

THE ETHICAL PRINCIPLE OF RISK GOVERNANCE: ANALYSIS OF THE DEVELOPMENT OF THE PRECAUTIONARY PRINCIPLE

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Abstract: Modern society needs to be vigilant and respond promptly to risks. The emergence of uncertainties not only may increase the probability of risks occurring but also may exacerbate their severity. Therefore, what ethical principle should be relied on to deal with risks characterized by uncertainty has become a problem to be solved. The precautionary principle is an important ethical principle for addressing and resolving risks with uncertain features. This article aims to explain the changes of the precautionary principle in risk governance from its origin, the expansion of its geographical scope, and the increase in its application fields; and focuses on demonstrating the continuous improvement of the precautionary principle in risk governance through the transformation from the weak precautionary principle governance model with limited effectiveness to the strong precautionary principle governance model with high effectiveness.

Keywords: risks, uncertainty, precautionary principle, ethical governance

El principio ético de la gobernanza del Riesgo. Análisis de la evolución del principio de precaución

Resumen: La sociedad moderna necesita estar alerta y responder con prontitud a los riesgos. La aparición de incertidumbres no solo puede aumentar la probabilidad de que ocurran, sino también que se agraven. Por lo tanto, “qué principio ético debe aplicarse para hacer frente a los riesgos caracterizados por la incertidumbre” se ha convertido en un problema que hay que resolver. El principio de precaución es un principio ético fundamental para abordar y resolver los riesgos con características inciertas. El presente artículo tiene por objeto explicar los cambios del principio de precaución en la gobernanza del riesgo desde su origen, la ampliación de su ámbito geográfico y el aumento de sus campos de aplicación, y se centra en demostrar la mejora continua del principio de precaución en la gobernanza del riesgo, a través de la transformación del modelo de gobernanza del principio de precaución débil, con una eficacia limitada, al modelo de gobernanza del principio de precaución fuerte, con una alta eficacia.

Palabras clave: riesgos, incertidumbre, principio de precaución, gobernanza ética

O princípio ético da governança de riscos: Análise do desenvolvimento do princípio da precaução

Resumo: A sociedade moderna necessita ser vigilante e responder prontamente a riscos. A emergência de incertezas não somente aumenta a probabilidade de riscos ocorrerem como também podem exacerbar sua gravidade. Assim, qual princípio ético deve ser adotado para lidar com riscos caracterizados pela incerteza, tornou-se um problema a ser resolvido. O princípio da precaução é um princípio ético importante para abordar e resolver riscos com características incertas. Esse artigo objetiva expor as mudanças do princípio da precaução na governança de riscos desde sua origem, a expansão de sua abrangência geográfica e ao aumento em seus campos de aplicação; e concentra-se em demonstrar a contínua melhora do princípio da precaução na governança de riscos através da transformação de um fraco modelo de governança baseado no princípio da precaução, com eficácia limitada, para um forte modelo de governança baseado no princípio da precaução, com alta eficácia.

Palavras chave: riscos, incerteza, princípio da precaução, governança ética

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Introduction

Risks mainly refer to undesirable events that may or may not occur(1). Among these, the risks that may lead to a large number of casualties, significant economic losses, or extensive environmental damage deserve particular attention. With the rapid development of technology, especially the emergence of “technological convergence”(2) and the appearance of “uncertain” emerging technologies(3,4) with the potential to create new industries or transform existing ones(5), the risks and their potential negative impacts have become increasingly alarming.

The precautionary principle is an ethical principle that emerges along with risks. Its fundamental proposition is: In the presence of certain scientific uncertainties, precautionary measures should be taken. Its core demand is to avoid potential risks from evolving into actual harm in the future. We need to prevent the occurrence of harm from the very beginning. This principle can change along with the changes in risks and the demands for risk governance.

Due to the insufficient understanding of the concept of the precautionary principle by the public, some people have misunderstood it, questioning its effectiveness and opposing its application. This may delay the governance process, leading to delayed and flawed governance. Therefore, this article examines the origin of the precautionary principle, its application in different regions, its application in different fields, and the changes in its effectiveness, in order to enable people to understand how the precautionary principle continuously improves itself and functions in a risk society.

