while outlining steps to ensure model transparency. However, as Schroeder (2021) points out, it is unclear how many individuals have the time and skills necessary to "backtrack" through complex science and identify value-based disagreements. A similar skepticism surrounds most people's ability to interrogate health economics models built by others, even if those models are made Open Source (Sampson et al., 2019).

There is wide agreement that transparency must play some role in managing values in science (Douglas, 2009; Elliott, 2017, 2022), but recent work has highlighted many unanswered questions, including *exactly* what information scientists should be transparent about and how (Elliott, 2021). A key concern is that there are obvious practical and cognitive limits to how much information scientists can provide and consumers can take in, respectively: the challenge seems to be to determine the right balance of content for different audiences in different contexts, but there are numerous factors to account for (Elliott, 2022b). Winsberg and Harvard (2024) argue that, at a minimum, transparency should enable the public to determine whether scientists have made decisions that fail to accord with their (the public's) values; they call this the "congruence criterion" (p.60). However, Winsberg and Harvard (2024) are pessimistic that this can be achieved in modelling. Assuming a decision-theoretic conception of values, they argue that modelling decisions are driven by an inchoate mix of epistemic and value assessments that are impossible to articulate; they call this the "inarticulability thesis" (Winsberg and Harvard, 2024, p. 56). Finally, even if transparency could be optimized, many argue that transparency alone is insufficient to manage values in science (Schroeder, 2021). As Eddy et al. (2012, p. 845) say, "A model can be transparent but yield the wrong answer": more generally, a model can be transparent but reflect the wrong values. Thus, it seems that transparency must be supplemented, at least, with a commitment to revision under some (undefined) circumstances.

While some think individual scientists should manage the influence of values, others assume this should occur at the level of the scientific community. An influential proposal of this kind is Helen Longino's (1990, 2002) "Social Value Management Ideal" (SVMI). This proposal centres the need for scientific communities to submit their practices and findings to *transformative criticism* from diverse perspectives. According to Longino (1990, 2002), scientific communities should maximize four conditions, which we interpret using examples from the LEAP project. First, *publicly recognized venues for criticism*: such venues exist across scientific communities (e.g., academic conferences, peer-reviewed journals) but in the context of the LEAP project, we interpret Longino as endorsing novel venues that encourage even wider model interrogation, such as Open Source model-sharing platforms and initiatives like the Mount Hood Challenge (Harvard et al., 2022; Kent et al., 2019). Second, *uptake of criticism*: the SVMI assumes that scientific communities should debate their methods and findings among diverse audiences, making revisions where justified. In the LEAP project, we take this as the intuitive (but seldom enacted) suggestion to present the model at various stages of development to members of different scientific disciplines, including health economics, computer science, respirology, immunology, forestry, etc. Third, *shared standards*: Longino (1990, 2002) argues that scientific communities must agree on what counts as acceptable reasoning and evidence. At one level, this condition points to the role that good practice guidelines play in health economics, reinforcing the intuition that these should be continually augmented and consulted. At another level, it points to the need to establish what members of *other* disciplines consider to be acceptable reasoning and evidence, particularly when it comes to fine-grained decisions (e.g., parameterizing the effectiveness of HEPA filters) that are not addressed by high-level guidelines. Finally, *tempered equality of intellectual authority*: the SVMI advises that scientific communities treat all members as equally capable of providing reasons and criticism, but remain respectful of domain expertise. We take this as the intuitive suggestion to encourage feedback on the LEAP model from health economists, climate scientists, respirologists, etc., but to weight respirologists' feedback more heavily when it concerns questions related to lung health (for example). Numerous philosophers of science have built on Longino's (1990, 2002) account, elaborating on the different types of diversity that are beneficial in scientific communities and why (Rolin, 2017).

