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RESEARCH ARTICLE



Beyond precautionary principle: policy-making under uncertainty and complexity

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ABSTRACT

The precautionary principle is a widely recognized approach in policy-making across various fields, emphasizing preventive action in situations of uncertain potential harm. However, its full potential remains unrealized due to implementation challenges. Our study analyzes policies related to face mask usage during the COVID-19 pandemic, characterized by significant uncertainty, time pressure, and potentially catastrophic consequences. We explore the challenges of balancing urgency against unforeseen negative consequences and determining the appropriate level of caution amid rapidly evolving scientific knowledge. To enhance the precautionary principle's effectiveness, we argue for integrating additional principles: transparency, fairness, and adaptability. Transparency fosters public trust and informed decision-making through clear communication of policy rationales, uncertainties, and tradeoffs. Fairness ensures the equitable distribution of policy intervention benefits and burdens, considering vulnerable populations' needs. Adaptability involves revising policies based on new information or changing circumstances, maintaining effectiveness and relevance. Our examination aims to provide insights and recommendations for improving the precautionary principle's utility in policy-making, particularly where timely, informed action is crucial.

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Introduction

The precautionary principle, a widely adopted approach in policy-making, is applied extensively in situations where actions are required before conclusive evidence becomes available (Ozonoff 2005). This principle advocates for preemptive measures in circumstances with hypothetical risks, even without definitive scientific evidence

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regarding the probability of these risks. In cases of serious or irreversible threats to human or ecosystem health, acknowledged scientific uncertainty should not be used as a reason to postpone preventive measures (Martuzzi and Tickner). The precautionary principle calls for action to prevent harm “even if some cause and effect relationships are not fully established scientifically” (Raffensperger and Tickner 1999).

According to the principle, when credible threats of harm exist, precautionary action should be taken, even without a full understanding of a proposed activity’s effects. The precautionary principle combines the ethical notion of duty to prevent harm with the realities of the limits of scientific understanding. This principle has been extensively used to defend or criticize various government decisions during the COVID-19 pandemic, such as testing, mask-wearing, and social distancing measures (Meßerschmidt 2020).

However, the precautionary principle should not be considered the ‘absolute principle’ for policy-making under conditions of uncertainty and urgency (Sandin 2006). Its application incorporates many ill-defined factors, such as “lack of scientific certainty” and “unacceptable harm,” which undermine the legal basis for government action and make its application susceptible to manipulation. Furthermore, if decisions based on the precautionary principle are later found to be incorrect, public trust in the government may be eroded, impacting the long-term resilience of policy responses.

The case of face masks during the COVID-19 pandemic exemplifies the challenges in applying the precautionary principle in practice. Initially, evidence on the efficacy of face masks in preventing respiratory infections was sparse and contestable, often derived from studies of previous influenza epidemics (Greenhalgh et al. 2020) with potentially limited relevance. Additionally, decisions on face mask usage had to be made urgently, despite the absence of scientific evidence due to the pressing need to combat the pandemic.

Under such conditions, decision-makers and governments face a dilemma: waiting for more conclusive evidence before acting might result in missed critical intervention opportunities, while decisive action based on inconclusive evidence that is later disproved could be perceived as reckless. Either situation could undermine public trust in the government. Another issue is the lock-in effects of specific policies.

Our paper analyzes face mask use policies during the COVID-19 pandemic, highlighting the challenges of applying the precautionary principle in guiding decisions under deep uncertainty and urgency. The principle can be used to justify a wide range of contradictory recommendations. For example, recommending the use of face masks as a mitigation measure may be justified based on the precautionary principle, despite the lack of scientific evidence and the much larger cost of unchecked COVID-19. However, recommending or mandating face masks for the entire population could cause shortages for frontline medical workers, create a false sense of security, and cause people to engage in risky behaviors. Hence, decision-makers must weigh the potential costs of incorrect policies when applying the principle.