1. The origin of the precautionary principle

The origin of the precautionary principle can be traced back to the “no harm” principle in the Hippocratic Oath(6). In the 1950s, some people in the United States used a similar view to the precautionary principle to oppose fluoridation of water, and in the 1960s, others used similar arguments to oppose nuclear energy; they believed that high doses of fluoride or nuclear radiation had known adverse effects, and thus, if not used properly, could cause widespread harm(7).

The concept of the precautionary principle first emerged in a draft German bill aimed at ensuring clean air in 1970 (the bill was passed in 1974), and was then known as “Vorsorgeprinzip”. It was intended to reduce and limit environmental risks from a safety perspective or to protect and improve natural conditions by predicting future environmental conditions(8). The country’s 1976 Environmental Report and 1986 Environmental Precautionary Guidelines also adopted the precautionary principle as the guiding principle for its environmental policies(9). It can be said that Germany’s environmental policies have provided a relatively specific and comprehensive elaboration of the precautionary principle. By “relatively specific”, it means that the requirements of the precautionary principle are relatively clear. This principle divides human actions into those that cause harm and those that cause risks. For actions that cause harm, the government should take all measures to prevent them; for actions that cause risks, the government should conduct risk analysis and order precautionary measures when deemed appropriate. This principle provides a legitimate reason for the German government to intervene in the daily lives of states and citizens under the name of good governance, as well as to plan the economy, technology, morality, and society(10,11). By “relatively comprehensive”, it means that the content of the precautionary principle covers responsibility to future generations, comprehensive and simultaneous research, action before scientific conclusions, and the burden of preventing harm through technological progress. The principle states that “responsibility to future generations means protecting the natural basis of life and avoiding irreversible damage such as forest decline”, so “harm to the natural world (that is, the world on which we all depend for survival) should be avoided in advance based on opportunities and possibilities; to “discover dangers to health and the environment as early as possible through comprehensive and simultaneous research, especially research on cause and effect”; to “take action before scientific conclusions are reached”; to “develop technological processes in all economic sectors that can significantly reduce the environmental burden (especially those caused by the introduction of harmful substances)”(12).

Since the 1980s, the precautionary principle has gradually become an important component of governance policies. The process of continuously enriching the concept and application scope of the precautionary principle at successive “International Conferences on the Protection of the North Sea” marked the beginning of its gradual introduction to the international stage of risk governance. The “Declaration of the International Conference on the Protection of the North Sea” formed at the first “International Conference on the Protection of the North Sea” held in Bremen in 1984 proposed that “for the protection of the North Sea, precautionary measures to control air quality through reducing emissions at the source should be determined based on the best available technology” and “detailed plans should be developed to take precautionary measures in response to emergencies and accidents”, which was the embryonic form of the precautionary principle in international agreements(13). At the “Second International Conference on the Protection of the North Sea” held in London in 1987, the “Ministerial Declaration” proposed the “principle of precautionary action” or “precautionary approach” under the name of the precautionary principle; the governance characteristics of the precautionary principle, which limits harm or negative impacts from the source regardless of whether there is sufficient scientific evidence to prove the causal relationship between actions and hazards, and the construction of a hazardous substance handling approach with the characteristics of a precautionary path, were clarified(14). At the “Ministerial Declaration of the Third International Conference on the Protection of the North Sea” held in The Hague in 1990, the term “precautionary principle” first appeared in the series of North Sea protection conferences(15). In 1995, at the “Fourth International Conference on the Protection of the North Sea”, the “Esbjerg Declaration” formed there made the precautionary principle the guiding principle for achieving the goal of ensuring the sustainable, sound and healthy state of the North Sea ecosystem, further enhancing the principle’s status in environmental risk governance(16). In 2002, the “Bergen Declaration” formed at the “Fifth International Conference on the Protection of the North Sea” initially expanded the application scope of the

precautionary principle to the field of genetically modified organisms, and focused on addressing and responding to the “inherent, potentially serious, irreversible and transboundary impacts” resulting from the release of genetically modified organisms, thereby “ensuring that the cultivation of genetically modified marine organisms is restricted within a safe range”(17).