Although the SVMI is widely endorsed, it is not without critiques. For one, Longino's demand for 'shared standards' faces a familiar difficulty: there are no universal standards that apply under all circumstances. Furthermore, there is nothing in the SVMI that releases scientists from having to hear from any particular set of individuals. Ostensibly, this obligates scientists to respond to a burdensome amount of criticism, including, potentially, criticism from scientists with ethically or politically problematic views (Rolin, 2017). For example, one might worry that the LEAP team will be forced to take feedback from scientists who deny climate change. One might ask: where should health economics modellers draw the line in terms of seeking and responding to feedback from scientists across the disciplines? Yet another criticism of the SVMI is perhaps even more worrisome: any critical process in science stands to be dominated by socially powerful voices (Kourany, 2008). This suggests the scientific communities may sometimes settle on methods and findings not through a process of good reasoning but of social pressure and coercion. Thus, though the SVMI relies on transformative criticism from diverse perspectives, it cannot ensure that *all*, and *only*, relevant perspectives will be represented.

3.2. Philosophers' values

Some argue that it is possible to use ethical reasoning to identify the *right* values to inform scientific decisions. Those who argue this, including Anderson (2004), Kourany (2010) and Brown (2020), suggest that ethical reasoning requires a range of inputs, including empirical information and evaluations from a variety of sources, meaning their proposals overlap with ones that prioritize consultation with various groups. Nonetheless, one distinct answer to the question 'whose values should inform scientific decisions?' that these proposals suggest is 'philosophers', or individuals who carry out principled ethical or philosophical reflection.

One of the most developed proposals of this kind is Janet Kourany's (2010, 2013) "Ideal of Socially Responsible Science" (ISRS), which emphasizes the development of *ethical codes* to guide the conduct of scientific research. In Kourany's (2013, p.95) words, developing such ethical codes would be "an ethically and epistemically normative project, one that looks deeply into the aims and attendant responsibilities scientists ought to set for themselves". Kourany's process places philosophers in a key role, as the participants with the "honed facility" for articulating, analyzing, clarifying, and criticizing arguments relevant to normative projects (Kourany, 2013, p. 98). On Kourany's view, ethical codes could be developed that would be both comprehensive and specific enough to guide scientific decision-making, though she concedes that ethical codes would not enable scientists to meet *all* their ethical responsibilities (Kourany, 2013, p.98).

Matthew Brown (2020, p. 209) argues that there is a tension in the ISRS: on the one hand, it implies that society should determine the appropriate values to guide scientific inquiry; on the other, it implies that the appropriate values should be determined by ethical reasoning. This is the tension between the values that society says it wants and the values philosophers say society *should* want: leaving it unresolved means the question of how to 'manage values' remains unanswered. Brown (2020, p. 210) further criticizes the ISRS for being "compliance-oriented" and developing ethical codes *prior* to inquiry. He argues that this "absolutist" stance will be of no help when pre-determined values fail to guide successful inquiry and therefore endorses "mutual revisability of values and standards" *throughout* inquiry instead. Brown's own (2020) "Ideal of Moral Imagination" (IMI) encourages philosophical reflection when deliberating about unforced choices (Brown, 2020, p. 186):

1. Identify the goal or task at hand.
2. Identify and imaginatively multiply options for how to carry out the task.
3. Determine the standards and values that are relevant to the situation.
4. Identify the legitimate stakeholders to consider and identify their interests.

Brown (2020, p. 187) argues that this will help scientists prevent *failures of moral imagination*, which he describes as a type of irresponsibility: "When scientists fail to recognize contingencies or fail to consider superior options where their decision has significant effects on stakeholders or other morally salient aspects."

The above proposals suggest at least three actions to help manage values in health economics modelling, including the LEAP project. First, following Anderson (2004), researchers could directly consult philosophers who specialize in ethics and ask for their input on modelling decisions. This approach has the potential benefit of introducing new, careful ways of thinking about modelling decisions— but also an obvious shortcoming: philosophers routinely disagree on ethical issues. The input received would likely depend on *which* philosopher was consulted, while input from multiple philosophers may or may not help modellers arrive at a decision, the 'rightness' of which would remain up for debate. Philosophers might also hold an idiosyncratic set of values, which the public might legitimately contest. Second, following Kourany (2010), health economists could advance initiatives to develop more ethically-oriented practice guidelines. For example, current guidelines (e.g., Caro et al., 2012) could be augmented using a process of consultation with interdisciplinary experts, people affected by models such as LEAP, and ethicists. To the extent that health economists value and rely on practice guidelines, the idea of augmenting them in this way has intuitive appeal. However, developing detailed normative guidance in health economics would take time and resources (Harvard and Winsberg, 2023), such an initiative would not inform projects like LEAP in the short-term, and the limitations of practice guidelines would still apply. Third, researchers could follow Brown's (2020) guidance for increasing philosophical reflection throughout the modelling process. Brown's (2020) proposal has the advantage of being highly actionable: arguably little stands in the way of modellers following Brown's (2020) suggestions. That said, Brown's (2020) proposal does not ensure that researchers' ethical reasoning will meet any particular standard. Furthermore, the IMI faces the criticism that it neglects to prioritize the values of the general public.

