

LEGAL

June 2025

Vol.04 No.01

ISSN(print) 3069-2342 ISSN(online) 3069-2350

TAIHANG GROUP PUBLISHING



PUBLISHER

Legal is published by **Taihang Spring Group LLC**, Texas , USA ;Tel. : (626) 557-2777;E-mail: legal@taihangspring.com,For submission instructions, subscription and all other information visit:[//www.taihangspring.com](http://www.taihangspring.com)

COPYRIGHT AND LICENSING

Authors retain copyright and grant the journal right of first publication with the work simultaneously licensed under a Creative Commons Attribution-ShareAlike 4.0 International License that allows others to share the work with an acknowledgement of the work's authorship and initial publication in this journal.

DISCLAIMER

The Publisher, Associations and Editors cannot be held responsible for errors or any consequences arising from the use of information contained in this journal; the views and opinions expressed do not necessarily reflect those of the Publisher, Associations and Editors.

ONLINE OPEN

Legal accepts articles for Open Access publication.Please visit:[//www.taihangspring.com](http://www.taihangspring.com) for information about Online Open.

Printed in Texas 2025

ISSN (print) 3069-2342

ISSN (online) 3069-2350

EDITORIAL BOARD

Editor-in-Chief

Dr. Zheng Wang

Zhejiang Hezhong Legal Technology & Intelligent Research Institute

Associate Editors

Prof. Jinxi Wang

China University of Political Science and Law

Prof. Chi Yin

*founding partner/attorney at East West Law, research scholar at the
U.S.-Asia Law Institute of New York University School of Law*

Prof. Lei Lei

China University of Political Science and Law

RF. Bin Wei

Digital Rule of Law Lab, Guanghua Law School, Zhejiang University

Prof. Qingfeng Li

Hangzhou Dianzi University

Prof. Yanqiong Cao

School of Law, Shanxi University

Publishing Director

Heyi Wang *Taihang Spring Group LLC*

LEGAL

TABLE OF CONTENTS

Volume 4 Number 1 June 2025

Articles

**Research on the Impact of the Brain-Computer Interface on the
"Duty of Care" in Negligent Criminal Law.....1**

Yanqiong Cao, Haosheng Wang

**Neuroethical Challenges of Brain-Computer Interface Regulations:
A Comparative Analysis of the U.S., EU, and China.....14**

Bin Wei, Shuyao Cheng, Xu Qian

The Logical Foundation of the Basic Principles of Criminal Law....37

Jianhui Wen

On the Logical Constraints on Legal Norms.....57

Zhiyu Xu, Lei Lei

**Breaking the Cocoon of a Millennial Logical Dilemma: Paradigmatic
Innovation in Logical Domain Theory and the Ultimate Resolution of
Paradoxes.....75**

Mingliang XU

**Inherent Defects in Smart Contract Dispute Resolution: Legal
Challenges and Solutions.....94**

Qingfeng Li, Jialu Qi

Research on the Impact of the Brain-Computer Interface on the "Duty of Care" in Negligent Criminal Law

Cao Yanqiong¹ Wang Haosheng²

Law School, Shanxi University, Taiyuan City, China 030031

Abstract

With the rapid advancements of the artificial intelligence technology field, the Brain-Computer Interface (BCI) technology has gradually expanded its applications into the realm of cognitive enhancement, and this transition itself, which triggers a fundamental challenge to the theory of “the duty of care” in the criminal negligence. The traditional determination of liability for negligence relies on the standard of "rational ordinary people", but the cognitive enhancement function of the BCI technology disrupt this foundational assumption, making the cognitive abilities and cognitive boundaries of some actors far exceed those of ordinary individuals. Consequently, this intensifies the risk of imbalance in the negligence liability determination and necessitates a higher standard for the obligation to evade harmful outcomes of those actors to be raised. Given the significant individual differences caused by the cognitive enhancement effect of the BCI technology, the current legal standards of determination of liability for negligent crimes in the criminal law have systematic deficiencies in addressing cognitive disparities. To deal with this situation, a new liability determination framework which is compatible with the cognitive enhancement function of the BCI technology must be established. This framework should integrate technical reliability assessments and the actual cognitive ability of actors to construct a stepped standard of duty of care. By implementing such a

1 Cao Yanqiong, Associate Professor of the Law School of Shanxi University, Doctor of China University of Political Science and Law, e-mail: 26705405@qq.com

2 Wang Haosheng, Graduate student of the Law School of Shanxi University, e-mail: 1372865745@qq.com

hierarchical mechanism, the boundaries of negligence liability can be refined, avoiding excessive legal scrutiny or omissions stemming from over-reliance technology.

Keywords

Brain-Computer Interface; Cognitive Enhancement; Duty of care; Criminal Negligence

Introduction

The technical specification conflicts caused by the Brain-Computer Interface (BCI) technology have gradually extended from the simple dimension of scientific ethics to the core area of the doctrine of criminal law. By intervening in brain neural signals to enhance the cognitive abilities of actors, this specialized function of the BCI has directly challenges the longstanding duty of care system for negligent crimes, which is predicated on the "rational ordinary people" standard. The crux of this challenge lies in that the BCI technology enhances the cognitive ability of the actor, and directly shakes the two major foundations that make the negligence crime under the Criminal Law established, which are the anticipation possibilities and the outcomes avoidance possibilities. Historically, criminal law assumes a uniform cognitive baseline among individuals. However, the BCI breaks the "cognitive" state where the cognitive abilities of all actors are at the same level, creating a cognitive hierarchy where some actors possess superior perceptual and analytical abilities. So, it poses a substantive challenge to the basic rule of the duty of care in negligent crimes. When development of technology leads to the differentiated distribution of the cognitive abilities of the actors, the traditional standard of duty of care can neither reasonably define the boundary of the anticipate possibilities of the users, nor cope with the requirements of their special outcome avoidance obligations. It highlights the mismatch between the paradigm of criminal law dogmatics and the reality of technological development, and it is urgent to establish a new theoretical framework of duty of care through reconstructing the criminal law dogmatics.

In the era of the BCI-driven cognitive transformation. The legal criteria for determining the duty of care in cases of criminal negligence face unprecedented challenges due to technological advances. Based on the judicial determination predicament of the duty of care caused by the cognitive enhancement effect of the BCI technology, and combined with the case law principles of relevant technologies in the field of artificial intelligence, which is aiming to construct a differentiated duty of care framework suitable for the BCI users, so that the criteria of the duty of care for

negligent crimes can keep abreast of the significant changes in the era of cognitive enhancement.

1 Challenges of the BCI Technology to the Duty of Care Theory in Negligent Crimes

1.1 The Failure of the Traditional "Rational Ordinary People" Standard

Under traditional criminal law, negligence liability is assessed using the “rational ordinary people” benchmark, which assumes uniform cognitive abilities across individuals, for instance: German criminal law theory emphasizes that the duty of care should be judged based on "social proportionality" assumption, which is, whether the actor constitutes a negligent crime depends on whether he or she can foresee and avoid the occurrence of the harm result. In Japan, the law has proposed the “new negligence theory”, which argues that the duty of foresee consequences should shift toward an obligation to avoid harm outcomes. However, this theory assumes that all actors share the same baseline of physiological cognitive ability. Chinese criminal law has absorbed the doctrines of the criminal laws of both Germany and Japan; Article 15 of the Criminal Law of China stipulates that the core of the duty of care in negligent crimes is the possibility of the actor foresees the occurrence of harm and the possibility of the actor avoiding the occurrence of harmful results. Just like the Germany and Japan, the criminal law of China also requires that the judgment standard for negligent crimes should follow the assumption of "rational ordinary people".

By intervening in cranial nerves, the BCI technology has realized the enhancement of the ability to obtain information of the actors as the main subject in the criminal law, making some individuals cognitive ability significantly beyond other ordinary persons.³ Especially, users of the BCI can notice some information that is not noticed by ordinary people through this technology, such as information that is temporarily hidden in the mind due to the defect and interference of ordinary people's attention, which will lead to a separation between the subjective predictive ability of the actor and the objective duty of care of the actor. If the assumption of "rational ordinary people" in traditional criminal law theory is still used as the judgment criterion for the duty of care in negligent crimes, which will trigger two extreme consequences: On the one hand, users of the BCI will bear the full obligation of anticipation, just because the cognitive enhancement function of the BCI has improved their cognitive ability,

³ Wu Xuyang, "Analysis of the Legal Rights System under the Background of the New Development of Brain-Computer Interfaces", Political and Legal Forum, no. 2 (2025), pp. 121-33.

which will overly compressed the application space of "failure to anticipate what was foreseeable" as stipulated in criminal law provisions, even makes those provisions lost their applicable scenarios. On the other hand, users of non-Brain-Computer Interface can even claim that there is an insurmountable gap between their cognitive abilities and those of technology users, and they should be completely exempted from obligation. This binary opposition situation not only challenges the principle of fairness in the application of traditional criminal law theory, but is also likely to vacillate the social application basis of negligent crimes.

1.2 Systematic Failure of the Foreseeability Obligation

With the continuous breakthroughs in the BCI technology, in the fields like transportation, it is possible to develop a risk early warning system based on cognitive enhancement function of the BCI technology, in addition to the motion control assistance type. Take the driving scenario as an example, the BCI devices can provide dynamic risk warnings to their users. If an actor fulfills the duty of care to check after receiving the risk warning and then drives a car, resulting in a crushing accident. Based on the current traditional criminal law theory, it is advisable for the actor to claim that he or she has fulfilled the due duty of care. However, in the process of the development of the BCI technology, whether the inspection behavior carried out by the actor based on the early warning of the BCI device is sufficient to eliminate the actor's duty of care needs to be discussed on a case-by-case basis: in a low risk situation, such early warning is unlikely to increase the actor's duty of care, while in medium and high risk situations, it will become the standard to enhance the actor's duty of care.

In the BCI device shows that low risk early warning situation, the actor puts forward the defense has the rationality of criminal law. The low risk warning itself is sufficient to indicate that the probability of the occurrence of such risk is very low. The actor subjectively does not reach the degree of "clearly know" which specific risks are about to occur. Therefore, it cannot be directly presumed that the actor has foreseen the harm result. Based on the reminder of the device and the experience of daily life, the actor's choice to ignore the such early warning was consistent with what is the thinking logic and behavioral patterns of the ordinary people. And also, the actor's judging that the probability of such risks occurring is minimal conforms to the standard of social correspondence. At this point, the actor's duty of care only needs to reach the level of the general duty of care of an ordinary person who has not used the BCI. There is no need to demand that the actor fulfill a higher duty of care due to cognitive enhancement function of the BCI.

When the actor, which is the user of the BCI receives the medium risk early warning of the BCI, the user should assume the responsibility of higher than the average person a duty of care, and the criteria for the validity of the defense claimed by them will also change accordingly. A medium risk warning indicates that the possibility of a hazard occurring has reached a level that cannot be ignored. At this time, if the actor as a user of the BCI, merely conducts a formal and simple inspection, such as getting off the vehicle to patrol without taking any practical measures, resulting in an accident, in fact, the actor subjectively underestimates the medium risk warning. It is the negligence with undue assumption to believe that a simple inspection can prevent an accident.

And when the actor received warning with a high risk, The criteria for determining the duty of care of the actor will be more stringent. At this point, the actor claims the accident to its defense space will be considerably narrowed. A high-risk warning means that the actor has the highest duty of care. If the actor chooses to continue driving and causes an accident, there is at least gross negligence subjectively, and they may even further reach the boundary of indirect intent due to their reckless indifference towards the fact that certain legitimate interests have been infringed.

1.3 The Intensification of the Outcome Avoidance Obligations

The cognitive enhancement function of the BCI technology does indeed bring about an increase in the obligation of anticipation. However, it also cannot be ignored that the increase in the obligation of anticipation will also lead to its expansion. The BCI technology, through its related functions of data analysis and risk early warning, may transform originally imperceptible risks into foreseeable ones. For example, in the medical field, if a doctor who uses the BCI technology as his or her assistant, the doctor finds that a patient's vital signs are in an abnormal range through such technology and fails to intervene in time, resulting in damage, the doctor should bear corresponding liability for negligence.

Through direct intervention of the cranial nerves, the BCI technology has greatly improved the user's decision-making speed and accuracy, and may even make the optimal decision probability of reaching one hundred percent. However, the cognitive enhancement effect of this technology should not be misunderstood as "absolutely error-free decision-making ability", otherwise it will lead to excessive criticism of the obligation to avoid the results borne by the user. Similarly, with the unceasing development and maturation of the technology, in the future, this kind of technology may demonstrate its reliability and accuracy which are nearly perfect. And based on these two characteristics of this technology, the BCI technology is highly likely to

dominate a certain industry without industry compulsion, put it another way, the BCI will shape the whole industry and become the new technical standard of the certain field. At this point, for personnel who are engaged in the related industries have not been equipped with the BCI devices and also without meeting the same standards of the BCI technology users, it is very likely that they will be identified as negligent.

In addition to avoid some of the harm results happened, the most important thing is making the right choice in a reasonable amount of time. Within the "Reasonable Time" range, the BCI technology enables the actor to no longer be in the repetitive dilemma of thinking and acting. However, if the BCI technology provides too many choices, causing the actor to procrastinate decision-makings and resulting in harmful consequences, how the responsibility should be determined? Within the scope of the concept of "Correct Choice", as humans with sound physiological functions, the BCI technology can only be a mechanical auxiliary tool, it cannot play a role in making decisions on behalf of the actor himself or herself.⁴ Just as in the Tesla case, although the Apollo self-driving system had some flaws, the court still held the perpetrator accountable for the negligence of relying too much on technology and failing to take over the vehicle in time. Therefore, the actor must independently decide and undertake the obligation to avoid the outcomes based on his or her social experience or professional abilities.⁵

2 The Judicial Determination dilemma of duty of Care Caused by the Brain-Computer Interface Technology

2.1 Obstacles to Fact-Determining Caused by the Black Box Nature of the Technology

The judicial determination predicament of the BCI technology essentially stems from the conflict between technical rationality and legal rationality. When algorithms of the BCI have predicted risks at an extremely fast speed, the criminal law however, requires the actor to recall the subjective cognitive state of the reaction at that time. And all of these just create a sense of disorientation and also simultaneously lead to difficulties in the application of the law, which are as follows: the BCI technology expands the cognitive boundaries of human beings, but at the same time affects the

⁴ Chen Bing and Liu Yongji, "Science and Technology Ethics and Legal Response: The Safe Development of Autonomous Driving", *Learning and Practice*, no. 2 (2025), pp. 45-52, doi:10.19624/j.cnki.cn42-1005/c.2025.02.008.

⁵ L'Enfant Plaza Sw, 'Collision Between a Sport Utility Vehicle Operating With Partial Driving Automation and a Crash Attenuator, Mountain View, California, March 23, 2018'.

logical basis of liability determination in law. Furthermore, the risk early warning data provided by the BCI technology is neither purely objective data nor purely subjective psychological states, but rather based on a paradigm of "human-computer hybrid cognition" between those two situations. And this cognitive form actually creates a brand-new subject in the criminal law.⁶ Further speaking, after the underlying logic of technological development becomes black-boxed and complex,⁷ judges will have to be in an awkward situation. Because they cannot understand the process of algorithmic decision-making in the same way as they evaluate human behaviors, but they still have to make judgments on the legal consequences of algorithmic decision-makings. And this leads to deviations in judicial judgments. Either the judges overly rely on the evidence of the BCI technology and directly equate the algorithm's "foresight" with the actor's already foresight.⁸ Or they just fall into the complete conservative side, directly deny the impact of technological development on human cognition, and still use the traditional standard of "ordinary rational person". All of these will cause the ambiguity of judicial judgment standards and further result in inconsistent judicial judgments.

2.2 The absence of legal evaluation criteria resulting from technical unreliability

At present, the BCI technology is still at the early stage of commercialization, and the problem of its unreliability is particularly prominent. On the one hand, there is a lack of unified technical evaluation standards for this kind of technology. Especially at the legal level, technical norms for the key technical standards of cognitive enhancement functions have not yet been established. On the other hand, the development of the BCI technology is highly black-boxed, which has intensified the difficulty of verifying the reliability of the technology. Manufacturers refuse to disclose the underlying logic of the core algorithms on the grounds of trade secrets. Even if it is disclosed, the unexplainable nature of algorithms based on autonomous learning may lead to the technology manufacturers themselves being unable to understand its logic.⁹ And this has forced relevant judicial decisions to rely highly on expert opinions,

⁶ Sheng Haojie, "The Challenges of Brain-Computer Interfaces to Criminal Law and Their Responses", *Journal of Southwest University of Political Science and Law*, 26.2 (2024), pp. 138-51.

⁷ Liu Xianquan, "The Evolution of Criminal Responsibility in the Era of Artificial Intelligence: Yesterday, Today, and Tomorrow", *Law*, no. 1 (2019), pp. 79-93.

⁸ Swati Aggarwal and Nupur Chugh, 'Ethical Implications of Closed Loop Brain Device: 10-Year Review', *Minds and Machines*, 30.1 (2020), pp. 145-70, doi:10.1007/s11023-020-09518-7.

⁹ Liu Xianquan, "The Impact of the Iterative Development of Artificial Intelligence on Criminal Responsibility for Property Crimes", *Journal of the National Prosecutors College*, 33.2 (2025), pp. 33-44.

further introducing new subjective risks. Compared with the mature supervision and management system of medical devices, at present, there is a lack of benchmark test norms for cognitive enhancement functions and also doesn't establish the relevant regulatory standards for neural data security. This not only provides space for technology manufacturers to evade legal responsibilities under the pretext of "experimental use", but also may lead to the further arbitrariness of judicial decisions due to the unreliability of the technology.

2.3 The vacuum in responsibility allocation caused by the non-attribution of technology

The non-imputability of the BCI technology has led to a systematic collapse of the legal responsibility allocation system, leaving the responsibility allocation in a vacuum state. If the impact of the BCI technology on the duty of care is not regulated separately, the current legal framework will face three risks in responsibility allocation: Firstly, users bear excessive responsibility. Based on the principle of "he who asserts must prove", the BCI users have to bear an excessive burden of proof for their defense that the device has failed to fulfill the corresponding risk avoidance obligations, which has caused considerable difficulties in safeguarding their own rights. Secondly, the technology manufacturers bear disproportionate responsibility. The court may impose excessive responsibility on the technology manufacturers. Due to the difficulty of the burden of proof, the court may avoid the difficulty in making judgments and rigidly attribute the responsibility solely to the "technical defect", which leads to the BCI technology manufacturers bearing excessive responsibility and also hinders the technological innovation and development, just because the technology manufacturers are afraid to take excessive responsibilities. Thirdly, there is a possibility of a complete liability vacuum where neither the users nor the manufacturers bear responsibility. If the users can prove that they have fulfilled their due duty of care, then the liability for harm results should be borne by the technology manufacturers. However, if the technology manufacturers also prove that they have fulfilled their legal obligations, such as making the algorithm transparent and regular reviews, then the technology manufacturers should not bear liability for harm results either. Those will lead the party involved into a predicament where there is no way to obtain legal redresses.

3 Legal Construction of Differentiated Duty of Care under the Challenges of the Brain-Computer Interface Technology

3.1 Define the Normative Boundaries Between Technical Defects and User Faults

To adapt to the development characteristics of the BCI technology, the traditional standard for determining the duty of care in negligent crimes in criminal law, "rational ordinary people", should be shifted to a hierarchical and categorized standard for negligent determination, achieving the following things:

Adhere to humanism.¹⁰ Research on the BCI technology should integrate findings from multiple scientific fields to establish minimum safety standards for such devices. This will ensure legal compliance and enable reasonable evaluations within the feasible scope of the technology. Secondly, it is necessary to be able to make a dynamic legal evaluation of the actions carried out by the actor, that is, to define the scope of the actor's duty of care by combining the objective actions specifically carried out by the actor and the subjective cognitive possibilities, avoiding excessive reliance on technical assumptions or ignoring the cognitive limitations of human beings. Finally, it is also necessary to establish the principle of accountability for technology-assisted decision-making to address the predicament where users of the BCI overly rely on technological development which caused them to abandon their subject status legally. This predicament should be attributed to the failure of the actor to fulfill the due duty of care rather than to the technology itself.

Don't have overly high expectations of users of the BCI technology. Due to the technical possibility of cognitive enhancement in the BCI technology, which is, in judicial decisions, it is easy to generate a perception that users of the BCI technology will inevitably reach the "perfect rational" state. Nonetheless, in fact, the BCI should be regarded as a technical auxiliary means rather than a matter-of-course legal basis for accountability reinforcement. The use of this technology by the actor in itself does not automatically enhance his or her duty of care. But in judicial practice, the objective behaviors and subjective purposes of the actor should not be ignored. The judges cannot mechanically presume that the actor "had fully foreseen the possible harm results based on cognitive enhancement of the technology and had the optimal decision-making ability, but did not take corresponding actions", or even merely criticized the actor on the grounds of "imperfect decision-making", thereby inappropriate expanding the scope of determining negligent crimes. As mentioned in the previous driving case, the low-risk warning of the BCI should not be automatically converted into the perpetrator's obligation to foresee; otherwise, it may

¹⁰ Lu Hui and Wang Zhijia, "Reflecting on the Ethical Dilemma and Solution of 'Brain-Computer Interface' Technology Based on Existentialism", *Research in Dialectics of Nature*, 39.8 (2023), pp. 69-75, doi:10.19484/j.cnki.1000-8934.2023.08.011.

lead to the abuse of the BCI technology and the risk of the perpetrator's liability limit being overly expanded. Or, due to technological uncertainty, the changes brought about by the BCI technology and the intersection of subjective cognitions and objective behaviors of the actor are completely denied, resulting in criminal law provisions lagging behind the development of real technology. Therefore, criminal law evaluation must strictly distinguish the cognitive enhancement effects of technological tools and the subjective aspects of the actor to prevent the traditional principle of liability attribution from being undermined due to technological intervention.

3.2 Introduce the Stepped Application Standards for "Reasonable Users"

The criteria for reconstructing the duty of care in negligent crimes can have more intuitive application measures in terms of technology, that is, classifying and managing the BCI devices and adjusting the degree of commercial investment in the market. Incorporate the factor of cognitive enhancement into the judgment criteria of the duty of care, and establish corresponding risk levels based on the degree of cognitive enhancement of the BCI technology users and the degree of intervention of the BCI technology and the social harmfulness. Differentiate the application of the duty of care. Apply different standards to different BCI users according to different levels and types to avoid the arbitrary and rigid one-size-fits-all phenomenon in judicial practice and achieve the coordinated development of judicial and technological development.

3.3 Add Special Liability Provisions for the Application of the Brain-Computer Interface technology

Due to the existence of the BCI, both the human behaviors as the subject of the criminal law and the object behaviors of the auxiliary tools are manifested through the human behaviors as the subject, confusing the boundary between human behaviors and technological behaviors. The criminal law should add relevant provisions to avoid subverting the basis of criminal law regulation.

Users of the BCI technology bear increased responsibilities. Based on the characteristics of the BCI technology, its users are bound to have stronger cognitive abilities compared to the ordinary people, and therefore they will also bear a higher duty of care. However, if the person who actively uses the BCI technology causes harmful results due to its cognitive enhancement effect, they shall bear increased responsibility. Joint liability for technical defects. manufacturers of the BCI devices who are aware that the devices have defects but still put them into commercial use shall bear corresponding responsibilities. If the user of the equipment has reached the

due duty of care and the harmful result occurs only due to the defect of the technical equipment, the users may claim exemption from liability to the corresponding extent and scope. The complete immunity of the user under special circumstances. Since the BCI technology eliminates the closed nature of the human brain,¹¹ which also means that this kind of technology is at risk of being hijacked by hackers.¹² When similar sudden situations occur and the user is unable to foresee or avoid the occurrence of harmful consequences, the user himself or herself shall be completely exempted from criminal responsibility by reference to force majeure. And for the vacuum of responsibility allocation caused by the non-imputability of the technology, corresponding rules should be established legally.

The top of the priority is to hold enterprises accountable for algorithm traceability, requiring the BCI technology manufacturers to establish traceability methods for the logic and data of their equipment's underlying algorithms and core algorithms, so when accidents happened, it will much easier to do the traceable check. And for the core algorithm, the number of regular checks should be stipulated. Secondly, a risk liability clause should be introduced. That is, if the manufacturer cannot prove that the harm results occurred due to improper operation by the user or external reasons, it should be presumed that there is a causal relationship between the harm results and the actions taken by the technology, and the manufacturer shall be held responsible for this. If the manufacturer has fulfilled the corresponding compliance obligations, its liability can be mitigated, but the manufacturer still should bear the corresponding compensation liability. Finally, a neutral third-party detection mechanism should be introduced to connect with the stepped application standards of "reasonable users", and a corresponding stepwise proof method should be constructed. The BCI users should bear the initial burden of proof, while relevant enterprises should bear the responsibility of providing algorithms and data. For the part of the evidence involving neural data information in the BCI, the burden of proof should be transferred to a neutral third party designated by the court, just to avoid evidence bias and privacy leakage caused by enterprises' independent proof. At the same time, institutions bearing the burden of proof should also be regulated. They cannot use the right of proof granted by law to collect, sell or even tamper with the BCI data of diverse actors. Ensure that the law is not abused as an excuse for crimes.

¹¹Li Xiaoyong, "Logical Justification and Institutional Conception of the Right to Mental Integrity in the Context of Brain-Computer Interface Technology," *Journal of Political Science and Law*, no. 3 (2024), pp. 45-57.

¹² Marcello Ienca and Pim Haselager, 'Hacking the Brain: Brain-Computer Interfacing Technology and the Ethics of Neurosecurity', *Ethics and Information Technology*, 18.2 (2016), pp. 117-29, doi:10.1007/s10676-016-9398-9.

Conclusion

Through the systematic deconstruction of the changes brought about by the cognitive enhancement effect of the BCI technology on the duty of care in negligent crimes, the dual impact of this technology on the duty of care in negligent crimes is revealed. At the normative level, the development of the BCI technology objectively raises the cognitive boundaries of actors, thereby enhancing the judgment criteria for the possibility of anticipation. At the subject level, if the duty of care of technology users is simply and mechanically expanded, it will fall into the fallacy of attribution of "omniscience presumption", which not only ignores the cognitive limitations of human beings as the subject of the criminal law, but also deviates from the basic position of criminal law humanism. In response to this theoretical predicament, by adopting a framework of hierarchical division of duty of care for the BCI users, in the dimension of foreseeable possibilities, establish a dual judgment criterion that combines the achievable scope of technology with the actual cognitive level of individuals. BCI technology should be regarded as a tool to assist human decision-making, so as to ensure human subjectivity and initiative while acknowledging the enhancement effect that technology brings to human cognition. In terms of the obligation of results avoidance, the objective criterion of "reasonable user" is proposed, by introducing technical norms and industry standards from science, neuro-philosophy and other sciences. Differentiated judgments based on individual cognitive abilities can truly achieve specific analysis of specific cases, reaching the objectivity of judgments and the fairness of liability attribution. Finally, in judicial practice, the judiciary authority should be vigilant against mechanical judgments, and use the rough applications standards just for pursuit the efficiency, avoiding to fall into the trap of the analogy. Only by improving the regulatory framework for emerging technologies can diminish the rigidity risks of criminal law stagnation caused by technological fear and risks of subject virtualization caused by technological radicalism, so that the safeguarding and promoting functions of criminal law norms can still play a part in the development process of emerging technologies. And further, provide corresponding regulatory basis for responding to the criminal law challenges brought by emerging technologies. It also provides a theoretical basis for formulating the legal regulatory framework of the BCI technology in the future.

Reference

- [1] Aggarwal, Swati, and Nupur Chugh, 'Ethical Implications of Closed Loop Brain Device: 10-Year Review', *Minds and Machines*, 30.1 (2020), pp. 145–70, doi:10.1007/s11023-020-09518-7
- [2] Ienca, Marcello, and Pim Haselager, 'Hacking the Brain: Brain–Computer Interfacing Technology and the Ethics of Neurosecurity', *Ethics and Information Technology*, 18.2 (2016), pp. 117–29, doi:10.1007/s10676-016-9398-9
- [3] Sw, L'Enfant Plaza, 'Collision Between a Sport Utility Vehicle Operating With Partial Driving Automation and a Crash Attenuator, Mountain View, California, March 23, 2018'
- [4] Liu Xianquan, "The Evolution of Criminal Responsibility in the Era of Artificial Intelligence: Yesterday, Today, and Tomorrow", *Law*, no. 1 (2019), pp. 79-93
- [5] Liu Xianquan, "The Impact of the Iterative Development of Artificial Intelligence on Criminal Responsibility for Property Crimes", *Journal of the National Prosecutors College*, 33.2 (2025), pp. 33-44
- [6] Wu Xuyang, "Analysis of the Legal Rights System under the Background of the New Development of Brain-Computer Interfaces", *Political and Legal Forum*, no. 2 (2025), pp. 121-33
- [7] Li Xiaoyong, "Logical Justification and Institutional Conception of the Right to Mental Integrity in the Context of Brain-Computer Interface Technology," *Journal of Political Science and Law*, no. 3 (2024), pp. 45-57
- [8] Sheng Haojie, "The Challenges of Brain-Computer Interfaces to Criminal Law and Their Responses", *Journal of Southwest University of Political Science and Law*, 26.2 (2024), pp. 138-51
- [9] Lu Hui, and Wang Zhijia, "Reflecting on the Ethical Dilemma and Solution of 'Brain-Computer Interface' Technology Based on Existentialism", *Studies in Dialectics of Nature*, 39.8 (2023), pp. 69-75, doi:10.19484/j.cnki.1000-8934.2023.08.011
- [10] Chen Bing, and Liu Yongji, "Science and Technology Ethics and Legal Response: The Safe Development of Autonomous Driving", *Learning and Practice*, no. 2 (2025), pp. 45-52, doi:10.19624/j.cnki.cn42-1005/c.2025.02.008

Neuroethical Challenges of Brain-Computer Interface Regulations: A Comparative Analysis of the U.S., EU, and China

Wei Bin

Research Professor, Guanghua Law School of Zhejiang University, binwei@zju.edu.cn

Cheng Shuyao

Doctoral Student, Guanghua Law School of Zhejiang University, 12102002@zju.edu.cn

Xu Qian*

Associate Professor, Guanghua Law School of Zhejiang University, qianxuxu@zju.edu.cn

***Corresponding Author: qianxuxu@zju.edu.cn**

Abstract

The rapid growth and real-world applications of brain-computer interfaces (BCIs) in medicine have given rise to a range of ethical and legal challenges. Despite various policy and regulatory studies conducted in response, there remains a lack of systematic research on BCIs regulation worldwide. This article introduces the fundamentals of BCIs and analyzes four ethical issues that emerge with their application: safety risks, privacy violation, individual autonomy, and social inequality. It then examines the current regulation of BCIs in the United States (U.S.), the European Union (EU), and China. This involves comparing their differences and analyzing their shortcomings. The study finds that the existing regulatory frameworks fail to adequately address these four ethical aspects. In response to this problem, it is recommended to establish a diverse regulatory toolbox that facilitates collaboration

among governments, industry, independent agencies, civil society, and international organizations. This toolbox should adopt targeted strategies for the four primary concerns identified: implementing tiered security standards, creating neural data classification systems, clarifying informed consent procedures, and ensuring equal access to BCIs. By integrating these precise measures, the toolbox aims to address the multifaceted challenges of BCIs comprehensively and support their ethical and sustainable development.

Keywords

brain-computer interfaces (BCIs); technical safety; privacy protection; informed consent; social inequality; regulatory toolbox

INTRODUCTION

Brain-computer interfaces (BCIs) are systems that enable direct communication between the brain and external devices, allowing control or interaction through neural activity (Lebedev & Nicolelis, 2006). The main goal of BCIs is to assist individuals with neuromuscular disorders, such as ALS, cerebral palsy, stroke, or spinal cord injury (Shih et al., 2012). Being employed in medical and therapeutic applications, BCIs offer rehabilitation possibilities for patients with neurological diseases, while its risks, particularly in a long term perspective, are mostly unknown (Bernal et al., 2021).

The last decade has witnessed increasing scholarly attention to neuroscience achievements and attendant ethical problems (Petoft & Abbasi, 2020). Safety issues, privacy violations, human autonomy problems, and social inequality are the primary concerns raised by BCIs. While BCIs enable brain-controlled communication and movement, they also pose safety risks such as bleeding and infection (Chen, 2023). Additionally, BCIs also raise privacy concerns due to their potential to monitor and alter brain activity (Naufel & Klein, 2020). In particular, the application of BCIs may affect users' sense of agency (Vlek, et al., 2014), which complicates the attribution of responsibility in infringements (Schönau et al., 2021). Furthermore, BCIs may exacerbate social inequality and widen class divides by enhancing human capabilities (Gordon & Seth, 2024). Given these issues, it is essential to develop coherent policies for responsible BCI development (Schmid et al., 2021). This leads to the critical question: Are current regulations adequate to address emerging ethical concerns surrounding BCIs? Further investigation is needed to assess existing regulations and provide a basis for future strategies.

This research examines the regulations of three major regions at the forefront of BCIs: the United States (U.S.), the European Union (EU), and China. These regions were selected due to their technological leadership and diverse regulatory approaches. The study provides a comparative analysis of global responses to BCIs, identifying regulatory gaps and proposing solutions to ethical challenges.

The article is structured as follows: Part II reviews the international progress of BCIs; Part III explores ethical issues of BCIs, including risks in safety, privacy,

autonomy, and social equality; Part IV compares current regulations in the U.S., EU, and China; and Part V presents a regulatory toolkit to address the identified issues.