2. Expansion of geographical scope

The Convention for the Protection of the Marine Environment of the North-East Atlantic, also known as the OSPAR Convention, which was formed at the Ministerial Meeting of the Oslo and Paris Commissions, has a broader geographical scope than the previous International Conferences for the Protection of the North Sea, but the applicable fields are similar. Therefore, there is a certain degree of mutual reference in the understanding and application of the precautionary principle between the two. For instance, the OSPAR Convention defines the precautionary principle as: “When there are reasonable grounds for concern that the introduction of substances or energy into the marine environment, directly or indirectly, may cause harm to human health, damage biological resources and marine ecosystems, deteriorate environmental quality or interfere with legitimate uses of the sea, precautionary measures should be taken even in the absence of conclusive evidence of a causal relationship between the input and the effect.” This is similar to the definition of the precautionary principle in the Ministerial Declaration of the Second International Conference for the Protection of the North Sea(18). The Treaty on European Union, also known as the Maastricht Treaty, has expanded the geographical influence of the precautionary principle from the North Sea and the North-East Atlantic to the entire European Union, and it can be applied in fields such as the environment, public health, and consumer protection(19). It also combines the goal of “a high level of protection” and the consideration of “the diversity of situations in different regions within the Community” with the precautionary principle(20).

Apart from Europe, other countries and regions around the world have also adopted the precautionary principle as an important principle of

national or regional policies, further expanding its influence. For instance, the Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa, or simply the Bamako Convention, marks an important beginning for many African countries to apply the precautionary principle to address the threat of hazardous waste. The convention recognizes that the volume of hazardous waste is constantly increasing and that its complexity poses an increasingly serious threat to human health and the environment. Therefore, it proposes that “Parties shall strive to adopt and implement precautionary approaches to address pollution problems, including but not limited to preventing the release of substances that may cause harm to human health or the environment before scientific evidence of such harm is obtained” and “Parties shall cooperate and take appropriate measures to implement the precautionary principle through the application of clean production methods to prevent pollution, rather than pursuing methods that allow emissions based on the assumption of environmental self-purification capacity”, and urges the contracting parties to effectively manage and restrict the cross-border transportation of hazardous waste in Africa(21). In the United States, precautionary thinking is also at play, with severe and irreversible harm being prioritized for precaution. For example, the “Precautionary Principle Ordinance” proposed by the San Francisco Board of Supervisors - which later evolved into “The San Francisco Precautionary Principle” in the San Francisco Environment Code(22): “In the presence of a threat of serious or irreversible harm to human health or the natural environment, the lack of full scientific certainty about cause and effect shall not be used by the City as a reason for postponing cost-effective measures to prevent environmental degradation or protect the health of its citizens”(23). Since then, San Francisco has become the first local government in the United States to clarify and implement the precautionary principle, providing a new path for the city to formulate and implement laws and policies related to health and the environment.

The Rio Declaration on Environment and Development, also known as the Rio Declaration,

for the first time expanded the geographical scope of the precautionary principle to the global level, making it a universal principle. Moreover, the declaration set “the threat of serious or irreversible harm”(24) as the premise for the widespread adoption of precautionary measures, enabling countries to protect human health and the ecological environment while also considering prudent development. The United Nations Framework Convention on Climate Change and the Convention on Biological Diversity, both adopted in the same year, also contributed to the globalization of the precautionary principle. The United Nations Framework Convention on Climate Change stipulates that “each Party shall take precautionary measures to predict, prevent or minimize the causes of climate change and mitigate its adverse effects.”(25) Although the Convention on Biological Diversity does not directly use the term “precautionary principle,” its content reflects the precautionary thinking that measures should be taken to avoid significant reduction or loss of biodiversity in the face of serious and irreversible harm with scientific uncertainty(26).

3. Expansion of Applicable Fields

The above-mentioned countries, regions and international treaties, while introducing the development of the precautionary principle, focus on demonstrating its continuous expansion in geographical scope and mainly concentrate on the environmental field (a considerable part only incidentally touches upon public health, genetically modified organisms, consumer protection and other fields), while the following policies and treaties show that the precautionary principle plays a major role in more fields.

The Cartagena Protocol on Biosafety, by emphasizing that the contracting parties should be aware that “modern biotechnology is developing rapidly, and the public is increasingly concerned about its potential adverse effects on biodiversity, as well as the risks it poses to human health” and that “if modern biotechnology is developed and utilized under adequate safeguards for the environment and human health, it will have great potential for human well-being”, thus “reaffirms the precautionary approach as set out in the Rio Declaration on Environment and Development”,