3.3. The general public's values

Many philosophers argue that value-laden decisions in science should be informed by the values of the general public[5] (Alexandrova, 2018; Douglas, 2005; Schroeder, 2021). A central question for them, then, is: by what procedure can the general public's values be elicited to inform scientific decisions? If we think that a proposed procedure would fail to elicit values that are truly representative of the general public's, then we might argue the proposal has more in common with ones that centre users' values, or the values of a *subset* of the general population (Section 3.4). What we consider in this section are proposals that mark the general public's as the *ideal* values to inform scientific decisions.

Building on her work that shows value judgments in science are inevitable, Douglas (2005) considers whose values should influence science that informs public policy. She reasons: "Regardless of which theoretical ideal of democracy one might hold, it is not acceptable for a minority elite to impose their values on the general populace" (Douglas,

[5] Some use the term "democratic values" to describe public values (e.g., Schroeder, 2021). We avoid this term so as to maintain a clear distinction between the general public's values and science users' values. As we show, philosophers have proposed to use what they call 'democratic' procedures to elicit the values of each of these groups.

2005, p. 156). It follows that science that informs public policy should reflect the general public's values. Douglas (2005) considers possible ways to achieve this, arguing that the ideal process would maximize interaction between citizens and experts and their mutual influence on each other. Accordingly, she endorses what she calls "analytic deliberative" processes: citizen panels, participatory research, or more generally "collaborative analysis". The hallmark of an appropriate process, she argues, is that citizens have *direct power* over technical studies and analyses (Douglas, 2005, p.158). She emphasizes that citizens should influence the values that shape the analyses, including by weighing the potential consequences of error, determining what kinds of uncertainties are acceptable/unacceptable, and informing assumptions. Perhaps the most obvious criticism of Douglas' (2005) proposal is that the processes she endorses do not guarantee that the values incorporated into science will be representative of the *general* public's. Douglas (2005, p.167) concedes that, in the case studies she reviews, the involved citizens recognize that they have an interest in the scientific issue at hand; it is unclear whether this undermines legitimacy. The same concern has been raised in health economics: although health economics modelling ultimately affects the general public, there is worry that only patients will participate in the process (Harvard and Werker, 2021; Harvard and Winsberg, 2023). Finally, Douglas (2005) acknowledges that "collaborative analysis" raises numerous practical questions, including what process citizens will follow to become involved, what their role will be, who will set the agenda, etc.— questions similar to ones Harvard and Werker (2021) raise about patient involvement in health economics modelling.

Like Douglas (2005), Anna Alexandrova (2018) and S. Andrew Schroeder (2021) argue that the general public's values are the right ones to inform science that affects everyone. Alexandrova (2018) suggests combining two different methods for eliciting public values: public participation in science (as described by Douglas, 2005) and deliberative polling, i.e., moderated group discussions among representative samples of the public (Fishkin, 2009). The methods that Schroeder (2018) endorses include deliberative democracy exercises, citizen science initiatives, public referendums, and population surveys. Alexandrova (2018, p.440) acknowledges that the success of these methods will depend on many factors (e.g., the proportion of scientists to non-scientists, how consensus is determined, checks on power imbalances) and concedes they will be "expensive, difficult to realize, and uncertain in their fruitfulness" (Alexandrova, 2018, p. 441). Schroeder (2021, p.554) suggests that scientists should at least use public values to inform their "top-line" results, e.g., what in health economics is called the 'base-case' analysis. For example, the LEAP team could use surveys to ask the general public how future wildfires should be represented in the context of uncertainty. The method endorsed by the majority of the public could then be used in the base-case analysis, while others could be used in sensitivity analyses. According to Schroeder (2021), when multiple research teams are investigating the same questions, using the public's values to inform common parameters will avoid the problem of "politicization", i.e., where people with conflicting values endorse different studies, depending on what assumptions they make. He further argues that incorporating public values into research would mean citizens would seldom need to scrutinize scientific studies for the influence of values: often, they could simply trust that those values are widely shared and have "a kind of legitimacy" (Schroeder, 2021, p.556).