1 FRONTIERS OF BCIS RESEARCH AND PROJECTS

1.1 The Development of BCIs

In the 1970s, Jacques J. Vidal first proposed the concept of brain-computer interface (BCI), using electroencephalogram (EEG) signals for communication between humans and machines (Vidal, 1973). BCIs enable users to control external devices via brain signals, assisting paralyzed patients in regaining movement through prosthetic limbs (Mak & Wolpaw, 2009).

Technological advances have led to key innovations in BCIs. In 2013, the U.S. Food and Drug Administration (FDA) approved the NeuroPace RNS System, the first BCI device for treating partial epilepsy. In 2019, Neuralink developed an advanced signal acquisition system for BCIs, which broke the channel count limits and improved the accuracy of targeting specific brain regions (Musk, 2019). Current research in BCIs is focused on restoring physical functions in individuals with disabilities, such as enabling communication for those who can no longer speak (Willett et al., 2021). China has also made strides in the field of BCIs. The newly developed BCIs enable the implantation of flexible electrodes into the brain via a minimally invasive procedure, thus eliminating the need for a craniotomy (Tang et al, 2023, Wang et al, 2023). In 2020, Zhejiang University successfully completed China's first clinical study of implantable BCI, enabling a 72-year-old paraplegic patient to precisely control external machinery with brain signals (Si et al, 2023).

Currently, BCI research is exploring not only the treatment of neurological diseases but also how the brain can record, process, utilize, store, and retrieve vast amounts of information at the speed of thought. However, the application of BCIs requires caution, as commercial interests may push premature neurotechnologies to market (Justo & Erazun, 2007), highlighting the need to uncover and address ethical concerns related to BCIs.

1.2 Projects of BCIs in U.S.- EU-China

As early as 1989, the U.S. government designated the last decade of the 20th century as the "Decade of the Brain". In 2014, the U.S. launched the BRAIN Initiative to explore the working mechanism of brain and develop new treatments for brain diseases (U.S. National Institutes of Health 2014). In 2019, the Advisory Committee to the NIH Director endorsed a report named "The BRAIN Initiative and Neuroethics" (U.S. National Institutes of Health 2019). This document created a set of neuroethics guiding principles, which emphasize the importance of assessing safety and protecting the privacy and confidentiality of neural data.

The Human Brain Project (HBP) is the largest brain science project in Europe, involving over 500 scientists and engineers from over 140 institutions (Human Brain Project 2023). In 2020, HBP shifted focus to three core scientific areas: brain networks, their role in consciousness, and artificial neural nets. HBP has also spurred neuroscience competition in the U.S. and China (Frégnac & Laurent, 2014). However,

ethical concerns, especially regarding consent and privacy, have been highlighted since its inception (Rose, 2014).

The China Brain Project, entitled “Brain Science and Brain-Inspired Intelligence”, is formulated as a 15-years plan (2016–2030) (Poo et al., 2016). In 2017, the State Council of China proposed Development Planning for a New Generation of Artificial Intelligence to study brain-like intelligence computing theories (Chinese State Council 2017). In 2021, the Ministry of Science and Technology officially announced the annual application guidelines for the major “Brain Science and Brain-like Research” project, involving 59 research fields and directions. Chinese tech companies are venturing into non-invasive BCIs, fostering the growth of several BCI startups, like Neuracle Tech, BrainCo and BrainUp. The BCI industry in China is thriving, with a developing industrial chain (China Electronics Standardization Institute 2021).

In general, the U.S., the EU, and China are at the forefront of BCIs development, making the ethical review of BCIs particularly urgent in these regions. Therefore, before delving into the current regulations, it is necessary to conduct a more systematic discussion of the ethical concerns associated with BCIs.

2 ETHICAL CONCERNS OF BCIS

2.1 Health and Safety Risks

BCIs have the potential to impact users’ physiological health and raise safety concerns. Existing research suggests that BCIs may cause some damage to the human body. MRI-based BCIs generate strong magnetic fields, potentially affecting neurological and cardiovascular functions (Birbaumer & Cohen, 2007). Steady-state visual evoked potential (SSVEP) BCIs may trigger epilepsy in long-term users (Bakardjian, Tanaka, & Cichocki, 2010). However, predicting these risks remains difficult due to ongoing technological development.

Additionally, the implantation of BCIs also presents safety issues. Although implanted devices are vital for capturing neuronal activity in invasive BCIs, the implantation procedure may inevitably disturb human tissue (Coin, Mulder, & Dubljević, 2020). During the implementation process, users may encounter various physical safety risks, including immune system rejection, infection of tissues, and blood vessels (Jawad, 2021).

Furthermore, the long-term effects of BCIs deserve attention. Prolonged neural compression from implanted BCIs may cause infections and glial injury (Schneider, Fins, & Wolpaw, 2012). Long-term BCI users may also experience brain plasticity issues, which could lead to irreversible effects (Tamburrini & Mattia, 2011). Over time, implanted components suffer from problems like corrosion, aging, and site movement, heightening the risk of malfunctions and errors (Hildt, 2011).

Security threats are another major issue. Computer hackers with technical expertise may hack into BCIs and manipulate users’ neural activity (Thompson, 2021). Given BCIs’ deep integration with the nervous system, cyberattacks could have severe consequences (Farahany, 2015).

2.2 Privacy Violation Issues

BCIs can extract sensitive information from users' brains, heightening concerns about privacy and data protection. They provide vast amounts of personal information, including health status, emotions, and personality traits (Lebedev & Nicolelis, 2011). Providers of BCIs may collect these data without users' awareness or consent, potentially for purposes beyond what was agreed (Vlek, et al., 2012). Research settings, especially in human trials of BCIs, could inadvertently expose private data (Klein, 2016). Moreover, remotely monitored chips in BCIs increase the risk of privacy breaches (McGee & Maguire, 2007).

Additionally, BCIs are vulnerable to cyberattacks, which can compromise personal data during storage or transmission (Schlaepfer & Fins, 2010). Direct transmission of brain signals to computers makes them susceptible to hacking. It has been shown that hackers may exploit BCIs to steal users' sensitive data, including PINs or bank details (Ienca & Haselager, 2016). Through technical means, hackers can directly infiltrate the neural processes of BCI users to extract confidential or sensitive information. With the increasing fidelity of BCI data, there is a potential risk of exposing more sensitive information (Müller & Rotter, 2017). Enhancing privacy protection has become an unavoidable issue in the advancement of BCIs.

2.3 Problems of Autonomy and Responsibility

BCIs also raise concerns about human autonomy, agency and responsibility. Algorithms in BCIs can analyze and influence users' emotions, thoughts, and decisions by processing vast neural data (Arendt, Scherr, & Romer, 2019). These issues become more pressing when BCIs autonomously modify algorithms through continuous, opaque processes (Reilly, 2020). The integration of intelligent algorithms and BCIs may blur the user's sense of agency, particularly when control shifts implicitly from the user to the intelligent device (Haselager, 2013). This uncertainty raises questions about whether actions performed through BCIs genuinely originate from the user's own thoughts or are influenced by algorithms (Aggarwal & Chugh, 2020). Similar ambiguity in tort and criminal cases could lead to significant controversy over the attribution of legal responsibility.

Additionally, "brain-hacking" threatens autonomy by allowing unauthorized monitoring or manipulation of psychological experiences (Yuste et al., 2017). Illicit interference with neural computations could alter users' decisions or even endanger their lives (Kellmeyer, 2021).

While concerns over BCIs are universal, regional responses are various based on cultural, legal, and social contexts. In the U.S., a strong tradition of individual rights shapes discussions on BCIs, emphasizing personal freedom, autonomy, and safeguards against misuse. The EU, guided by regulations like the General Data Protection Regulation (GDPR), prioritizes data protection and individual autonomy over personal data. China, characterized by rapid technological advancement and a focus on collective welfare, may seek a balance between individual rights and broader societal considerations in the development of BCIs.

2.4 Difficulties of Social Equality

In the near future, BCI research may shift towards enhancing human biological abilities, potentially exacerbating disparities in mental capacity, resource allocation, and social status (Nandwani et al., 2024). This raises the ethical challenge of balancing individual rights with the common good. Given the typical personal differences among BCI users, improvements for one user may not necessarily benefit others. As such, determining whether to allocate public resources for system upgrades could be challenging (Richman, 1989).

In this context, BCIs present unique challenges across different regions. In the U.S., the privatized healthcare system may exacerbate disparities in BCI access based on income, with wealthier individuals gaining early access to innovations (Chien, 2022). The EU's inclusive healthcare and education systems promote more equitable BCI distribution but require careful management of public funding. In China, disparities in BCI access may arise due to differences in urban and rural technological infrastructure.

3 CURRENT REGULATIONS OF BCIS

In response to these concerns, it is vital to assess if the current regulatory frameworks can handle the new risks of BCIs. Currently, direct regulation of BCIs remains limited, with most guidelines rooted in medical ethics. The U.S., the EU and China are the leading regions in BCIs regulation, indicating international trends in this area. The following sections will analyze their regulatory frameworks, highlighting key distinctions and potential deficiencies likely to arise from the evolving state of BCIs.

3.1 Regulation of BCIs in the U.S.

The regulation of BCIs in the U.S. operates at both federal and state levels, creating a decentralized and multi-layered framework.

At the federal level, multiple agencies share oversight responsibilities. The Food and Drug Administration (FDA) classifies BCIs as medical devices under Code of Federal Regulations (CFR), focusing on their safety and effectiveness. The Federal Trade Commission (FTC) monitors marketing practices under Section 5 of the FTC Act, aiming to prevent deceptive advertising related to BCIs (Blank, R. H., 2023). The Consumer Product Safety Commission (CPSC) primarily focuses on the physical safety of BCIs to ensure they do not pose harm to users. However, there is no specific federal regulations for BCIs, and the neural data can only be treated as conventional health data under Health Insurance Portability and Accountability Act (HIPAA). This oversight gap leaves users exposed to risks such as algorithmic manipulation and unauthorized neural data use (Bublitz, 2013).

State-level initiatives have introduced novel regulatory approaches. In 2021, Minnesota's House Bill No. 424 established neural rights in its amendment, banning cognitive manipulation and securing mental integrity (Minnesota State Legislature 2021). While aligning with emerging neuroethics research, the Bill lacks provisions for subconscious data extraction, third-party data use, and liability for device malfunctions. In 2024, Colorado amended its privacy act to include biological data,

such as neural data, within the category of sensitive data (Colorado General Assembly 2024). Unlike Minnesota's focus on cognitive manipulation, Colorado emphasizes commercial data governance, reflecting its tech-sector influence. However, its protections do not extend to non-commercial research BCIs and overlook the dual nature of neural data as both medical and behavioral information. While the regulations in Minnesota and Colorado exemplify state-level innovation, their narrow scopes underscore the need for federal harmonization.

Overall, BCI regulation in the U.S. remains fragmented. While state initiatives represent steps forward, their limited scope and enforcement challenges highlight the need for a national strategy that balances innovation with protections for human rights.

3.2 Regulation of BCIs in The EU

The EU's regulatory approach to BCIs is anchored in a layered legal framework that prioritizes data protection, human rights, and ethical accountability. Although there is no specific law for BCIs in Europe, various data protection regulations provide substantial protection for BCI users.

The Data Protection Directive (Directive 95/46/EC) set general rules for data privacy across both public and private sectors, laying the foundation for later data protection laws (Greenberg, 2019). In 2018, the General Data Protection Regulation (GDPR) replaced earlier frameworks, focusing on practical and comprehensive data protection (Kuner, 2012). The GDPR is crucial in protecting neural data, requiring risk assessments, informed consent, and greater control for users over their data. However, challenges remain. Neural data is not explicitly classified under the GDPR, creating interpretive difficulties since its sensitivity goes beyond conventional biometric data (Rainey et al., 2020). Anonymization, central to GDPR exemptions, does not fully address the risk of reidentification, as neural data often contains unique, traceable patterns (Finn et al., 2015, Dove & Phillips, 2015). Although anonymization techniques reduce the likelihood of information leakage, they do not fully ensure the safety and privacy of BCI users (Parker & Bull, 2015). This gap highlights the need for updated legal interpretations or additional guidelines to better align with neurotechnological developments.

Other regulations, such as the EU Charter of Fundamental Rights (CFR) and the European Convention on Human Rights (ECHR), protect privacy and autonomy, offering ethical safeguards against discriminatory or coercive BCI use. The Medical Devices Regulation (MDR) applies to BCIs considered medical devices, ensuring they meet safety and effectiveness standards. However, these rules remain fragmented, and greater regulatory harmonization within the EU could help balance innovation with rights protection.

In summary, EU regulations protect the data rights of BCI users, but lack tailored rules for neural data risks. Updated legislation or clearer legal interpretations are crucial for enhancing protection while promoting innovation in neurotechnology.

3.3 Regulation of BCIs in China

China's regulatory framework for BCIs encompasses personal data protection laws, biomedical regulations, and ethical guidelines, with the 2021 Personal Information Protection Law (PIPL) serving as the cornerstone.

Although the PIPL does not specifically mention neural data, it defines sensitive personal information as information that could threaten a person's dignity or safety if disclosed (Standing Committee of the Thirteenth National People's Congress of the People's Republic of China 2021). This definition logically includes neural data since it can reveal sensitive details like health status, religious beliefs, and emotions.

Based on this legal interpretation, neural data is subject to the most stringent protections under the PIPL, including mandatory explicit consent and enhanced security measures. However, obtaining meaningful consent from BCI users remains a challenge. BCIs often collect data passively and continuously, making it impractical to obtain repeated, explicit user approval over time. The PIPL requires clear disclosure of data usage, but real-time data processing in BCIs complicates transparency, as users may not fully grasp how their neural data is processed.

Furthermore, the PIPL requires transparency in automated decision-making and permits users to opt out. Yet, the real-time feedback systems in BCIs make it hard to distinguish between automated and human-driven decision-making. Additionally, withdrawing consent for automated functions may disrupt core BCI operations, limiting user control.

Beyond the PIPL, several medical laws partially apply to BCIs, such as the Biosecurity Law and the Measures for the Administration of the Clinical Usage of Medical Devices. The former mitigates biosecurity risks linked to BCIs, while the latter standardizes clinical protocols, ensuring safety and efficacy. Ethical guidelines, including the Guidelines for Ethical Research on Brain-Computer Interfaces, further emphasize human rights, risk minimization, and ethical compliance in BCI development.

Despite these measures, gaps persist. Regulatory fragmentation between data privacy, biomedical oversight, and ethical guidelines complicates enforcement. China's regulatory approach, while robust in structure, requires tighter alignment between data protection, ethical governance, and sector-specific regulations to balance innovation with fundamental rights.

3.4 Comparison and Analysis Of Regulation In Three Regions

Generally, the U.S., EU, and China each have region-specific regulations for BCIs. The most pertinent regulations from these regions are listed in Table 1.

Table 1. Key regulations related to BCIs in the U.S., the EU, and China		
Region	File Name	Main Content Related to BCIs
United States (U.S.)	Minnesota House Bill No. 424	It proposes a series of individual rights related to neurotechnology.
	Colorado Privacy Act (CPA)	It includes biological data, such as neural data, within the category of sensitive data.

	New York Assembly Bill 3196	It proposed a statewide pilot program for BCIs in homes.
	Code of Federal Regulations (CFR)	It classifies BCIs as medical devices and sets standards for their safety, effectiveness, and marketing.
	Federal Trade Commission Act	It regulates BCI marketing to prevent deceptive claims about safety, function, and benefits.
	Consumer Product Safety Act (CPSA)	It safeguards consumers from unreasonable physical risks associated with products, including BCIs.
	Health Insurance Portability and Accountability Act(HIPAA)	It ensures the privacy and security of neural data in healthcare applications.
	The Privacy Act	It ensures data protection and compliance in BCI regulation by governing personal information use.
	The American Data Privacy and Protection Act (ADPPA)	It could contribute to BCI regulation by setting strict data privacy and security standards for data processing.
European Union (EU)	Regulation (EU) 2018/1725 of the European Parliament and of the Council	It outlines the legal requirements for the processing of personal data, including neural data in BCIs.
	General Data Protection Regulation(GDPR)	It establishes the guidelines and standards for data protection within the EU, which are also applicable to neural data.
	The European Convention on Human Rights(ECHR)	It may influence BCI regulation by ensuring compliance with human rights standards, particularly regarding privacy, autonomy, and freedom from discrimination.
	Charter of Fundamental Rights of the European Union(CFR)	It can guide BCI regulation by ensuring ethical standards, fundamental rights protection, and legal accountability in neurotechnology use.
	EU Treaty	It offers a legal basis for harmonizing BCI regulation while ensuring ethical and data protection compliance.
	The Medical Devices Regulation (MDR)	It may play a key role in regulating BCI by ensuring safety, efficacy, and compliance with medical standards.
China	Personal Information Protection Law of the People's Republic of China(PIPL)	It can strengthen BCI regulation by enforcing strict data protection, consent requirements, and cross-border data transfer restrictions.

	Measures for the Ethical Review of Biomedical Research Involving Humans	It may be instrumental in BCI regulation by ensuring ethical oversight and protecting human participants.
	Measures for the Administration of Clinical Use of Medical Devices	It sets out guidelines and procedures for the clinical use of medical devices, including BCIs.
	Biosecurity Law of the People's Republic of China	It proposes a series of rules to prevent and address biosecurity risks, including those affecting BCIs.
	Opinions on Strengthening the Ethical Governance of Science and Technology	It outlines five ethical principles for new technology, including BCIs.
	Guidelines for Ethical Research on Brain-Computer Interfaces	It stipulates the basic principles and specific ethical rules of BCI researches.

Pertaining to the four legal aspects of BCIs in Part III, the U.S., the EU, and China have various regulation with distinct focuses. A detailed analysis of the table is presented as follows.

3.4.1 Safety Regulation

BCI regulations in the U.S., EU, and China reflect distinct legal priorities but share critical gaps. The U.S. maintains fragmented oversight through medical device and data protection frameworks, struggling to address the unique risks of neurodata. The EU's GDPR focuses on privacy through strict data limits but neglects dynamic neural interpretation challenges. China's state-driven governance emphasizes societal security through strict pre-market approvals. However, all regulations face key challenges. Users may not fully understand the risks of sharing neural data, making informed consent unreliable. Meanwhile, cross-border neural data transfers create legal loopholes, making accountability unclear. In addition, present approval systems fail to address risks from AI-driven updates after deployment. More importantly, current regulations treat BCIs as standalone devices rather than tools that reshape brain functions over time. To close these gaps, global cooperation is needed, combining flexible risk management with clear protections for neural data and human rights.

3.4.2 Privacy Protection

The U.S., the EU and China adopt distinct regulatory approaches to privacy protection in BCIs, each with systemic gaps. The U.S. relies on fragmented state-level laws, such as The Minnesota Bill, lacking a unified federal framework. This inconsistency leaves gaps in protecting neural data from corporate influence. The EU's GDPR enforces strict consent rules and broad data protections, but it does not explicitly classify neural data, limiting its effectiveness (Sommaggio et al., 2017). China's PIPL sets strict conditions for information processing, yet vague algorithmic oversight allows compliance loopholes. These gaps create risks in cross-border data transfers and user control. More critically, none of these systems fully address BCI-specific challenges, such as the sensitivity of real-time neural data, difficulties in securing meaningful

consent, and risks from dual-use neurotechnologies. Without stronger international cooperation and clearer regulatory measures, existing frameworks will struggle to protect neural privacy in this rapidly evolving field.

3.4.3 Individual autonomy

The U.S., EU, and China exhibit distinct approaches to BCI user autonomy. The U.S. prioritizes explicit neural rights through decentralized state laws, yet lacks federal coordination and clear enforcement measures. The EU grounds protections in human dignity under Article 3 CFR but offers no BCI-specific operational rules, relying ambiguously on GDPR's data principles. China's PIPL focuses on restricting automated decisions, framing user autonomy as data control under state-centred governance rather than neurocognitive liberty. All three systems share critical flaws: vagueness in defining technical compliance (e.g., neural data boundaries), weak enforcement against corporate exploitation, and reactive rather than preventive safeguards for emerging neurotechnological harms. They also fail to address real-time neural manipulation risks, favoring abstract rights over practical safeguards. A globally unified standard is needed—one that combines ethical clarity with strong enforcement to ensure both user autonomy and accountability in BCI governance.

3.4.4 Social equality

Regarding social equality issues in the field of BCIs, the U.S., the EU, and China have different governance approaches. The U.S. employs market-driven, sector-specific regulations, such as FDA oversight, which prioritize innovation but neglect disparities in access to cognitive enhancement. The EU emphasizes ethics in data protection, but inconsistent national policies weaken efforts to address BCI-related inequalities. China promotes fairness through state-led ethical guidelines, which, despite lacking enforcement tools, reflect a global pattern where non-binding guidelines outpace concrete legislation. Common critical gaps persist: reactive policy-making fails to address cost-driven access barriers. None of these systems effectively balance technological progress with fair access, increasing the risk of deepening socioeconomic divides as BCIs advance. Addressing these shortcomings requires proactive legal frameworks that prioritize equity, ensuring that neurotechnologies benefit all of society rather than reinforcing existing inequalities.

4 BCI REGULATION: A WAY FORWARD

Analyses of U.S., EU, and Chinese regulations suggest that current frameworks may not fully address the risks associated with BCIs. Effective management of emerging technologies requires a multi-dimensional approach (Hankin & Read, 2016), shifting from rigid 'command and control' strategies to 'responsive regulation' that allows for flexibility based on the specifics of the technology (Gunningham, 2012). Lessons from nanotechnology suggest that industry and civil society can proactively mitigate technological risks alongside governments (Malakar, Lacey, & Bertsch, 2022). In view of the collaborative governance model of nanotechnology, a regulatory toolbox

should be developed that integrates multiple regulators and tailored measures for BCIs.

4.1 Establishing BCIs regulatory toolbox

Regulation of BCIs needs to unite efforts from governments, industry, independent organizations, civil society, and international bodies. Therefore, a structured regulatory toolbox should be established, to bring together views from various stakeholders. The toolbox should focus on the following aspects.

4.1.1 Government Adaptability

Governments should prioritize enhancing the adaptability and foresight of regulatory frameworks. Given the rapid evolution and interdisciplinary nature of BCIs, the transition from static regulations to a dynamic framework is critical. Adaptive regulation, such as regulatory sandboxes, could balance innovation with risk assessment (Ranchordas & Vinci, 2024). Additionally, smart regulatory platforms using big data and AI can further enhance precision in monitoring technological changes (Zetzsche et al., 2017).

4.1.2 Industry Self-Regulation

The private sector plays a significant role through self-regulation and collaboration. Cross-industry alliances should be built to develop common standards and best practices for new technologies (Adobor, 2011). Incentive mechanisms, such as tax breaks for companies excelling in data privacy, can further promote adherence to ethical standards. Blockchain-based regulatory tracking also enhances transparency and ethical compliance (Allena, 2020).

4.1.3 Independent Institutions

Independent institutions, such as public-private research labs, can stress-test new BCIs for ethical and legal risks (Battisti, 2014). Additionally, independent ethical review bodies may also serve as neutral arbitrators in BCI-related disputes, developing standardized ethical assessment frameworks for evolving technologies. Responsible innovation agreements between independent institutions, companies, and governments should clearly define safety, accountability, and risk mitigation strategies (Voegtlin & Scherer, 2017).

4.1.4 Public Involvement

Civil society groups, including non-governmental organizations (NGOs) and advocacy groups, can push for regulation of BCIs through public opinion. These public groups also play a vital role in driving awareness and educating the public on BCI-related issues. They should actively provide diverse feedback in the early stages of BCI regulation, ensuring the latest standards reflect diverse social needs.

4.1.5 International Cooperation

International organizations could work together to establish a cross-border

neurotechnology regulatory network, reducing regulatory fragmentation and compliance gaps worldwide. Such regulatory networks should involve different countries to harmonize national standards and ensure ethical consistency (Verdier, 2009).

4.2 Regulation of Technical Safety

Ensuring technical security is a top priority in the development of BCIs, given their non-negligible impact on human health and vulnerability to cyberattacks.

4.2.1 Risk-Based Safety Evaluations

The regulation of BCIs should start with a risk-based approach, where safety evaluations are stratified based on the degree of invasiveness of BCIs. Invasive BCIs involving surgical implantation should be subject to the most stringent standards, followed by semi-invasive and non-invasive BCIs. Safety criteria must evolve with technological advances and clinical evidence. In addition, penalties should be commensurate with both the harm caused and the regulatory violations.

4.2.2 Lifecycle Security Regulation

To mitigate risks, safety oversight should extend across the entire technology lifecycle of BCIs, from the initial design phase to post-market surveillance. Strict protocols must be followed for safe operation and removal, while continuous safety monitoring is essential to address long-term effects of BCIs. Device providers must be prohibited from disabling devices without user consent, protecting against unauthorized manipulation or abandonment.

4.2.3 Self-Regulation on Algorithm Transparency

Industry associations should collaborate with regulators to establish safety and transparency standards for BCI algorithms. Regulators can mandate that BCIs providers should “label” their algorithms with key details such as provider information, technical standards, and data protection protocols (Yi, 2021). This approach improves traceability, reduces information asymmetry, and fosters accountability and trust.

4.2.4 Specialized Regulatory Agencies

Governments should establish dedicated regulatory bodies for BCIs, drawing from frameworks governing high-risk technologies, like the International Commission on the Clinical Use of Human Germline Genome Editing. These agencies would oversee certification, enforce adaptive safety standards, and conduct continuous risk assessments, ensuring ethical and technical compliance. By integrating interdisciplinary expertise, they can proactively address emerging challenges in BCI development and deployment.

4.2.5 Public Engagement and Oversight

A robust BCI regulatory framework necessitates proactive public engagement and

independent oversight. Establishing an interdisciplinary advisory body, akin to Google's Advanced Technology External Advisory Council (ATEAC), should integrate expertise from medicine, AI, neuroscience, law, and ethics. This institution should bring together a variety of professionals to assess the security levels and technical risks of BCIs in advance, and make recommendations on the application of BCIs accordingly.

4.3 Personal Information Protection

The expanding adoption of BCIs and the escalating volume of collected data underscore the pressing need for robust personal information protection. To address the new challenges, future BCIs regulations should focus on the following areas.

4.3.1 Standardized Information Processing Procedures

Governments should develop standardized procedures for processing personal information from BCIs. Parties processing this information should clearly disclose the purpose, method, and scope of data use and obtain explicit consent from users. For sensitive information like neural data, separate consent and official approval are required. Commercial use of neural data should be explicitly prohibited to prevent exploitation, and users should retain the right to withdraw consent at any time.

4.3.2 Classification of Neural Data

A structured classification of neural data is essential, categorizing it into public, general, and special data. Public data should follow predefined access protocols, while private data remains user-controlled. Based on the sensitivity of the data, private data can be further divided into general data and special data. Special data, which impacts personal dignity or security, requires stricter regulations. General data, with less risk, can follow standard protocols. In cases of public security threats, state access may be justified under stringent legal constraints.

4.3.3 Preventing Malicious Information Writing

Strict regulations must govern BCI data writing, requiring prior regulatory approval to activate this function. BCIs providers should implement continuous monitoring systems to detect and prevent malicious alterations. In addition, a traceability system for information writing should be established to track data input origins. Providers should encrypt the input data and submit regular reports to authorities to address any security threats promptly.

4.3.4 Industry-wide Standards and International Guidelines

Apart from formal regulations, soft tools can also provide a flexible approach to protecting users' rights. Multiple parties (e.g. BCIs developers, potential users, and research management organizations) should collaborate to establish industry-wide standards and clarify the responsibilities of all involved entities. A comprehensive self-regulatory system would ensure that BCIs operate within ethical and technical standards. Furthermore, international cooperation is vital in establishing shared ethical

norms for neurotechnology, facilitating global governance of this emerging field.

4.4 Safeguards for Informed Consent

Informed consent is a fundamental right that ensures individual autonomy, especially in the context of emerging technologies like BCIs. Regulation in this area should pay attention to the following aspects.

4.4.1 *Dynamic Informed Consent Systems*

As BCIs involve complex interactions between human cognition and machine intelligence, the associated risks must be disclosed to users before application. However, given the unpredictable nature of BCIs, a static consent model may fall short. A dynamic informed consent framework should be adopted, ensuring continuous user engagement. This model would provide real-time updates on technological changes, allowing users to reassess and reaffirm consent throughout the BCI lifecycle, thereby enhancing autonomy, transparency, and ethical oversight.

4.4.2 *Managing Expectations of BCI users*

A key aspect of informed consent is ensuring users grasp the full implications of BCI use. The current media overstatement has increased the public expectation of BCIs (Gilbert et al., 2019). To mitigate this risk, professionals, BCIs experts, and regulators should provide accurate information to correct misconceptions and facilitate informed decision-making. For those with cognitive impairments, authorized agents should be appointed to make decisions about the use of BCIs, mirroring ethical guidelines for human trials (Zeng, Sun, & Lu, 2021).

4.4.3 *Liability Frameworks for BCIs Infringements*

While informed consent is a preventive measure, it must also be backed by strong post-infringement liability frameworks. The complexities of neurotechnology, including unpredictable impacts and opaque BCIs algorithms, complicate liability allocation. To address these challenges, a classified review system should be developed to trace neural data and identify key points leading to infringements. Laws must clearly define standards for damages and penalties in BCIs-related cases, offering users multiple avenues for seeking justice and compensation.

4.4.4 *Ethical Committees and Policies*

Protecting informed consent requires adherence to ethical standards. BCIs manufacturers, developers, and clinical trial organizations should establish ethics committees to monitor compliance with ethical standards and policies. These committees would regularly review and update policies based on new ethical considerations (Marchant, Tournas, & Gutierrez, 2020). Appointing ethics officers within these organizations would ensure that the day-to-day operations of BCIs adhere to established ethical norms, promoting greater accountability (Adobor, 2006).

4.5 Guarantees of Equality in BCIs

Advancements in biotechnology are propelling BCIs beyond medical applications into human enhancement, raising ethical concerns about exacerbating social inequalities due to uneven access. Addressing these disparities necessitates comprehensive regulatory and policy interventions.

4.5.1 Government's Role in Ensuring Equality and Fairness

Governments are crucial in ensuring equal access to BCIs and safeguarding against unfair treatment. They should guarantee equal access to BCIs by implementing policies that promote broad availability, such as subsidies or public health programs for economically disadvantaged groups. Additionally, to combat algorithmic discrimination, governments should promote the reasonable disclosure of BCIs algorithms. This would help mitigate the “black box” problem by making algorithms more understandable, thereby reducing potential biases.

4.5.2 Public Policy for Fair Access to BCIs

Establishing robust public policies is crucial for ensuring the equitable and ethical deployment of BCIs. For instance, Spain's 2021 Charter of Digital Rights emphasizes universal access to digital technologies (The President of the Government of Spain 2021), a principle that should extend to BCIs to mitigate disparities among vulnerable groups. Policies should also enforce non-discriminatory BCI use in employment, education, and healthcare, preventing systemic biases in neurotechnology adoption.

4.5.3 Industry's Responsibility in Reducing Bias

Industry associations and professional societies should work to reduce algorithmic bias in BCIs. By establishing discrimination warning systems, industries can proactively identify and address potential biases in their algorithms. These systems would monitor for discriminatory outcomes and ensure fairness across different demographics, such as race, gender, and socioeconomic status. Additionally, industry associations could cooperate with third-party certification bodies to evaluate BCIs algorithms, granting certifications based on safety and fairness standards.

4.5.4 NGO and Media Oversight for BCIs Accountability

NGOs, think tanks, and journalists could serve as critical watchdogs in BCI ethics, scrutinizing corporate compliance with fairness standards. For example, NGOs could investigate how companies implement algorithms, whether they contribute to social disparities, and how they align with industry standards. Public oversight increases transparency and applies social pressure on companies to prioritize fairness and minimize inequalities in BCIs.

5 CONCLUSION

The rapid evolution of neurotechnology, driven by the big data revolution, has significantly accelerated the development of BCIs. However, this progress raises pressing ethical concerns, particularly in security, privacy, human agency, and social

equity. While BCIs present challenges that may seem futuristic, it is imperative for legal scholars to anticipate neurotechnological advancements and proactively propose regulatory solutions (Lawrence, Shapiro, & Fins, 2019). This study conducts a comparative analysis of BCI regulations in the U.S., EU, and China, revealing that existing frameworks are ill-equipped to mitigate emerging risks. A comprehensive, multi-stakeholder regulatory approach is essential, integrating government oversight, industry self-regulation, independent agencies, civil society engagement, and international cooperation. By prioritizing proactive governance, this research aims to foster interdisciplinary discourse and global collaboration, ensuring the ethical and sustainable development of BCIs.

ACKNOWLEDGMENTS

This research is supported by the MOE Frontier Science Center for Brain Science & Brain-machine Integration, Zhejiang University, Hangzhou, China.