has thoroughly extended the focus and application of the precautionary principle to the field of biotechnology. At the same time, the Cartagena Protocol on Biosafety, based on the precautionary principle, “addresses issues such as biodiversity and biosafety (protecting human health and the environment from potential adverse effects of modern biotechnology products), and provides a comprehensive and holistic approach for the conservation of biodiversity, the sustainable use of natural resources, and the fair and equitable sharing of benefits arising from the utilization of genetic resources”(27), significantly enhancing the status of the precautionary principle in the governance of biotechnology. Additionally, the Stockholm Convention on Persistent Organic Pollutants, which aims to protect human health and the environment from chemical substances and strengthen the management of chemicals, incorporates chemicals, especially toxic and harmful ones, into the application objects of the precautionary principle(28). Similar to the Cartagena Protocol on Biosafety, this convention is also influenced by the Rio Declaration, taking the precautionary principle in the Rio Declaration as the benchmark for chemical governance. It is particularly worth noting that this convention is one of the earlier international treaties to link scientific uncertainty with the precautionary principle.

If the Rio Declaration made the precautionary principle a universal principle, then the report named “The Precautionary Principle” formulated by the World Commission on the Ethics of Scientific Knowledge and Technology of UNESCO has made it a truly multi-field universal principle. The report states that “when human activities may cause morally unacceptable harm, and such harm is scientifically possible but not yet certain, actions should be taken to avoid or mitigate such harm; morally unacceptable harm refers to harm to humans or the environment that threatens human life or health, or is serious and actually irreversible, or is unfair to the present or future generations, or is imposed without fully considering the human rights of those affected”(29). This “working definition” creatively shifts the trigger for precautionary measures from direct harm or harmful effects to morally unacceptable harm. This not only more closely links the precaution-

ary principle with ethics but also constrains the triggering and application of restrictions and bans in precautionary measures within a reasonable range, thereby facilitating scientific and technological development and social progress.

Since the promulgation of the above-mentioned treaty until today, there have been countless declarations, guidelines, policies and regulations applying the precautionary principle to specific fields such as medical research and development, infectious disease prevention and control, artificial intelligence, autonomous driving, and synthetic biology, making the precautionary principle a significant ethical principle in the world and making precautionary thinking and approaches generally the basis and starting point of policymaking. However, the specific expressions of the precautionary principle in various policies are diverse and complex, sometimes making it difficult for people to clearly understand it and even leading to misunderstandings. Therefore, it is necessary to analyze them by type and weigh them in application.

4. Changes in governance models

4.1 Limited governance of the weak precautionary principle

The weak precautionary principle is an early version of the precautionary principle (it even predates the prior principle and became the main target of criticism for the prior principle). Although this version is still occasionally invoked today due to its certain rationality, its limited governance effectiveness has hindered its application in the governance of emerging technology risks.

4.1.1 Pay attention to potential serious and/or irreversible risks

One of the characteristics of the weak precautionary principle is its focus on potential serious and/or irreversible risks. This is exemplified by the precautionary principle mentioned in the “Meeting on Sustainable Development” held by the Economic Commission for Europe (ECE). It states: “To achieve sustainable development, policies must be based on the precautionary principle. Environmental measures must anticipate,

prevent, and eliminate the root causes of environmental degradation. In the face of a threat of serious or irreversible harm, measures to prevent environmental degradation must not be postponed on the grounds of scientific uncertainty” (30).

Although the above-mentioned policies have touched upon severe and irreversible harm, it was Cass R. Sunstein who refined and theorized them. Sunstein’s “Catastrophic Harm Precautionary Principle” states that when catastrophic consequences are possible, special precautionary measures should be taken to deal with the worst-case scenario (31). This principle requires people to be aware of the underestimation and cognitive lag of catastrophic harm (possibly due to the “availability heuristic” and “scope neglect” theories mentioned when discussing survival risks), and thus calls for precaution in advance. Emphasizing precaution in advance is a common feature of any precautionary principle, which is in line with the forward-looking governance of emerging technology risks and is reasonable. Additionally, Sunstein, based on this principle, pointed out that risks can be divided into risks with known probabilities of possible consequences (narrowly defined risks) and risks with unknown probabilities of possible consequences (which he called uncertainties), and focused the governance concern of the precautionary principle on risks with unknown probabilities of possible consequences. This limited scope of concern will result in a limited scope of risk governance, thereby affecting the effectiveness of the precautionary principle in risk governance. Sunstein’s “Irreversible Harm Precautionary Principle” emphasizes that regulatory agencies can choose to postpone decisions when lacking information on the possibility and severity of risks to prevent irreversible harm (32). This principle proposes an important preventive measure, that is, to suspend the application process and wait for scientific research to increase the scientific information available for risk-benefit assessment. This measure can effectively prevent the occurrence of risks, but due to its singleness, it lacks flexibility in responding to risks.