We argue that an additional set of principles, such as transparency, fairness, and adaptiveness, should be applied to address the limitations of the precautionary principle. Transparency involves the clear communication of policy rationales,

uncertainties, and potential tradeoffs, fostering public trust and informed decision-making. Fairness requires the equitable distribution of benefits and burdens associated with policy interventions, taking into account the needs of vulnerable populations. Adaptiveness entails the capacity to revise policies in response to new information or changing circumstances, ensuring that policy interventions remain effective and relevant.

In conclusion, the precautionary principle, while valuable in guiding policy-making under uncertainty, is not without its challenges and limitations. By incorporating additional principles such as transparency, fairness, and adaptiveness, we can better address these shortcomings and enhance the utility of the precautionary principle in situations characterized by uncertainty and urgency. Our paper aims to provide valuable insights and recommendations for improving policy-making processes, particularly in contexts where timely and informed action is crucial to prevent potentially catastrophic outcomes. By integrating these complementary principles into decision-making processes, we strive to develop a more comprehensive framework for addressing the inherent shortcomings of the precautionary principle in the context of policy-making under uncertainty.

Literature review: the precautionary principle and its limitation

The precautionary principle dictates that when an activity poses potential harm to human health or the environment, precautionary measures should be taken, even if some cause-and-effect relationships have not been fully established scientifically (Ashford et al. 1998). This principle has been applied across diverse fields, including climate change (Farber 2015) and synthetic biology (Wareham and Nardini 2015). Climate scientists have long argued for more decisive actions to address climate change, despite the lack of scientific certainty, to prevent irreversible consequences (Shaw 2009).

The precautionary principle has historically been applied in situations where avoiding false negatives was more critical than avoiding false positives (Persson 2016). Government interventions based on the principle could have long-lasting effects, even if later deemed unnecessary due to new information (Hansen and Tickner 2013). Therefore, incorporating an evolutionary perspective and addressing uncertainty is crucial for ensuring “adaptive flexibility” in policy decisions (Rammel and van den Bergh 2003).

Critics argue that the precautionary principle, while morally appealing, does not provide much practical guidance (Sunstein 2002). When operationalized, it is often implemented as an ideological principle for systemic-level governance rather than a tool for go/no-go decisions (Vorhies 2012). The principle requires a more formalized, situation-specific framework for operationalization (Lyons, Ahrens, and Salter-Green 2000), and its legal obligations are unclear (Vlek 2009). Critics claim it is unscientific (Resnik 2003) and too underspecified to serve as a legally binding decision-making tool (Marchant 2003). Moreover, the principle’s definition and application vary across domains, and its interpretation can differ even within the same country (Stacey 2016).

Applying the precautionary principle during an unprecedented crisis, such as COVID-19, presents unique challenges as policymakers face time pressure to make decisions with immediate and potentially catastrophic consequences. Given the principle's pitfalls, it is essential to guide decision-making with additional principles ensuring good governance and resilience.

Complex systems are limited by different types of uncertainty, which can hinder our understanding of cause-and-effect relationships. Uncertainty often results from more than a simple lack of data or inadequate models and is not easily reduced due to the nature of the problem being studied. Requiring absolute “proof” of harm before taking action can be ideologically motivated or show a fundamental misunderstanding of the limits of science. Complex problems typically involve three general types of uncertainty: statistical, model, and fundamental (Carpenter 2003; Stirling and Gee 2002).

Minimizing unintended adverse consequences caused by actions taken based on the precautionary principle is essential. Comba et al. (2004) argue that explicitly acknowledging the value systems used is important, especially when a utilitarian approach is not appropriate. They propose an alternative “maximin” principle aimed at preventing the worst possible consequences of any action, which aligns with the precautionary principle.

Key elements of precautionary action include increasing transparency in decision-making, making scientific and ethical assumptions explicit, expanding stakeholder involvement, and instituting post-implementation follow-up measures for continuous risk reduction (Comba et al. 2004; Aven and Renn 2009). Experimentation and precaution are compatible when experiments are conducted at a different scale than the scale at which precaution is necessary (Carpenter 2003; Funtowicz and Ravetz 1993). A precautionary approach requires appropriate research and monitoring, especially after releasing a technology or chemical into the world. Decisions must be periodically reexamined based on new information. The research agenda of private and public institutions should reflect broad social goals beyond developing marketable products (Wynne 2011).