REFERENCES

- [1] Adobor, H. (2006). Exploring the role performance of corporate ethics officers. *Journal of Business Ethics*, 69(1), 57–75. <https://doi.org/10.1007/s10551-006-9068-7>
- [2] Adobor, H. (2011). Alliances as collaborative regimes: An institutional based explanation of interfirm collaboration. *Competitiveness Review: An International Business Journal*, 21(1), 66-88. <https://doi.org/10.1108/10595421111106238>
- [3] Aggarwal, S., & Chugh, N. (2020). Ethical implications of closed loop brain device: 10-year review. *Minds and Machines*, 30(1), 145–170. <https://doi.org/10.1007/s11023-020-09518-7>
- [4] Allena, M. (2020). Blockchain technology for environmental compliance: Towards a “choral” approach. *Environmental Law Review*, 50(4), 1055–1103. <https://dx.doi.org/10.2139/ssrn.3456977>
- [5] Arendt, F., Scherr, S., & Romer, D. (2019). Effects of exposure to self-harm on social media: Evidence from a two-wave panel study among young adults. *New Media & Society*, 21(11-12), 2422-2442. <https://doi.org/10.1177/1461444819850106>
- [6] Bakardjian, H., Tanaka, T., & Cichocki, A. (2010). Optimization of SSVEP brain responses with application to eight-command brain–computer interface. *Neuroscience Letters*, 469(1), 34-38. <https://doi.org/10.1016/j.neulet.2009.11.039>
- [7] Battisti, S. (2014). Social innovation in living labs: The micro-level process model of public-private partnerships. *International Journal of Innovation and Regional Development*, 5(4–5), 328–348. <https://doi.org/10.1504/IJIRD.2014.064146>
- [8] Bernal, S. L., Celdrán, A. H., Pérez, G. M., Barros, M. T., & Balasubramaniam, S. (2021). Security in brain-computer interfaces: state-of-the-art, opportunities, and future challenges. *ACM Computing Surveys (CSUR)*, 54(1), 1-35. <https://doi.org/10.1145/3427376>
- [9] Birbaumer, N., & Cohen, L. G. (2007). Brain–computer interfaces: Communication and restoration of movement in paralysis. *The Journal of Physiology*,

579(3), 621–636. <https://doi.org/10.1113/jphysiol.2006.125633>

[10] Blank, R. H. (2023). United States policy on BCIs: Funding research, regulating therapies, and commercializing consumer technology. In V. Dubljević & A. Coin (Eds.), *Policy, identity, and neurotechnology: Advances in neuroethics* (Vol. 10, pp. 189-206). Springer. https://doi.org/10.1007/978-3-031-26801-4_11

[11] Bublitz, J. C. (2013). My mind is mine? Cognitive liberty as a legal concept. In E. Hildt & A. G. Franke (Eds.), *Cognitive enhancement* (pp. 233-264). Springer. https://doi.org/10.1007/978-94-007-6253-4_19

[12] Chen Y (2023). Research on the risks associated with BCI. *Theoretical and Natural Science*, 8(1), 253. <https://doi.org/10.54254/2753-8818/8/20240403>

[13] Chien, C. V. (2022). The Inequalities of Innovation. *Emory LJ*, 72, 1. <https://doi.org/10.2139/ssrn.3157983>

[14] China Electronics Standardization Institute 2021. Brain-computer interface standardization white paper 2021 edition. Retrieved March 16 2025 from <https://max.book118.com/html/2021/0825/7006000045003165.shtm>

[15] Chinese State Council 2017. A new generation of artificial intelligence development plan. Retrieved March 16 2025 from <https://flia.org/wp-content/uploads/2017/07/A-New-Generation-of-Artificial-Intelligence-Development-Plan-1.pdf>

[16] Coin, A., Mulder, M., & Dubljević, V. (2020). Ethical aspects of BCI technology: What is the state of the art. *Philosophies*, 5(4), 31. <https://doi.org/10.3390/philosophies5040031>

[17] Colorado General Assembly 2024. Colorado House Bill 24-1058. Retrieved March 18, 2025 from https://leg.colorado.gov/sites/default/files/2024a_1058_signed.pdf

[18] Dove, E. S., & Phillips, M. (2015). Privacy law, data sharing policies, and medical data: A comparative perspective. In D. A. Gkoulalas & G. Loukides (Eds.), *Medical data privacy handbook* (pp. 639–678). Springer. https://doi.org/10.1007/978-3-319-23633-9_24

[19] Farahany, N. A. (2015). Neuroscience and behavioral genetics in US criminal law: An empirical analysis. *Journal of Law and the Biosciences*, 2(3), 485-509. <https://doi.org/10.1093/jlb/lsv059>

[20] Finn, S. E., Huber, M., Rilling, J., Gollub, R., Griggs, R., Kosslyn, S., & Buckner, R. (2015). Functional connectome fingerprinting: Identifying individuals using patterns of brain connectivity. *Nature Neuroscience*, 18(11), 1664-1671. <https://doi.org/10.1038/nn.4135>

[21] Frégnac, Y., & Laurent, G. (2014). Neuroscience: Where is the brain in the Human Brain Project? *Nature*, 513(7516), 27-29. <https://doi.org/10.1038/513027a>

[22] Gilbert, F., Pham, C., Viana, J. N. M., & Gillam, W. (2019). Increasing brain-computer interface media depictions: Pressing ethical concerns. *Brain-Computer Interfaces*, 6(3), 49–70. <https://doi.org/10.1080/2326263X.2019.1655837>

- [23] Gordon, E. C., & Seth, A. K. (2024). Ethical considerations for the use of brain–computer interfaces for cognitive enhancement. *PLoS biology*, 22(10), e3002899. <https://doi.org/10.1371/journal.pbio.3002899>
- [24] Greenberg, A. (2019). Inside the mind’s eye: An international perspective on data privacy law in the age of brain-machine interfaces. *SSRN Electronic Journal*, 29, 79. <https://dx.doi.org/10.2139/ssrn.3180941>
- [25] Gunningham, N. (2012). Regulatory reform and reflexive regulation: Beyond command and control. In E. Brousseau, T. Dedeurwaerdere, & B. Siebenhüner (Eds.), *Reflexive governance for global public goods* (1st ed., pp. 85–104). MIT Press. <https://doi.org/10.7551/mitpress/9780262017244.003.0042>
- [26] Hankin, S. M., & Read, S. A. K. (2016). Governance of nanotechnology: Context, principles and challenges. In F. Murphy, E. McAlea, & M. Mullins (Eds.), *Managing risk in nanotechnology: Innovation, technology, and knowledge management* (pp. 29–49). Springer. https://doi.org/10.1007/978-3-319-32392-3_3
- [27] Haselager, P. (2013). Did I do that? Brain–computer interfacing and the sense of agency. *Minds and Machines*, 23(4), 405–418. <https://doi.org/10.1007/s11023-012-9298-7>
- [28] Hildt, E. (2011). Brain-computer interaction and medical access to the brain: Individual, social and ethical implications. *Studies in Ethics, Law, and Technology*, 4(3). <https://doi.org/10.2202/1941-6008.1143>
- [29] Human Brain Project 2023. Short overview of the Human Brain Project. Retrieved March 16, 2025 from <https://www.humanbrainproject.eu/en/about/overview/>
- [30] Ienca, M., & Haselager, P. (2016). Hacking the brain: Brain–computer interfacing technology and the ethics of neurosecurity. *Ethics and Information Technology*, 18(1), 117–129. <https://doi.org/10.1007/s10676-016-9398-9>
- [31] Jawad, A. J. (2021). Bioethics of medical devices based on brain computer interfaces (BCI). *Journal of Clinical Research & Bioethics*, 12(8), 1–3. <https://doi.org/10.35248/2155-9627.21.S8.003>
- [32] Justo, L., & Erazun, F. (2007). Neuroethics and human rights. *The American Journal of Bioethics*, 7(5), 16–18. <https://doi.org/10.1080/15265160701290272>
- [33] Kellmeyer, P. (2021). Big brain data: On the responsible use of brain data from clinical and consumer-directed neurotechnological devices. *Neuroethics*, 14(1), 83–98. <https://doi.org/10.1007/s12152-018-9371-x>
- [34] Klein, E. (2016). Informed consent in implantable BCI research: Identifying risks and exploring meaning. *Science and Engineering Ethics*, 22(6), 1299–1317. <https://doi.org/10.1007/s11948-015-9712-7>
- [35] Kuner, C. (2012). The European Commission’s proposed data protection regulation: A Copernican revolution in European data protection law. *Bloomberg BNA Privacy and Security Law Report*, 6(1), 1–16. <https://ssrn.com/abstract=2162781>
- [36] Lawrence, C., Shapiro, Z. E., & Fins, J. J. (2019). Brain-computer interfaces and

the right to be heard: Calibrating legal and clinical norms in pursuit of the patient's voice. *Harvard Journal of Law & Technology*, 33(1), 167–189. <https://jolt.law.harvard.edu/assets/articlePDFs/v33/04-Lawrence.pdf>

[37] Lebedev, M. A., & Nicolelis, M. A. (2006). Brain–machine interfaces: past, present and future. *TRENDS in Neurosciences*, 29(9), 536–546. <https://doi.org/10.1016/j.tins.2006.07.004>

[38] Lebedev, M. A., & Nicolelis, M. A. (2011). Toward a whole-body neuroprosthetic. *Progress in Brain Research*, 194, 47–60. <https://doi.org/10.1016/B978-0-444-53815-4.00018-2>

[39] Mak, J. N., & Wolpaw, J. R. (2009). Clinical applications of brain-computer interfaces: current state and future prospects. *IEEE reviews in biomedical engineering*, 2, 187–199. <https://doi.org/10.1109/RBME.2009.2035356>

[40] Malakar, Y., Lacey, J., & Bertsch, P. M. (2022). Towards responsible science and technology: How nanotechnology research and development is shaping risk governance practices in Australia. *Humanities and Social Sciences Communications*, 9(1), 17. <https://doi.org/10.1057/s41599-021-01028-w>

[41] Marchant, G., Tournas, L., & Gutierrez, C. I. (2020). Governing emerging technologies through soft law: Lessons for artificial intelligence—an introduction. *Jurimetrics*, 61(1), 1–18. <https://ssrn.com/abstract=3761871>

[42] McGee, E. M., & Maguire, G. Q. (2007). Becoming borg to become immortal: Regulating brain implant technologies. *Cambridge Quarterly of Healthcare Ethics*, 16(3), 291–302. <https://doi.org/10.1017/S0963180107070326>

[43] Minnesota State Legislature 2021. Minnesota House Bill 424. Retrieved March 18, 2025 from <https://legiscan.com/MN/text/HF424/id/2265099>

[44] Müller, O., & Rotter, S. (2017). Neurotechnology: Current developments and ethical issues. *Frontiers in Systems Neuroscience*, 11(1), 93. <https://doi.org/10.3389/fnsys.2017.00093>

[45] Musk, E. (2019). An integrated brain-machine interface platform with thousands of channels. *Journal of medical Internet research*, 21(10), e16194. <https://doi.org/10.2196/16194>

[46] Nandwani, R., Palanikumar, S., Singh, S. S., & Balading, J. M. (2024). Cognitive and Mobility Enhancement through Brain-Machine Interfaces and Neuroengineering. *Berkeley Pharma Tech Journal of Medicine*, 4(2), 22–42. <https://doi.org/10.52243/bptjm.v4i2.61>

[47] Naufel, S., & Klein, E. (2020). Brain–computer interface (BCI) researcher perspectives on neural data ownership and privacy. *Journal of Neural Engineering*, 17(1), 016039. <https://doi.org/10.1088/1741-2552/ab5b7f>

[48] Parker, M., & Bull, S. (2015). Sharing public health research data: Toward the development of ethical data-sharing practice in low- and middle-income settings. *The Journal of Empirical Research on Human Research Ethics*, 10(3), 217–224. <https://doi.org/10.1177/1556264615593494>

[49] Petoft, A., & Abbasi, M. (2020). Current limits of neurolaw: A brief overview.

- Médecine & Droit, 2020(161), 29-34. <https://doi.org/10.1016/j.meddro.2019.11.002>
- [50] Poo, M., Du, J., Ip, N. Y., et al. (2016). China brain project: Basic neuroscience, brain diseases, and brain-inspired computing. *Neuron*, 92(3), 591-596. <https://doi.org/10.1016/j.neuron.2016.10.050>
- [51] Rainey, S., Tully, M., Wise, R., & Ruck, K. (2020). Is the European data protection regulation sufficient to deal with emerging data concerns relating to neurotechnology? *The Journal of Law and the Biosciences*, 7(1), 1–19. <https://doi.org/10.1093/jlb/lsaa051>
- [52] Ranchordas, S., & Vinci, V. (2024). Regulatory sandboxes and innovation-friendly regulation: Between collaboration and capture. *Italian Journal of Public Law*, 16, 107. <https://doi.org/10.2139/ssrn.4696442>
- [53] Reilly, C. M. (2020). Brain-machine interfaces as commodities: Exchanging mind for matter. *The Linacre Quarterly*, 87(4), 387–398. <https://doi.org/10.1177/0024363920930882>
- [54] Richman, D. D. (1989). Public access to experimental drug therapy: AIDS raises yet another conflict between freedom of the individual and welfare of the individual and public. *The Journal of Infectious Diseases*, 159(3), 412–415. <https://doi.org/10.1093/infdis/159.3.412>
- [55] Rose, N. (2014). The Human Brain Project: Social and ethical challenges. *Neuron*, 82(6), 1212-1215. <http://dx.doi.org/10.1016/j.neuron.2014.06.001>
- [56] S. National Institutes of Health 2014. BRAIN 2025: a scientific vision. Retrieved March 15, 2025 from <https://acd.od.nih.gov/documents/reports/06052014report-BRAIN.pdf>
- [57] Schlaepfer, T. E., & Fins, J. J. (2010). Deep brain stimulation and the neuroethics of responsible publishing: When one is not enough. *JAMA*, 303(8), 775-776. <https://doi.org/10.1001/jama.2010.140>
- [58] Schmid, J. R., Friedrich, O., Kessner, S., & Jox, R. J. (2021). Thoughts unlocked by technology—a survey in Germany about brain-computer interfaces. *NanoEthics*, 1-11. <https://doi.org/10.1007/s11569-021-00392-w>
- [59] Schneider, M. J., Fins, J. J., & Wolpaw, J. R. (2012). Ethical issues in BCI research. In J. R. Wolpaw & E. W. Wolpaw (Eds.), *Brain-computer interfaces: Principles and practice* (pp. 373-383). Oxford University Press. <https://doi.org/10.1093/acprof:oso/9780195388855.003.0024>
- [60] Schönau, A., Dasgupta, I., Brown, T., Versalovic, E., Klein, E., & Goering, S. (2021). Mapping the dimensions of agency. *AJOB neuroscience*, 12(2-3), 172-186. <https://doi.org/10.1080/21507740.2021.1896599>
- [61] Shih, J. J., Krusienski, D. J., & Wolpaw, J. R. (2012, March). Brain-computer interfaces in medicine. In *Mayo clinic proceedings* (Vol. 87, No. 3, pp. 268-279). Elsevier. <https://doi.org/10.1016/j.mayocp.2011.12.008>
- [62] Si, X., Zhou, Y., Li, S., et al. (2023). Brain-computer interfaces in visualized medicine. In Z. Liu (Ed.), *Visualized medicine: emerging techniques and developing frontiers* (Vol. 1199, pp. 127-153). Springer.

https://doi.org/10.1007/978-981-32-9902-3_7

[63] Sommaggio, P., Mazzocca, M., Gerola, A., & Ferro, F. (2017). Cognitive liberty: A first step towards a human neuro-rights declaration. *BioLaw Journal*, 3, 27–45. <https://dx.doi.org/10.15168/blj.v0i3.255>

[64] Standing Committee of the Thirteenth National People's Congress of the People's Republic of China 2021. The Personal Information Protection Law of the People's Republic of China. Retrieved March 19, 2025 from https://nmca.miit.gov.cn/zwgk/zcwj/flfg/art/2021/art_0bb3c8d9e620423fb4deeb85e1b751c5.html.

[65] Tamburrini, G., & Mattia, D. (2011). Disorders of consciousness and communication: Ethical motivations and communication-enabling attributes of consciousness. *Functional Neurology*, 26(1), 51–54. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3814505>

[66] Tang, X., Shen, H., Zhao, S., et al. (2023). Flexible brain–computer interfaces. *Nature Electronics*, 6, 109–118. <https://doi.org/10.1038/s41928-022-00913-9>

[67] The President of the Government of Spain 2021. The Digital Rights Charter. Retrieved March 19, 2025 from https://citiesfordigitalrights.org/sites/default/files/140721-Carta_Derechos_Digitales_RedEs_compressed.pdf

[68] Thompson, K. (2021). Committing crimes with BCIs: How brain - computer interface users can satisfy actus reus and be criminally responsible. *Neuroethics*, 14(Suppl. 3), 311 - 322. <https://doi.org/10.1007/s12152-019-09416-5>

[69] U. S. National Institutes of Health 2019. BRAIN 2.0 neuroethics: enabling and enhancing neuroscience advances for society. Retrieved March 15, 2025 from <https://braininitiative.nih.gov/vision/nih-brain-initiative-reports/brain-20-neuroethics-enabling-and-enhancing-neuroscience>

[70] Verdier, P. H. (2009). Transnational regulatory networks and their limits. *Yale Journal of International Law*, 34(1), 113. <https://ssrn.com/abstract=1333201>

[71] Vidal, J. J. (1973). Toward direct brain-computer communication. *Annual review of Biophysics and Bioengineering*, 2(1), 157–180. <https://doi.org/10.1146/annurev.bb.02.060173.001105>

[72] Vlek, R. J., Steines, D., Szibbo, D., et al. (2012). Ethical issues in brain–computer interface research, development, and dissemination. *Journal of Neurologic Physical Therapy*, 36(2), 94–99. <https://doi.org/10.1097/NPT.0b013e31825064cc>

[73] Vlek, R., van Acken, J. P., Beursken, E., Roijendijk, L., & Haselager, P. (2014). BCI and a User's Judgment of Agency (pp. 193–202). Springer Netherlands. https://doi.org/10.1007/978-94-017-8996-7_16

[74] Voegtlin, C., & Scherer, A. G. (2017). Responsible innovation and the innovation of responsibility: Governing sustainable development in a globalized world. *Journal of Business Ethics*, 143(1), 227–243. <https://doi.org/10.1007/s10551-015-2769-z>

- [75] Wang, J., Wang, T., Liu, H., et al. (2023). Flexible electrodes for brain-computer interface system. *Advanced Materials*, 35(47), 2211012. <https://doi.org/10.1002/adma.202211012>
- [76] Willett, F. R., Avansino, D. T., Hochberg, L. R., Henderson, J. M., & Shenoy, K. V. (2021). High-performance brain-to-text communication via handwriting. *Nature*, 593(7858), 249-254. <https://doi.org/10.1038/s41586-021-03506-2>
- [77] Yi, J. (2021). Law and accountability in the age of digital twinning. *Oriental Law*, 4, 90.
- [78] Yuste, R., et al. (2017). Four ethical priorities for neurotechnologies and AI. *Nature*, 551(7679), 159-163. <https://doi.org/10.1038/551159a>
- [78] Zeng, Y., Sun, K., & Lu, E. (2021). Declaration on the ethics of brain-computer interfaces and augment intelligence. *AI Ethics*, 1, 209–211. <https://doi.org/10.1007/s43681-020-00036-x>
- [79] Zetzsche, D. A., Buckley, R. P., Barberis, J. N., & Arner, D. W. (2017). Regulating a revolution: From regulatory sandboxes to smart regulation. *Fordham Journal of Corporate & Financial Law*, 23(31), 91–98. <https://doi.org/10.2139/SSRN.3018534>

The Logical Foundation of the Basic Principles of Criminal Law

Wen Jianhui

School of Literature and Law, Tianjin University of Science and Technology, Tianjin, China, 1067788748@qq.com

Abstract

The principle of the law of crimes and punishment, the principle of equal application of criminal law and the principle of appropriateness of crime and punishment have their logical foundations in the law of sameness, the law of non-contradiction and the law of excluded middle at the macroscopic, mesoscopic and microscopic levels, respectively, to lay down their status as the guiding principles of the administration of justice. The principles derived from the three basic principles of criminal law also have their own logical foundations and guide practice in their respective jurisdictions. The basic principles of criminal law are closely aligned with the "three publics" principle of social governance; the three basic principles of criminal law take the three laws of logic as their common logical foundation; the three basic principles of criminal law can be summarized in a single sentence: applying the legal mix of crime and punishment equally to all offenders. The logical formula is: $(P \leftrightarrow \neg C) \rightarrow (P \leftrightarrow \neg C)$, which is the general logical formula of the basic principles of criminal law.

Keywords

basic principles of criminal law; principle of legality of crimes and penalties; principle of equal application of criminal law; principle of appropriateness of punishment and crime.

Law is the bottom line of morality, and logic is the bottom line of law. In this view, the bottom line of criminal justice is legal logic, and revealing the underlying logic of the basic principles of criminal law is an important cornerstone for the construction of legal logic, especially criminal law logic, however, the theoretical exploration of explaining the basic principles of criminal law from the perspective of logic is still insufficient. This paper attempts to consolidate the logical foundation of the basic principles of criminal law, to promote the application of logic in jurisprudence and the development of legal logic, to advance the value-oriented jurisprudence characterized towards the legal science underpinned by necessity and objective law, to provide high-quality legal knowledge corpus for the

development of the judicial scene of artificial intelligence, and to add bricks and mortar to the construction of China under the rule of law. In judicial practice, mastering the logical anchor of the basic principles of criminal law, it is possible to class line miscellaneous, easy, and better play the guiding role of the basic principles of criminal law.

1 Logical roots of the generation of fundamental principles of criminal law

Logical thinking manifests three regularities in the subjective world, namely, the law of identity, the law of contradiction and the law of exclusion, which are collectively known as the three basic laws of logical thinking. Criminal law, at the macro, meso and micro levels, is based on the three laws of logic and has formed its own three basic principles.

1.1 The principle of legality as an incarnation of the same law

In the macroscopic world of thinking, the same law is necessarily followed. In the practice of the rule of law in criminal matters, the macroscopic world of thinking, for all people in the whole society, the principle of the legality of crime and punishment is the basic principle, which is the treasure of the law-abiding citizens and the talisman of the criminals. So, in the macroscopic world, the principle of the law of crime and punishment and the same law have any relationship, and what is the relationship?

1.1.1 *Consistency of the principle of legality with the same law*

Statutory definition of crime. Article 3 of China's Criminal Law provides that If a crime is expressly provided for by law, it shall be criminalized and sentenced in accordance with the law ; if a crime is not expressly provided for by law, it shall not be criminalized and sentenced. This is the provision of China's criminal law on the principle of legality of crime and punishment. "The law expressly provides for the commission of crimes", this sentence indicates that whether or not constitute a crime is the criminal law legislation; "in accordance with the law conviction and punishment", this sentence indicates that criminal justice should be in accordance with the provisions of the criminal law conviction and punishment. The provisions of the Criminal Law on crime are a generalization, including basic crime, aggravated crime, mitigated crime, preparatory crime, attempted crime, suspended crime, accomplished crime, principal crime, accessory crime, coerced crime, abettor, and one crime or several crimes. The sum total of judicial convictions for various types of harmful acts should be fully consistent with the criminal law profiles. The crime profile (C) of the legislative crime is the

standard for determining the various specific crimes (C) of the judicial crime, and the legislative crime and the judicial crime have the inherent consistency, whose logical formula is: $C=C$.

Legalization of penalties. The language of criminal law is simple and concise and needs to be understood accurately and comprehensively. Article 3 of the Penal Code stipulates that criminal justice activities should be based on the standard of criminal legislation, the meaning of which is clearly that the crime of legislation (C) is the criterion for the determination of the crime of justice (C), which is the law of crime, so does the meaning of this provision contain the law of the penalty, and that the legal penalty of legislation (P) is the criterion for the determination of the judicial penalty of the sentence of the pronounced penalty (P)? Split from the sentence "convicted and sentenced in accordance with the law", "sentenced in accordance with the law" should be understood to include the legal penalty. The legal penalty for a crime under criminal law is a combination of one or more types and degrees of punishment. The application of penalties to criminals in judicial trials consists of two types of cases, one of which is the direct application of penalties in accordance with the legal penalties prescribed by the criminal law for crimes, and the other is the determination of specific penalties in accordance with the rules set out in the criminal law. The total range of judicially applicable penalties for a crime and the range of legal penalties stipulated in the criminal law should be fully equivalent. The logical formula for the legalization of penalties, that is to say, the penalties applicable to criminals in criminal justice must be those stipulated in the criminal law legislation, is: $P=P$.

The principle of legality of crimes and penalties realizes the characterization of the act. The statute of punishment is divided into two cases, one of which is the configuration of punishment for the crime of legislation, and the other is the statutory punishment is linked to the crime of legislation through the rules of criminal law, both of which cannot be separated from the crime of legislation, demonstrating that the crime of legislation is the anchor of the punishment, and that the crime and the statutory punishment appear together as a crime-penalty collocation with the logical formula $C \wedge P$. In the practice of the rule of law of the criminal law, the crime and the punishment ($C \wedge P$) are closely linked and inseparable, and the crime of legislation (C) and legislative punishment (P) of the crime and punishment configuration has a certain range, so that it has a greater adaptability; judicial crime (C) and judicial punishment (P) of the crime and punishment match with certainty, to facilitate the

execution of punishment. From the range of the legislative crime-penalty configuration to the determination of the judicial crime-penalty match, it always follows the logical path that the legislative crime-penalty configuration determines the judicial crime-penalty match, with the logical formula: $(C \wedge P) \rightarrow (C \wedge P)$, which is the logical formula of the principle of the legality of the crime-penalty.

The law of identity is one of the basic laws of formal logic, which means that in the same thinking process, concepts and judgments must be used in the same sense and cannot be used in different senses. The law of identity aims to maintain the certainty of thinking. The law of identity includes the identity of concepts and the identity of judgments. Using a concept in the same sense means $A = A$; using a judgment in the same sense means $p \rightarrow p$. The identity of crime ($C = C$) and the identity of punishment ($P = P$) in the principle of legality of crimes and punishments are essentially the same as the identity of concepts ($A = A$) in the law of identity; the identity of crime and punishment ($C \wedge P \rightarrow C \wedge P$) in the principle of legality of crimes and punishments is actually equivalent to the identity of judgments ($p \rightarrow p$) in the law of identity. It can be seen that in legal logic, the principle of legality of crimes and punishments is essentially equivalent to the law of identity, and the principle of legality of crimes and punishments is the expression of the law of identity in criminal law, with its underlying logic being $(C \wedge P) \rightarrow (C \wedge P) \Leftrightarrow (p \rightarrow p)$.

1.1.2 *Logical error in violation of the principle of legality of crime and punishment*

In criminal justice, any violation of the principle of legality of crime and punishment is a violation of the same law, because in the underlying logic, the principle of legality of crime and punishment is equivalent to the same law. A violation of the principle of legality of crime and punishment is primarily a violation of the legality of crime ($C \neq C$) or a violation of the legality of punishment ($P \neq P$). For example, Criminal Trial Reference No. 310, the case of Sun Jing's intentional destruction of property. Sun Jing took advantage of her position to fraudulently obtain more than 320,000 copies of the company's dairy products and disposed of most of the fraudulently obtained dairy products by feeding them to pigs. Sun Jing used his position, cheated the company's property, should be recognized as the crime of misappropriation, and subsequent behavior is the handling of stolen goods, does not have a separate evaluation significance. And the behavior of dairy products for pigs, is a use of property, just too extravagant waste, but does not belong to the intentional destruction of property behavior, does not have the significance of criminal law evaluation. Therefore,

the charge prosecuted in this case (the crime of misappropriation of duties) was correct, but the charge (the crime of destroying property) and the reason for the trial court's decision did not conform to the objective reality and violated the principle of the law of crime and punishment. The court in this case put the charge in a confused way, failing to convict for acts that constituted a crime and attaching a charge to acts that did not constitute a crime, in violation of the same law.

In the field of criminal law logic, anything that violates the same law is a violation of the principle of legality of crime and punishment, because in legal logic, the principle of legality of crime and punishment is the incarnation of the same law. For example, after the Shaoxing peace conference in 1141 A.D., Qin Hui instigated his cohort Wan Qi Seol to present to the Song Emperor a fabrication of Yue Fei's resistance to the Jin Dynasty when he embraced the troops not to save, abandonment of positions and many other "crimes" of the report. After that, qin hui and then buy Zhang junk, Wang Gui, Wang Jun to falsely accuse Yue Fei son of Yue Yun had written to Zhang Xian want to start a mutiny with. Shaoxing eleven years in September, Zhang Xian was arrested and imprisoned; October Yue Fei and Yue Yun were also arest and imprisonment. Has resigned from the home, the old general Han Shizhong cannot help, go to ask Qin Hui Yue Fei what crime, Qin Hui brashly replied: "Yue Fei' son Yun and Zhang Xian book is not clear, the matter is not necessary?" Han Shizhong said angrily: "groundless ' three words, how to convince the world!" According to Qin Hui's authorization, Yue Fei's three men were soon sentenced to death. ^[1] Yue Fei was murdered in Hangzhou's Wind Pavilion the night before the Spring Festival in the 12th year of Shaoxing (1142). In this famous historical case, Yue Fei's father and son did not commit the criminal act of mutiny and rebellion, but they were charged with " unfounded crimes", which violated the same law and the principle of the law of criminal punishment.

1.2 The principle of equal application of criminal law is the same as the non-contradictory law

In the interconnected and comparative world of mesoscopic thinking, the law of non-contradiction is followed. In the practice of the rule of law in criminal matters, the principle of equal application of criminal law is the norm for offenders from a mesoscopic point of view. The principle of equal application of criminal law and the law of non- contradiction belong to the mesoscopic world. Is there any relationship between the principle of equal application of criminal law and the law of non-contradiction and what is the relationship?

1.2.1 **Fitting of the principle of equal application of criminal law with the law of non-contradiction**

Article 4 of our Criminal Code provides that all persons who commit a crime are equal in the application of the law. No one is allowed to have privileges beyond the law. This is China's criminal law provisions on the principle of equal application of criminal law, which is also traditionally referred to as "the prince commits the same crime as the common people", whose most basic implication is that the same crime is subject to the same punishment, the same case is sentenced to the same penalty, and the same case is not allowed to exist different penalty, and the $C \wedge P$ denotes the crime profiles and legal penalties stipulated in the legislation, and the judicial conviction and sentence can realize the equal application of criminal law only by taking the crime-penalty configurations stipulated in the legislation as the standard. The principle of equal application of criminal law can only be realized by taking the configuration of crime and punishment as the standard, and by using $\neg(C \wedge P)$ to indicate that the specific crimes judicially sentenced and the sentences pronounced have not been based on the profiles of crimes and statutory penalties stipulated in the criminal law as the standard. The logical formula of the principle of equal application of criminal law is: $\neg((C \wedge P) \wedge \neg(C \wedge P))$. The principle of equal application of criminal law embodies judicial fairness, that is, "the prince commits the same crime as the common people", and its scope of application is mesoscopic.

The law of non-contradiction, which is also one of the fundamental laws of formal logic, is that two contradictory or opposing concepts cannot be used at the same time to refer to the same object in the same thought process; nor can one conclude both what an object is and what it is not. The law of non-contradiction aims to maintain consistency in thinking. The formula of the law of non-contradiction at the conceptual level is: $A \neq \neg A$, and at the judgment level is: $\neg(P \wedge \neg P)$. It is obvious that the principle of equal application of criminal law is the formulaic expression of the law of non-contradiction of logical thinking at the level of judgment.

1.2.2 *Logical error in the violation of the equal application of criminal law*

From the perspective of the materialistic view of history, looking dialectically at the law of the application of penalties, looking at human history, and looking at both domestic and foreign countries, in slave and feudal societies, the ruling class enjoyed the criminal justice policy of "lenient and light", while the ruled class suffered from the criminal justice policy of "strictly

And severely "This is an open and systematic inequality in the administration of justice. [2] The principle of hierarchical privilege in China's feudal criminal law is most centrally embodied in the Eight Discussions, but it is not limited to the scope of the Eight Discussions; for example, respectability and inferiority in blood and in status can be punished by different penalties for the same crime. [3] and to this day, due to a variety of reasons, the same case is still a large number of different judgments, which seriously jeopardizes the authority of the socialist rule of law in our country and undermines the people's sense of fairness. 2023 the first half of the year, the national court concluded 545,000 cases of first instance criminal cases, the first instance of criminal conviction rate of 88.68%, the first instance of criminal adjudication has been changed and remanded for re-trial rate of 1.65%. [4] Reversal and remand rate Although the rate is only 1.65%, the number is still 8,993, involving many people and many families, which is enough to draw our attention. If a case has been dealt with fairly and impartially in the first trial, the case will not be re-sentenced in the second trial or remanded for retrial; whereas a first trial judgment being re-sentenced in the second trial or remanded for retrial indicates that it must exist the result of a concurrent judgment in the logical form of $(C \wedge P) \wedge \neg(C \wedge P)$, which obviously violates the law of non-contradiction. The rate of second-instance corrections and remands reflects the number of corrected disparate verdicts in similar cases, and in fact the total number cases will be greater than the number of corrected disparate verdicts in similar cases.

1.3 The principle of proportionality between crime and punishment is implicitly linked to the law of excluded middle

1.3.1 Fitting of the principle of proportionality of crime and punishment with the law of excluded middle

In the world of micro thinking, which reflects on the internal contradictions of individuals, the qualitative analysis of things follows the law of the middle of the row. In the criminal trial, from the micro point of view, for the offender, the principle of appropriateness of crime and punishment is the sublate of the crime and the resolution of the contradictory relationship between crime and punishment. The principle of appropriateness of crime and punishment belongs to the same microcosm as the law of the center, so is there any relationship between the principle of appropriateness of crime and punishment and the law of the center, and what is the relationship?