Soazig Le Bihan (2023) has identified two major problems with using the general public's values to inform scientific decisions: *polarization* and *marginalization*. Polarization describes a situation in which population subgroups have conflicting views, while marginalization refers to the subjugation or disenfranchisement of communities within a population. As Le Bihan (2023, p.3) points out, polarization means there is often no such thing as the 'general public's' values: "If the public is divided into two opposite sides, for example, one faction justifiably deems the democratic processes' outputs as a win, while the other justifiably sees them as a loss". As for marginalized communities, insofar as science could incorporate the general public's values, they would have reasons to distrust it. Indeed, Le Bihan (2023) worries, the general public's values might be *prejudicial*. Anticipating this problem, Schroeder (2021) offers two solutions. First, public values should be "filtered" and "laundered", removing politically illegitimate (e.g., racist, sexist) values and values based on false empirical beliefs (Schroeder, 2021, p.554). Second, where minority values are held by a group subject to exclusion or discrimination, these values should be given extra weight as a form of compensation (Schroeder, 2021 p.558). Le Bihan (2023) is critical of these solutions. For one, knowing which values warrant 'filtering' and 'laundering', she argues, will depend on a moral judgment and be far from a straightforward process. Furthermore, it is unclear how *exactly* minority values will be given extra weight and why the majority should agree to this system (Le Bihan, 2023, pp.7-8).

3.4. Science users' values

In a discussion focused on applied climate science, Parker and Lusk (2019, p.1645) argue that "insofar as a *service to users* is being provided, the values of *users* ought to be employed". Parker and Lusk (2019) emphasize the management of inductive risk: they assert that scientists should consider who will use their results to make decisions and what errors those users (i.e., decision-makers) most want to avoid. In subsequent work, Lusk (2020, 2021) aims to explain how privileging users' values in scientific decision-making (rather than the general public's) can be politically legitimate. On Lusk's (2020, 2021) view, scientific decision-making should be structured and legitimated through a process of *deliberative democracy*. Scientific decisions, then, are politically legitimate to the extent that they are subject to deliberation and that deliberation attains relevant democratic ideals (e.g., fairness, reciprocity, equality, absence of coercion (Lusk, 2020, p. 997)). Thus, Lusk (2020, 2021) argues that public engagement in research can help manage values in science even if the individuals engaged are not representative of the general public. For Lusk (2020, 2021), what matters is that the individuals engaged in research have the opportunity to discuss ideas, give reasons, share and change their values—and the values that will ultimately guide the science are made transparent through deliberation. He stresses that a legitimate purpose of deliberation is to explore and clarify one's interests, and that one appropriate function of user-informed science is to scrutinize other research (Lusk, 2020, p. 1000).

Perhaps the most detailed proposal for *how* scientific research can be informed by users' values is Parker's (2024) 'Epistemic Projection' (EP) approach. According to it, stakeholders' values should be mapped at the outset of an investigation to an epistemic research problem: "a set of epistemic goals, preferences, and constraints" (Parker, 2024, p.19). Epistemic goals refer to the knowledge sought through the investigation, epistemic preferences to desirable features of research, and epistemic constraints to *required* features of research (Parker, 2024, p. 21). These include: 1) *Inductive risk desiderata*, which concern a study's evidential standards; 2) *Prioritization desiderata*, which specify which epistemic goals take priority when trade-offs must be made; 3) *Method desiderata,* i.e., research strategies, data sets, models, concepts, methods, analysis tools, etc.; and 4) *Form-of-conclusion desiderata,* which describe the desired form of research conclusions (e.g., precision, resolution, terminology, etc.). For each, Parker (2024) provides an example of the sort of question that could be asked of stakeholders at the outset of an investigation. Interpreting these examples and adapting them to the LEAP project, we can envision asking stakeholders five questions: *1) What information about asthma and air quality is most relevant to your social/-ethical goals?; 2) Would some errors in findings, more than others, impede the pursuit of your social/ethical goals?; 3) Are some of your research goals more important than others with respect to your social/ethical goals?; 4) Would certain research methods (data sets, etc.) be better suited to your social/ethical goals? 5) Would it facilitate your social/ethical goals to express research findings in a particular form?* According to Parker (2024, p.28), the epistemic research problem "constitutes a brief for the research to be undertaken: scientists' job is to design and carry out a study that achieves the specified epistemic goal(s) in a way that satisfies the specified epistemic desiderata. In doing so, scientists, qua scientists, will need to respect basic constraints on epistemically adequate science".