Transparency, fairness, and adaptiveness are essential in addressing the limitations of applying the precautionary principle for policymaking under uncertainty and complexity. A participatory approach is justified by the fundamental fairness of democratic decision-making and the belief that a broad range of experiences leads to better science and decision-making. Transparency also helps ensure accountability among decision-makers (Carpenter 2003; Jasanoff 2003).

In conclusion, the precautionary principle is a valuable tool for public policy, but its application is not without challenges. Understanding the different types of uncertainty and their implications is critical for effective policymaking. Furthermore, incorporating principles of transparency, fairness, and adaptiveness in applying the precautionary principle can help address its limitations and improve the decision-making process under conditions of uncertainty and complexity.

Policies on the uses of face masks during the COVID-19 pandemic

Although the use of face masks is a standard practice among medical workers and patients with respiratory illnesses, people had rarely been required to wear masks in public as a public health measure to slow the spread of an infectious disease before COVID-19. For example, face mask use was not mandatory in any of the countries hard hit by SARS in 2003, and a study shows that only 4% of people wore face masks in public in Singapore during SARS (Sim, Moey, and Tan 2014). More importantly, there was no conclusive evidence that using face masks is effective in preventing respiratory infections during epidemics (Greenhalgh et al. 2020).

In fact, the World Health Organization (WHO) advised against the widespread wearing of face masks during the initial stages of the COVID-19 pandemic, stating that healthy individuals only need to wear a mask if they are taking care of a person with COVID-19 or if they are coughing or sneezing. WHO's guidelines were motivated by three additional considerations besides the lack of evidence on the efficacy of face masks: improper and inconsistent use, a potential increase in risky behavior, and potential shortages for frontline medical workers (Howard et al. 2021).

In the absence of evidence, expert advice becomes policy information for decision-making. As the global health authority, WHO's face mask guidelines significantly influenced policy decisions worldwide. Public perception and national policies on the use of face masks shifted dramatically after March 2020, when asymptomatic transmission was discovered to be a primary path of infection. Studies showed that carriers of the virus are most infectious in the initial post-infection period when infected individuals show few or no symptoms at all (Howard et al. 2021) and that 40%–80% of infections are caused by asymptomatic individuals (Ferretti et al. 2020). Droplets discharged by these people are a major mode of virus transmission (WHO 2020), which means that the widespread use of face masks by the public can mitigate the spread of the virus.

The prevalence of asymptomatic transmission significantly altered the policy calculus, and the use of face masks in all or some public settings was recommended or mandated by many countries, becoming a common practice over time. If masks are worn to protect wearers from getting infected, then it might be justified to let individuals decide whether to use them or not. However, policy interventions in the form of face mask mandates would be required and justified if masks are worn to protect others from being infected by asymptomatic individuals. Hence, the choice of wearing a face mask did not remain a matter of individual preference but that of public health. The cost of not wearing a face mask and the impact of COVID-19, its extent and duration, relegated the need for conclusive scientific evidence to the background.

The available evidence on asymptomatic transmission caused the WHO to reverse its stance on face masks, stating that governments should “make wearing a mask a normal part of being around people.” Following the WHO's lead, the US Centers for Disease Control and Prevention (CDC) initially did not recommend the public to wear face masks but later shifted course to recommend “that people wear cloth face coverings in public settings and when around people who don't live in your household” on June 28th, 2020.