Article 5 of China's Criminal Law stipulates that the severity of the penalty should be

commensurate with the crime committed and the criminal responsibility borne by the offender. This is the principle of appropriateness of crime and punishment under China's Criminal Law, which is also referred to by some as the principle of appropriateness of crime and responsibility. The provisions of the criminal law on crime are a generalized provision, including the form of criminal constitution, the form of crime stop, the form of complicity, as well as the form of the number of crimes and other situations, the configuration of the legal penalty for the crime is also one or a number of types of penalties and penalties of the combination. The application of criminal law in a criminal trial is not to configure a suitable penalty for a crime, but to choose to determine a specific crime and to fit a determined sentence among the crime profiles and legal penalty ranges stipulated in the criminal law. The principle of appropriateness of crime and punishment requires that the judiciary must choose to apply an appropriate combination of crime and punishment to criminals in terms of their crime and criminal responsibility among the ranges of crime and punishment stipulated in the criminal law, with $(P \leftrightarrow \neg C)$ ^[5] denoting an appropriate combination of crime and punishment, and $\neg(P \leftrightarrow \neg C)$ denoting the other combinations of crime and punishment. The meaning of the principle of appropriateness of crime and punishment is that, select $(P \leftrightarrow \neg C)$ in the case of $(P \leftrightarrow \neg C) \vee \neg(P \leftrightarrow \neg C)$, the logical formula of which is: $(P \leftrightarrow \neg C) \vee \neg(P \leftrightarrow \neg C) \vdash (P \leftrightarrow \neg C)$.

The law of excluded middle means that two mutually exclusive ideas cannot be false at the same time, one of them must be true. It is usually expressed as A or $\neg A$, or symbolized as $A \vee \neg A$. From the logical structure, it can be seen that the logical constants of the law of exclusion and the principle of appropriateness of punishment and crime are the same, i.e., both of them have the same logical nature. In other words, the principle of appropriateness of crime and punishment is implied in the law of exclusion, and the principle of appropriateness of crime and punishment is the inevitable requirement of the law of exclusion in the application of criminal law. In criminal justice, the principle of appropriateness of crime and punishment can be realized only if the requirements of the Law of Exclusion are logically complied with. The principle of appropriateness of crime and punishment embodies judicial justice and is used to solve the problem of quantitative criminal responsibility, and its scope of application is microscopic. Relative to the law of exclusion, the principle of appropriateness of crime and punishment has a richer connotation. In the conviction and sentencing of specific crimes in specific cases, impunity, light punishment for serious crimes, heavy punishment for minor crimes, and acquittal verdict are all cases of inappropriate sentencing, which violate the principle of appropriateness of crime and punishment, as well as the law of excluded middle,

is logically incorrect.

1.3.2 Logical error in violation of the principle of proportionality of crimes and penalties

The logical error of one-sided preventionism. The principle of proportionality requires that, in the administration of criminal justice, criminals must be subjected to penalties appropriate to the crimes they have committed and to their criminal responsibility. In the context of preventivism, there is a tendency to apply heavier penalties to make an example of a person in order to prevent the occurrence of crime in society. We label the heavier penalty as P^+ , then the logical formula for applying heavier penalty to a crime is $C \wedge P^+$, in which the penalty applied to the criminal is to suffer on behalf of others. Obviously, one-sided preventionism in the application of penalties is contrary to the result $(P \leftrightarrow \neg C)$ of applying penalties in accordance with the principle of appropriateness of crime and punishment. This result is labeled $\neg(P \leftrightarrow \neg C)$, then the actual reasoning process is: $(P \leftrightarrow \neg C) \vee \neg(P \leftrightarrow \neg C) \vdash \neg(P \leftrightarrow \neg C)$.

The logical error of one-sided leniency in the lightening of penalties. The criminal justice policy of "leniency and severity" is a helpless move of the relative lagging behind of the legal system of the society in the transition period; with the civilized progress of the society tending to be harmonious and smooth, the leniency of punishment will become a trend, and the criminal justice policy of "leniency and severity" will be the direction of the evolution of the paradigm of the criminal policy. The criminal justice policy of "lenience and light" will be the direction of evolution of the criminal policy paradigm.^[2] In the judicial trend of lighter penalties, we need to be vigilant against the indulgence of criminals. We mark the application of lighter penalties to criminals as P^- , then the logical formula for the application of lighter penalties to crimes is $C \wedge P^-$, in which the lighter penalties applied to criminals are not only suspected of indulging criminals, but also in danger of encouraging crimes. It can be seen that the leniency of the application of one-sided penalties is not compatible with the result of the application of penalties in accordance with the principle of the appropriateness of crime and responsibility $(P \leftrightarrow \neg C)$, marked $\neg(P \leftrightarrow \neg C)$, then the logical reasoning of the application of this criminal law is: $(P \leftrightarrow \neg C) \vee \neg(P \leftrightarrow \neg C) \vdash \neg(P \leftrightarrow \neg C)$.

2 Logical basis of the principle of derivation of the fundamental principles of criminal law

The fundamental principles of criminal law have their derivatives. The basic principles have their logical foundation, and the derived principles also have a logical basis. A logical analysis of the principles derived from the basic principles of criminal law will help to provide a thorough understanding of the basic principles of criminal law and to highlight the guiding significance of the basic principles of criminal law.

2.1 Logical basis of the principle of derivation of the principle of legality

2.1.1 No crime without law, no punishment without law

The maxim "Nullum crimen sine lege, nulla poena sine lege", first expressed in Latin by Feuerbach, the father of modern criminal law, in his textbook on criminal law in 1801, is a maxim and a classic expression of the principle of legality of crimes and penalties, i.e., as long as there is no provision for the enactment of a law, there is no crime and no penalty. Legislation has stipulated that the behavior is a crime recorded as C, the law does not expressly provide that it is a crime recorded as $\neg C$, then, because the law does not expressly stipulate that the behavior is a crime, the judiciary cannot be recognized as a crime, the logic of the form: $\neg C \neq C$; legislation has stipulated that the legal penalty is recorded as P, the law does not expressly stipulate that the penalty is recorded as $\neg P$, then, because the law does not expressly stipulate the legal penalty, the judiciary cannot be sentenced to the penalty, the logic of the form: $\neg P \neq P$.

It can be seen, logically, "no crime without express provisions of the law, no punishment without express provisions of the law", expresses the basic meaning of the principle of criminal justice, is the principle of criminal justice in the "concept of the same" another way of expression, and does not contain the "judgment of the same" aspect of the meaning, therefore, "no crime without express provisions of the law, no punishment without express provisions of the law" is not the full meaning of the principle of criminal justice, will call it the principle of criminal justice. The meaning of "the same judgment" is not included. Therefore, "no crime without express provisions of the law, no punishment without express provisions of the law" is not the full meaning of the principle of the statute of limitations on crimes and punishments, and it is not appropriate to call it the classic expression of the principle of the statute of limitations on crimes and punishments, but rather the early expression of the principle of the statute of limitations on crimes and punishments. It is not appropriate to call it the classic expression of the principle of legality of crime and punishment, but rather an early expression of the principle.

2.1.2 The principle of prohibition of criminalization by analogy

Criminal analogy is for the law does not punish the express provisions of the criminal behavior, with the method of inference, than attached to invoke the nature of its behavior is similar to the law, and then convicted and sentenced. In the slave society and feudal society criminal analogy had been widely applied, is the ruling class used to crime and punishment of an important authority. Ancient Chinese criminal law has "than attached to invoke", that is, similar to the provisions of analogical reasoning. The Han Book- criminal law, the Han emperor ordered the court lieutenant encountered difficult cases cannot judge, to be the case and the reference law on the report. But only limited to doubtful prisons. By the Sui Dynasty, it became the tradition, and was carried on until the end of the Qing Dynasty and the beginning of the Republic of China. China's criminal legislation in the late Qing Dynasty and the early Republic of China, by the influence of European capitalist countries legislation, in the criminal law in the abolition of the principle of analogy. Although there were repeated attempts, the criminal law of 1997 abolished the analogy system and explicitly replaced it with the principle of legality of punishment. The reason why the analogical system was abolished, because the analogical conviction is analogical reasoning, and analogical reasoning is contingent reasoning, its conclusion does not have the inevitability, [6] that is, according to the analogical reasoning that the crime C_2 , is not necessarily the same as the criminal law of the crime C_1 , which violates the law of the same, and its logical formula: $C_1 \neq C_2$, the prohibition of the principle of the analogical conviction of the logic of the formula is: $\neg(C_1 = C_2)$.

2.1.3 Prohibition of the retroactive application of legislation

The principle of prohibition of retroactive application of new laws means that a new law may not be applied retroactively to acts that have not been tried or judged before its application, unless the application of the new law is more favorable to the perpetrator. In the old criminal law, there were acts that were not criminalized (denoted as $\neg C$), and there were acts that were criminalized and assigned statutory penalties (denoted as $C \wedge P$), while in the new criminal law, the same acts are criminalized or even more serious crimes and assigned heavier statutory penalties (denoted as $C^+ \wedge P^+$), then the logical formula of the principle of prohibition of retroactivity is: $\neg(C^+ \wedge P^+)$.

If the effect of felony law is allowed to be retroactive, then it will result in the act which is not stipulated as a crime in the criminal law being convicted and punished, or the act which is

stipulated as a misdemeanor in the criminal law being found to be a felony and punished with a heavier penalty, which can be seen in the logical process of retroactivity of felony law as $\neg C \vee (C \wedge P) \vdash (C^+ \wedge P^+)$. Obviously, this is untenable, because the antecedent does not contain the variant of the consequent, and it cannot be deduced at all. Therefore, re-law retroactivity cannot be logically established.

2.1.4 Prohibition of extrajudicial criminalization and extrajudicial sentencing

The law of crime is recorded as C , and extrajudicial incrimination is recorded as $\neg C$. Then, extrajudicial incrimination creates the situation of $C \wedge \neg C$, which is obviously logically undesirable. The logical form of prohibiting extrajudicial incrimination is: $\neg(C \wedge \neg C)$. The legal form of punishment is P , and extrajudicial punishment is $\neg P$. Then, extrajudicial punishment creates the situation of $P \wedge \neg P$, which is obviously and logically incorrect. The logical form of extrajudicial punishment is: $\neg(P \wedge \neg P)$. In ancient China, in addition to the formal provisions of the legal code, there were extrajudicial punishments, such as "relocation", "charging", "dispatch", "lynching" and "death by lynching". "In the Tang Dynasty and the subsequent dynasties, the legal death penalty was expressly provided for only by hanging and beheading, but as an extrajudicial torture, lynching has been used since the Song Dynasty, until the end of the Qing Dynasty when lynching was abolished. [7] Extrajudicial incrimination and extrajudicial use of punishment are, logically, contradictory to justice and the law, and cannot be justified.

2.2 Logical basis for the equal application of the principle of derivation of criminal law

2.2.1 Prohibition of sentencing on the basis of the person

Throughout human history, members of the ruling class in hierarchical societies have enjoyed a criminal justice policy of "lenience and light" after committing crimes, which has manifested itself in inequality in the administration of justice. For example, the Tang Law of China provides for more detailed hierarchical privileges of feudal bureaucrats in the application of justice. The Tang Law also stipulates that where a person has more than one official title, he may first take the higher title, and then take the lower title and the successive titles. Those who were removed from office because of their official status could still be appointed at a lower level one year later. In addition, there was a system of offsetting prison sentences by removing official titles. [8] By the time mankind entered a democratic society, the concept of equality became more and more deeply rooted in people's hearts, countries gradually

abandoned the practice of "treating people differently based on their status or situation", and chose the principle of sentencing for crimes .

From the point of view of the application of criminal law, can be divided into two types, namely, the "punishment according to the person" (IAP) and the "punishment for the crime" (CAP), which are in essence the punishment for the crime and the punishment for the non-cause of the crime, which logically belongs to an opposing relationship, and in accordance with the law of non-contradiction, it can be expressed as follows: $(IAP) \vee (CAP)$. Instead, the practice of "treating people according to their needs" is rejected, and the principle of punishment based on crime is chosen, which realizes the equal application of the criminal law in terms of the punishment for crimes. Since this reasoning process is a specific application of the law of non-contradiction, it can be seen that the law of non-contradiction implies the principle of equal application of criminal law. The principle of equal application of penalties necessarily opposes the judicial application of criminal law in a discriminatory manner.

2.2.2 Prohibition of "Strike Hrd"

Strike Hard means to strike hard and fast, in accordance with the law, and to crack down on the activities of criminal elements. New China has carried out a total of four "crackdowns": the first in 1983; the second in 1996. The third crackdown was carried out in 2001, with the addition of online operations to track down fugitives, also known as the "crackdown of the new century"; the fourth crackdown was carried out in 2010. Logically, there is a logical problem with the Strike Hard, because the Strike Hard are staged, which results in the same crime being tried during the Strike Hard with a heavier penalty, and after it without the heavier penalty, which results in the phenomenon of different penalties for the same crime. The logical form is $(C \wedge P) \wedge \neg(C \wedge P)$, it is obvious that the strict crackdown has distorted the fairness of justice and violated the principle of equal application of criminal law. The Strike Hard has inherited the wisdom of law and judicial tradition of the ancient "chaos with heavy punishment", which has its own reasonable place of existence, but its shortcomings need to be restrained and avoided, that is, we must abandon the strict fight, that is, only " follow promptness" and not " follow severeness".

2.3 Logical basis for the derivation of the principle of proportionality of crime and punishment

2.3.1 Prohibition Absolute indeterminate sentences

Absolute indeterminate sentences are the symmetry of relative indeterminate sentences, a penal system in which only the type of sentence is determined at the time of sentencing and the duration of the sentence is not specified at all. Judicial indeterminate sentence, the relationship between crime and punishment cannot be determined, the principle of appropriateness of crime and punishment cannot be realized, the logical formula is recorded as: $\neg(P \leftrightarrow \neg C)$. In the history of China, there have been indeterminate sentences; in the Qin Dynasty, corporal punishment was used in conjunction with penal servitude, which was neither a life sentence nor a fixed term of imprisonment, but an indeterminate sentence. Instead, it was an indeterminate sentence, and the punishment of hard labor was generally waived through a "pardon". At the beginning of the Han Dynasty, the Qin system was followed, and corporal punishment was still used in conjunction with hard labor, with an indeterminate term of imprisonment. It was only after Emperor Wendi's reform of the penal system that the penalty of hard labor was given a term of imprisonment. ^[9] Although the principle of legality of crime and punishment requires that the legality of crime is a profile of offenses and the legality of punishment is a range, this is fundamentally different from judicially imposed absolute indeterminate sentences. In order to facilitate the execution of the sentence, the judicial pronouncement of the sentence should have a quasi-number, the absence of a quasi-number, ambiguous, so that the principle of appropriateness of crime and punishment cannot be implemented, in logic, it violates the principle of appropriateness of punishment and crime. The logical idea of absolute indeterminate sentences is the opposite of the principle of appropriateness of crime and punishment: $(P \leftrightarrow \neg C) \vee \neg(P \leftrightarrow \neg C) \vdash \neg(P \leftrightarrow \neg C)$.

2.3.2 Prohibition of bend the law for the benefit of relatives

China's criminal law provides for the crime of favoritism and perversion of the law, i.e., the act of judicial staff members who pervert the law for their own benefit or for the sake of their own feelings, who knowingly subject an innocent person to prosecution, or who knowingly shield a guilty person from prosecution, or who intentionally contravene the facts and the law by making perverse rulings in the course of criminal trial activities. Bend the law for the benefit of relatives is a reaction to the principle of appropriateness of crime and punishment, and a negation of the principle of appropriateness of crime and punishment, the logical form of which is noted as: $\neg(P \leftrightarrow \neg C)$. Bend the law for the benefit of relatives is different from arbitrary sentencing of crimes and punishments, the act of bending the law for personal gain is contrary to the principle of appropriateness of crime and punishment, while the act of Arbitrary

sentencing of crimes and punishments is contrary to the principle of legality of crime and punishment, so it can be seen that the bending of the law for personal gain and arbitrary sentencing of crimes and punishments are two levels of things that cannot be compared with each other. According to the principle of appropriateness of crime and punishment, only the crime committed by the offender and the criminal responsibility he or she should bear are the basis of punishment, and the private feelings and interests of judicial officers are not the basis of punishment for the offender.

3 Logical basis for the application of the fundamental principles of criminal law

The basic principles of criminal law are based on the three major laws of logic at the macro, meso and micro levels, and they share a common underlying logic, which together leads to a logical general formula for the basic principles of criminal law.

3.1 The logic of the external linkage of the fundamental principles of criminal law

Openness, fairness and justice are the basic principles of modern social governance. The principle of openness means that the relevant rules and standards are formulated "openly" to ensure the orientation and legitimacy of management activities and systems. The essence of the principle of fairness is to create a fair atmosphere and a fair environment, to ensure the fairness of management activities and systems, and to enhance people's sense of fairness. So that each participant enjoys equal status in the law, is not discriminated against, and has equal opportunities to participate in competition on a fair basis. The essence of the principle of fairness is to ensure the effectiveness and consistency of management activities and systems through a fair process of enforcing the "law" (rules and standards), and to treat and deal with the rights and responsibilities of social participants in a fair manner, so that they can enjoy their rights and bear their responsibilities equally.

The application of criminal law should adhere to the principle of "three publics". Publicity in criminal law, i.e., the principle of legality, means that the application of criminal law should be based on the provisions of the criminal law and that criminal law legislation should be made public. The logic of this is expressed in the formula: the principle of openness→ the principle of legality of crime and punishment. Adherence to the principle of legality of crime and punishment, is to take the law as the standard in judicial practice, and to oppose the

subjective arbitrariness of judicial officers, therefore, fundamentally speaking, it is the materialist position to adhere to the principle of openness and the principle of legality of crime and punishment. Historically, the opposite of the principle of legality of crimes and punishments is the rule that "if the punishment is not known, the power is unmeasurable", which means that if the criminal law is not publicized, its power is infinite. This sentence is from the "Justice in the Left Biography of the Spring and Autumn Period", which was written in the sixth year of the reign of Duke Zhao. Zuo Zhuan - Zhaogong Sixth Year" records that Zi Chan of Zheng cast the penal book, and Shuxiang of Jin sent a letter to condemn it, which said, "If the people know that there is a pardoning, then they will not be jealous of the top." Du Yu of the Western Jin dynasty annotated: "When power is transferred to the law, the people do not fear their superiors." In the Tang dynasty, Kong Yingda and others further elaborated on Du's annotation, stating: "Since the punishment is unpredictable and the authority is unfathomable, the people fear their superiors. Now, laws are established to define this, and inscribed tripods are used to demonstrate it. The people know that those in power cannot exceed the law to punish them, nor can they manipulate the law to grant favors. Therefore, power is transferred to the law, and thus the people no longer fear their superiors." However, logically, if the criminal law is not known, then the crime is not known; if the crime is not known, then the norms are not known; if the norms are not known, then people dare not act. Thus, the consequence of not publicizing the criminal law is that it leaves people cowering in bewildered fear. This is a policy of foolish people and a society of terror under dictatorship and the rule of man, which is rejected by civilized and democratic societies.

Fairness in criminal law, i.e., equality for all in the application of penalties, adheres to the viewpoint of linkage and comparison, and creates fairness in the administration of justice. The logic of this is expressed in the formula: the principle of fairness → the principle of equal application of criminal law. Adherence to the principle of equal application of criminal law means that in judicial practice any person who commits a crime is equal in the application of the law. No one is allowed to have privileges beyond the law. Therefore, fundamentally speaking, adhering to the principle of fairness and the principle of equal application of criminal law is to view and deal with the issue of crime from the point of view of connection, which is the embodiment of the connection viewpoint in Marxist philosophy in the principle of criminal law.

Justice in criminal law is an inherent requirement of the principle of proportionality between

crime and punishment, which upholds the view of dialectical unity between crime and punishment, so as to achieve judicial justice. The logic of this is expressed in the formula: the principle of justice \rightarrow the principle of appropriateness of crime and punishment. To adhere to the principle of the appropriateness of crime and punishment means that in judicial practice the severity of the penalties applied to criminals should be commensurate with the crimes they have committed and the criminal responsibility they have assumed, and that the contradictory relationship between crime and punishment should be properly resolved. Fundamentally, therefore, adherence to the principle of justice and to the principle of appropriateness of punishment and crime is the application in criminal practice of the principle of the particularity of contradictions, which is based on concrete analysis of specific problems, and is the use of the Marxist viewpoint of development to analyze and solve the problem of guilt and responsibility.

3.2 Harmonization of the underlying logic of the basic principles of criminal law

Although the three basic principles of criminal law directly reflect the requirements of the three basic laws of logic at the macro, meso and micro levels, each of these principles is also based on the theoretical foundation of the three basic laws of logic; in other words, the three basic laws of logical thinking are the logical foundation of each of the basic principles of criminal law. In order to reveal the consistency of the underlying logic of the basic principles of criminal law, we have created the following truth table of the basic principles of criminal law.

Table 1: Truth table of basic principles of criminal law

C	P	$(C \wedge P) \rightarrow (C \wedge P)$	$\neg((C \wedge P) \wedge \neg(C \wedge P))$	$(P \leftrightarrow \neg C) \vee \neg(P \leftrightarrow \neg C) \quad P \vdash \leftrightarrow \neg C$
1	1	1	1	1
1	0	1	1	1
0	1	1	1	1
0	0	1	1	1

As can be seen from the above table, firstly, the basic principles of criminal law are identical in terms of truth value, indicating that they have an equivocal relationship, i.e., the basic principles of criminal law encompass and demonstrate each other. This shows that the three basic principles of criminal law are the three sides of the criminal law, or that the basic principles of criminal law are the information entanglement of the criminal law at the macro,

meso and micro levels. Secondly, the underlying logic of the basic principles of criminal law is eternal truth, which means that no matter what the situation is, the statement of eternal truth is always correct, that is, the basic principles of criminal law are scientifically valid in the field of criminal law, this is exactly the logical basis of the basic principles of criminal law as the basic principles of criminal law.

The basic meaning of the basic principle of the law of crime and punishment is: (1) the judicial conviction is based on the standard of the crime of the criminal law: (2) the pronounced sentence is based on the standard of the legal sentence ; (3) the conviction and sentencing is based on the standard of the configuration of the crime and punishment stipulated in the criminal law. Expressed as a logical formula: $(C \wedge P) \rightarrow (C \wedge P)$. As long as the implementation of the law of crime and punishment, can realize the same crime with the same penalty; also only the law of crime and punishment, can ensure the same crime with the same penalty. Therefore, logically the principle of legality of crime and punishment is equivalent to the principle of equal application of criminal law. The most basic meaning of the law of exclusion is to make the right determination when judgment must be made. The basic meaning of the principle of appropriateness of punishment is the necessity of imposing an appropriate penalty for a crime, and this "appropriate penalty is $(P \leftrightarrow \neg C)$ " [5], which is nothing but a further illustration of the principle of the legality of the crime and the punishment. Therefore, the principle of the legality of crime and punishment is logically consistent with the principle of the appropriateness of crime and punishment. As can be seen, the three basic principles of criminal law share a common underlying logic.

3.3 Logic of integrated application of fundamental principles of criminal law

3.3.1 Logical formulas for the application of penalties

Criminal liability includes retributive and preventive liability. The degree of completion of the crime varies, and if the crime is completed, the offender is liable for retribution and should be sentenced to retribution, which is for a crime that has already been committed. If the crime is not completed and no damage has been caused, the offender is liable for prevention and should be sentenced to preventive punishment, which is for crimes that have not yet been committed. If the crime is not completed but damage is caused, the offender is liable for both retributive and preventive liability. Denoting criminal liability by P, retributive liability by P_n , and preventive liability by P_r , the logical formula for criminal liability is $P = P_n + P_r$, and the sentence imposed in accordance with $(P_n + P_r)$ is the liability sentence. [5] And as mentioned

earlier, the principle of appropriateness of crime and punishment requires the relationship between crime and punishment as $(P \leftrightarrow \neg C)$, that is, $(P_n + P_r) \leftrightarrow \neg C$. The formula intuitively expresses the logical relationship between crime, responsibility and punishment.

For the State to realize that punishment is effective in disciplining criminals and that criminals should be duly punished rather than encouraged, it is the ideal logic of applying punishment that the offender should lose no less than what he gains by committing a crime. Let us assume that the amount of satisfaction that the offender can gain by committing a crime is G (Gain), and the amount of deprivation or suffering that the penalty inflicts on the offender is P (Punishment). The logical formula for the application of the penalty is $P \geq G$.

3.3.2 General logical formula for the comprehensive application of the fundamental principles of criminal law

Combined application of the principle of legality of crime and punishment and the principle of equal application of criminal law. The logical formula of the principle of equal application of criminal law is: $\neg((C \wedge P) \wedge \neg(C \wedge P))$, which indicates that $(C \wedge P)$ and $\neg(C \wedge P)$ cannot coexist, so which one should prevail? According to the principle of legality of crime and punishment $(C \wedge P) \rightarrow (C \wedge P)$, the legislative configuration of crime and punishment is the judicial standard for conviction and sentencing, therefore, equal application of criminal law results in $(C \wedge P)$.

The principle of equal application of criminal law is used in combination with the principle of proportionality of crime and punishment. Guided by the principle of legality, the principle of equal application of criminal law results in judicial practice $(C \wedge P)$. In further discussing the specific relationship between C and P , it is necessary to combine the principle of appropriateness of crime and punishment, and the conclusion of combining the principle of appropriateness of crime and punishment is to choose to apply $(P \leftrightarrow \neg C)$ in the administration of justice, therefore, the result of the combined application of the three basic principles of criminal law can be summarized as $(P \leftrightarrow \neg C)$. In short, the three basic principles of criminal law can be summarized in a single sentence: the equal application of the legal mix of crime and punishment to all offenders. The logical formula is: $(P \leftrightarrow \neg C) \rightarrow (P \leftrightarrow \neg C)$, which is the logical general formula of the basic principles of criminal law.

References

- [1] [Yuan] Tuo Tuo. (1985).The History of the Song Dynasty: Biography of Yue Fei [M]. Beijing: Zhonghua Book Company, 2375-2394.
- [2] Wen Jianhui. (2021). The Paradigm of Criminal Policy from the Perspective of Materialist Historiography. Xinjiang Social Sciences, (04), 90-101+169.
- [3] Gao Shaoxian.(2001).Essentials of Chinese Penal History [M]. Beijing: Law Press, 142.
- [4] Supreme People's Court. Normalization! The Supreme Court Publishes Main Judicial Trial Data Quarterly [EB/OL]. <https://www.court.gov.cn/zixun/xiangqing/408422.html>.
- [5] Wen Jianhui. (2023). Logical Analysis of the Basis of Punishment. Guangxi Social Sciences, (01), 120-126.
- [6] Ma Liyuan. (1998). On the Logical Basis of Abolishing the Analogy System in the New Criminal Law. Hebei Law Review, (03), 84. DOI: 10.16494/j.cnki.1002-3933.1998.03.034.
- [7] Lin Minjing, Shen Wewei. Understanding Extrajudicial Torture in Traditional China through Lingchi [N]. Democracy and Legal System News, 2020-01-19(006).
- [8] Liu Shuangzhou. (2014). History of Chinese Law [M]. Beijing: University of International Business and Economics Press, 83.
- [9] Wang Hongzhi. The Merits and Demerits of Punishments in the Qin and Han Dynasties [N]. Procuratorial Daily, 2021-10-21.
- [10]Wen Jianhui. (2014). Outline of the Theory of Irrational Crime. Lanzhou Journal, (09), 98-105.

On the Logical Constraints on Legal Norms*

XU Zhiyu^{**}、LEI Lei^{***}

Abstract

The problem of the logical constraints of legal norms can be divided into three levels: the "practical problem", the "specific problem" and the "meta-problem". At the level of the "meta-problem", the normative logic skepticism negates the possibility of making logical inferences from valid legal norms, but it points out the possibility of normative logic dealing with the normative statements of the idealized director. By the conception of the idealized director, legal norms must satisfy the two logical constraints of inference-licensing and consistency, and deontic logic can account for the forms of existence of these two constraints. In legal practice, the judiciary creates laws under the constraints of deontic logic through the "refraction mode".

Key Words

legal norms; normative logic ; permission; consistency; refraction mode

Introduction

In the methodology of law, the judicial process is considered to follow the logical deduction from general norms to individual norms, that is, the "judicial syllogism";¹The sources of these constraints on legal norms are often considered to be logical.

There are discussions at three levels, namely the "practical problem", the "specific problem" and the "meta-problem", regarding the logical constraints on legal norms. The "practical problem" discusses how to apply logical rules in the application of legal norms, and the "specific problem" discusses what logical rules are followed by legal norms, For example, what kinds of legal norms cannot coexist logically, and what kinds of legal norms can be obtained logically from other kinds of legal norms. However, these specific problems are faced with many challenges. For example, there are disputes about whether the conflict between norms in the form of "one ought to do

* The Ministry of Education funded late major project in Philosophy and Social Sciences "Research on Jurisprudence in the Mirror of a New Era" (21JHQ012).

** PhD Student, School of Politics and Public Administration, China University of Political Science and Law

*** Qian Duansheng Chair Professor and Doctoral Supervisor of China University of Political Science and Law

¹ Vgl. Karl Larenz. (1991). *Methodenlehre der Rechtswissenschaft*, Berlin: Springer-Verlag, 271-277.

something" and "it is prohibited to do something" is logical inconsistent, and whether individual norms can be obtained logically from general norms. ²These problems also lead to disputes about practical problems: in the case where the relationship between logic and law is unclear, does the judge create laws or apply laws? In my opinion, it is difficult to solve these problems because we have not clarified what the nature of logic of legal norms is and in what sense it constrains legal norms. Therefore, we must return to the level of the "meta-problem" to discuss the logical constraints on legal norms. .

I will first discuss the "meta-problem" about the constraints of legal norms. Then, based on the discussion of the meta-problems, I will discuss of the "specific problem", and finally move on to the "practical problem". In the first part of this article, by the discussion of normative logic skepticism, I will illustrate in what sense normative logic can constitute constraints on legal norms. In the second part, by explaining the semantics of Standard Deontic Logic (SDL), I will justify the logical constraints on legal norms. In the third part, I will explain how these constraints work in judicial practice.

The Possibility of logical constraints on legal norms

There are lots of advantages to assume that legal norms are indeed validly constrained by logical rules: We can not only explain our intuition about legal reasoning, but enable the existing legal arguments, which generally play a good role in legal practice, to be based on a stable and rational foundation. However, the "success" of this concept does not mean that it is actually valid - at most, this can only be defended by pragmatical arguments. Jörgen Jörgensen proposed: "So we have the following puzzle: According to a generally accepted definition of logical inference only sentences which are capable of being true or false can function as premisses or conclusions in an inference; nevertheless it seems evident that a conclusion in the imperative mood may be drawn from two premisses one of which or both of which are in the imperative mood."³ This problem is therefore called "Jörgensen's Dilemma".

In the years of debate, Jörgensen's Dilemma has been summarized as a conflict between two horns: ① Imperative sentences do not have truth value (true or false), and since logic only deals with sentences that are true or false, imperative sentences cannot be the premisses or conclusions of logical inferences (Horn 1, or the Prohibition Thesis); ② The normative arguments in our daily lives seem obviously valid, so imperative sentences can be the premisses or conclusions of logical inferences (Horn 2, or the Permission Thesis). ⁴the "Prohibition Thesis" can be reconstructed into such a

² See Kramer, M. H. (2024). *Rights and Right-Holding: A Philosophical Investigation*, Oxford: Oxford University Press, 28-34; Jörgensen, J. (1938). Imperatives and Logic, *Erkenntnis* Vol.7, 290.

³ Jörgensen, J. (1938). Imperatives and Logic, *Erkenntnis* Vol.7, 290.

⁴ See Coyle, S. (2020). Facing Jörgensen's Dilemma, *Northern Ireland Legal Quarterly* Vol. 55 No.4, 351-353; Leon-Untiveros, M. (2016). Jörgensen's Dilemma: The Quest for Semantic Foundation of Imperatives, *Phainomenon* Vol. 15, 120.

set of arguments:

- ① Imperative sentences cannot be true or false;
- ② The premises and conclusions of logical inferences are, and can only be, sentences that are true or false.
- ③ Therefore, imperative sentences cannot be the premises or conclusions of logical inferences.

The "Permission Thesis" does not constitute an argument, but is merely an intuition, and thus requires further argumentation from its supporters.⁵

In this process, supporters of the so-called "normative logic skepticism" claim, legal norms can not be dealt by logic. If they are true, then there are no so-called "logical constraints" on legal norms. In the process of reflecting on normative logic skepticism, I will not only re-establish the constraints of normative logic on legal norms, but also explain the nature of such constraints..

Normative Logic Skepticism

The basic viewpoints of normative logic skepticism are: ① Normative sentences can not be true or false, therefore cannot be premises or conclusions of logical inferences; ② Propositions about the existence of norms (that is, normative statements or normative sentences) may be the premises and conclusions of logical inferences, and the intuitively valid inferences about norms proposed by the Permission Thesis are inferences about normative statements; or ②' The intuitively valid inferences about norms proposed by the Permission Thesis are invalid.