There are at least two difficulties with the EP approach. First: who counts as a 'user' or 'stakeholder'? In contexts like the LEAP project, one might argue that users are people living with asthma, or otherwise affected by it. However, LEAP focuses on asthma prevention as well as treatment; everyone is a potential future asthma patient. Furthermore, cost-effectiveness models like LEAP affect the general public as tax-payers. Even setting costs aside, some asthma prevention policies could, in principle, affect the general population. For example, if a model like LEAP suggested reducing unnessary antibiotic use to help prevent asthma, this might result in policies that reduce access to antibiotics: how the public values this reduced access against a marginal benefit in asthma reduction would then become relevant. To be sure, if a model is built for private use, with no externalities that affect the public, then users' values could be distinct and interesting— but such cases are rare in health economics. Ultimately, if the users of policy-relevant science are the general public, then the proposal to incorporate users' values into science collapses into the proposal to use the public's values, with all its attendant problems.

EP's second difficulty concerns whether sufficient information can be provided to scientists in the form of a 'brief' at a study's outset. To start, one might question to what extent science users will be capable of answering the questions that the EP approach asks of them. Answering a question like "*Would certain research methods (data sets, etc.) be better suited to your social/ethical goals?",* for example, requires not only some understanding of research methods but of one's own social/ethical goals. Settling on goals of this kind may or may not be an easy task for an individual or a group, if science users/decision-makers are working together and expected to speak to scientists with a unified voice. To make the EP approach work, it is likely that science users would require some sort of support in thinking through and identifying their social/ethical goals and answering the questions asked of them. Parker (2024, p.31) acknowledges that "it is an empirical question how adept anyone is at the process of epistemic projection", which points to the need for empirical research to establish how the EP approach would work in practice. This includes identifying what sort of support (if any) science users would need to participate in it.

Still, even if we assume that science users will be capable of understanding research methods and settling on their own social/ethical goals, it seems that the EP approach ultimately demands excessively fine-grained information. For example, imagine that users inform LEAP modellers that wrongly inferring that HEPA filters will reduce asthma by *x*% or more is worse than the opposite mistake (i.e., wrongly inferring they will not). What Parker (2024) seems to suggest is that this will allow modellers to privilege methodological choices that are less likely to err in the first way and more likely to err in the second way. However, this raises the question: are modellers to follow this advice above all else, *come what may*? Answering in the affirmative raises an obvious problem: protecting against one type of error above all else will soon lead to methods that will drive to a pre-determined conclusion. It is not clear how Parker's (2024) proposal blocks this or where she recommends drawing the line. Furthermore, suppose that users tell modellers that it is more important to predict what will reduce asthma exacerbations than to predict what will prevent asthma onset. Would this imply that users would always prefer a model that is minimally successful at predicting asthma exacerbations and useless at predicting what will prevent asthma onset over one that is useless at predicting asthma exacerbations but excellent at predicting what will prevent asthma onset? This is questionable. What seems to be required is not just simple information in the form of 'users consider Type I error to be worse than Type II error' or 'users consider goal A more important than goal B', but detailed information about *how much worse* and *how much more important*. Yet it is hard to see how users could provide this information upfront in a sufficiently fine-grained way to inform modellers' decision-making.