The cost-benefit analysis for mandating face masks was altered by the presence of asymptomatic disease transmission. Additionally, the concerns related to the supply of medical-grade masks were alleviated as homemade cloth masks were found to be effective. While protecting wearers themselves from infection requires consistent, proper use of medical-grade masks, protecting others from infection has less stringent requirements, and cloth masks are just as effective as medical-grade masks (Howard et al. 2020; Davies et al. 2013)

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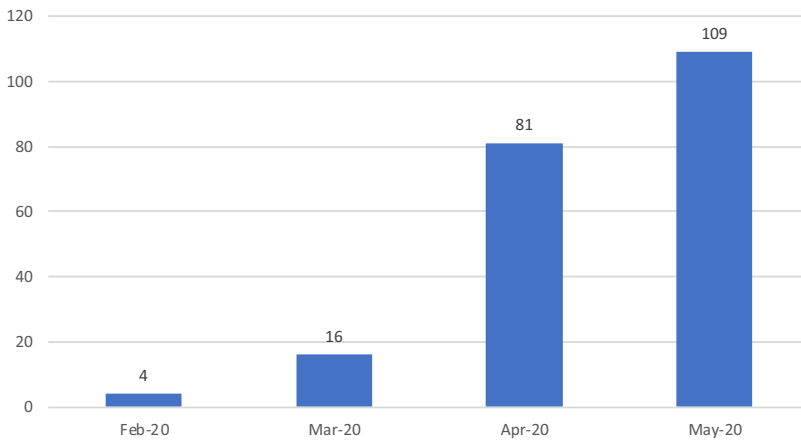


Figure 1. A number of countries that require face masks in some or all public spaces (February–May, 2020). What countries require masks in public or recommend mask? <https://masks4all.co/what-countries-require-masks-in-public/>

normal part of being around people.” Following the WHO’s lead, the US Centers for Disease Control and Prevention (CDC) initially did not recommend the public to wear face masks but later shifted course to recommend “that people wear cloth face coverings in public settings and when around people who don’t live in your household” on June 28th, 2020 (Figure 1).

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Additional evidence on the effectiveness of face masks emerged with time. Systematic reviews of existing evidence suggest that near-universal wearing of non-medical-grade face masks in public, complemented by other public health measures, could successfully reduce COVID-19’s effective-R below 1.0, thereby stopping community spread (Howard et al. 2020). Experts noticed that countries or economies in which the wearing of face masks was widespread from the start of the virus outbreak (such as mainland China, South Korea, Japan, Thailand, Vietnam, Hong Kong, and Taiwan) recorded much lower infection rates. In Europe, where there is some cultural resistance against face mask use, nations that mandated face masks early on in the pandemic experienced fewer cases and deaths relative to their neighboring countries that did not do so (Beswick 2020).

However, controversy and debate over face masks continued. In the US, although the CDC revised its guidelines to recommend face mask use, practices varied significantly within the country, and many political leaders refused to wear masks in public despite the CDC’s advisory. There was a lack of consensus among US scientists and public health experts on face masks, and many of them argued that more conclusive

Table 1. Distribution of countries based by face mask policies, May 2020–September 2021.

	May-20		Sep-21	
	Number of countries	Percentage	Number of countries	Percentage
Masks not recommended	50	25%	21	11%
Masks recommended	17	9%	19	10%
Masks required parts of Country	20	10%	19	10%
Masks required for the whole country	107	54%	133	67%
Universal Mask Usage	4	2%	6	3%
Total	198		198	

What countries require masks in public or recommend masking up? <https://masks4all.co/what-countries-require-masks-in-public/>

evidence was needed. Table 1 shows the distribution of countries based on policies toward face masks. The data shows that masks were universally mandated in 152 out of 198 economies in September 2021 (77%).

The precautionary principle could have guided decision-makers to mandate the use of facemasks in the early stages of the COVID-19 outbreak. In hindsight, the potential benefits could have been the containment of the outbreak with not much cost if additional concerns—availability, proper use, and strict adherence to other precautionary measures—are allayed. On the other hand, the precautionary principle could serve as a foundation to not mandate the use of face masks as conclusive scientific evidence is not present and the cost in terms of concerns discussed above outweighs the potential benefits—if there is no asymptomatic transmission. Additionally, the ethical basis for mandating facemask use is weak if it is a matter of personal choice and individual freedom. However, as new information emerges, the cost-benefit changes drastically. The new information, in this case, could be categorized in two ways: (1) conclusive scientific evidence about the effectiveness of masks, and (2) utility of cloth facemasks, which are more readily available than medical-grade surgical facemasks.