It should be particularly noted here that not all supporters of normative logic skepticism agree the following Thesis of the irrationality of legal argumentation: The reasoning in legal argumentation is based on will rather than reason. This is because Thesis① and the Thesis of the irrationality of legal argumentation cannot be derived from each other. Quite a number of the supporters of normative logic skepticism merely hold the view that norms can not be dealt with by formal logic, yet they believe that formal logic should be followed in the process of norm formulation and interpretation. In addition, from the perspective of the history of philosophy, the motivation for some advocates of normative logic skepticism is to separate practical reason from formal logic, and they claim that the argumentation of norms can conform to practical reason without formal logic.

The "realist argumentation" of norms is the most common argument of normative logic skepticism. This argument holds that existence of norms is similar to that of natural entity, natural entity exists in the natural world, and norms exist in the legal system. The existence of natural entity makes it only possible for logic to "talk about" it, that is, it becomes the truth-maker of a proposition, but it cannot become premises or conclusions of logical inferences; similarly, the existence of norms also makes it so

⁵ Ross, A. (1968). *Directives and Norms*, New York: Humanity Press, 139-140.

that logic can only "talk about" norms, and cannot make norms premises or conclusions of logical inferences. Norms can only be the truth-maker of those "normative statements" that talk about norms.⁶

There are stronger version and a weaker version in the "realist argumentation". The most famous of the weaker versions comes from Hans Kelsen. He pointed out that norms cannot contain both an imperative or prescriptive and an indicative or descriptive factor. The former is the meaning of an act of thought, while the latter is the meaning of an act of will. Truth and falsity are properties of statements or assertions, while validity and invalidity are not properties of the norm, but of the existence of the norm. A false statement is still a statement, but the invalidity of the existence of a norm means that the norm no longer exists.⁷ Kelsen emphasized that although both norms and statements have an inherent connection with language, the similarity between norms and statements is only *prima facie*. On the other hand, a normative statement that describes whether a norm exists or not is a kind of statement.

The stronger version, on the other hand, posits the existence of a "normative world". Robert Walter holds the view that whether a proposition is true or false does not depend on whether it conforms to the actual state of affairs in a certain factual world it describes, but rather on the fact that this proposition is regarded by people as a reasonable interpretation of the factual world. Therefore, Walter does not confer a special ontological status on the "factual world" and the propositions that describe the "factual world", but rather they have the same status as other statements that are considered reasonable by people. Thus, those statements about norms that are regarded as reasonable can also be considered as propositions possessing truth values, and there is also a corresponding "normative world". Furthermore, Walter supports a normative statement theory similar to that of Kelsen, and classifies the intuitively valid inferences about norms as logical inferences among the normative statements that describe the normative world.⁸ Regarding the question of "whether general norms can logically deduce individual norms", Walter gives a negative response: those normative statements that seem to describe individual norms and are derived from the normative statements describing general norms cannot create a new individual norm that exists in the normative world, but merely re-express the general norm.⁹ In other words, Walter believes that the proposition about a general norm and the proposition about an individual norm deduced from it have the same meaning and describe the same general norm. Thus, Walter denies the existence of logical relationships between norms. He treats the intuitively valid logical inferences about norms as the logical relationships between normative statements. Moreover, following Kelsen's approach in his later years, Walter denies that the logical inferences between

⁶ "Normative statement" refers to a proposition that discusses whether a individual norm exists in the legal system. This concept is often used, but different scholars have given it different names. For example, von Wright calls it "normative propositions", and Kelsen calls it "normative statement".

⁷ Kelsen, H. (1973). *Law and Logic*, in: *Essays in Legal and Moral Philosophy*, selected by Ota Weinberger, trans. By Peter Heath, Dordrecht: D. Reidel Publishing Company, 230.

⁸ Walter, R. (1996). Jörgensen's Dilemma and How to Face it, *Ratio Juris* Vol.9 No.2, 169-170.

⁹ Walter, R. (1997). Some Thoughts on Peczenik's Replies to "Jörgensen's Dilemma and How to Face it", *Ratio Juris* Vol.10 No.4, 393.

normative statements can be indirectly applied to the norms themselves.

There always seems to be exceptions for general norms, which also supports one of the arguments of normative logic skepticism, I conclude it as "exception argumentation". It seems that all general norms have exceptions, and these exceptions are inexhaustible. This makes it necessary, in the inference from a general norm to a special norm, that the general norm as the premise must conjoin an infinite number of exceptions as premises. However, a well-formed formula in classical logic is always a finite symbol string. Therefore, when general norms are in logical inferences, they cannot be formalized into well-formed formulas. Sean Coyle, for example, believes that the deontic logicians simplify the norms in moral and legal arguments into simple universal propositions such as "Love your neighbor" (which he calls "Jørgensen sentences"), but in actual moral and legal arguments, such sentences are hardly ever used.¹⁰ A more radical view holds that even in statements, the inference from a universal proposition to a singular proposition is not necessarily logically valid. A typical example is that some scientific theories expressed as universal propositions have counterexamples, but we do not regard such a proposition as "false" or "erroneous", but merely consider that the scope of this proposition must be narrowed. In this way, even if a universal proposition is true, the singular propositions that can be deduced from it are not necessarily all true. ¹¹These illustrate the two forms of "exception argumentation", the first form requires its opponents to retain the classical definition of logical implication and admit that general norms cannot be formalized into well-formed formulas, the second form requires them to directly give up the classical definition of logical implication. And both of these points are difficult for the opponents of normative logic skepticism to accept.

Reflection on Normative Logic Skepticism

Normative logic skepticism is, for who attempts to "solve" Jørgensen's Dilemma, must be responded to directly. Relatively, the "exception argumentation" is easier to refute. The "exception argumentation" often comes from the supporters of some informal logic. Whether logic is the ontological structure of the world or the epistemological structure of argumentation is a long-standing issue in the philosophy of logic, and contemporary philosophy of logic supports more the latter view.¹² However, unlike our static assumptions about the ontological structure of the world, the propositions used in the process of argumentation are often defeasible. Thus, if logic is regarded as the epistemological structure of a certain type of argumentation, one will give up the principle of bivalence in classical logic and the concept of validity derived from it, which is characterized by truth preservation, and instead use the principle of the validity in argumentation. But it can be seen that there is a significant difference between the validity of an argumentation and the validity of

¹⁰ Coyle, S. (2020). Facing Jørgensen's Dilemma, *Northern Ireland Legal Quarterly* Vol.55, No.4, 351-353.

¹¹ Mikael M. Karlsson, (1995). Defeating the Inference from General to Particular Norms, *Ratio Juris* Vol.8 No.3, 273-276.

¹² Weinberger, O. (1999). *Against the Ontologization of Logic: A Critical Comment on Robert Walter 's Tackling Jørgensen ' s Dilemma*, *Ratio Juris* vol. 12 No. 1, 97.

logic. The validity in argumentation places more emphasis on the procedural issues of the argument rather than the truth preservation of the reasoning, because the dynamic process of argumentation needs to pay attention not only to the truth of the premises, but also to the reasoning from the premises to the conclusion. However, when we mention logical validity, we are more eager to pursue a static and constant standard, which serves as the limit that the dynamic process of argumentation intends to approach.

The realist argumentation is persuasive. Its persuasive force aspects lie in the following three points: ① As an directive issued by legislators, law is a performative action. Legal norms are not representative statements. They aim to provide reasons rather than represent the existing reasons; ② Under the background of positivism, legal statements about what legal norms are depend on facts, and it is entirely possible that there are seemingly illogical norms in law; ③ According to ① and ②, if we follow Kelsen and regard legal norms as taking the quasi-mental attitude of legislators towards specific states of affairs as a necessary condition, then in the sentences describing the existence of legal norms, the sentences about those specific states of affairs of the norms will be in an intensional context. For example, in the sentence "The legislator supports taxing all the rich", "taxing all the rich" is in an intensional context. If Hans is rich, although "taxing all the rich" implies "taxing Hans", the sentence "The legislator supports taxing all the rich" does not imply "The legislator supports taxing Hans", because the legislator may not even know who Hans is, let alone hold a certain mental state towards him.

Therefore, Those dealt with by normative logic should have the following characteristics: ① Representativeness, that is, sentences that reflect the facts in the world; ② Extensionality, that is, it is able to transform the sentences about specific states of affairs in the sentences describing the quasi-mental attitude of legislators towards specific states of affairs into an extensional context, so that logical inferences can be made about it.

In the following text, we will propose the concept of an "idealized director" and point out that those dealt with by normative logic is not the will of real legislators, but the will of the "idealized director", so as to meet the above requirements. The "idealized director" imitates the non-normative idealization method in meta-ethics. There is no need to consider whether the quasi-mental state of the idealized director towards states of affairs itself meets the requirements of moral normativity, but only needs to meet the requirement of non-conflict. In other words, each legislator has an "idealized director" relative to him. This director retains all his desire states, but only has complete empirical knowledge. The idealized director only needs to possess sufficient non-moral information, enabling them to recognize the potentially conflicting states of affairs in the world without contradiction and maintain psychological coherence. This coherence has two requirements: consistency and inference-licensing. The former means that once the premises of a logical inference are accepted, the conclusion cannot be denied. The latter means that when accepting the premises, one

not only cannot deny the conclusion, but also must accept the conclusion.¹³

The mental states of the idealized directors, which possess these two characteristics, can be explained with the theory of high-order attitudes proposed by Simon Blackburn. For the idealized directors, not only do they have desires for specific states of affairs, but due to their complete empirical knowledge, they also have high-order desires that their own desires conform to logical requirements. For example, the idealized director may desire that all subjects pay taxes, or may desire that all subjects do not pay taxes. However, he opposes desiring that all subjects both pay and do not pay taxes. He also opposes desiring that all subjects pay taxes while lacking the desire for subjects to pay taxes. Therefore, he will not desire that all subjects both pay and do not pay taxes, nor will he desire that they pay taxes while not desiring that those under his governance pay taxes. In this way, the idealized director opposes inconsistent desires within himself and also opposes the inconsistency of his own desires. The former corresponds to the principle of inference-licensing, and the latter corresponds to the principle of consistency.

The trouble is that there are two types of "inconsistency" in legal norms, namely, "ought to do vs. permitted to do (something is an obligation and at the same time not an obligation)" and "ought to do vs. forbidden to do (something is an obligation and at the same time prohibited)". Can both of these two types of inconsistency be supported?

Mark Schroeder has defined the attitude of "Inconsistency-Transmitting". An attitude is inconsistency-transmitting if two instances of this attitude are inconsistent with each other when they have incompatible contents. Intentions and beliefs are both attitudes of "inconsistency-transmitting". If the attitude of the legislator's requirement is of this kind, then it is easy to explain that "ought to do something" and "be prohibited from doing something" in the normative system are inconsistent, because it means that the authority has a demanding attitude towards a set of inconsistent contents (p and $\neg p$) at the same time.¹⁴ This can explain the possibility of logical inconsistency between "ought to do something" and "be prohibited from doing something", but it cannot explain the logical inconsistency between "ought to do something" and "be permitted not to do something (not ought to do something)".

According to Kelsen, norms, as the meaning of acts of will, express attitudes towards certain states of affairs. However, in addition to having attitudes towards states of affairs expressed through norms, legislators also have attitudes towards norms expressed through the creation of norms. In my opinion, if we want to impose certain constraints on the extreme irrationality of legislators, we must rule out the possibility of the simultaneous existence of opposing attitudes towards norms. That is to say:

Legislators cannot hold both a supportive attitude and an unsupportive attitude towards a certain norm.

¹³ Schroeder, M. (2024). *Noncognitivism in Ethics*, New York: Routledge.115-116.

¹⁴ Schroeder, M. (2024). *Noncognitivism in Ethics*, New York: Routledge.139-140.

Suppose someone asserts the proposition p . The proposition that someone believes in this natural state of affairs can be written as $b(p)$. The negation of the proposition p is $\neg p$, and the proposition that someone believes in the negation of the proposition p in this natural state of affairs can be written as $b(\neg p)$, while the proposition that someone does not believe in the proposition p in this natural state of affairs can be written as $\neg b(p)$. An idealized person with sufficient knowledge of the real world cannot simultaneously believe the proposition p and the proposition $\neg p$.

In this example, we can impose the following requirement on the idealized individual: One cannot believe both p and $\neg p$ (or disbelieve p). We term "believing" as an attitude towards a proposition. As stated above, the act of a legislator creating a norm is not merely a simple natural state of affairs; rather, through his act of will, it expresses an attitude towards the norm (which we refer to as support and non-support). The attitude of a legislator in supporting the existence of norm n is denoted as $s(n^*)$, where n^* represents the normative statement: Norm n exists. By drawing an analogy with the attitude b of "believing", we can conclude that for an idealized director, $s(n^*)$ and $s(\neg n^*)$ are inconsistent. This is because the function of a norm is to provide reasons to guide people's actions. If norm n both exists and does not exist, then it is impossible to achieve the guiding purpose of the norm.

I assume that participants in practical argumentation, just like those in theoretical argumentation, must be sincere, that is, they cannot hold contradictory attitudes towards the statements they express. This requirement endows the statements expressed by each participant in the argumentation with two different aspects. The first is the aspect of the natural state of affairs, that is, whether the participants in the argumentation express these statements in a certain way (such as speaking with their mouths or writing with a pen). The second is the aspect of the idealized argumentation field, that is, if the participants in the argumentation are idealized, whether they can assert the proposition expressed by this statement without conflict. We assume that an arguer expresses the assertion of the proposition p and also expresses the non-assertion of the proposition p . At this time, this arguer will be accused of insincerity. But he can claim that it is just a mistake and that he wants to retract the assertion of the proposition p . Then, although at the level of the natural state of affairs he has expressed the assertion of the proposition p and the assertion of the proposition $\neg p$ (according to the previous text, not asserting the proposition p is equivalent to asserting the proposition $\neg p$), at the level of the argumentation field, the proposition p no longer exists. Similarly, a sincere legislator must also follow similar rules: he cannot both support the existence of the norm n and support the non-existence of the norm n . According to Kelsen's assertion, all norms established by authorized legislators are valid norms, and we can put them all at the level of the natural state of affairs; after the process of argumentation, by eliminating those norms that are both supported and opposed by the legislator among the valid norms, the remaining norms are the norms that enter the level of the idealized argumentation field.

Participants in theoretical argumentation have diverse ways of expressing their attitudes towards propositions. Among them, there are two most important types: One

is the "elliptical expression", that is, expressing the assertion of a proposition by directly stating it. The other is the "complete expression", that is, reporting the assertion of a proposition by stating the state of affairs of one's assertion of this proposition. However, the way in which legislators express their attitudes towards norms generally only be carried out through elliptical expressions. That is, they change the norms themselves by using normative modal words such as "(not) allowed" and "(not) ought to", rather than expressing their attitudes towards the norms. A person can express a certain negative attitude towards the proposition *p* by stating "I do not assert *p*", but a legislator generally will not express a similar negative attitude towards the existence of the norm *n* that he does not want to create in a similar way.

This is because the complete expression of the legislator's attitude towards the norm is not to state his own attitude, but rather the act of "creation" itself and the act of "non-creation" which is the opposite of the act of creation. The act of "creation" can be carried out in various ways, but the act of "non-creation" can only be carried out through silence or abolishing.

However, the ideal director cannot express a negative attitude towards a certain norm through "silence". The reason is that an idealized normative system established by the legislator is presupposed to be complete. That is to say, in every real or hypothetical situation, every choice is either permitted, prohibited, or required.¹⁵ But the legislator cannot cover the behaviors of an infinite number of subjects. This requires the legislator to ensure the integrity of his own normative system by setting some rules, such as "What is not prohibited by law is free", "No crime without a legal provision", "What is not authorized by law is prohibited", etc. These rules give specific meanings to the legislator's silence on individual norms, rather than simply expressing opposition to the norms. The legislator also cannot express a negative attitude towards a norm through "abolish" because he can only abolish the existent norms, and not on the absent norms.

If we agree that the legislator's attitude towards a norm cannot be inconsistent, then we also agree that normative modal words such as "permitted" and "ought to" can directly express the attitude towards the norm. Correspondingly, when the legislator makes inconsistent statements regarding the normative words, then this legislator is either making a mistake or being insincere. For a legislator who makes a mistake, he holds false beliefs and thus fails to realize that his attitude towards the norm is inconsistent. When he realizes this, he will either seek to correct the norm or transform into an insincere legislator. As for an insincere legislator, since his attitude towards behavior is false, the norms he formulates cannot participate in the rational discourse about norms.

In conclusion, we have basically explained the "meta-problem" of the logical constraints on legal norms. In summary, although normative logic skepticism refutes the possibility of logical inferences at the level of valid norms, normative logic can

¹⁵ Gibbard, A. (1993). *Wise Choices, Apt Feelings*, Oxford: Clarendon Press, 88.

instead deal with the will of the idealized director. There are two main principles about the will of the idealized director: consistency and inference-licensing, which will constitute the source of the logical constraints on legal norms.

Justification of logical constraints on legal norms

After explaining the "meta-problem", this section will move on to the level of "specific problems" and elaborate on how the semantics of Standard Deontic Logic (SDL) accounts for the inference-licensing and consistency of the will of the ideal director, thereby transforming these two characteristics into logical constraints.

Standard Deontic Logic

In the middle of the 20th century, with von Wright establishing the first formal deontic logic system and the new-established possible world semantics expanding into generalized modal logic, logicians discovered a new train of thought for assigning values to norms: while retaining the assignment of truth values to propositions, deontic modalities are interpreted as relations between possible worlds. This train of thought seems to solve Jørgensen's dilemma at one stroke, and because it is based on the field of modal logic, the reliability and completeness of the logical system are also well resolved.

The standard deontic logic system uses a language L_d expanded from the propositional logic language L_p . Its initial symbols are divided into three categories:

The first category includes countably infinite propositional symbols: $p_0, p_1, p_2, \dots, p_m, \dots$, where m is a natural number;

The second category includes three connectives: O, \neg, \rightarrow .

The third category includes two punctuation marks: $(,)$.

A formula of L_d is only a string of symbols constructed according to the following rules:

- (1) A single propositional symbol;
- (2) If α is a formula, then $\neg\alpha$ and $O\alpha$ are formulas;
- (3) If α and β are formulas, then $(\alpha \rightarrow \beta)$ is a formula.

The following logical connectives are defined as supplements:

- (1) $(\alpha \wedge \beta) =_{df} \neg(\alpha \rightarrow \neg\beta)$;
- (2) $(\alpha \vee \beta) =_{df} \neg\alpha \rightarrow \beta$;
- (3) $(\alpha \leftrightarrow \beta) =_{df} (\alpha \rightarrow \beta) \wedge (\beta \rightarrow \alpha)$;
- (4) $P\alpha =_{df} O\neg\alpha$;

(5) $F\alpha = \text{df } O\neg\alpha$.

The basic semantics of this logical system can be formalized as follows:

Given a non-empty set W , R is a binary relation on W . Given a set $F(Ld)$, the elements in it are arbitrary well-formed formulas. The valuation V is a function from $W \times F(Ld)$ to the value set $\{0, 1\}$. For any well-formed formulas $\alpha, \beta \in Ld$ and any element $w \in W$ in W , the following holds:

- (1) $V(\neg\alpha, w) = 1$ if and only if $V(\alpha, w) = 0$;
- (2) $V(\alpha \rightarrow \beta, w) = 1$ if and only if $V(\alpha, w) = 0$ or $V(\beta, w) = 1$;
- (3) $V(O\alpha, w) = 1$ if and only if for any $w' \in W$, if wRw' , then $V(\alpha, w') = 1$;
- (4) $V(P\alpha, w) = 1$ if and only if there exists a $w' \in W$ such that wRw' and $V(\alpha, w') = 1$;
- (5) $V(F\alpha, w) = 1$ if and only if there does not exist a $w' \in W$ such that wRw' and $V(\alpha, w') = 1$.

In addition to the tautologies and inference rules of propositional logic being valid, the standard deontic logic also adds a new axiom $O(\alpha \rightarrow \beta) \rightarrow O\alpha \rightarrow O\beta$ and an inference rule $\alpha \vdash O\alpha$.¹⁶

In addition, we can reflect some unique philosophical properties of norms by endowing the structure $\langle W, R \rangle$ with certain characteristics, and these structural characteristics will also be reflected in the syntactic system in the form of adding axioms. This system can be conveniently further expanded into a first-order predicate deontic logic.

The core of this semantics lies in the understanding of possible worlds. In the possible world semantics of deontic logic, we can imagine countless possible worlds similar to our real world, and each norm will select some possible worlds from these possible worlds, and in these possible worlds, the states of affairs involved in the norms conform to the situations described by the norms. We call such possible worlds "deontic ideal worlds". Furthermore, we define that "the state of affairs A ought to be realized" means that in all deontic ideal worlds, the proposition "the state of affairs A is realized" is true; "the state of affairs A is prohibited from being realized" means that in all deontic ideal worlds, the proposition "the state of affairs A is realized" is false; "the state of affairs A is permitted to be realized" means that there exist deontic ideal worlds in which the proposition "the state of affairs A is realized" is true. Thus, we correspond the truth or falsehood of norms with deontic modal words to the truth or falsehood of propositions without deontic modal words in deontic ideal worlds. The deontic modal words imposed on states of affairs correspond to the specific relations existing between possible worlds.

What kind of world is a "deontic ideal" one? In legal norms, which kind of world is

¹⁶ Hilpinen, R., McNamara, P. (2013). Deontic Logic: A History Survey and Introduction, in Gabby, D., Horty, J., Parent X.(eds.) *Handbook of Deontic Logic and Normative Systems*. College Publications, 36-47.

deontic ideal should be regarded as determined by the legislator.¹⁷ That is to say, through issuing instructions, the legislator determines which kind of world belongs to the deontic ideal world, or in other words, provides a specific model of the deontic logic of law. However, as mentioned above, real-life legislators lack sufficient non-moral information, making the deontic ideal world they set up possibly logically imperfect. Therefore, the "deontic ideal world" should be established by the idealized director relative to each legislator, and form a constraint on real-life legislators.

Meta-normative justification of logical constraints

It is generally believed that as a meaningful sentence, a norm has an important difference from a statement, that is, it can provide reasons for actions (or practices). In the field of practical reasoning, taking the beliefs and desires of the agent as premises respectively, the goals of the agent can be obtained. Among them, there may be two kinds of inconsistencies in the desires of the agent, that is, the agent may desire two incompatible states of affairs or have a vague attitude towards the same state of affairs (or the propositions describing such an attitude are inconsistent with each other). The former will lead to the logical unrealizability of the agent's goal, and the latter will lead to the inability to determine whether the agent has a certain desire. They respectively correspond to the two properties of the idealized director, namely consistency and inference-licensing.

Therefore, for a legislator as an agent, there are at least two "meta-norms": Firstly, the legislator must desire a world in which all the propositions described by him are consistent. Only such a world is realizable, that is, the "principle of realizability"; Secondly, the desires of the legislator must be clear. He cannot desire and not desire the same state of affairs. In other words, the statements describing the legislator's desires must be consistent. Such a statement is exactly the interpretation of the axioms and inference rules involving deontic modalities in SDL: For the deontic inference rule $\alpha \rightarrow O\alpha$, it requires that all deontic ideal worlds must be logically consistent worlds, and the logical theorems in the real world must also be valid in the deontic ideal world; For the K axiom $O(\alpha \rightarrow \beta) \rightarrow O\alpha \rightarrow O\beta$, it requires the clarity of the legislator's desires, and there should be no conflict attitudes in desires.

The openness of the axioms of modal logic makes the above axioms or inference rules not absolutely necessary, and these are not the only possible axioms. However, these two axioms or inference rules ensure that such modal logic is normal. Non-normal logical systems that do not use these axioms or inference rules will allow the emergence of worlds with confused or inconsistent attitudes of the legislator, which is not what we desire. According to our further requirements for the legislator, we can also expand our deontic logic system and add more axioms as "meta-norms".

Semantic justification of logical constraints

1. semantic justification of consistency

¹⁷ Stelmach, J. Brozek, B. (2006). *Methods of Legal Reasoning*. Dordrecht: Springer, 31.

Firstly, as previously stated, a model determines the truth values of formulas over a set of possible worlds. For a certain possible world $w \in W$ and a formula α , we can denote $V(\alpha, w) = T$ as $\langle W, R, V \rangle \models_w \alpha$. If for any $w \in W$, $\langle W, R, V \rangle \models_w \alpha$, then α is said to be valid in the model $\langle W, R, V \rangle$, and it is denoted as $\langle W, R, V \rangle \models \alpha$.

For any propositions α and β , for any model M , if $M \models \alpha$, then $M \not\models \beta$, and if $M \models \beta$, then $M \not\models \alpha$. In this case, α and β are called a set of contradictory propositions.

That is to say, if proposition α and proposition β are contradictory, then in any situation, proposition α and proposition β have different truth values. It can be proven that if α represents any formula, then the proposition " $O\alpha$ " and the proposition " $\neg O\alpha$ " form a logical contradiction. Similarly, " $P\alpha$ " and " $\neg P\alpha$ ", " $F\alpha$ " and " $\neg F\alpha$ " also form contradictory expressions. From an intuitive semantic perspective, they respectively mean: ① In all deontic ideal worlds established by the will of the legislator, it is impossible that α is true in all deontic ideal worlds while α is false in some deontic ideal worlds; ② In all deontic ideal worlds established by the will of the legislator, it is impossible that α is true in some deontic ideal worlds while α is false in all deontic ideal worlds.

However, obviously, in such possible world semantics, it is easy to prove that " $O\alpha$ " and " $F\alpha$ " ("ought to do" vs "ought not to do") do not form a contradiction. Intuitively, consider such a situation: A legal provision states that "Concluding a contract is permitted, and not concluding a contract is also permitted." One lawyer claims that "Concluding a contract is obligatory", and the other claims that "Concluding a contract is prohibited." Obviously, the claims of these two lawyers are both wrong. That is to say, in this case, these two propositions have the same truth value: both can be false. But whether they can both be true is still controversial. If they cannot both be true, then "There should be no conflict between 'ought to do' and 'ought not to do'" is the logical constraint that legal norms should follow. Here, we need to further examine the nature of the R relation. This requires us to return to the philosophical discussion: What is the relationship between the world where the legislator is and the ideal world he establishes?

It is easy to prove that if the conflict between "ought to do" and "ought not to do" constitutes a logical inconsistency, then there exists $w' \in W$ such that wRw' . In the semantics of possible worlds, we call this property "serial". There is controversy regarding the intuitive interpretation of this property. However, in the philosophy of law, this interpretation can be regarded as "for a possible world where there is a legislator with the power to formulate norms, there is always an ideal possible world envisioned by the legislator". According to the semantics of possible worlds, if such an ideal possible world does not exist, then the legislator cannot formulate norms. That is to say, if the legislator can formulate norms, then there must be such an ideal possible world. Given that the world is consistent, seriality implies that the content of

the norms formulated by the legislator must be logically realizable.¹⁸ It can be further proved that if we accept seriality, then we will accept the following axiom*: $O\alpha \rightarrow P\alpha$.

In conclusion, if we accept axiom*, then the relationship between "ought to do" and "ought not to do" becomes a logical inconsistency. Although these two can both be false, they cannot both be true, forming a "contrary relation". I agree with this acceptance because, as mentioned above, if the conflict between a pair of "ought to do" and "ought not to do" is not regarded as a logical contradiction, then in the model-theoretic semantics, the normative system corresponding to this conflict will be incomprehensible.¹⁹

2. semantic justification of inference-licensing

The technical issues involved in the reasoning from general norms to individual norms are much more complicated. Two common ways of simulation are " $O\forall x (Tx \rightarrow Rx)$ " and " $\forall x (Tx \rightarrow ORx)$ ",²⁰ The intuitive semantics of the former is that for any object in the domain, the following state of affairs is obligatory: if it has the property T, then it has the property R; the intuitive semantics of the latter is that for any object in the domain, if it has the property T, then the following state of affairs is obligatory: it has the property R.

Common works on legal methodology simply reduce the major premise in this reasoning, by combining deontic logic and first-order predicate logic, to " $\forall x (Tx \rightarrow ORx)$ ".²¹ Intuitively in terms of semantics, it means that for any element in the domain, if it has the property T, then in all deontic ideal worlds, it has property R. And the problem precisely lies in the issue of "domain". The property T is a property in the real world rather than in the deontic ideal world. If this predicate is a relation on the set of individuals in the real world, then if there are individuals in the deontic ideal world that do not exist in the real world, there will be gaps. In terms of the theory of the "exception argument" in the previous text, it means that the legislator cannot consider all future situations and provide exceptions when legislating in the real world. Even if we adopt the attitude of normative logic skepticism, such gaps will still cause difficulties: from the existence of general norms, the existence of individual norms cannot be rationally deduced. Technically speaking, if we want to ensure the validity of " $\forall x (Tx \rightarrow ORx)$ ", " $Ta \rightarrow ORa$ " and avoid such gaps, then we must use a kind of "constant domain semantics", keeping the individuals in the real world and all deontic ideal worlds the same, so that the domain in the reasoning remains consistent throughout. However, this kind of semantics has great limitations. From a philosophical perspective, the volitional behavior of the legislator cannot focus on the

¹⁸ The logical realizability here is only the minimum requirement, and it does not require "being realizable" physically, but merely means that this world can be conceived. Vgl. Joeden. (2010). *Logik im Recht*, Berlin: Springer-Verlag.

¹⁹ Compared with M. H. (2024). *Rights and Right-Holding: A Philosophical Investigation*, Oxford: Oxford University Press, 28-34.

²⁰ Stelmach, J. Brozek, B. (2006). *Methods of Legal Reasoning*. Dordrecht: Springer, 35.

²¹ Alexy, R. (1991). *Theorie der juristischen Argumentation : die Theorie des rationalen Diskurses als Theorie der juristischen Begründung*. Frankfurt am Main: Suhrkamp Verlag, 274.

increase and decrease of elements in the real world to adjust the exception premises in the norms, making the elements in the possible world envisioned by the legislator always consistent with those in the real world.

Another serious problem with this reduction is that it will trigger a special case of the "Chisholm Paradox". It is easy to prove that $\forall x (\neg Tx \rightarrow (Tx \rightarrow ORx))$, and further that $\forall x \neg Tx \rightarrow \forall x (Tx \rightarrow ORx)$. That is to say, if all objects in the domain do not have the property T, then there is the "norm" $\forall x (Tx \rightarrow ORx)$. This is obviously absurd: if no one in the world kills, then there exists the norm "If anyone kills, then he should be sentenced to death".²²

According to the previous research results of modal logic, It is better to use " $\forall x (Tx \rightarrow Rx)$ ". The domain in this sentence only includes the deontic ideal world and does not include the real world. From the perspective of the philosophy of logic, the classical transformation is a transformation of "modality de re", while this transformation is a transformation of "modality de dicto". It can be proved that a proposition of modality de re implies a proposition of modality de dicto if and only if the set of elements in the deontic ideal world in the real world is a subset of the set of elements in the real world; a proposition of modality de dicto implies a proposition of modality de re if and only if the set of elements in the real world is a subset of the set of elements in the deontic ideal world. For the theory of legal norms, it is more reasonable to assume that the set of elements in the real world is a subset of the set of elements in the deontic ideal world.

In this way, the reasoning from general norms to individual norms can be expressed as " $\forall x (Tx \rightarrow Rx)$, $OTa \rightarrow ORa$ ". The validity of this formula can be easily proved. However, its drawback is also quite obvious: the property T is not always desired by the legislator, especially in criminal law norms. Taking "Those who commit murder should be sentenced to death" as an example, it seems to imply that the minor premise must be "Murder should be committed". Here, it is necessary to stratify the deontic ideal world semantically and introduce the order among deontic ideal worlds.²³ In essence, the legislator first conceives an optimal deontic ideal world. Once this ideal world cannot be realized, it will "fall" into a sub-optimal deontic ideal world. In such conditional norms, the deontic modal word "O" expressing "ought" points to the sub-optimal deontic ideal world, rather than the optimal deontic ideal world.

Thus, the argument from general norms to individual norms, that is, the logical constraint of "reasoning permission", is preliminarily established.

²² This argument is derived from an extension of the "Chisholm Paradox" in deontic propositional logic. See Hilpinen, R., McNamara, P. (2013). Deontic Logic: A History Survey and Introduction, in Gabbay, D., Horty, J., Parent X.(eds.) *Handbook of Deontic Logic and Normative Systems*. College Publications, 85.

²³ See Carmo, J. Jones, A. (2002). Deontic Logic and Contrary-to-duties, in *Handbook of Philosophical Logic*, Second Edition, Vol.8, Gabbay and F. Guenther(eds), Kluwer Academic Publishers, 265-344.

Working mechanism of logical constraints on legal norms

In this section, we will examine how the inference-licensing constraints and consistency constraints operate to restrict the application of legal norms in practice. Intuitively, there exist logical relationships among valid legal norms, and such logical constraints can be directly applied to legal norms. However, the skepticism regarding deontic logic renders this intuition indefensible. If, as stated above, deontic logic is applicable to the normative statements about the deontic ideal world created by the idealized director, then does there exist a reflexive application? That is, will the logical reasoning of normative statements reflect on the valid norms, and will the logical relationships between normative statements be reflected as the logical relationships between the original norms?

This seems to be the only possible way, because only when all legal norms are either obtained from the legislator or through deductive reasoning from the norms issued by the legislator can it be said that the discovery of legal norms is not based on the will of the judiciary, but on rational reasoning. However, this line of thought presupposes a premise, that is, reason can only be realized based on deductive reasoning. For example, when a judge derives an individual norm from the general norm of the legislator, under the premise that the reflexive model holds, it is a form of deductive reasoning and is of course rational. But if the reflexive model does not hold, then this kind of inference is no longer deductive reasoning and is not considered rational. However, in all arguments, there are a large number of non-deductive reasoning, and since they are supported by appropriate reasons, they are not irrational.