4. Discussion

The foregoing analysis of the literature might lead readers to feel pessimistic: there is no strategy for 'managing values' in science that is free from philosophical criticism. Moreover, modelling teams in health economics face practical constraints that challenge the strategies that philosophers suggest. Many health economic models, such as LEAP, are highly complex and involve hundreds or thousands of decisions to develop. These decisions can be technical and difficult, or at least time-consuming, for people outside the field to understand. Given this complexity, health economics modelling is usually done by teams, where there is a division of expertise and of labour; seldom will every team member be involved in every decision. Finally, health economics modelling takes place within institutional settings that impose limits: at least, researchers are usually required to finish projects by a specified deadline and to stay on budget. In this context, demanding that patients or the public be involved in modelling, or that modellers engage in principled ethical reasoning, or even clearly document all their decisions, creates tensions. There is no perfect solution to alleviate these tensions, nor to remove the overarching threat of technocratic influence over public decisions. 'Managing values' in science can only be a process of risk mitigation, not elimination. That said, we argue that the process of 'managing values' should be seen as a positive opportunity, one that encourages researchers to centre the goal of public trust in science, recognize the philosophical challenges to achieving that goal, and develop novel means to address them.

The above considerations lead us to conclude: every health economics modelling project should involve a *meta-ethical process*. That is, on a project-by-project basis, modelling teams should consider how it will make its decisions, knowing that *all* decisions have potential ethical significance (indeed, to say a decision has no such significance is an ethical judgment). As we have shown, scientists whose goal is to manage value judgments appropriately have many strategies to choose from. Each has its own strengths and weaknesses but they are generally compatible with one another (Elliott, 2022), which invites modelling teams to judge what combination of strategies is best, ethically-speaking, in their context. This requires careful thinking about what outcomes, exactly, modelling teams aim to optimize. In turn, empirical research in needed to observe those outcomes and evaluate the effects (intended and unintended) of employing different strategies.

In current practice in health economics, we expect that practical considerations, like budget, time constraints, and human resources, will play a central role in determining how decisions are made within modelling teams. While we strongly support making stakeholders— including patients, clinicians, decision-makers, and members of the general public— an integral part of modelling teams, we recognize that the benefits of involving all team members in every single decision are unlikely to outweigh the costs. Reflecting on the philosophical literature and practical considerations, we suggest that modelling teams consider three possible ways to make decisions: 1) *Democratization:* involve all team members in a decision; 2) *Pre-identification:* identify the 'right' values to inform a decision, in advance of the decision, e.g., by following practice guidelines or consulting another source outside the team; 3) *Transparency:* invite modellers to make decisions independently, but to be transparent about that decision; if it is difficult to be fully transparent about a decision, invite modellers to be transparent about the difficulty. These three strategies can all be applied within a single modelling project: for example, a team might decide that some modelling decisions should involve all team members (*Democratization*), while others should be informed by published modelling guidelines (*Pre-identification*), or left to modellers to make independently (*Transparency*). This invites modelling teams to deliberate at the start of a project about which decisions should be managed using which strategy.

To inform early deliberations about decision-making strategies, we suggest that modelling teams reflect upon the unique features of different modelling decisions, including factors like uncertainty, expected impact on model results, technical complexity, applicability of published modelling guidelines, etc., as well as their downstream social impact. In this process, we have found it worthwhile to think in terms of different 'types' of decisions that teams might expect to encounter in the modelling process. For example, what we call *guideline decisions* are decisions where the best course of action is recommended by practice guidelines, e.g., decisions around the discount rate. What we think of as *opaque decisions* are decisions that the modellers consider to be difficult to be transparent about or explain to people outside their technical specialty, e.g., decisions around calibration methods. And *pivotal decisions* are decisions where the best choice is uncertain, it will have a significant impact on results, or it is likely that different team members would steer modellers in different directions (Harvard and Winsberg, 2023). An example of a pivotal decision in the LEAP project is how to represent the severity of future wildfire in Canada (Section 2). While the relationship between 'types' of modelling decisions and the choice of strategy to inform them is far from straightforward, we have found it useful to contemplate this relationship.

This paper has provided a critical review of the philosophical literature on 'managing values' in science, with a focus on health economics modelling. Further research is needed to understand the effects of applied strategies to 'manage values' in health economics modelling and better inform the design of such strategies. In the future, a combination of philosophical and empirical work may help answer the normative question: how should health economists manage value judgments in modelling?

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