4.1.2 Emphasize the cost-benefit trade-off

Emphasizing the cost-benefit trade-off is also a characteristic of the weak precautionary prin-

ciple. A typical example of this feature is the weak precautionary principle included in the environmental policies issued by the UK Department for Environment, Food and Rural Affairs. While focusing on the “significant risk of major harm”, this principle also stresses the importance of considering the cost of measures and tends to adopt a cost-benefit analysis approach.

To ensure that precautionary measures are commensurate with the likelihood of risks occurring, this principle distinguishes between two scenarios: “scientific knowledge is not yet conclusive” and “there are sufficient grounds to judge”, along with corresponding countermeasures. For the former scenario, the countermeasure is “as long as the cost-benefit analysis indicates it is reasonable, we can take precautionary measures to limit the spread of potentially hazardous materials or pollutants”; for the latter scenario, the countermeasure is “promptly take relatively low-cost actions to avoid potential greater harm in the future” (33).

The commonality of the two countermeasures lies in their use of the cost-benefit trade-off approach. The advantage of this approach is that it can minimize the occurrence of potential risks with low probability and/or low severity, causing widespread panic in society, as well as prevent the waste of human, material, and financial resources due to disproportionate precautionary measures compared to the actual risk level. The difference between the two countermeasures is that the latter is timely, while the former is lagging. The reason is that the logic of this countermeasure is to obtain sufficient scientific knowledge first, then make a trade-off based on that knowledge, and then take proportionate actions; if the scientific knowledge is insufficient, the actions cannot be implemented. For emerging technologies with uncertainties, specific cases with sufficient scientific knowledge can easily conduct cost-benefit trade-offs and take corresponding countermeasures; however, for specific cases with high scientific uncertainty, the practical effect of cost-benefit trade-offs is rather limited. Therefore, although emphasizing the trade-off is reasonable in general, in the governance of emerging technology risks, this method has limitations in its scope of application.

4.1.3 Emphasizing that the regulator bears the burden of proof

The third characteristic of the weak precautionary principle is that it places the burden of proof on the regulator rather than the regulated. Under this conception of the weak precautionary principle, the burden of proof lies with the regulatory body, which is responsible for envisioning potential harms and taking regulatory actions in advance; meanwhile, developers of new technologies do not need to prove that their technologies will not have negative impacts⁽³⁴⁾. The advantage of this feature is that it saves the energy of the developers and converters of new technologies, reduces their burden, builds a more relaxed relationship between regulators and the regulated, and is conducive to the accelerated development of emerging technologies in a more lenient regulatory environment.

However, it is unreasonable to place the burden of proof on regulators. One reason is that the number of technological research and development activities is huge, while the number of regulators is extremely limited. If the number of regulators is blindly expanded to cope with the numerous technological research and development activities and to identify specific matters with risks from the details of the research and development process, it will lead to excessively high governance costs and make regulatory activities unsustainable. The second reason is that the knowledge background of regulators may not match the rapidly evolving cutting-edge technological research and development activities. For some rapidly developing emerging technologies, only the researchers themselves have a better understanding of the potential risks involved. The third reason is that some regulated entities may conceal or disguise their technological activities, making it impossible for regulators to actually bear the burden of proof, as they may not be able to obtain genuine and effective information and data about the technological research and development activities, and thus cannot make evaluations and decisions.

Overall, the weak precautionary principle focuses on potential severe and/or irreversible risks and emphasizes the cost-benefit trade-off. These two

characteristics have a certain rationality. However, the weak precautionary principle with these two features can only deal with risks with known probabilities of occurrence, but cannot effectively respond to risks with scientific uncertainties promptly, thus having certain limitations in the governance of emerging technology risks. In addition, the requirement for regulators to bear the burden of proof under the weak precautionary principle cannot be achieved due to the diversity, complexity and uncertainty of knowledge in emerging technologies. However, the weak precautionary principle is still a type of precautionary principle, and thus has the forward-looking governance goal that is common to all precautionary principles. From this perspective, it has already surpassed the traditional lagging risk governance principles.