The relationship between normative statements should have a refractive influence on legal norms. The applicators of legal norms first acquire a set of beliefs regarding the existence of norms based on these norms, which is also known as a set of normative statements. After the logical relationships between normative statements are determined, we may find that there are certain problems within this set of norms. Corresponding to the constraints of inference-licensing and consistency, it may turn out that the needed norms are absent, or there are norms that conflict with each other. In other words, guided by deontic logic, the judiciary makes a constrained "continuation" of legal norms.

Gaps in legal norms

First, we examine the situation where there is a gap in the norms we need. This is not the common situation of a legal gap beyond the legislator's plan in the methodology of law. Instead, it is a gap caused by the fact that we are unable to directly and logically obtain the individual norms from the original norms. Such a gap needs to be fulfilled by the constraints of inference-licensing.

A typical example in Jørgensen's Dilemma: In the judicial syllogism $O\forall x (Tx \rightarrow Rx)$, $OTa \rightarrow ORa$, since it no longer expresses the logical relationship between norms, the

legislator cannot derive individual norms from general norms. The most typical obstacle here is the existence of a large number of exceptions relative to general norms. In classical legal methodology, the negation of the conjunction of the premises of these exceptional situations is generally taken as part of the premise of the general norm. However, this is the result of handling by the methodology formed over time in legal practice, not a logical rule, and it cannot rule out the situation where there are exceptions with unclear hierarchies in legal practice. In this case, the deontic ideal world created by the legislator may be in chaos (that is, the propositions describing it are logically inconsistent), which requires us to conduct dynamic argumentation to solve it.

Subsequently, according to the judicial power granted by the legislator, we will refractionally add the derived norms described by the normative statements about the existence of derived norms obtained from the normative statements about the existence of norms (for example, deriving the individual norms described by the normative statements about the existence of individual norms from the normative statements about the existence of general norms) to the set of applicable norms, thus obtaining a new set of norms.

Conflicts in legal norms

Next, we will discuss the situation of normative conflicts. In such cases, we need to carry out subsequent creation based on the consistency constraints.

For example, $O\forall x (Tx \rightarrow Rx)$ and $\neg O\forall x (Tx \rightarrow Rx)$ are obviously in conflict. Intuitively, the former expresses that "it is obligatory that any individual with the property T has the property R"; the latter expresses that "it is not obligatory that any individual with the property T has the property R". Based on the interpretation of normative statements and the semantics of possible worlds that we have established, these two sentences describe the states of affairs in the deontic ideal world established by the legislator. The accurate semantics of the former is that "in all the deontic ideal worlds established by the legislator, any individual with the property T has the property R", and the accurate semantics of the latter is that "it is not the case that in all the deontic ideal worlds established by the legislator, any individual with the property T has the property R". The logical contradiction in the normative statements is obvious. However, this does not mean that the world created by the norms is logically contradictory or inconsistent. This "possible world" actually has similar logical characteristics to our real world, that is, it is not a logical object..

Subsequently, according to legal rules, the methods of legal dogmatics, and even value judgments, we will discard some of the inconsistent propositions. Furthermore, by assuming that the propositions in the newly obtained set of normative statements are all true, the appliers of legal norms can obtain a new set of norms. And this new set of norms no longer reflects to the set of the original norms, but is refracted into a new set of norms.

The necessary condition for the establishment of the refraction theory lies in a subtle

property of norms: norms are not completely independent of the mind. For the objective world that can be extremely regarded as independent of the mind, if there is a possible conflict between the objective world and logic, we cannot hope or require the objective world to conform to logic; but for norms and their legislators, this can be achieved. In this sense, the ultimate realization of norms is generated by the interaction between the judiciary and the legislator. Therefore, norms are a cooperative undertaking.

Conclusion

This article arrives at three conclusions: Firstly, in terms of meta problems, deontic logic does not deal with valid norms, but rather with the norms created by the idealized director. Inference-licensing and consistency are two principles of the will of the idealized director. Regarding specific problems, the semantics of possible worlds in deontic logic demonstrates the two logical constraints of inference-licensing and consistency on legal norms. In practical problems, the judiciary completes the "continuation" of legal norms through the "refraction model" guided by deontic logic, thus accomplishing the cooperative undertaking of legal norms.

Breaking the Cocoon of a Millennial Logical Dilemma: Paradigmatic Innovation in Logical Domain Theory and the Ultimate Resolution of Paradoxes

Mingliang XU

Zhejiang Hezhong Legal Technology Intelligent Research

Institute, Hangzhou, Zhejiang, 310016

Abstract

Traditional logic has long been trapped in the paradoxes of substantive implication, incomplete conceptual relations and logical paradoxes. The theory of logical domains achieves a systematic breakthrough of traditional logic by reconstructing implication relations, completing the conceptual system and unifying logical laws. This article unfolds from three aspects, namely the core of the theory, application value and historical significance, to demonstrate its milestone role in the paradigm innovation of logic and provides new ideas for solving the millennial logical dilemma.

Keywords

logic domain theory; substantial implication; conceptual relationship; logical paradox; paradigm innovation

Introduction

Logic, as a core discipline exploring the laws of human thinking, has been constantly evolving on the path of pursuing precision and universality since Aristotle established the formal logic system in the fourth century BCE. From the syllogism of ancient Greece to the symbolic revolution of modern mathematical logic, logic has continuously deepened the depiction of reasoning rules through the iteration of formal tools. However, while this development has promoted the progress of the discipline, it has also gradually exposed profound contradictions that are disconnected from human natural thinking, which are concentratedly manifested in three core predicaments.

First of all, the truth-value paradoxes of material implication have become an

insurmountable obstacle for traditional logic. Since Frege simplified “if p then q ” to the truth-functional operation of “ $\neg p \vee q$ ”, the field of logic has long been confronted with the paradox that “false propositions implies all propositions”. For instance, the statement “If the moon were made of cheese, then the earth would be square” is judged as a true proposition in the system of substantive implication. This kind of formalized treatment that divorces from semantic relevance reduces logical deduction to a mere game of symbols, seriously deviating from human intuitive understanding of conditional propositions.

Secondly, the incompleteness of the theory of conceptual relation restricts the depth of logical analysis. Traditional logic has only established four categories and six types of relations, namely, sameness, inclusion (true inclusion in, true inclusion), pure intersection (the so-called conceptual intersection relationship usually referred to), and total difference (opposition, contradiction). It is unable to explain the subcontrary relationship (both the subcontrary relation and the pure intersection relation belong to the intersection relation) which widely exists in natural languages, that “it is impossible for both propositions to be false but possible for both to be true (it is impossible for both to be negated but possible for both to hold true)”. For example, in the conceptual domain of “triangle”, the logical connections between the complement of “obtuse triangle” and “right triangle”, namely “non-obtuse triangle” and “non-right triangle”, have always lacked a systematic explanation within the traditional framework. This results in the failure of conceptual operations in complex semantic scenarios.

Finally, the unsolvable predicament of logical paradoxes continuously challenges the self-consistency of the logical system. The self-referential proposition represented by the liar paradox, “This statement is false”, constantly triggers the logical contradiction of “both true and false” through the circular negation of substantive implication. Although scholars such as Russell and Tarski have attempted to avoid paradoxes by methods of hierarchical theory and language hierarchy and other methods, they have never been able to fundamentally eliminate the threat these paradoxes pose to the logical foundation.

The root cause of these predicaments essentially lies in the fact that traditional logic overly pursues formalization while neglecting the semantic essence. Logical rules should originally be the refinement of the laws of human thinking. However, when the semantic connection between the formal system and natural language is severed, logic loses its core value as a cognitive tool. The theory of logical domain precisely addresses this crux of the problem and systematically reconstructs the traditional logical framework through a dual-track model of “semantic anchoring + logical deduction”. Through four major breakthroughs, namely, innovating the implication relationship, completing the conceptual system, unifying logical laws, and resolving logical paradoxes, this theory not only fills the theoretical gap in the history of both Chinese and foreign logic but also promotes logic to return from the “labyrinth of

formalization” to the essence of human thinking, opening up a revolutionary new direction for the development of the discipline.

1. The Subversive Reconstruction of Material Implication

1.1 The Defects of Traditional Material Implication

In the traditional logical system, material implication simplifies the conditional proposition “ $p \rightarrow q$ ” (if p , then q) into the truth-value operation form of “ $\neg p \vee q$ ” (not p or q). Although this approach demonstrates simplicity in mathematics and symbolic logic, it has given rise to serious logical paradoxes and semantic ruptures.

Firstly, the disconnection between truth-value operation and semantics leads to counterintuitive conclusions: According to the rules of material implication, as long as the antecedent p is false, regardless of the content of the consequent q , the entire proposition “ $p \rightarrow q$ ” is always true. For example, the proposition “if the moon were made of cheese, then the earth would rotate in the opposite direction around the sun” was judged to be a true proposition under material implication. This result completely deviates from human semantic understanding of conditional propositions. In natural language, “if...then...” usually requires a causal, logical or correlative connection between the antecedent and the consequent, while material implication only focuses on the mechanical operation of the truth table, reducing the conditional relationship to a pure combination of truth values.

Secondly, the formal distortion of logical relations makes it difficult for material implication to deal with complex semantic scenarios. Traditional logicians have attempted to make the ambiguity of natural language precise through formal methods, but the excessive simplification of material implication leads to the deviation of logical derivation from daily thinking. For example, in legal reasoning, the validity of the proposition that “if someone intentionally kills a person, then they should bear criminal responsibility” depends on the substantial connection between “intentional homicide” and “criminal responsibility”. However, material implication simplifies it into a truth-value operation, which may lead to the absurd conclusion that “if someone does not intentionally kill a person (the antecedent is false), then any act should bear criminal responsibility (the consequent can be arbitrarily true)”. This distortion not only weakens the practicality of logic as a thinking tool, but also exposes the limitations of formal methods in dealing with semantic richness.

1.2 The Innovative Path of the Logical Domain Theory

1.2.1 Introduce the Closed Exhaustive Disjunction “Y”

In view of the defects of traditional substantive implication, the logic domain theory introduces the closed exhaustive disjunctive symbol “Y” (representing the strong

disjunctive relation of “either...or...” to reconstruct the implication formula:

$$(p \rightarrow q) \leftrightarrow ((\neg p \vee q) \wedge (\neg p \vee p)) \leftrightarrow (\neg p \vee (p \wedge q)) \leftrightarrow (\neg p \vee q) \rightarrow (\neg p \vee q)$$

The core of this reconstruction lies in emphasizing that “either $\neg p$ or q must be true”, that is, the two form a sub-contrary or contradictory relationship (equivalent to the fact that “ p and $\neg q$ are in an opposing or contradictory relationship”). Different from traditional material implication, the logical domain theory requires that the validity of “ $p \rightarrow q$ ” must be based on the substantial logical connection between the antecedent and the consequent, rather than a simple combination of truth values. For example, in the proposition that “if it rains (p), then the ground is wet (q)”, “ $\neg p \vee q$ ” indicates that “either it does not rain, or it rains and the ground is wet”. This statement forcibly establishes a semantic connection between p and q , avoiding the arbitrary implication of irrelevant propositions.

1.2.2 The Strict Distinction of Proposition Types

The logical domain theory clearly demarcates the boundary between domain propositions and general propositions:

Domain propositions, represented by “ $p \rightarrow q$ ” and “ $\neg p \vee q$ ”, require a logical connection at the semantic level between the antecedent and the consequent, making $\neg p$ and q form a sub-contrary or contradictory relationship. This proposition reflects the essential cognition of conditional relationships in human thinking, that is, “when p is true, q cannot be false”. For instance, “if a number is divisible by 10 (p), then it is divisible by 5 (q)”, which is “ $p \rightarrow q$ ”, and its equivalent form is “ $\neg p \vee q$ ” (“either the number is not divisible by 10, or it is divisible by 5”), reflecting the necessary connection between p and q .

General propositions, that is, factual propositions, such as “ $\neg p \vee q$ ”, only describe the factual state of “not p or q ” from the perspective of truth values, without involving semantic connections. For example, “today is not Monday ($\neg p$), or tomorrow is Thursday (q)”. In general propositions, only the combination of truth values is concerned, while the temporal logical relationship between “today” and “tomorrow” is ignored.

The breakthrough of the logical domain theory lies in the introduction of “closed exhaustive disjunction” (symbolized as “ \vee ”, meaning “either...or...”). The closed exhaustive disjunction proposition, that is, the domain proposition ($\neg p \vee q$), indicates that either $\neg p$ or q must be true, and both cannot be false simultaneously, thus completely ruling out the possibility of $(p \wedge \neg q)$. This is something that a general proposition ($\neg p \vee q$) cannot achieve.

The equivalent form of the proposition ($p \rightarrow q$), namely ($\neg p \vee q$) (read as “either not p or q ”), as an expression of a binary truth function, the validity of its logical semantics is deeply rooted in the formal system of propositional logic. When detached from the

established logical domain, factual proposition expressions such as $(\neg p \vee p)$, $(\neg q \vee q)$, $(\neg p \vee q)$, etc., due to the lack of constraints of the truth-value operation rules, will lose the foundation of logical deduction. At this point, these expressions can neither be verified through the semantic judgment criteria of well-formed formulas nor participate in effective logical reasoning, thus losing their analytical value at the level of propositional logic. This profoundly reveals that the interpretation and logical analysis of any propositional function must rely on specific logical domain frameworks and rule systems such as $(\neg p \vee p)$, $(\neg q \vee q)$, etc. Otherwise, it will lead to the dissolution of the logical meaning of the expressions and degenerate into a meaningless accumulation of symbols.

1.2.3 The Paradoxical Deduction of Illegal Conversion

Domain proposition can unidirectionally imply a general propositions (that is, when “ $p \rightarrow q$ ” is true, “ $\neg p \vee q$ ” must be true), but the two cannot be mutually and equivalently transformed. If this rule is violated, it will lead to illegal logical conversion and give rise to paradoxs.

We know that the valid formula $\neg p \leftrightarrow ((\neg p \vee q) \wedge (\neg p \vee \neg q))$ holds, and its essence is to restore the logical meaning of “not p” through the conjunction of general propositions. However, if the domain proposition “ $p \rightarrow q$ ” is illegally equivalent to the general proposition “ $\neg p \vee q$ ”, and the derivation is carried out according to the rules of material implication, the following contradiction will occur:

From “ $(p \rightarrow q) \leftrightarrow (\neg p \vee q)$ ”, combined with propositional logic, we can get:

$$\neg p \rightarrow ((p \rightarrow q) \wedge (p \rightarrow \neg q))$$

In the consequent, since $(p \rightarrow \neg q)$ is equivalent to $(q \rightarrow \neg p)$, the formula of the consequent is: $(p \rightarrow q) \wedge (q \rightarrow \neg p)$, and thus it becomes “ $p \rightarrow q \rightarrow \neg p$ ”, that is “ $p \rightarrow \neg p$ ”. (If p is true, then not p must be true, which is a contradiction).

Symmetrically, from “ $(\neg p \rightarrow q) \leftrightarrow (p \vee q)$ ”, combined with propositional logic, we can get:

$$p \rightarrow ((\neg p \rightarrow q) \wedge (\neg p \rightarrow \neg q))$$

In the consequent, since $(\neg p \rightarrow \neg q)$ is equivalent to $(q \rightarrow p)$, the formula of the consequent is “ $(\neg p \rightarrow q) \wedge (q \rightarrow p)$ ”, and thus it becomes “ $\neg p \rightarrow q \rightarrow p$ ”, that is “ $\neg p \rightarrow p$ ”. (If $\neg p$ is true, then p must be true, which is a contradiction).

The logical paradox of “ $p \leftrightarrow \neg p$ ” formed by the above derivation is rooted in the illegal equivalence between domain propositions and general propositions, ignoring the essential differences in semantic relevance between the two.

1.2.4 The Unified Integration of Logical Laws

The logical domain theory realizes the organic unity of the law of excluded middle,

the law of contradiction, and the law of sufficient reason through the equivalent relation of “ $(p \rightarrow q) \leftrightarrow (\neg p \downarrow q) \leftrightarrow (p \uparrow \neg q)$ ”:

“ \downarrow ” (sub-contrary or contradictory relation) reflects that either $\neg p$ or q must be true, and concretizes the law of excluded middle as the logical constraint between propositions. For example, in the proposition that “if a number is divisible by 10 (p), then it is divisible by 5 (q)”, “ $\neg p \downarrow q$ ” ensures that at least one of “a number is not divisible by 10” and “it is divisible by 5” is true, excluding the invalid proposition where the antecedent is false and the consequent is irrelevant.

“ \uparrow ” (opposition or contradictory relation) requires that either p or $\neg q$ must be false, reflecting the guarantee of the law contradiction for logical consistency. For example, in the proposition that “if a number is divisible by 10 (p), then it is divisible by 5 (q)”, “ $p \uparrow \neg q$ ” prohibits the contradictory statement that “a number can be divisible by 10 (p), but it can not be divisible by 5”.

A valid conditional proposition “ $p \rightarrow q$ ” needs to satisfy both the law of excluded middle, that is, “either $\neg p$ or q must be true”, and the law of non-contradiction, that is, “either p or $\neg q$ must be false”. This integration sublimates the logical laws from scattered rules into an organic system of mutual definition, completely changing the situation where the three laws in traditional logic were independent of each other.

Through the above reconstruction, the logical domain theory not only solves the truth-value paradox of material implication, but also lays a theoretical foundation for logic that is more in line with the essence of human thinking through the deep integration of semantics and logic.

2. The Pioneering Breakthrough of the Conceptual Domain Theory

2.1 The Completion of the Conceptual Relationship System

2.1.1 *The Addition of the Sub-contrary Relationship: The Crucial Puzzle Piece of the Logical Relationship Map*

In the study of conceptual relationships, traditional logic has long been confined to four categories of relationships, encompassing six types in total, namely, identity, inclusion (proper inclusion and inclusion), pure intersection (the so-called conceptual intersection relationship), and total difference (opposition and contradiction). The incompleteness of this theoretical system has given rise to numerous difficulties in logical analysis. The logical domain theory has made a breakthrough by introducing the sub-contrary relationship, thus filling this millennial gap. The sub-contrary relationship refers to the logical connection between two concepts, which means that “they cannot both be false, but they can both be true (they cannot both be negated, but

they can both be affirmed)”. Its core value lies in the perfection of the rules for logical deduction between concepts.

Based on the principle of logical duality, the logical domain theory clearly states that if S and P are in an opposition relationship, then $\neg S$ and $\neg P$ must be in a sub-contrary relationship. Taking the conceptual domain of “triangle” as an example, “obtuse triangle” and “right triangle” are typically in an opposition relationship, which means that they cannot both be true, but they can both be false (such as in the case of an acute triangle). Its complementary sets, “non-obtuse triangle” and “non-right triangle”, form a sub-contrary relationship: in any classification of triangles, “non-obtuse” and “non-right” cannot both be false (there is no triangle that is neither obtuse nor right), but they can both be true (an acute triangle satisfies both simultaneously). The clarification of this relationship enables logical reasoning to handle negative statements in natural language more precisely, avoiding logical loopholes caused by the lack of such a relationship.

2.1.2 The Refined Classification of the Opposition Relationship: A Multidimensional Deconstruction from the Perspective of the Logical Domain

The definition of the opposition relationship in traditional logic is rather general. Through the conceptual domain polygon model, the logical domain theory subdivides the opposition relationship into three subtypes, significantly improving the precision of logical analysis:

Relative contradictory relationship: The opposition relationship exhibits contradictory characteristics within a specific universe of discourse. For example, “obtuse triangle” and “non-obtuse triangle” form a contradictory relationship (either one or the other) within the conceptual domain of “triangle”, but when placed in the broader domain of “polygon”, they degrade into an opposition relationship (there are other possibilities such as quadrilaterals). This relativity reveals the context-dependence of conceptual relationships and breaks through the cognitive limitation of the absolutization of the contradictory relationship in traditional logic.

Parallel opposition relationship: It is an incompatible relationship between same-level species concepts under the same genus concept. For example, “obtuse triangle”, “right triangle” and “acute triangle” are all sub-concepts of “triangle”, which are mutually exclusive and can both be false (when the object of discussion does not belong to the category of triangles). This type of relationship is the main manifestation of the opposition relationship in traditional logic. However, the logical domain theory makes its logical attributes clearer by clarifying the hierarchical structure.

Non-parallel opposition relationship: It is the incompatibility among concepts across levels. For instance, “triangle” and “square”, “right triangle” and “non-triangle”, etc., belong to geometric concepts at different levels. Although they do not form a

opposition relationship at the same level, within the more abstract domain of “plane figure”, the two also have an opposition nature (a figure cannot belong to these two categories simultaneously). This classification expands the applicable scope of the opposition relationship, enabling logical analysis to cover conceptual conflicts in complex semantic scenarios.

2.2 Logical Treatment of Imaginary Concepts and Empty Concepts

2.2.1 The Framework of “Conceptual Domain W”: A Logical Revolution Breaking Through the Limitations of Reality

In traditional logic, imaginary concepts (such as “unicorn”) and empty concepts (such as “a round square”) are often excluded from logical operations because they lack real-world references, which severely limits the universality of logic. The theory of “conceptual domain W” endows all concepts (whether real or imaginary) with logical legitimacy by introducing the contextual anchoring of the “possible world”. The core of this framework is to liberate logical analysis from the shackles of the real world and instead focus on the logical relationships of concepts within specific semantic fields.

In the “conceptual domain W”, each concept is regarded as a logically real concept. Its existence does not depend on real-world counterparts but derives its meaning through the relational network with other concepts. This setting allows logical rules to function properly in fictional, hypothetical, or abstract contexts, greatly expanding the application boundaries of logic.

2.2.2 Case Analysis: The Logical Rebirth of Virtual and Real Concepts

“Unicorn”: The relationship construction of fictional concepts

In the real world, the “unicorn” is a non-existent virtual concept. However, in the “conceptual domain W of mythical creatures”, it forms a parallel opposition relationship with the “Pegasus” (both belong to mythical creatures but are mutually exclusive), and a relative contradictory relationship or a contradictory relationship with the “non-unicorn” (in the context of mythological narratives, creatures are either one or the other). By clarifying the conceptual domain, the logical domain theory enables propositions such as “the unicorn has one horn” and “the Pegasus has no horn” to obtain valid truth-value judgments, achieving the logical processing of fictional concepts.

“The Round Square”: A clear definition of contradictory concepts

As a typical empty concept, “the round square” cannot exist both in reality and in logic because it violates the law of contradiction. Through the rules of the “conceptual

domain W”, the logical domain theory clearly defines it as “an invalid concept that violates the law of contradiction”. This definition avoids the ambiguous treatment of contradictory concepts in traditional logic. Instead of simply excluding them or assigning them meaningless truth values, it confirms their invalidity through logical rules, thus maintaining the consistency of the logical system. In a specific conceptual domain, propositions such as “the round square is not round” and “the round square is not square” can also be true propositions.

This innovative treatment of virtual concepts and empty concepts not only solves the difficult problem of conceptual operations that have long troubled logic, but also drives the shift of logical analysis from “reality mapping” to “thinking construction”. When logical rules can handle all possible concepts without hindrance, logic truly achieves the leap from studying “laws of reality” to exploring “laws of thinking”, providing more powerful analytical tools for fields such as philosophy, linguistics, and artificial intelligence.

By completing the system of conceptual relationships and innovating the rules of conceptual operations, the theory of logical domain has thoroughly transformed the traditional theory of logical concepts. This breakthrough not only fills the theoretical void but also reshapes the relationship between logic and human thinking. Logic is no longer confined to the static classification of real-world objects, instead, it has become a thinking engine capable of dynamically handling diverse semantics and constructing complex conceptual networks.

3. The Resolution and Prevention of Logical Paradoxes

3.1 The Diagnosis of the Essence of Paradoxes

3.1.1 The Handling Defects of Self-referential Propositions in Traditional Logic

The existence of logical paradoxes is like the sword of Damocles hanging over the head of logic, challenging the self-consistency of the logical system for a long time. The dilemma of traditional logic regarding paradoxes is centrally reflected in the failure of dealing with self-referential propositions. And the root of this problem lies in the formal defects of material implication. Taking the liar paradox as an example, when the proposition is stated as “this sentence is false”, if it is symbolized as “ $p \rightarrow \neg p$ ” (p represents that “this sentence is false” and $\neg p$ represents that “this sentence is true”), based on the rules of material implication in traditional logic, it will fall into a circular negation where “if p is true, then $\neg p$ must be true; if $\neg p$ is true, then p must be true”. This contradiction stems from the fact that material implication simplifies the conditional relationship into truth-value operations, ignoring the semantic correlation between the antecedent and consequent of the proposition, enabling self-referential propositions to continuously generate logical contradictions through formal rules.

In the framework of traditional logic, the particularity of self-referential propositions is obscured by formal symbols. For instance, in Russell's paradox ("whether the set consisting of all sets that do not contain itself contain itself") also leads to the logical collapse of the relationship between "belonging to" and "not belonging to" due to the excessive simplification of material implication. This way of handling not only fails to truly resolve the paradox but also intensifies the generation of contradictions through formal derivation, exposing the vulnerability of traditional logic when dealing with complex semantics.

3.1.2 *The Judgment Criteria of the Logical Domain Theory*

The theory of the logical domain fundamentally redefines the determination criteria of valid conditional propositions and provides a brand-new perspective for resolving paradoxes. This theory explicitly requires that a legitimate conditional proposition " $p \rightarrow q$ " must satisfy the condition that " p and $\neg q$ form an opposite or contradictory relationship". This criterion emphasizes the substantial logical connection between the antecedent and the consequent of a proposition, rather than merely the correspondence of truth values. Under this rule, the paradoxical nature of self-referential propositions is directly negated. Because self-reference is essentially the self-negation of the same proposition (for example, in " $p \rightarrow \neg p$ ", p and $\neg p$ are actually positive and negative expressions of the same content), they neither form an opposite relationship (an opposite relationship requires the incompatibility of two different concepts) nor a contradictory relationship (a contradictory relationship needs to be based on a clear division of the logical domain), so they do not possess the validity of logical reasoning.

The theory of the logical domain further points out that the emergence of paradoxes stems from the neglect of the semantic relevance of propositions by traditional logic. When the validity of " $p \rightarrow q$ " relies solely on the truth table, self-referential propositions can take advantage of the loopholes in the formal rules to generate contradictions in the absence of substantial logical connections. By introducing the determination condition of the "opposite or contradictory relationship", the theory of the logical domain sets a semantic threshold for the validity of propositions, cutting off the generation path of paradoxes from the source.

3.2 Examples of Paradox Resolution

3.2.1 *The Ineffectiveness Proof of the Liar Paradox " $p \rightarrow \neg p$ "*

Taking the liar paradox "This sentence is false" as an example, the theory of the logical domain reveals its invalidity through a three-step analysis:

i. Lack of semantic relevance:

In " $p \rightarrow \neg p$ ", both p and $\neg p$ point to the same proposition "This sentence is false",

which is essentially a circular expression of self-reference. According to the theory of the logical domain, the antecedent and consequent of a valid conditional proposition need to have independent semantic content. However, here p and $\neg p$ are actually repetitions of the same concept or proposition and cannot form an “opposite or contradictory relationship”. For example, if p is defined as “It is raining” and $\neg p$ is defined as “It is not raining”, the two form a contradictory relationship because they describe different states. But in the liar paradox, p and $\neg p$ do not provide any substantial distinction, thus they do not meet the basic requirement of a valid proposition.

ii. The logical relationship does not hold:

From the perspective of the equivalent formula of $(p \rightarrow q)$ in the theory of the logical domain, which is “ $\neg p \vee q$ ”, the liar paradox can be transformed into “ $\neg p \vee \neg p$ ” (either “this sentence is true” or “this sentence is true”). This expression neither conforms to the characteristic of “both cannot be false” of the sub-contrary relationship (it is impossible for two identical propositions to have one true and one false), nor can it form an effective logical deduction. In traditional logic, “ $p \rightarrow \neg p$ ” is given legitimacy due to the truth-value operation of material implication. However, in the theory of the logical domain, the lack of its internal logical relationship directly leads to its judgment as an invalid proposition.

iii. Cutting off the root of the contradictory cycle:

The logical domain theory negates the inferential value of “ $p \rightarrow \neg p$ ” by emphasizing semantic relevance. When a self-referential proposition fails to meet the judgment criteria of valid conditional propositions, the contradictory cycle of “being both true and false” triggered by it loses its logical foundation. This implies that the liar paradox is not an inevitable result of logical rules, but a pseudo-proposition caused by the formal defect of traditional logic.

3.2.2 Redefining the Logical Boundaries to Eliminate the Contradictory Cycle

The resolution of the liar paradox by the logical domain theory is essentially a redefinition the logical boundaries. Traditional logic, due to its excessive reliance on formalization, includes self-referential propositions within the scope of valid reasoning, resulting in the emergence of logical contradictions. In contrast, the theory of the logical domain, through semantic constraints, clearly demarcates the boundaries of the validity of propositions: any proposition that is self-referential or lacks semantic relevance is not allowed to enter the legitimate field of logical reasoning.

This redefinition of boundaries not only solves the problem of the liar paradox, but also provides a unified solution for other types of logical paradoxes (such as Russell’s paradox and the barber paradox). For example, in Russell’s paradox, the concept of “all sets that do not contain themselves”, due to the contradiction between the relationships of “containing” and “not containing” caused by self-reference, is also

judged as an invalid concept under the logical domain theory because of the lack of effective semantic connection. By shifting the focus of logical analysis from formal truth values to semantic essence, the theory of the logical domain has achieved a fundamental transformation in logic from “passively tolerating paradoxes” to “actively preventing paradoxes”, laying a solid foundation for constructing a self-consistent logical system.

To sum up, the logical domain theory has successfully eliminated the threat of logical paradoxes by innovating the criteria for the validity of propositions. This breakthrough not only ended the millennial logical dilemma but also propelled logic back to its essence as the “science of the laws of thought”. It provides reliable logical support for the theoretical development in fields such as philosophy, mathematics, and artificial intelligence.

4. The Significance of the Paradigm Revolution of the Logical Domain Theory

4.1 Methodological Shift: From Form-Priority to Semantic-Driven Cognitive Regression

The revolutionary nature of the logical domain theory is first manifested as a fundamental shift in methodology. It has subverted the logical development path since Frege’s principle of “form taking precedence over semantics”, reestablished the cognitive principle of “semantics determining form”, and made logic truly become a “science of thinking” that conforms to the natural thinking of human beings.

4.1.1 The Principle of Semantic Priority: The Foundation of Logical Rules in Natural Language

Traditional logic pursues the formal simplicity of mathematics and strips the meaning of propositions into pure truth-value symbols (such as “p” and “q”), leading to the disconnection between logical rules and the intuitive thinking in natural language. In contrast, the logical domain theory emphasizes that logical forms must be rooted in semantic associations. For instance, the validity of the conditional proposition “ $p \rightarrow q$ ” no longer depends on the mechanical determination of the truth table, but rather on whether “p and $\neg q$ form an opposite or contradictory relationship”. This criterion directly corresponds to the “intuition of meaning association” in human daily thinking. When we say “If we study hard (p), we will get good grades (q)”, the implicit premise is that “studying hard but not getting good grades ($p \wedge \neg q$)” is unacceptable, which is exactly the semantic anchoring of “p and $\neg q$ cannot both be true” in the logical domain theory.

The profound significance of the principle of semantic priority lies in restoring the

essential attribute of logic as a "thinking tool". Traditional logic's formalization overly pursues the self-consistency of the symbolic system, yet forgets that the ultimate goal of logical rules is to serve human cognition. By introducing semantic categories such as "sub-contrary relationship" and "relative contradictory relationship" into the formal system, the logical domain theory brings logical deduction closer to the complex semantic structure of natural language. For example, in the interpretation of legal provisions and the deduction of scientific hypotheses, it can more accurately capture the substantial logical connections between propositions and avoid reasoning fallacies caused by semantic distortion.

4.1.2 Context Dependence: The Dual-domain Definition of Proposition Validity

The dual-domain framework of the "concept domain W" and the "proposition domain w" proposed by the logical domain theory marks the formal acceptance of context dependence in logic. Traditional logic assumes that propositions have universal validity beyond context. For example, " $p \rightarrow q$ " is determined solely by truth values. However, the logical domain theory points out that the meaning and truth values of propositions must be examined in specific contexts.

The concept domain W defines the semantic boundaries of concepts. For instance, the contradictory relationship between "obtuse triangle" and "non-obtuse triangle" only holds in the domain of "triangles", while it is an opposing relationship in the domain of "polygons".

The proposition domain w restricts the applicable scope of propositions. For example, the proposition "If it rains, then the ground is wet" is valid in the "open-air environment domain", but does not hold in the "indoor environment domain".

The theoretical construction of this context dependence breaks the formal myth of the "one-size-fits-all" approach in traditional logic, enabling logical analysis to dynamically adapt to the contextual changes in natural language. For example, in literary criticism, the proposition that "unicorns symbolize purity" has logical legitimacy in the "mythological text domain", but it is invalid in the "real biological domain" due to the vacuity of the concept. Through the dual-domain framework, the logical domain theory provides precise logical modeling tools for such complex semantic scenarios, promoting logic to return from "symbolic operations divorced from context" to "context-sensitive thinking deductions".