Furthermore, governments and the WHO issued advisories almost every month, if not every week, which means that decisions needed to be taken (change or no-change) in a very short and dynamic policy cycle, creating an urgency for policymakers. In the next section, we draw on a literature review and empirical observations to recommend a course of action based not just on the precautionary principle but other principles that address limitations discussed in this section.

Beyond precautionary principle: transparency, fairness and adaptiveness

In hindsight, more widespread face mask use could have flattened the epidemic curve in many countries and saved a significant number of lives. Greenhalgh et al. (2020) argue that due to the severity of the pandemic, indirect evidence of benefit combined with the low risk of harm should outweigh the lack of direct evidence on the efficacy of face masks. As a result, their use by the public should have been recommended. Nevertheless, there is no strong basis for the argument that the precautionary principle would necessarily justify mandating the wearing of face masks for everybody.

In this section, we present three additional principles that can be employed to address the limitations of the precautionary principle as a basis for policymaking

under uncertainty and urgency. We will also illustrate how these principles have been applied in practice.

The transparency principle

Transparency in policy decisions is crucial during the current pandemic. The high level of uncertainty implies that information about the virus, containment or mitigation measures, and the efficacy of such measures may not be available when key decisions need to be made. It is critically important for governments to be transparent about the uncertainties involved in their decisions, as well as the evolving nature of their responses.

Governments should clearly communicate the limitations of specific policies or measures through regular updates. As a growing number of countries mandate the use of face masks, governments must provide accurate and honest information about the limitations of such measures and emphasize the importance of maintaining other measures, such as social distancing and handwashing.

However, governments face a challenging choice in these situations. They may be reluctant to publicize the uncertainty of the information available, as it may lead people to ignore recommendations. Governments could also lose credibility and public trust if it is later revealed that the evidence used to justify policy decisions was insufficient (Menon and Goh 2005). For example, when the French government recommended the use of face masks—a reversal of previous policies—people accused it of previously lying to the public about the necessity of wearing face masks (Sage 2020).

Singapore and Taiwan have been regarded as success stories in their management of COVID-19 (Barron 2020), and transparency, along with effective public communications, have been cornerstones of many COVID-19-related policies—including those on face masks in these economies. The Singapore government employed various channels for its public communications—print, digital, and social media—to spread awareness about precautionary measures (Lazar 2020). Government officials held regular press conferences to communicate policy decisions and their underlying rationale (Thet 2020). In Taiwan, the government transparently communicated information on available stocks, production plans, distribution plans, etc., for face masks and other essential commodities to prevent panic buying (Ngerng 2020).

In the context of the precautionary principle, the transparency principle assumes importance in two dimensions: the resolution of uncertainty through scientific inquiry, and the decision-making process. Transparency legitimizes decisions based on the principle, addressing concerns about its legal significance (Meßerschmidt 2020). More importantly, by communicating about the uncertainty and the decision-making process, policymakers can afford to change their decisions as new information emerges and navigate the uncertainty without risking the erosion of public trust.

The fairness principle

In addition to transparency, fairness plays a crucial role in the application of the precautionary principle. While arguments supporting the principle often focus on the

overall effectiveness of policy decisions, the equity of these decisions should also be considered. Ashford (2005) contends that even in the absence of significant uncertainty, the precautionary principle must be preferred in cases where the primary concern is the fairness of resultant harms and benefits. Cooney and Dickson (2012) argue that in advocating the principle's application in biodiversity conservation, the precautionary principle alters the allocation of costs and benefits, making fairness an essential consideration. The cost-benefit paradigm influences alternatives and choices for policy decisions, thereby emphasizing the importance of fairness in policy formulation (Munda 2017).

In fact, fairness plays a role in operationalizing the precautionary principle. The change in the cost-benefit paradigm may facilitate decision-making based on the principle. In the case of face masks, the efficacy of cloth face masks makes mandating their use less demanding as supply concerns become irrelevant. Hence, even in the absence of conclusive evidence, the principle can be used to make decisions if fairness can be ensured.