4.2 Effective governance under the strong precautionary principle

Compared with the weak precautionary principle, the strong precautionary principle has a stronger effect on risk governance. This enhanced governance effect is achieved through a more explicit division of responsible subjects and types of responsibility under this principle, as well as a more proportionate risk governance mechanism.

4.2.1 Clear responsibility subjects and types

The strong precautionary principle advocated by Noah M. Sachs, Frida Kuhlau, and others has made significant contributions to clarifying the responsible subjects and types.

Frida Kuhlau and others have proposed that both the regulated and the regulators should bear corresponding responsibilities. First, the regulated are the main bearers of the burden of proof; that is, the scientific community and individual participants have the responsibility to conduct information retrieval and prove, based on the retrieved information, that their research is not related to the assumed threats. Whether the responsibility should be borne by individual researchers or by the scientific community or the entire scientific field depends on the specific circumstances (for example, when expressing concerns about the intentions of a peer's research project, the indi-

vidual has the responsibility to bear the burden of proof; while in the risk review of dual-use technologies, the scientific community or the entire scientific field should bear the burden of proof). Second, the regulators have both the burden of proof and the responsibility for action. On the one hand, they need to provide information to prove that the risk is credible, and on the other hand, they need to take actions (i.e., precautionary measures) to respond effectively(35).

Here, there is a sequence in the burden of proof for researchers and regulators. Researchers should take the lead in shouldering the burden of proof, and the burden they bear is heavier. This is because the scientific uncertainty of emerging technologies means that regulators have access to information about emerging science much later than researchers on the front lines. In other words, regulators' understanding of emerging technologies depends on researchers' disclosure of information about emerging technologies. However, if researchers, as the regulated party, bear the burden of proof alone, it may affect their normal research progress. Therefore, the intervention and participation of regulators are needed.

The manifestation of the regulator's responsibility for action is to take precautionary measures to deal with risks. There are two bases for determining what precautionary measures to take. One is the "severity of the risk as a necessary prerequisite for taking precautionary measures"(36) proposed by Noah M. Sachs in his strong precautionary principle. That is to say, it is necessary to set up a "serious risk threshold" in advance, and based on the ratio of the risk level to the threshold, determine the implementation of precautionary measures, including comprehensive bans, restrictions, labeling and warning requirements, etc. Another approach is the "thresholds of seriousness and credibility" method proposed by Kuhlen et al. This method scientifically compares the severity and credibility of risks related to knowledge, technology, materials, etc. with the set thresholds, and takes commensurate precautionary measures based on the size of the ratio to the threshold. Among them, for risks that are less severe and less likely to occur compared to the threshold, the main responsibility of the regulator is to establish a risk awareness improvement mechanism and

encourage scientists to understand the outside world's concerns about technological risks; for risks that are more severe and more likely to occur compared to the threshold, the responsibility of the regulator is to call on and supervise a small number of scientists engaged in dangerous technology research to take greater cautionary responsibilities(37,38). It is not difficult to see that the latter is more conducive to regulators truly shouldering the responsibilities they should bear. The reason lies in that the latter places the credibility (i.e., the possibility of risk occurrence) on an equal footing with the severity, thus avoiding paying excessive and unnecessary governance costs due to "speculative concerns". This makes the extent of precautionary measures not only commensurate with the severity of the risk but also with the degree of uncertainty of the risk; thereby reasonably covering the entire range of emerging technology risks and "treating the right disease", preventing the situation where governance measures do not match the degree of risk.

In addition to the burden of proof and the responsibility for actions, Sachs also proposed that regulators should assume the role of "risk gatekeeper" and "decider". He assigned regulators the roles of "risk gatekeeper" and "decider". The responsibility of the "risk gatekeeper" is, on the one hand, to urge the supporters of actions or products to assume the burden of proof and conduct thorough research to prove the safety of the technology, thereby minimizing risks; on the other hand, it is to conduct "risks review" and "risk assessment" before actions with potential risks start or before products with potential risks enter the market - identifying which risks are serious and worthy of regulation. The responsibility of the "decider" is to determine whether the supporters of actions or products have fulfilled the burden of proof for verifying the safety of the actions or products(39).

Overall, the responsibility of researchers comes first, while that of regulators takes precedence. This division of responsibility and allocation of duties can not only give due attention to the scientific uncertainty characteristics of emerging technologies and ensure the safety of scientific research activities; but also minimize the burden on researchers and provide a relatively relaxed envi-

ronment for scientific research, thereby ensuring the healthy development of emerging technologies.