4.2 The Value of Interdisciplinary Application: From the Logical Revolution to Cognitive Empowerment

The innovation of the logical domain theory is not limited to the field of logic itself, it also provides breakthrough analytical tools for fields such as artificial intelligence, philosophical research, and education through the output of methodology.

4.2.1 Artificial Intelligence: The Logical Cornerstone of Contextual Reasoning

In the field of artificial intelligence, the construction of knowledge graphs and decision-making in complex scenarios has always been plagued by context dependence and semantic ambiguity. The formal methods of traditional logic find it difficult to handle the polysemy in natural language (for example, “Apple” can refer to both a fruit and a brand) and context switching (such as the different impacts of “rain” in the “traffic domain” and the “agricultural domain”). However, the dual-domain model of the logical domain theory provides a key path to solve this problem:

Context stratification of knowledge graphs: Through the “concept domain W”, hierarchical divisions are made of entity relationships (such as the “mammal domain” and the “marine organism domain”), enabling AI to recognize the validity of “whales are mammals” in the biological domain and avoid cross-domain confusion.

Scene adaptation of decision-making logic: In an autonomous driving system, the validity of the proposition “If heavy rain is detected (p), then drive at a reduced speed (q)” depends on the contextual setting of the “open road domain”. The logical domain theory helps AI systems dynamically adjust reasoning rules in different scenarios (day/night, urban/rural) by clarifying the boundaries of the proposition domain w, achieving decision-makings that conform to human intuition.

The construction of this contextualized reasoning model will drive AI to upgrade from “pattern matching based on data statistics” to “semantic understanding based on logical rules”, laying a logical foundation for the development of general artificial intelligence.

4.2.2 Philosophical Research: A New Analytical Tool for Modality and Metaphysics

In the field of philosophy, the logical domain theory provides breakthrough solutions to long-standing controversial issues such as modal logic and the ontology of fictional objects:

Intra-domain interpretation of modal propositions: Traditional modal logic’s portrayal of “possibility” relies on possible world semantics, but lacks an accurate definition of the concept domain. Through the contextual anchoring of the “concept domain W”, the logical domain theory gives logical significance to the proposition “Unicorns may exist” in the “mythical creature domain”, while in the “real biological domain”, it is only a virtual concept, avoiding cross-domain confusion of modal propositions.

The logical positioning of fictional objects: Regarding metaphysical issues such as

“Does a golden mountain exist?” and “Is a round square self-contradictory?”, the logical domain theory points out that the logical status of fictional objects should be determined by the concept domain they belong to. “Golden mountain” is a legitimate concept in the “imagination domain” (forming a contrary relationship with “silver mountain”), while “a round square” is invalid in the concept domain of any possible world due to violating the law of contradiction. However, propositions like “A round square is not round” and “A round square is not square” can still be true. This kind of analysis resolves the ontological disputes in traditional philosophy about the “existence” of fictional objects, and transforms the issues into judgments of logical relationships within the concept domain.

In addition, the discovery of the conceptual sub-contrary relationship provides a new tool for semantic analysis in analytic philosophy. For example, when discussing the binary thinking of “either black or white”, the logical domain theory reveals that “not black” and “not white” form a sub-contrary relationship in the domain of colors (there is a gray area), thereby providing a logical basis for criticizing extreme thinking.

4.2.3 In the Field of Education: Logical Innovation in the Cultivation of Critical Thinking

The core objective of logical education is to cultivate rational thinking ability. However, due to excessive formalization in traditional logical teaching, students often fall into “symbol worship” and overlook the semantic logic in natural language. The logical domain theory innovates logical education through the following approaches:

Breaking the binary opposition thinking: Through the teaching of the sub-contrary relationship, students can understand the logical relationship that “not both false but can both be true (not both negated but can both hold)”, for example, in the domain of “youth”, there is an intermediate state (ordinary youth) between “non-progressive youth” and “non-backward youth”, thus avoiding the simplistic judgment of “either-or”.

Strengthening context sensitivity awareness: Through the training of the dual-domain model, students can learn to define the concept domain and the proposition domain first when analyzing propositions. For instance, when analyzing “All swans are white”, they can consciously distinguish the different logical truth values between the “domain of real swans” and the “domain of swans in fairy tale”.

Logical training that returns to the essence of thinking: Through examples of resolving paradoxes (such as ineffective proof of the liar paradox), students can understand that logical rules are not symbol games divorced from reality, but rather the formal presentation of human thinking laws, thus establishing a logical cognitive view of “semantics first, form as a supplement”.

This educational innovation will contribute to the cultivation of students' critical thinking. It enables them to conduct rigorous formal reasoning and keenly identify semantic traps in natural language, truly achieving the transformation from logical ability to cognitive ability.

4.3 Historical Positioning: The “Copernican Revolution” in Logic

The emergence of the logical domain theory marked a fundamental shift in logic from the “Aristotle-Frege” tradition to the “laws of thinking in natural language” tradition, and its historical significance can be comparable to Copernicus' “heliocentric theory”.

4.3.1 Transcending Traditional Formal Logic: From Symbolic Games to the Science of Thinking

Since Frege mathematized logic, formalization has become the dominant direction of the discipline's development. Although this approach brought the precision of the symbolic system, it has led to logic gradually becoming a “toy for mathematicians”. The paradoxes of material implication, the incompleteness of conceptual relationships, and the unsolvability of paradoxes are essentially the products of excessive formalization. The revolutionary nature of the logical domain theory lies in its rediscovery of the essential object of logic: logic should not be a mathematical branch that studies the truth values of symbols, but a cognitive science that studies the laws of human thinking.

This transcendence is manifested in three aspects:

Resetting of research objectives: Shifting from pursuing the perfect self-consistency of the symbolic system to explaining and regulating human natural thinking;

Reconstruction of the theoretical foundation: Taking semantic association as the premise of logical form, and not vice versa;

Expansion of the application boundaries: Moving from the narrow circle of mathematical and logical philosophy back to various fields that serve human cognition (such as artificial intelligence, philosophy, and education).

4.3.2 The Profound Significance of the “Copernican Revolution”: Reconstructing the Essential Definition of Logic

Just as Copernicus subverted the “geocentric theory” and repositioned the earth, the theory of the logical domain has overturned the disciplinary stereotype that “logic is formalization” and endowed logic with new essential connotations:

Logic is the formalization of the laws of thinking, not a mirror image of the real world.

The real conceptualization of virtual concepts' logic demonstrates that the object of logic is the concept domain constructed by thinking, rather than direct mapping of the external world. This provides a theoretical foundation for logic to break free from the limitations of reality and explore possible worlds.

The legitimacy of logical rules stems from human thinking intuition. The discovery of the unity of the three laws and the sub-contrary relationship is essentially a formalized refinement of intuitions such as "either-or" and "not both false" in human natural thinking , providing an empirical basis in cognitive science for logical rules.

Logic serves as a bridge connecting language, thinking, and the world. Through the dual-domain framework, logic has for the first time systematically dealt with the complex relationships among language contexts, thinking rules, and world category, becoming a universal tool for interdisciplinary cognitive research.

From a more macroscopic perspective of intellectual history, the emergence of the logical domain theory marks the awakening of logic from the alienation of "instrumental rationality". When logical rules once again conform to the essential characteristics of human thinking, they are no longer an intellectual game for a select few, but become a cognitive tool for all people to understand the world and construct knowledge. This return might precisely be the crucial turning point for logic to redefine its own mission after the quagmire of formalization for thousands of years.

The paradigm revolution of the logical domain theory is not only a theoretical breakthrough within the field of logic, but also a significant leap in human beings' understanding of their own thinking laws. By subverting material implication, completing conceptual relationships, resolving logical paradoxes, and reshaping the essence of logic, it has constructed a new logical system that is "context-sensitive, semantically self-consistent, and open to application". When the dual-domain framework and the rule of the unity of the three laws of this theory are extended to a broader cognitive field, what we witness is not just the rebirth of logic, but also new possibilities in the entire field of cognitive science. From the contextual reasoning of artificial intelligence to the conceptual analysis in philosophy, from the cultivation of critical thinking in education to the logical construction of possible worlds by humanity, the theory of the logical domain is weaving a new cognitive network that connects thinking and existence.

The history of logic is the history of humanity's continuous pursuit of the thinking's clarity. The emergence of the logical domain theory marks that we have finally broken through the cocoon of formalization and started to freely navigate in the infinite domain of thinking. This might not be the end, but a new starting point. At this starting point, logic truly becomes the "science of thinking", and humanity's exploration of the essence of its own cognition thus embarks on a broader journey.

Conclusion Summary of Theoretical Value and Future Prospects

The logical domain theory has accomplished a systematic paradigmatic innovation of traditional logic with four core breakthroughs: subverting material implication, completing conceptual relationships, unifying logical laws, and resolving logical paradoxes.

This theory not only puts an end to the truth-value paradoxes caused by material implication, the incompleteness of the conceptual relationship theory, and the insoluble dilemmas of logical paradoxes, but also reshapes the essence of logic as the “science of thinking” through the dual-track mode of “semantic anchoring + logical deduction”, enabling logical rules to return from a formal symbolic game divorced from semantics to the essential laws of human natural thinking. Its theoretical value combines historical breakthroughs and practical extensibility:

Internally within the field of logic, it fills the conceptual gaps in the history of both Chinese and Western logic, and constructs a self-consistent semantic-logic unified system.

In external applications, it provides brand-new tools for the contextual reasoning of artificial intelligence, the modal analysis in philosophy, and the cultivation of critical thinking in education. This marks a significant leap in human cognition of thinking laws, from the formal surface level to the semantic essence.

Looking ahead, the “dual-domain” analytical framework and the “unifying the three laws” rule of the logical domain theory are expected to be further extended to fields such as cognitive science, linguistics, and decision science, facilitating the construction of context-sensitive logical models in interdisciplinary research. As the theory is applied implemented in more complex semantic scenarios, it may lead logic to evolve from a “breaker” for long-standing dilemmas to a “thinking engine” that reshapes the human cognitive paradigm, providing an eternal theoretical foundation for exploring the essence of intelligence, the logic of language, and the construction of possible worlds.

References

- [1] Zhang, J.J. (2016). The Hierarchy Theory of Implication: Clarifying the Mystery of the “Paradoxes of Material Implication”. *Academic Research*, (12).
- [2] Zhang, J.J. (2015). Re-discussion on the “Paradoxes of Material Implication” from the Perspective of Formal Implication. *Seeker*, (6).
- [3] Zhang, J.J. (2012). On the “Paradoxes of Material Implication” from the Perspective of Formal Implication. *Academic Research*, (4).
- [4] Cheng, Z.T. (2011). On the “Paradoxes of Implication” and Their

Counterexamples. *Academic Research*, (8).

[5] Feng, M. (2010). *A Study of Relevance Logic*, Shanghai: East China Normal University Press.

[6] Peng, Y.L., Ma, Q.R. (2010). *Dictionary of Logic (Revised Edition)*, Shanghai: Shanghai Lexicographical Publishing House.

[7] Zhang, Q.Y. (2004). *Nine Chapters on the Philosophy of Logic*, Nanjing: Jiangsu People's Publishing House.

[8] Ke, H.Q., Liang, Q.Y. (2002). On Material Implication, Formal Implication and Logical Implication. *Academic Research*, (6).

[9] Chen, B. (2000). *An Introduction to the Philosophy of Logic*, Beijing: Renmin University of China Press.

[10] Xu, M.L. (1993). A Discussion on the Extension of Concepts and Their Relationships. *Thinking and Wisdom (formerly "Logic and Language Learning")*, (4).

[11] Vyacheslav M. Matetsky. (1992). *Dictionary of Modern Logic*, Beijing: Renmin University of China Press.

[12] Cheng, Z.T. (1990). *Modern Logic and Traditional Logic*, Guangzhou: Jinan University Press.

[13] Wu, J.G. (1989). *Principles of General Logic*, Beijing: Higher Education Press.

[14] Zhang, J.J. (1988). On the Relationship between Traditional Deductive Logic and Classical Logical Calculus: A Discussion with Comrades Du Xiushi, Lin Bangjin, etc. *Journal of Hebei University*, (1).

[15] Zhu, X.M. (1987). *Philosophical Logic in Modern Western Countries*, Shanghai: Fudan University Press.

[16] Lin, B.J. (1985). Formal Logic and Mathematical Logic are Two Different Disciplines. *Social Science Front*, (1).

[17] Lin, B.J. (1985). *Restrictive Logic*, Guiyang: Guizhou People's Press.

[18] Kneale, W., Kneale, M. (1985). *The Development of Logic*, Beijing: Commercial Press.

[19] Jiang, T.J. (1984). *Studies on the History of Western Logic*, Beijing: People's Press.

[20] Logic Teaching and Research Section of the Department of Philosophy, Renmin University of China. (1983). *Formal Logic*, Beijing: Renmin University of China Press.

[21] Russell, B. (1982). *Introduction to Mathematical Philosophy*, Beijing: Commercial Press.

[22] Compilation Group of General Logic. (1982). *General Logic*, Shanghai: Shanghai People's Press.

[23] M, S.K. (1980). *An Introduction to Mathematical Logic*, Shanghai: Shanghai People's Press.

[24] J, Y.L. (1979). *Formal Logic*, Beijing: People's Press.

Inherent Defects in Smart Contract Dispute Resolution: Legal Challenges and Solutions

Li Qingfeng*

Law school of Hangzhou Dianzi University, LQF@hdu.edu.cn

Qi Jialu

**Law school of Hangzhou Dianzi University,
232340004@hdu.edu.cn**

Abstract

With the continuous development of smart contracts, new types of disputes involving smart contract transactions are increasing day by day, giving rise to smart contract dispute resolution mechanism. The mechanism is embedded in smart contracts as a new type of dispute resolution in the form of code and can respond promptly when disputes arise. In the course of practice, although the smart contract dispute resolution mechanism has demonstrated its efficiency beyond the traditional dispute resolution mechanism, it has also gradually revealed its potential risk points. Based on the analysis of the current legal framework, it can be seen that the inherent defects of the smart contract dispute resolution mechanism are centered on the three dimensions of misconduct of the adjudicating body, lack of procedural justice, and disconnection of effectiveness. Therefore, it is necessary to propose solutions to the inherent defects, by improving the access threshold of the adjudicating body, setting up uniform and clear adjudication norms and evidence review procedures, perfecting the adjudication validity determination and multi-dimensional relief measures and other optimization paths, to further give full play to the advantages of the high efficiency and security of the smart contract, in order to look forward to realizing the symbiosis of value between the technological trust and the judicial credibility.

Keywords

Smart Contract, Dispute Resolution, Decentralized justice

INTRODUCTION

Since the concept of Bitcoin was first proposed in 2008, blockchain technology has opened the door to a new world for mankind, and its application in the legal field has also covered multiple areas such as judicial depositions, enforcement, and the right to personal information in the past decade. Back in 2019, General Secretary Xi Jinping stressed the need to strengthen blockchain standardization research and enhance international discourse and rule-making power during the 18th collective study of the Political Bureau of the Central Committee.¹ From the technical level, blockchain is advancing from Blockchain 1.0 (digital currency), Blockchain 2.0 (distributed application, the smart contract, and virtual machine) to Blockchain 3.0 (cross-chain interaction, multi-chain fusion, and value internet). From the legal level, the Supreme People's Court has continuously issued relevant judicial interpretations on the application of blockchain in the judicial field during the two years of 2021 and 2022, which will help blockchain technology to be rapidly integrated into all aspects of judicial adjudication, and lay down a judicial guarantee for China's digital transformation.² As a representative work of blockchain technology, smart contract provides a relatively safe transaction environment and high execution efficiency for on-chain transactions due to its technical characteristics that distinguish it from traditional transaction methods. Relying on blockchain and Ethereum technology, it is endowed with the characteristics of “decentralization” and “anonymity”. However, the development of technology cannot absolutely avoid disputes, and will even generate on-chain disputes that are different from traditional disputes.³

In order to solve the new type of on-chain disputes, the smart contract dispute resolution mechanism has gradually emerged in history and has rapidly become one of the important means of “ruling the chain with the chain”. This mechanism is different from the traditional dispute resolution mechanism, but it directly uses the technology platform and code embedding to input the corresponding procedures into the smart contract, suspend the execution of the smart contract and intervene in the dispute resolution after the dispute arises, and the measures related to the different types of smart contract dispute resolution mechanism intervening in the dispute resolution are also presenting the phenomenon of differentiation. The dispute resolution mechanism adopted by smart contracts mainly resolves disputes directly on the chain, but due to the special characteristics of blockchain, Ethereum and other technologies, the dispute resolution mechanism of smart contracts is endowed with a process different from the traditional dispute resolution mechanism. However, the seemingly efficient and flexible smart contract dispute resolution mechanism is still a product of the foreign rule of law framework. In the transplantation application of smart contract dispute resolution mechanism under the technology without borders, it

¹ See Zhiming Zheng and Wangjie Qiu, ‘我国区块链发展趋势与思考 [Development Trend and Thinking of China's Blockchain]’ (2020) 1 *Bulletin of National Natural Science Foundation of China* 5.

² See Wenting You, ‘民法典对智能合约的法律规制 [The Legal Regulation of Smart Contracts by Chinese Civil Code]’ (2023) 12 *Theory Monthly* 125.

³ See Jinfan Yang, ‘基于区块链的纠纷解决机制研究 [Research on the Blockchain-based Dispute Resolution Mechanism]’ (2021) 4 *Journal of Shaanxi Normal University(Philosophy and Social Sciences Edition)* 163.

can be found that there are still inherent deficiencies and defects under the framework of the rule of law in China, such as the fairness of the group decision-making on the chain, the legal effect of the chain judgment, and the lack of review procedures and so on, which are still unable to be effectively solved. Therefore, it is necessary to analyze the inherent defects of the smart contract dispute resolution mechanism under the existing legal framework of our country from the current situation of the smart contract dispute resolution mechanism and improve the smart contract dispute resolution mechanism with a localized vision, to substantially solve the problems of smart contract dispute resolution.

1 STATUS of APPLICATION of SMART CONTRACT DISPUTE RESOLUTION MECHANISMS

In today's digital wave, smart contracts are used in many fields such as supply chain management, real estate transactions, financial services, etc., relying on their own characteristics, while China's judicial field relies on blockchain to create a smart judicial collaboration system. As of February 2024, data from the Dune Analytics analysis platform shows that the number of smart contracts on the Ethereum chain has exceeded 50 million, and the value of virtual currencies held by smart contracts with different applications has exceeded \$300 billion.⁴ As a carrier of the technical practice of “code is law”⁵, smart contracts not only provide an enforcement paradigm that reconstructs traditional contractual relationships, but also have a profound impact on the rules of group autonomy driven by technology.⁶

1.1 The Creation of Smart Contract Dispute Resolution Mechanisms

Smart contracts based on blockchain technology were introduced in 2015 with the help of Ether, and have been widely used in many areas of social practice due to their decentralization, non-tampering, automatic execution, and other features that can reduce transaction costs and improve transaction efficiency. The 2018 China Blockchain Industry White Paper published by the Ministry of Industry and Information Technology (MIIT) states that a smart contract is an event-driven, stateful, multi-recognized procedure that runs on top of a blockchain and is capable of automatically processing assets according to preset conditions. Plus, the biggest advantage of smart contracts is the use of procedural algorithms to enforce contract

⁴ See Xiangfu Zhao and Long He, ‘以太坊智能合约安全漏洞检测 [Ethereum Smart Contract Security Vulnerability Detection]’ (2024) 8 *IEEE Spectrum* 57.

⁵ A foundational concept articulated by Lawrence Lessig in his seminal work *Code and Other Laws of Cyberspace*, positing that the software architecture of the Internet—its code—constitutes a regulatory mechanism comparable to legal norms. Within this framework, those who design and control code exercise a form of regulatory authority, raising critical questions regarding its normative legitimacy and democratic accountability. In recent developments, this concept has evolved with the rise of smart contracts, which embed legal agreements directly into executable code. This technological shift significantly reconfigures the relationship between law and code by enabling the automatic enforcement of rights and obligations without the need for traditional legal institutions.

⁶ See Ye Wu, ‘元宇宙：法律图谱与规范逻辑 [Metacosmos: Legal Mapping and Normative Logic]’ (2023) *China Renmin University Press* 70.

terms instead of humans.⁷ In order to be able to better apply smart contracts and achieve the effect of avoiding disputes, scholars in the field of law have begun to carry out in-depth research on smart contracts, but most of the literature only stays on the contractual attributes of smart contracts and does not peek into the fact that the smart contract as a technology in itself still has the possibility of generating risks. Even though the automatic execution of smart contract transactions can reduce some of the disputes from the source, it will not eliminate the disputes because of the automatic execution.⁸ Quite the contrary, unique new types of disputes are spawned in the operation of smart contracts. The anonymity of smart contracts leads to the difficulty of identifying the capacity of civil subjects, the automatic enforceability leads to the limitation of the free will of the parties, and the decentralization excludes traditional dispute resolution mechanisms, among other risks.

The fundamental reason why smart contract disputes are “new” is that the risks arising from smart contracts due to their technological characteristics cannot be applied to dispute resolution mechanisms under the traditional rule of law framework. Under the current framework of the rule of law, the “life journey” of a traditional contract generally needs to go through the process of contract formation, entry into force, performance and so on. The conclusion and execution of a contract, as a civil legal act of the parties, is usually made in the form of an expression of intent, and the contract is concluded through an offer or a promise. After the contract is formed and comes into effect, the parties abide by the relevant legal principles and perform their obligations in accordance with each other, thus fulfilling the purpose of the contract. From the Civil Code of the People's Republic of China contract and relevant judicial interpretations, it is not difficult to see that traditional contract disputes involve the meaning of the expression is not true, the performance does not comply with the agreement and so on many levels; in the practice of the level of the contract disputes are endless, the areas involved are also very extensive. However, in the implementation of smart contracts, there are still risks that cannot be solved by the existing rule of law theories and norms. During the operation of the smart contract, the parties as the chain user will be in an anonymous state, in the smart contract data transmission link, through the asymmetric key technology for the subject of communication and exchange. This operation can effectively alleviate the problem of data security and privacy protection, but at the same time, it will also cause practical difficulties in identifying the real subject. In addition, the smart contract is still essentially a computer programme written in code, and the meaning is presented through the form of code, while constituting an unchangeable smart contract. In the case of automatic enforcement, although it can to a certain extent avoid the traditional contract performance does not meet the agreement and other disputes, in fact, the automatic enforcement will limit the change of the parties' meaning, resulting in the traditional dispute resolution mechanism of the cost of relief. Not only that, smart

⁷ Ministry of Industry and Information Technology Information Center (中华人民共和国工业和信息化部信息中心), *White Paper on China's Blockchain Industry* (2018) (《2018 年中国区块链产业白皮书》) 99.

⁸ See Wulf Kaal, 'Evolution of Law: Dynamic Regulation in a New Institutional Economics Framework' (2024) 1 in *Festschrift In Honor Of Christian Kirchner* 2-3.

contract transactions may cause disputes due to code errors, code loopholes, hacker attacks, prediction machine errors, and changes in policies and regulations.

In summary, in the process of technological development, there does not exist an flawless technology. The birth of emerging technologies is highly likely to give rise to frontier legal issues. The governance of science and technology still needs to follow the ever-extending regulatory logic. By embedding smart contract dispute resolution mechanisms, the operation of the smart contracts becomes more secure, thereby providing enhanced protection for the rights and interests of on-chain users.

1.2 Application of Smart Contract Dispute Resolution Mechanisms

The decentralized and pseudonymous nature of smart contracts persist as permanent attributes of the technology.⁹ Under the existing rule of law framework, in order to truly overcome the potential risk points of the automatic execution process of smart contracts, it is necessary to governance mechanisms must be embedded within blockchain's architectural infrastructure. Specifically, a dispute management module can be preset in the contract code, so that when the system detects a dispute arising from a transaction, it will automatically activate the execution pause mechanism and initiating an on-chain coordination process simultaneously. This dynamic adjustment mechanism allows for adaptive correction of the smart contract execution path through the negotiation results verified by multiple parties while maintaining the decentralized nature of the blockchain. The idea was initially conceived by Vitalik Buterin, the founder of Ethereum, in the aftermath of "The DAO" in 2016, and focused on the creation of a Decentralized Court, or "Distributed Court".¹⁰ Subsequently, a series of European and American technology companies began to implement the idea on the public chain, and successively released more than a dozen dispute resolution solutions that were also based on blockchain technology but in different forms, which in turn evolved into three different types of smart contract dispute resolution mechanisms, namely the crowd-sourcing model, the arbitration model, and the court model. The crowd sourcing model represented by Kleros, Aragon Court, and Jur (Open Layer) is essentially a conversion of the dispute resolution method in which a third-party authority intervenes into a method in which a non-special smart contract user adopts a specific way of dispute adjudication.¹¹ The arbitration mode adds an arbitration clause when the user signs a smart contract, with details of when and how to apply arbitration for disputes are terms negotiated ex ante by contracting parties, Confideal and Codelegit are the representative institutional models under this mode. In October 2019, Hangzhou Internet Court applied blockchain smart contract technology to the judicial field for the first time, and for automated dispute resolution across contract lifecycle phases.¹² This smart contract

⁹ See Wulf A. Kaal and Craig Calcaterra, 'Crypto Transaction Dispute Resolution' (2018) Spring *The Business Lawyer* 54-58.

¹⁰ See Jinfan Yang, '基于区块链的纠纷解决机制研究 [Research on the Blockchain-based Dispute Resolution Mechanism]' (2021) 4 *Journal of Shaanxi Normal University(Philosophy and Social Sciences Edition)* 166.

¹¹ See Xuhui Fang, 'ODR——多元化解解决电子商务版权纠纷新机制 [ODR——A New Mechanism to Solve E-commerce Copyright Disputes in Multiple Ways]' (2017) 4 *Legal Forum* 157.

¹² Cyberspace Administration of China, 'The First Blockchain Smart Contract Judicial Application Launched: New Technology Builds a "Smart Line of Defense" for Online Integrity' (Cyberspace Administration of China, 29 December 2019) https://www.cac.gov.cn/2019-12/31/c_1579328270387357.htm accessed 19 March 2025.

judicial application is deployed on top of the alliance chain, and is mainly applied to the whole process of contract signing, performance, and dispute resolution, to achieve the purpose of improving the rate of contract fulfillment and boosting the efficiency of smart contract execution, as well as resolving a small number of possible breaches of contract with high efficiency, speed, and low cost. With the in-depth application of smart contracts in the judicial field, the Supreme People's Court issued the Opinions of the Supreme People's Court on Strengthening the Judicial Application of Blockchain, aiming to deepen the construction of the national smart courts and guide the direction of typical scenarios of blockchain application in the judicial field.¹³

Smart contract disputes exhibit distinctive attributes compared to conventional contractual conflicts, and the smart contract dispute resolution mechanism is also special compared to the traditional dispute resolution mechanism, i.e., resolving disputes arising from smart contracts on top of blockchain technology. Firstly, the smart contract dispute resolution mechanism is algorithmically integrated into smart contract architectures, which can be suspended through technical means to reduce the loss in time; secondly, the final solution reached through the smart contract dispute resolution mechanism can still be executed by the smart contract, to achieve the purpose of the smart contract. From the above special features, it can be seen that the smart contract dispute resolution mechanism has, to a certain extent, put forward a remedy for the potential risks that may be brought about by the anonymity and automatic execution of smart contracts. At the same time, the smart contract dispute resolution mechanism relying on the blockchain can resolve disputes at transaction-layer speed. To resolve disputes, the current different modes of the smart contract dispute resolution mechanism can be a total of different types of smart contract dispute resolution mechanism for users to choose according to their situation, the cost and complexity of the process. In addition, the smart contract dispute resolution mechanism avoids the problems of reduced speed and automation of transaction execution caused by traditional litigation, game-theoretic incentive models and cryptographic algorithms to construct a decentralized dispute justice platform, and records the execution of the smart contract and the dispute resolution process on the blockchain to ensure the authenticity of the data on the blockchain.¹⁴

In general, both domestic and international practice environments, as well as the dual academic fields of technology and jurisprudence, have actively responded to and practiced the efficient development and safe application of smart contract technology. The smart contract dispute resolution mechanism has emerged in the wave of the times and is developing rapidly, providing better rights and interests protection solutions for smart contract users and even blockchain users.

¹³ See Fuhui Sun, '〈最高人民法院关于加强区块链司法应用的意见〉理解与适用 [Understanding and Applications of "Opinions of the Supreme People's Court on Strengthening Blockchain Application in the Judicial Field"]' (2022) 4 *China Journal of Applied Jurisprudence* 31-34.

¹⁴ Yann Aouidef, Federico Ast and Bruno Deffains, 'Decentralized Justice: A Comparative Analysis of Blockchain Online Dispute Resolution Projects' (2021) March *Frontiers in Blockchain* 2.

2 INHERENT DEFECTS IN SMART CONTRACT DISPUTE RESOLUTION MECHANISMS

The application of smart contract dispute resolution mechanism in practice has gradually formed an algorithmic justice ecosystems – decentralized governance frameworks. The smart contract dispute resolution mechanism based on blockchain and code can, to a certain extent, reduce the ambiguity and uncertainty in the interpretation of the relevant rules compared to the traditional dispute resolution mechanism.¹⁵ However, the reality is that, as Ethan Katsh, the father of online dispute resolution, observed, the speed with which technology generates disputes exceeds its ability to resolve them.¹⁶ Although the smart contract dispute resolution mechanism has shown better performance than the traditional dispute resolution mechanism in dealing with smart contract disputes, it is still impossible to ignore the inherent defects that may exist in itself.

2.1 Vacuum exists in access and performance of smart contract dispute adjudicators

2.1.1 Unrestricted Adjudicator Qualification Thresholds

In the Rule of Law Social Governance Doctrine in China, dispute resolution often takes the introduction of a third party or a third-party authority, supplemented by a neutral third party to achieve fairness and justice through the corresponding procedures. To solve the problems it may involve, the smart contract did not introduce the leading party of dispute resolution, only based on the blockchain technology so that the cryptographically enforced peer-to-peer adjudication protocols. Smart contracts are algorithmically enforced agreements devoid of legal subjectivity.¹⁷ Compared to traditional contracts, smart contracts transmute relational trust into cryptographic verification and obligations relationships, laws and regulations under the representation of meaning, thus allowing trusted transactions and operations to be carried out without the backing of trust. In short, the trust between people in traditional contracts is transformed into technological trust under the technical means of “decentralized justice”, showing a technological fiduciary displacement.

Because of the characteristics of smart contracts techno-centric design of blockchain-native mechanisms, most of the dispute resolution methods under the smart contract dispute resolution mechanism are only based on some specific conditions as the standard for the entry threshold of the adjudicator, rather than a substantive examination of the corresponding qualifications, which almost belongs to the state of zero threshold compared with the traditional dispute resolution

¹⁵ See Aifei Chen, ‘区块链共谋的反垄断监管 [Antitrust Supervision of Blockchain Collusion]’ (2022) 4 *Modern Law Science* 152-153.

¹⁶ Yann Aouidef, Federico Ast and Bruno Deffains, ‘Decentralized Justice: A Comparative Analysis of Blockchain Online Dispute Resolution Projects’ (2021) March *Frontiers in Blockchain* 2.

¹⁷ Andreas M Antonopoulos and Gavin Wood, 精通以太坊: 开发智能合约和去中心化应用 (喻勇, 杨镇, 阿剑, 任露露 and Elisa Jiang trs, 机械工业出版社 2019) 134.

mechanism.¹⁸ For example, in the role of juror in Kleros for handling disputes, users only need to pledge PNK tokens to become juror candidates, and the probability of eventually being able to become a juror in smart contract dispute handling is directly proportional to the number of tokens being pledged.¹⁹ In the practice of Aragon Court, Jur, Juris, and other platforms, it can be seen that the resolution of smart contract disputes is similar to Kleros, which adopts the token method to select the adjudicator candidate. On the contrary, the traditional dispute resolution mechanism, whether it is arbitration or litigation is bound to intervene in the authoritative personnel with legal qualifications as a public third party, to the existing laws and regulations as the benchmark, in the evidence of both parties to make a just, fair and legal decision. Therefore, the smart contract dispute resolution mechanism only based on the number of tokens to determine the qualification of the adjudicator to intervene in the dispute is not in line with the entry threshold of legal dispute resolution.

2.1.2 Lack of norms for the performance of adjudicators in smart contract disputes

In addition to the problem of the low entry threshold of adjudicators in the smart contract dispute resolution mechanism, there is no unified and clear guidance for adjudication in the process of dispute resolution, i.e., adjudicators exercise unrestrained discretionary authority and are not bound by authoritative norms. In the practice of smart contract dispute resolution mechanism, the adjudicator is not bound by any legal norms, but by the “Schelling point” incentive mechanism in the game theory, the adjudicator is expected to make the so-called “fair and just” majority decision in order to get more tokens by the stake-weighted voting incentivized by cryptoeconomic rewards.²⁰ The majority decision is expected to be “fair and just” in order to get more tokens. Based on Thomas Schelling's game theory, in the absence of communication or trust, “Schelling Points” can reflect the behaviour that each person expects the other to do. In short, in smart contracts with anonymity and decentralization features, adjudicators cannot communicate and there is no basis for trust, and groups are more likely to make profit-maximizing conformity over substantive justice, thus forming decentralized justice on blockchain technology. For example, the dispute resolution mechanism in Kleros adopts a game-theoretic incentive mechanism, which believes that it is necessary to ensure the honesty of adjudicators through an incentive mechanism, so as to achieve fairness and justice in dispute resolution.²¹

However, decentralized justice that relies on game-theoretic incentives fail to satisfy core juridical principles at the legal level. Adjudicators are incentivized to vote in favour of the side they believe the majority of adjudicators will support, which is a

¹⁸ See Jiaqi Huang, ‘智能合约众包争议解决机制的探究：基本特征、现实困境与完善路径 [Exploring the Smart Contract Crowdsourcing Dispute Resolution Mechanism: Fundamental Characteristics, Realistic Dilemmas and Improvement Paths]’ (2024) 4 *Commercial Arbitration & Mediation* 62.