Access to vital resources varies considerably among different segments of the population, which should be taken into account when making decisions. For instance, individuals with lower socio-economic status may find it more challenging to procure face masks to comply with mandates. The fairness principle states that no additional harm should be suffered by the most vulnerable groups as a result of policy decisions. In the context of face mask policies, the fairness principle would require governments to prioritize the allocation of face masks to essential workers, the elderly, and people with co-morbidities. In the Philippines, the government launched a program to distribute free face masks to poor households with senior citizens, pregnant women, and people with serious health issues to maintain minimum health standards for everyone.

Furthermore, controlling a highly infectious disease like COVID-19 is not just a public good prone to free-riding; it also represents a “weakest link” or “aggregate effort” public good that requires most—if not all—people to make sacrifices. This implies that measures adhering to the fairness principle will be more effective, as (near-) universal compliance with safety measures is required.

The potential challenge in applying the fairness principle is that fairness for one group of people may be achieved at the expense of another group when there is a shortage of goods or services. For example, in countries where face masks are in short supply, mandating face mask use could disproportionately put medical workers at risk. Conversely, not recommending—or discouraging—the use of face masks could shift risks to essential workers (e.g. those in public transport and logistics) who closely interact with large numbers of people daily.

The adaptiveness principle

High levels of uncertainty, urgency, and evolving risks can make the use of evidence in policy-making challenging. Action must be taken based on incomplete information and inconclusive evidence that are subject to change. The adaptiveness principle can help craft response strategies in novel situations where evidence is limited or non-

existent. This principle is promoted by opponents of the “predict then act” strategy, who argue that policy-makers should embrace the concept of robust decision-making. This approach posits that policy interventions should be adaptable to as many alternative futures and scenarios as possible, rather than being overly specific or precise (Littell et al. 2011). During crises, the impact of policy decisions may create immediate feedback that necessitates a change in policy decisions (Senge 2006). Thus, the adaptiveness principle encompasses not just policy implementation but also policy evaluation.

In other words, adaptiveness implies that crisis responses should be designed to reduce harm from as many alternative futures as possible, rather than being optimized for particular scenarios. With such an approach, policymakers can significantly alter or even reverse specific policies based on new information or changing circumstances without deviating from their overall response strategies.

In the case of COVID-19, instead of adopting a rigid stance against face mask use due to inconclusive evidence regarding their effectiveness, a more appropriate response based on the adaptiveness principle would be to promote face mask use given a reasonable probability of their effectiveness, while preserving policy space to change course if subsequent evidence shows otherwise.

Incorporating the adaptiveness principle into overall governance strategies is one way of overcoming the scarcity of evidence in extreme or novel situations. Government adaptiveness, agility, and flexibility can be achieved through decentralization and polycentricity (Huitema et al. 2009), as less hierarchical decision-making systems make governance models more resilient (Armitage et al. 2009). One example of decentralization comes from Germany, where the city of Jena made the use of face masks mandatory despite no such decisions at the federal or regional level (Hugger 2020).

Another example is from Singapore, where the government was able to make a U-turn on face mask mandates relatively early in the pandemic. The government initially discouraged its citizens from wearing masks in public due to a lack of evidence of their effectiveness against disease spread but took initiatives to ensure the supply of masks. As new information emerged, the Singapore government was flexible enough to change policy direction and mandate face masks in public places. Lawrence Wong, the co-chair of the multi-ministry task force in charge of Singapore’s COVID-19 pandemic response, explained, “We updated our advice on masks based on the latest scientific evidence: the finding that people without symptoms or very mild symptoms could be spreading the virus” (Min and Phua 2020).

There are several challenges in applying the adaptiveness principle. One of the primary difficulties is resistance to change, particularly in situations where established policies or institutions have a significant stake in the status quo. Additionally, adaptive policymaking requires a willingness to experiment, take risks, and learn from failures, which may conflict with risk-averse attitudes and expectations of policymakers and stakeholders. Third, the application of the adaptiveness principle may raise concerns about accountability and legitimacy, as it may lead to frequent changes in policy decisions.