4.2.2 Proportional risk management

Proportional risk governance is also known as proportionate risk governance. Proportionality is an important feature of the principle of the strong precautionary principle. It can expand the scope and effectiveness of this principle. The proportionality of the strong precautionary principle has two meanings. One meaning is that the precautionary measures envisioned and taken should be commensurate with the expected level of protection, that is, the actor adjusts the measures according to the selected protection level⁽⁴⁰⁾; the other meaning is that the precautionary measures should be commensurate with the severity of the risk and the possibility of its occurrence⁽⁴¹⁾.

Regarding the so-called “expected level of protection” in the first meaning, it should be noted that when dealing with emerging technologies, blindly pursuing zero risk is unrealistic. The first reason is that technological progress is always accompanied by risks, and there are no completely risk-free technological research and development activities; the second reason is that the extreme pursuit of approaching zero risk may require excessive human and material resources, and such a pursuit is not sustainable. Therefore, what “expected level of protection” that aims to achieve is risk control and appropriate protection. The situation of risk control and appropriate protection can fundamentally be regarded as not causing survival risks to humans, that is, not causing serious and irreversible impacts on human survival and development. When the universal goal faces specific emerging technology research and application, it can be set more specifically based on this universal goal and the relevant scientific information of the specific technology. For the so-called “designed and adopted precautionary measures” in the first meaning, it should be noted that complete prohibition may be one of the feasible methods to deal with potential risks, but it is not the only method. Other specific precautionary measures include taking restrictions, strengthening control, reducing exposure, adopting temporary limit values, providing advice to

high-risk groups, using safer research procedures or products for substitution, etc.

If the first layer of proportionality sets the macro framework for risk governance for the strong precautionary principle, then the second layer of proportionality gives the direct requirements for risk governance for this principle. The most in line with the direct requirements of proportionality is Per Sandin’s strong precautionary principle. Sandin’s precautionary principle emphasizes: if there is a threat and this threat is uncertain, then some compulsory action must be taken; the analysis of specific matters and their precautionary measures should be conducted in four dimensions: threat, uncertainty, command and action⁽⁴²⁾.

The “threat” in the dimension of threat mainly refers to a certain undesirable state that is caused by humans and may occur. The judgment of the size of the threat generally includes the severity (whether it is severe or not), reversibility (reversible or irreversible), and preventability (preventable or not preventable)⁽⁴³⁾. The “uncertainty” in the dimension of uncertainty refers to the state of our understanding or lack of understanding of possible world states. The judgment basis of the size of uncertainty is the level of our understanding of a certain action or product, that is, the reasonable degree of the risks disclosed by scientific evidence (the accuracy of the risks disclosed by scientific evidence). The lower the accuracy, the higher the uncertainty. The “command” in the dimension of instructions is also called regulations. These instructions can be classified into allowable, reasonable, recommended, and mandatory based on the degree of mandatoryness. The “action” in the dimension of action refers to what actions to take to respond to the threat, and the division of action caution and leniency is based on the scope of taking actions. The broader the scope of action, the more cautious it is, and the opposite indicates a more lenient situation. From this, it is easy to see that the requirement of “the risk governance means being commensurate with the severity and/or the possibility of risk occurrence” as proposed by Sandin is reflected in “the instructions and actions being commensurate with the threats and uncertainties”, thereby making the flexibility and operability of the precautionary principle in risk governance stronger.

Conclusion

Appropriate risk governance is a prerequisite and important guarantee for the stable development. How to handle the potential risks and safeguard the reasonable interests and development potential of both the current and future generations is of vital importance to the survival and prosperity of humanity.

Although the precautionary principle is generally forward-looking, not all precautionary principles are effective in the risk governance of emerging technologies. The limitations of the weak precautionary principle in terms of governance scope lead to its deficiency in effectiveness, thus making it not fully applicable. Critically inheriting the reasonable features of the weak precautionary principle and further developing the strong precautionary principle, which has a wide governance scope, flexible governance measures,

clear responsibilities, and strong operability, is more in line with the demands of contemporary risk governance characterized by rapid development and obvious uncertainty. In conclusion, strong precautionary principle is one of the important ethical principles in contemporary risk governance. Formulating corresponding norms, targeted guidelines and policies in combination with this ethical principle and specific real-world circumstances is the key next step to effectively control risks and ensure the stable development of society.

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