¹⁹ Clément Lesaege, Federico Ast and William George, *Kleros Short Paper v1.0.7* (September 2019) <https://kleros.io/whitepaper.pdf>

²⁰ Thomas C Schelling, *The Strategy of Conflict*, trans Zhao Hua (Huaxia Publishing House 2011) 57.

²¹ See Aifei Chen, ‘区块链智能合约纠纷解决的可能性边界 [The Possibilities for Blockchain Smart Contract Dispute Resolution]’ (2024) 5 *Journal of Comparative Law* 199.

consensus-driven decisions lack normative safeguards. From a legal point of view, a fair and just adjudication should satisfy both substantive and procedural justice, including independent and neutral adjudicators, lawful and fair procedures, correct application of the law, and safeguards and remedies for the rights of the parties. The smart contract dispute resolution mechanism relies only on the adjudicator's own judgement and is cryptoeconomic expediency, which obviously deviates from the application of law in the true sense.²² As Habermas' idea of procedural justice advocates, fair and just adjudication is the cornerstone of the rule of the law society, and procedural justice is needed to guarantee substantive justice, and the combination of legal professionalism and social consensus to achieve "visible justice".²³ The efficiency-fairness tradeoff is indisputable, but it is undeniable that values such as fairness and just procedures in traditional dispute resolution mechanisms and even in traditional legal frameworks are of broader legal significance. ²⁴Obviously, the lack of corresponding norms for smart contract dispute adjudicators will inevitably affect the fairness and justice of dispute resolution.

2.2 Disclosure of Evidence and Review Mechanisms for Smart Contract Disputes are Too Simple

2.2.1 Evidence disclosure mechanism for smart contract disputes needs urgent clarification

The principle of "whoever asserts, whoever produces evidence" is one of the important principles of the discovery mechanism, and the law grants the parties the right to make their own assertions, while at the same time giving them the duty to do so.²⁵ The self-executing nature of smart contracts and the immutability of the code make them naturally have the attribute of "self-authenticating evidential status", thus easily triggering the misunderstanding that "the disclosure of evidence has already been completed by the technology". In addition, the smart contract dispute resolution mechanism compared with the traditional dispute resolution mechanism, there is a more special way of generating and fixing evidence. This includes generation-type evidence and transformation-type evidence. Generation-type evidence refers to the transaction information generated on the chain and fixed along with the execution process of the smart contract; transformation-type evidence refers to the form of evidence generated in the physical world relying on blockchain technology and transformed into data on the chain, which is mostly the evidence submitted by the parties to the dispute. On the one hand, an oversimplified evidence disclosure mechanism may lead to passive reliance on the technology black box by adjudicators, which may lead to ignoring challenges to some evidence and incorrectly determining the facts of the case. On the other hand, the principle of technological neutrality does

²² Yann Aouidef, Federico Ast and Bruno Deffains, 'Decentralized Justice: A Comparative Analysis of Blockchain Online Dispute Resolution Projects' (2021) March *Frontiers in Blockchain* 6.

²³ See Xiaojun Gong, '哈贝马斯程序正义思想及其现代意蕴 [Habermas' Thought on Procedural Justice and Its Modern Implications]' (2012) 11 *People's Tribune* 144.

²⁴ See Aifei Chen, '区块链智能合约纠纷解决的可能性边界 [The Possibilities for Blockchain Smart Contract Dispute Resolution]' (2024) 5 *Journal of Comparative Law* 201.

²⁵ *Zhonghua Renmin Gongheguo Minshi Susong Fa* [Civil Procedure Law of the People's Republic of China] (adopted 1991, amended 2021), art 67.

not mean that technology can replace the legal process, over-reliance on technical means such as hash value comparison, thus neglecting the substantive judgement of the evidence. At the same time, the evidence disclosure mechanism in the smart contract dispute resolution mechanism neither permits parties to provide further clarification on doubtful evidence nor allows them to submit supplementary evidence.

Users and adjudicators of smart contracts are distributed around the world, with multidisciplinary participant backgrounds, and legal cultures and specific legal norms are not shared and quickly understood, as they are distinctly political in nature.²⁶ The smart contract dispute resolution mechanism lacks clear and specific standards for the submission of evidence, and the evidence submitted by the parties to the platform before the commencement of the adjudication and the evidence fixed in the operation of the smart contract will become the entire basis for the adjudication. Currently, the lack of uniform evidence standards in the smart contract dispute resolution mechanism not only fails to guarantee the completeness of evidence submission, but also easily leads to the deviation of the adjudication results, thus forming ‘islands’ of evidence disclosure under different modes.

2.2.2 The Excessive High Threshold of the Evidence Review Mechanism in Smart Contract Disputes

The blockchain evidence involved in smart contract disputes is different from that in traditional disputes, and the impose heightened evidentiary scrutiny. Under China's existing legal framework, what can't be avoided no matter what kind of evidence is the examination of its authenticity, legality, and relevance. The first case of national blockchain deposit in Hangzhou Internet Court was decided, which for the first time confirmed the legal effect of electronic data deposited using blockchain technology and clarified the method of reviewing and judging blockchain electronic deposits. Therefore, the blockchain evidence determination method, not only requires authenticity, legality, and relevance determination, but also requires to evidence of solid evidence, the way of evidence is in line with the relevant provisions of the electronic data and the evidence of the size of the proof of power determination.²⁷ For example, the qualification review of the evidence deposit platform, the credibility review of the technical means of evidence collection, and the review of the integrity of evidence preservation.

The blockchain evidence involved in smart contract disputes is different from that in traditional disputes, and the review of blockchain evidence is more difficult.²⁸ Since the evidence in smart contract disputes is essentially composed of code, there will likely be difficulties in reviewing and identifying the evidence. In practice, both the authoritative third party in the traditional dispute resolution mechanism and the adjudicator in the smart contract dispute resolution mechanism often do not receive professional training in the field of computers, and thus lack the professional ability to

²⁶ Yannick Gabuthy, ‘Blockchain-Based Dispute Resolution: Insights and Challenges’ (2023) *Games* 14(5) 75, 5.

²⁷ Hangzhou Huatai Yimei Cultural Media Co Ltd v Shenzhen Daotong Technology Development Co Ltd (杭州华泰一媒文化传媒有限公司诉深圳市道同科技发展有限公司) (Hangzhou Internet Court, [2018] Zhe 0192 Minchu No 81), 6.

²⁸ Larry D Wall, ‘“Smart Contracts” in a Complex World’ (Federal Reserve Bank of Atlanta, July 2016) <https://www.atlantafed.org/cenfis/publications/notesfromthevault/1607.aspx>

review the code. Code, as a form of linguistic expression, converts meanings into a way that technology allows to be executed, but for the parties and adjudicators, it is tantamount to increasing the epistemic barriers to evidentiary review smart contracts and the disputes that arise from them. If the adjudicator is unable to read the relevant evidence, it means that it is difficult for him or her to ascertain the facts of the case. Therefore, how to review the evidence in the form of code or the contract itself has become the most critical dispute resolution difficulty.²⁹ Under such circumstances, if the dispute resolution mechanism for smart contracts fails to provide a uniform and clear mechanism for disclosing and reviewing evidence, it will not be conducive to the making of fair and just decisions.

2.3 Legal Effect and Remedies for Smart Contract Dispute Decisions Still Unclear

2.3.1 Uncertainty about the legal effect of smart contract dispute awards

In traditional dispute resolution mechanisms, both arbitration and litigation require the generation of legally binding instruments such as awards and judgements that comply with legal norms and can only come into effect after the rules for entry into force stipulated in the law have been met. At the same time, the effective award has legal coercive force, and can provide the parties to force the other party to fulfill their obligations and other guarantees. Generally speaking, the entry into force of the award, judgement needs to meet the content of the legal, legal form, and legal procedures at the same time. Legal content means that the content of the decision, judgement must be ruled in accordance with the law, in accordance with the law and take into account the rationale; legal form means that the seal of the institution must be stamped, and the content of the instrument is complete, including the elements required by law; legal procedure means that in accordance with the provisions of the law and to meet the rules of the entry into force of the service. The majority decision under the game-theoretic incentive mechanism has neither a uniform and clear basis for decision-making, nor does it adequately examine the evidence to determine the facts of the case, and it does not substantively safeguard the parties' right to debate and participate in the procedure.³⁰

In addition, awards made under the smart contract dispute resolution mechanism rely on blockchain technology to make awards automatically enforceable. However, in essence, awards that have coercive and safeguard measures should be legal and effective, and the automatic enforcement of awards under the smart contract dispute resolution mechanism after a majority decision by the adjudicator clearly lacks a review of the legitimacy of the award. The automatic enforcement of smart contracts implies that the parties have substitutes traditional legal trust with cryptographic certainty, which to a certain extent eliminates the right to dispose of the contract in certain circumstances, including the process of contract enforcement and the enforcement of the award. As a matter of fact, technical trust is not sufficient to

²⁹ See Aifei Chen, '区块链智能合约纠纷解决的可能性边界 [The Possibilities for Blockchain Smart Contract Dispute Resolution]' (2024) 5 *Journal of Comparative Law* 201.

³⁰ See Aifei Chen, '区块链智能合约纠纷解决的可能性边界 [The Possibilities for Blockchain Smart Contract Dispute Resolution]' (2024) 5 *Journal of Comparative Law* 199.

completely exclude the possibility of judicial intervention, and complete technical trust does not fully protect the legitimate rights and interests of the parties. Undoubtedly, the improvement of efficiency is one of the major advantages of smart contracts, but if it is sacrificed by compromising fundamental legal safeguards and restricting the parties' dispositive rights, it is still highly questionable and controversial whether smart contracts can fulfill the legal expectations expected by society.

2.3.2 Lack of Remedies After Smart Contract Dispute Adjudication

In the traditional dispute resolution mechanism, the rules for the entry into force of different types of judgments, i.e., the parties appealing against the judgement and requesting a second trial, are clearly stipulated, thus fully guaranteeing the parties' right to procedural remedies. Post-judgement remedies can play a positive role in correcting erroneous decisions, upholding procedural justice, safeguarding the parties' right to participate, balancing differences in litigation capacity, and promoting the uniform application of the law, among other aspects. The smart contract dispute resolution mechanism does not provide for post-decision remedial measures, and its decisions are automatically enforced. In this case, it is very easy to lead to the party's right to participate in the process can not be guaranteed, the wrong decision can not be corrected promptly and the party suffering irreparable losses. In essence, the lack of post-adjudication remedies in the smart contract dispute resolution mechanism clearly violates the original intention of the smart contract dispute resolution mechanism embedded in the smart contract.

Although some smart contract dispute resolution mechanisms provide for an appeal mode, the high cost of appeal and the solidified adjudication model prevent the appeal mode from realizing its true role. Specifically, if a party is dissatisfied with the decision, he or she can file an appeal, and the cost of the appeal is mainly used to increase the number of adjudicators or to pay for the cost of adjudication again. For example, Kleros provides that if a party is dissatisfied with a juror's decision, he or she may appeal, with twice as many jurors as in the first instance, and with a corresponding increase in fees,³¹ while JuryOnline provides that users may arbitrate once for free, with a corresponding fee for a second appeal. In the case of incremental fees, the parties may give up pursuing the protection of their rights based on cost and transaction efficiency, which leads to the automatic enforcement of erroneous judgments. The adjudication model of the smart contract dispute resolution mechanism, in a nutshell, is group decision-making³². Group decisions made under a model without a uniform and clear basis for adjudication and with simplified procedures for reviewing disclosure of evidence not only fail to guarantee the effectiveness of adjudication, but also increase the barriers to taking remedial measures, making it more difficult and costly for users to defend their rights. Even if

³¹ Clément Lesaege, Federico Ast and William George, *Kleros Short Paper v1.0.7* (September 2019) <https://kleros.io/whitepaper.pdf>

³² 'Group Decision-Making', also known as collective decision-making, refers to the process in which multiple participants collaboratively engage in decision analysis and formulation to leverage collective wisdom. In the context of dispute resolution through smart contracts, it refers to a decision-making process where the majority consensus of decentralized mechanisms, such as blockchain-based voting and random jury systems, determines the resolution outcome.

the appeal model increases the number of adjudicators, it will not be able to obtain a fair decision in a substantive sense. Due to the shortcomings of the smart contract dispute resolution mechanism, the remedial measures taken are still “treating the symptoms but not the root cause”.

To sum up, the smart contract dispute resolution mechanism seems to be efficient and safe, but it actually hides inherent defects. Firstly, there is a lack of effective constraints on the access and performance of adjudicators; blockchain technology relies on DAO governance or algorithmic arbitration, and adjudicators have neither legal qualifications nor uniform adjudication norms. Second, although relying on blockchain to ensure data authenticity, the evidence disclosure and review mechanism lacks procedural safeguards and ignores the substantive review of evidence relevance and legality. Finally, the effectiveness of the ruling and the relief system is not connected with the legal framework, and the result of the ruling has not been included in the judicial confirmation procedure, so the wrong ruling faces the double dilemma of “technological irreversibility” and “no judicial relief”. While actively using technology for digital governance, there is still a need to pay attention to the blind spots in governance under the heavy use of technology.

3 THE OPTIMISATION PATH OF SMART CONTRACT DISPUTE RESOLUTION MECHANISMS

While the decentralization feature of smart contracts relying on blockchain technology is reshaping the transaction paradigm, the endogenous defects of its dispute resolution mechanism are facing a deep conflict between ‘technological rationality’ and ‘juridical values’. The current smart contract dispute resolution mechanism, whether crowdsourcing model or arbitration model, relies excessively on code logic to maintain automatic enforcement and decentralized justice, resulting in an imbalance of power and responsibility of the adjudicator, formal review of evidence, and structural lack of remedial channels, which continue to erode the legitimacy of the system. These deficiencies not only expose the obstacles to the adaptation of the existing technological architecture to legal principles, but also highlight the deep-seated contradiction of the disordered synergy of the on-chain and off-chain governance systems. Therefore, it is necessary to propose solutions to the inherent defects in a targeted manner, and at the same time, further bring into play the advantages of efficient and secure smart contracts in anticipation of realizing the value symbiosis of technological trust and judicial credibility.

3.1 Building a full-cycle regulatory system for access and performance of adjudicators

While striking a balance between efficiency and fairness and justice, attempts have been made to establish an access and evaluation system for adjudicators. The zero-threshold access of adjudicators in the smart contract dispute resolution mechanism, even though it is compatible with the technical concept from the purpose of pursuing high efficiency and safety, is essentially a disregard of the traditional legal

principles. Compared to the traditional dispute resolution mechanism, the adjudicator in the smart contract dispute resolution mechanism is not restricted by strict professional knowledge, but professional knowledge is still a necessary element for procedural justice.³³ Firstly, based on not reducing the efficiency of smart contracts themselves, attempts are made to classify smart contract disputes according to the different points of dispute or the complexity of the case. By way of case diversion, the reality of no or low entry threshold for adjudicators is further weakened. In addition, a professional knowledge test is set up for users to become referee candidates, and referee candidates are classified according to their professional level. Candidates with higher levels of expertise will be matched with more complex cases, and vice versa for simpler cases, thus improving the accuracy and efficiency of adjudicator dispute resolution to a certain extent. Secondly, to ensure the openness and authenticity of the process of ‘recruitment and selection’ of adjudicators, and to ensure the effective operation of game theory and incentive mechanism, the transparent implementation of the procedure will undoubtedly provide further positive feedback for the fairness and impartiality of dispute resolution. Finally, the adjudicator should also establish a post-decision evaluation mechanism, which can contain objective factors such as the speed of dispute handling, the number of disputes handled, and subjective factors such as the evaluation of the parties to the disputes, and further to the adjudicator's professional competence and other comprehensive interpretation, so that the adjudicator can deal with the disputes in the process of continuous acceptance of supervision and evaluation.

While focusing on the adjudicator itself, the smart contract dispute resolution mechanism still needs to formulate unified and clear adjudication norms to ensure the normality and consistency of dispute resolution. Essentially, the lack of adjudication norms in smart contract dispute resolution results from a structural mismatch between the decentralized technology architecture and the traditional legal value system. Existing adjudication activities rely on highly fragmented platform autonomy rules, which lack substantive absorption of traditional legal principles (e.g., procedural due process, principle of proportionality) and fail to form a technically enforceable uniform standard. This double disconnect leads to the dilemma that similar disputes may face “different judgments for similar cases”, which seriously undermines the predictability and authority of the adjudication results. In addition, the dispute resolution of smart contracts usually relies on the incentive mechanism of game theory to motivate the adjudicators to make a more consistent majority judgement, so as to prevent the value of “interest-only theory” from disrupting the normal process of dispute handling. However, the majority decision under the incentive mechanism does not necessarily mean a fair and just judgement, so it is extremely important to formulate a general consensus judgement specification for the accuracy of the judgement result. The adjudication norms of smart contract disputes should contain principle provisions and specific adjudication norms, the principle provisions pay more attention to the adjudicator's fairness, impartiality, independent voting and other

³³ James Metzger, ‘Decentralized Justice in the Era of Blockchain’ (2018) *International Journal of Online Dispute Resolution* 79.

behavioral constraints, and the specific adjudication norms are more inclined to theoretically apply the existing legal norms in order to improve the accuracy of the dispute resolution. Based on the entry threshold of adjudicators and the establishment of adjudication norms, it tries to carry out full-cycle constraints and supervision on adjudicators, so as to further rectify the subject misconduct in the process of intelligent dispute resolution.

3.2 Establishment of a tiered process for disclosure and review of evidence in disputes

In the process of dispute resolution, the smart contract dispute resolution mechanism lacks specific rules and procedures for evidence disclosure and review, and fails to safeguard the legal rights of the disputants to cross-examine and submit additional evidence. Smart contract disputes involve both generative and transformative evidence, and the current dispute evidence disclosure and review process needs to break through the limitations of ‘chain data worship’ and adopt layered governance from a legal perspective to further reconstruct procedural justice. Through the construction of layered dispute evidence disclosure and review standards, the smart contract dispute resolution mechanism can further obtain higher quality evidence, which plays a more important role in the restoration and determination of the facts of the case. The core of hierarchical review lies in the dynamic balance between differentiated verification standards and the right to cross-examine, i.e., different types of evidence are given differentiated standards of evidence disclosure and review. For example, generative evidence (such as transaction hash, and timestamp) is categorized into the automated review layer, relying on the inerrancy of blockchain technology to achieve efficient formal verification; while transformative evidence (evidence submitted by the parties) is incorporated into the substantive review layer, with the help of a credible execution environment to achieve cross-validation under privacy protection, and the adjudicator will make a value judgement of the relevance and legitimacy of the evidence based on specific adjudication specifications. At the same time, in order to protect the disputing parties' right to cross-examine, the optimized path of transforming code logic into visual evidence chains can be adopted so that the disputing parties can view and cross-examine the evidence promptly. At the technical level, this layered architecture can rely on blockchain technology to guarantee the efficiency advantage of evidence review; at the legal level, the composite rule of technical rigidity and legal flexibility fills the fault of the application of the traditional procedural rights in the smart contract, and ultimately realizes the evidence review from the “data truth” to the “factual credibility”. Ultimately, it realizes the paradigm upgrading of evidence review from “data truthfulness” to “factual credibility”.

With regard to the dilemma of evidence review in smart contract disputes, consideration can also be given to the use of technical means to further fix the evidence, so as to determine the legitimacy and authenticity of the source and collection of evidence. Some foreign scholars have pointed out that the contractual content related to the transaction, the applicable substantive law and procedural law, and the dispute resolution norms adopted after the dispute arises can be set as the

parameters in the smart contract, and embedded into the code of the smart contract through the form of code.³⁴ If a smart contract dispute arises under such circumstances, the corresponding transaction parameters can be used directly as evidence to prove the main facts, which ensures the legality and authenticity of the evidence and further enhances the efficiency of dispute resolution. Based on the domestic blockchain distribution and public regulation level, domestic scholars believe that the technical means can allow domestic regulators to further determine the state of a particular smart contract market, which has a significant effect on reducing the cost of regulation and enforcement, and enhancing the strength of regulation.³⁵ The mechanism of evidence disclosure and review in smart contract disputes is governed by the combination of technology and law, which is essentially to rebuild ‘visible justice’ in the code order, not only to safeguard the autonomy value of decentralized justice of smart contracts relying on blockchain technology, but also to realize the re-balance between technical rationality and legal rationality through the institutional embedding.

3.3 Improvement of mechanisms for the convergence of the effectiveness of awards and multidimensional remedies

Although awards under the smart contract dispute resolution mechanism can be automatically enforced by relying on smart contracts, they are not subject to the same legal validity as awards and judgments under the traditional dispute resolution mechanism. To put it simply, whether the judgement made by the smart contract dispute resolution mechanism has legal effect is still a blank state. In the case of technical trust can not completely exclude judicial intervention, how to connect the smart contract dispute resolution mechanism and the traditional dispute resolution mechanism has become a top priority. There is a structural conflict between the decentralized justice of smart contracts and the centralized authority structure of China's current legal system. The confirmation of the legal effect of the smart contract dispute resolution mechanism is by no means a simple rule repair for the existing legal framework, but has become a pilot test for the transformation of legal paradigm in the digital era. The core lies in the reconstruction of the relationship between law and technology, and the law needs to shift from an ‘external regulator’ to an ‘endogenous architect’, and deeply participate in the design of technology through the codification of rules. In addition, technology needs to be transformed from a ‘disruptive force’ to a ‘rule of law-enhancing tool’, with legal values embedded in the code layer. For the smart contract dispute resolution mechanism, we can refer to the online dispute resolution mechanism, through the legitimacy review of the content and procedure of the ruling to confirm the legal effect of the ruling. Only by realizing the two-way transformation of technology and law can the system of on-chain adjudication and off-chain validity be truly closed, so that decentralized governance and legal order can move from antagonism to symbiosis.

³⁴ Darcy W.E. Allen, Aaron M. Lane & Marta Poblet, ‘The Governance of Blockchain Dispute Resolution’ (Fall 2019) *Harvard Negotiation Law Review* 88-89.

³⁵ See Aifei Chen, ‘区块链智能合约纠纷解决的可能性边界 [The Possibilities for Blockchain Smart Contract Dispute Resolution]’ (2024) 5 *Journal of Comparative Law* 204.

Whether and how further remedies can be applied to the awards under group decision-making in the smart contract dispute resolution mechanism remains the ultimate safeguard of the parties' rights. First, in the appeal mode of the smart contract dispute resolution mechanism, the relevant costs should be reduced to alleviate the economic pressure of the parties, so that a smaller economic cost can be exchanged for the possibility of a correct ruling. At the same time, different dispute resolution methods can be introduced in the appeal mode, to a certain extent, weakening the impact of the existing deficiencies in the smart contract dispute resolution mechanism on the accuracy of the decision. Secondly, some scholars hold the view that “blockchain technology may lead to a society in which traditional laws are replaced by autonomous rules”, and with the introduction of blockchain technology and corresponding smart contracts, more and more people are calling for the abandonment of the traditional legal contractual framework and its replacement by autonomous rules on the blockchain.³⁶ In essence, however, a majority decision made by an adjudicator who is a layperson, even with the help of his or her own understanding and relevant adjudicative norms, does not necessarily imply that the decision is legal and sensible. In the current process of legal development, only the current framework of the rule of law can provide predictable results for the parties, and only the current effective legal norms can provide convincing results for the parties. With technology still a black box, it is undeniable that centralized justice remains the last line of defence in maintaining social justice.

4 CONCLUSION

As an interdisciplinary product combining two fields, technology and law, smart contract dispute resolution mechanisms face the challenges of innovation and integration. A smart contract is a digitally defined commitment that can be executed automatically and with minimal human intervention.³⁷ The functional realization of smart contracts is made possible by the birth of blockchain technology, and the combination of the two is regarded in the computer field as a landmark upgrade in the blockchain world.³⁸ As the application of blockchain technology and smart contract technology continues to penetrate into the judicial field, scholars in China have focused their research on the specific application of smart contracts in the dimension of “derivation theory”, with a view to maximizing the use of the advantages of smart contracts in China's legal environment.³⁹ Summarizing the current research results, the overall research seldom involves the ‘ontological’ dimension of the original

³⁶ Primavera De Filippi and Samer Hassan, ‘从“代码即法律”到“法律即代码”——以区块链作为一种互联网监管技术为切入点 [From “Code is law” to “Law is code” : Taking Blockchain as an Internet Regulatory Technology as the Entry Point]’, trans Lei Zhao and Jianfeng Cao, (2018) 5 *Science Technology and Law Chinese-English Version* 14.

³⁷ See Xiaoxu Ma, Maoling Luo, Fan Yang, Jinbao Wang, Min Xiao and Fei Tang, ‘基于零知识证明的跨链隐私智能合约 [Cross-chain Privacy Smart Contract Based on Zero-knowledge Proof]’ (2024) 2 *Communications Technology* 166.

³⁸ See Tianyuan Hu, Zecheng Li, Bixin Li and Qihao Bao, ‘智能合约的合约安全和隐私安全研究综述 [Contractual Security and Privacy Security of Smart Contract: A System Mapping Study]’ (2021) 12 *Chinese Journal of Computers* 2486.

³⁹ See Aifei Chen, ‘区块链智能合约纠纷解决的可能性边界 [The Possibilities for Blockchain Smart Contract Dispute Resolution]’ (2024) 5 *Journal of Comparative Law* 196.

transaction on the smart contract chain and the supporting dispute resolution mechanism. In fact, smart contract as a code as the form of expression of the technology carrier, is still part of the product of human intelligence, and can not do to avoid disputes, smart contract dispute resolution mechanism was born due to the needs of smart contract users.

Based on the analysis of the current legal framework, it can be seen that the inherent defects of the smart contract dispute resolution mechanism are concentrated in the three dimensions of the adjudicator's misconduct, the lack of procedural justice and the disconnection of the effectiveness of the articulation. The low entry threshold of adjudicators and the lack of uniform and clear norms in adjudication, whether the majority decision under the game theory incentive mechanism has legitimacy and fairness still cannot be guaranteed; the lack of dispute evidence disclosure and review mechanism, ignoring the importance of evidence for the determination of the facts of the case, and depriving the parties of the right to confrontation; the validity of the decision can not be recognized by the current law, and the obstruction of further remedial paths, which make the smart contract dispute resolution mechanism unable to play its expected function. All of these have prevented the smart contract dispute resolution mechanism from fulfilling its expected functions. With regard to the inherent defects of the mechanism, we propose an optimization path based on the existing legal framework. To build a full-cycle regulatory system for access and performance of adjudicators to improve the quality of adjudicators and enhance the accuracy and legitimacy of adjudication. At the same time, a hierarchical procedure for disclosing and reviewing evidence in disputes has been set up to clarify the importance of evidence in fact-finding and to safeguard the parties' right to cross-examine. In addition, it has perfected the mechanism of convergence and multi-dimensional relief for the effectiveness of decisions, providing the last line of judicial defence for the protection of rights.

The development of technology is just like a wave surging forward, smart contracts as one of the key technologies of technology-enabled justice, not only need to use its advantages to help the construction of justice, but also need to use legal means to solve its potential risks, and ultimately achieve the optimization of the dispute resolution mechanism of smart contracts and China's judicial construction of the synergistic innovation.

REFERENCES

- [1]Aouidef, Y., Ast, F., & Deffains, B. (2021). Decentralized justice: A comparative analysis of blockchain online dispute resolution projects. *Frontiers in Blockchain*, March, 1–9.
- [2]Antonopoulos, A. M., & Wood, G. (2019). *Mastering Ethereum: Building smart contracts and DApps* (Y. Yu, Z. Yang, J. A. Jian, L. Ren, & E. Jiang, Trans.). Mechanical Industry Press.
- [3]Chen, A. (2024). 区块链智能合约纠纷解决的可能性边界 [The possibilities for blockchain smart contract dispute resolution]. *Journal of Comparative Law*, 5, 196–208.
- [4]Chen, A. (2022). 区块链共谋的反垄断监管 [Antitrust supervision of blockchain collusion]. *Modern Law Science*, 4, 145–157.
- [5]Cyberspace Administration of China. (2019, December 29). The first blockchain smart contract judicial application launched: New technology builds a “smart line of defense” for online integrity. https://www.cac.gov.cn/2019-12/31/c_1579328270387357.htm
- [6]De Filippi, P., & Hassan, S. (2018). 从“代码即法律”到“法律即代码”——以区块链作为一种互联网监管技术为切入点 [From “Code is law” to “Law is code”]. *Science Technology and Law Chinese-English Version*, 5, 7–18.
- [7]Fang, X. (2017). ODR——多元化解解决电子商务版权纠纷新机制 [ODR: A new mechanism to solve e-commerce copyright disputes]. *Legal Forum*, 4, 155–160.
- [8]Gabuthy Y. (2023). Blockchain-Based Dispute Resolution: Insights and Challenges. *Games* 14(5) 75, 1–9.
- [9]Gong, X. (2012). 哈贝马斯程序正义思想及其现代意蕴 [Habermas’ thought on procedural justice and its modern implications]. *People’s Tribune*, 11, 144–145.
- [10]Huang J., (2024). 智能合约众包争议解决机制的探究：基本特征、现实困境与完善路径 [Exploring the Smart Contract Crowdsourcing Dispute Resolution Mechanism: Fundamental Characteristics, Realistic Dilemmas and Improvement Paths]. *Commercial Arbitration & Mediation*, 4, 50–71.
- [11]Hu, T., Li, Z., Li, B., & Bao, Q. (2021). 智能合约的合约安全和隐私安全研究综述 [A study on smart contract security and privacy security]. *Chinese Journal of Computers*, 12, 2485–2514.
- [12]Kaal, W., & Calcaterra, C. (2018). Crypto transaction dispute resolution. *The Business Lawyer*, Spring, 1–59.
- [13]Kaal W. (2024). Evolution of Law: Dynamic Regulation in a New Institutional Economics Framework, in *Festschrift In Honor Of Christian Kirchner*, 1, 1-18.
- Lesaege, C., Ast, F., & George, W. (2019). Kleros short paper v1.0.7. <https://kleros.io/whitepaper.pdf>
- [14]Ma, X., Luo, M., Yang, F., Wang, J., Xiao, M., & Tang, F. (2024). 基于零知识证明的跨链隐私智能合约 [Cross-chain privacy smart contract based on zero-knowledge proof]. *Communications Technology*, 2, 166–172.
- [15]Metzger, J. (2018). Decentralized justice in the era of blockchain. *International Journal of Online Dispute Resolution*, 69–81.
- [16]Ministry of Industry and Information Technology Information Center. (2018).

White paper on China's blockchain industry (《2018 年中国区块链产业白皮书》). China Information Industry Press.

[17]Sun, F. (2022). 《最高人民法院关于加强区块链司法应用的意见》理解与适用 [Understanding and applications of “Opinions of the Supreme People's Court on Strengthening Blockchain Application in the Judicial Field”]. *China Journal of Applied Jurisprudence*, 4, 31–42.

[18]Schelling, T. C. (2011). *The strategy of conflict* (Z. Hua, Trans.). Huaxia Publishing House.

[19]Wall, L. D. (2016, July). “Smart contracts” in a complex world. Federal Reserve Bank of Atlanta. <https://www.atlantafed.org/cenfis/publications/notesfromthevault/1607.aspx>

[20]Wu, Y. (2023). 元宇宙：法律图谱与规范逻辑 [*Metacosmos: Legal mapping and normative logic*]. China Renmin University Press.

[21]Yang, J. (2021). 基于区块链的纠纷解决机制研究 [Research on the blockchain-based dispute resolution mechanism]. *Journal of Shaanxi Normal University (Philosophy and Social Sciences Edition)*, 4, 163–176.

[22]You, W. (2023). 民法典对智能合约的法律规制 [The legal regulation of smart contracts by Chinese Civil Code]. *Theory Monthly*, 12, 125–134.

[23]Zhao, X., & He, L. (2024). 以太坊智能合约安全漏洞检测 [Ethereum smart contract security vulnerability detection]. *IEEE Spectrum*, 8, 56–58.

[24]Zheng, Z., & Qiu, W. (2020). 我国区块链发展趋势与思考 [Development trend and thinking of China's blockchain]. *Bulletin of National Natural Science Foundation of China*, 1, 2–6.

Taihang Legal Spring Quarterly

Call for Papers

Taihang Legal Spring Quarterly is a peer-reviewed legal journal that publishes quarterly. We welcome substantial articles and shorter works including legislative commentaries, case notes, and legal theory. As an independent journal focused on fostering global legal scholarship, we encourage multi-angle discussions on contemporary legal issues from scholars and practitioners worldwide. For submission guidelines and formatting requirements, please refer to the **Call for Papers PDF** available on our website. For inquiries about submissions, review timelines, or special issue proposals, contact our editorial team.

Call for Reviewers

To enhance our journal's academic quality and strengthen our anonymous peer-review system, *Taihang Legal Spring Quarterly* invites legal experts and scholars to join our reviewer panel. We welcome self-recommendations or nominations of qualified candidates to support the journal's development. Interested applicants should contact us at legal@taihangspring.com.