Conclusion

In cases of deep uncertainty where the pace of uncertainty resolution is rapid, the basis of policy decisions shifts from principle-based (precautionary in this instance) to evidence-informed. In this article, we examine the major hurdles related to the precautionary principle that could hinder this shift. These hurdles include an evolving evidence base, uncertainty, pragmatic operationalization of the precautionary principle, and policy-cycle (urgency) related significance of the principle. To address these concerns, we advocate for three additional principles—transparency, fairness, and adaptiveness—alongside the precautionary principle to facilitate the use of evidence in policymaking and to enable the revision of decisions previously based solely on the precautionary principle.

Firstly, transparency in the decision-making process is crucial in crisis response. Decision-makers should be transparent about the uncertainties involved and acknowledge that their responses are necessarily contingent and evolving, given that crucial information about the effectiveness of various policy options may be unavailable when key decisions are made. Rather than constraining the policy space, the transparency principle creates room for governments to adjust, alter, or even reverse earlier decisions when new information emerges.

The fairness principle should be applied to ensure that no additional harm is imposed on the most vulnerable groups. In the case of face masks, this would require governments to prioritize the supply of face masks to these groups. The fairness principle allows for the pragmatic operationalization of decisions based on the precautionary principle.

Lastly, the adaptiveness principle informs the development of response strategies for situations—especially unprecedented ones—in which evidence is limited or non-existent. This means that response strategies should prevent as much harm as possible while preserving policy space for adjustments when new evidence emerges.

Overall, these three principles augment the relevance of the precautionary principle beyond the early stages of the policymaking cycle, encompassing formulation, implementation, and policy evaluation.

Although the use of these additional principles alongside the precautionary principle will not lead to a single “best” policy, it can help narrow down the list of viable policy alternatives in ex-ante policy analysis and rule out those that are obviously worse off by imposing constraints based on a set of criteria for robust policies, such as transparency, fairness, and adaptiveness. More importantly, it allows for greater attention to the process of decision-making as opposed to the outcome of decision-making, which is opaque and highly unpredictable. Improving key attributes of the decision-making process can greatly enhance the prospects for better outcomes.

The integration of additional principles serves to address the limitations of the precautionary principle in dealing with deep uncertainty in policymaking. These principles enhance the robustness of policy responses by considering multiple criteria and accounting for various uncertainties. By prioritizing the protection of public health and the environment, they can help avert catastrophic outcomes. Moreover, they promote the examination of a full range of options and the exploration of alternative pathways to achieve desired policy outcomes. The implementation of multiple actions

based on these principles can range from informing the public about risks and uncertainties while further studies are conducted, to imposing restrictions on potentially harmful activities and phasing out those activities where evidence suggests they may be particularly problematic.

Good governance principles are essential in safeguarding against the erosion of public trust in government. The continuous and iterative process of integrating these principles should prioritize transparency, fairness, and adaptiveness in decision-making, allowing for the revision or reversal of policy directions and balancing short-term consequences with long-term flexibility and adaptability. These principles also encourage the articulation of tradeoffs among key values in decision-making, promoting a more comprehensive understanding of potential consequences.

By incorporating these principles into the assessment of various policy options, decision-makers can better navigate the challenges posed by deep uncertainty and develop more robust, flexible, and effective policy responses. The integration of these principles should be a continuous, iterative process, consistently seeking sustainable ways to reduce the adverse impacts of economic activity on public health. Through the application of these principles, policymakers can enhance the prospects of better outcomes and foster more resilient, equitable, and adaptive policy frameworks.

There are a few limitations of the study. A potential overemphasis on theoretical aspects might undermine the applicability of the suggested principles to real-world policy contexts. Additionally, the paper may not thoroughly address the interactions between the precautionary principle and the proposed supplementary principles, or the challenges of implementing them in tandem. A more comprehensive and nuanced analysis, incorporating case studies and diverse stakeholder perspectives, could strengthen the case for these additional principles and better inform their implementation.

Disclosure statement

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