

Co-evolution of Technology and Society: Value Tensions, Ethical Critical Thinking and Risk Construction

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Abstract

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Against the backdrop where technology is deeply integrated into social life, clarifying the interactive relationship between technology and society as well as its value dimensions is of vital importance. Based on two theoretical perspectives, namely technological determinism and co-evolution theory, this paper systematically discusses the mutual influences between technology and society with specific cases including artificial intelligence and gene editing. The research reveals that technology can boost economic development and transform lifestyles, yet it may also trigger environmental crises and ethical dilemmas. Meanwhile, social demands, policies and regulations, and cultural concepts profoundly shape the developmental trajectory of technology. On this basis, the paper underscores the necessity of fostering a critical mindset, and proposes practical strategies such as educational guidance and policy regulation to balance the positive and negative effects of technology. It provides theoretical references and practical approaches for addressing technological challenges and achieving sustainable development.

Keywords: Engineering Ethics, Technology and Society, Critical Thinking, Technological Ethics, Risk Construction.

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1 Introduction

1.1 Research Background and Significance

As the core driver of development and transformation in modern society, science and technology have permeated all spheres of society. From the widespread prevalence of smartphones and the Internet in daily life, the large-scale application of automated equipment and artificial intelligence in industrial production, to breakthroughs in aerospace exploration and advances in gene editing technology in biomedicine, science and technology exert influences covering every facet of human activities. While reshaping production efficiency and people's

lifestyles to drive social operation, technology also profoundly molds political structures, economic forms and cultural values.

From the socioeconomic perspective, technological innovation serves as the core engine for industrial upgrading and economic growth. Taking the information technology industry as an example, continuous breakthroughs in semiconductor processes have exponentially boosted chip performance, directly driving the iterative upgrading of terminals such as computers and smartphones, spawning a massive information industry and generating enormous economic value. The rise of the Internet has completely overturned the

operational logic of traditional commerce. The flourishing of emerging formats including e-commerce and the sharing economy has accelerated the deep integration of the global trade system and the restructuring of economic patterns. Statistical data indicates that the contribution rate of technological innovation to global economic growth has been rising over recent decades, rendering it an indispensable pillar of the modern economic system.

In terms of social life, technological progress has brought all-round convenience. Advances in high-speed railways and civil aviation have largely compressed geographical distances and strengthened economic and cultural exchanges across regions. The global popularization of genetic testing and minimally invasive surgery has enhanced the accuracy of disease diagnosis, shortened patients' recovery cycles and significantly extended human life expectancy. The emergence of online education platforms has broken the temporal and spatial barriers of traditional education, facilitated the dissemination of high-quality educational resources to remote areas, and enabled residents in underdeveloped regions to access education.

Nevertheless, adverse side effects accompanying technological advancement have gradually emerged. Large-scale application of industrial technologies has led to overexploitation of natural resources and aggravated ecological pollution, with global climate change and biodiversity loss becoming urgent practical issues. While gene editing technology can cure hereditary diseases, its therapeutic applications have sparked fierce debates over the protection of human gene pool diversity and ethical boundaries. Although the popularization of artificial intelligence greatly facilitates human life, it inevitably triggers employment shocks: certain occupations are replaced by automated systems, leaving hundreds of thousands facing unemployment risks.

The "social mirror" attribute of technology (Li Bocong, 2002) suggests that the evolution of technology is constrained by structural social factors including social institutions and cultural concepts, and in turn reshapes human value systems. Therefore, systematic exploration of the social dimensions and

value orientation of technology carries profound practical significance. By dissecting the interactive mechanism between technology and society, we can fully recognize the dual-edged nature of science and technology in social development, and further reveal the logic linking social demand drivers, cultural value choices and institutional norms behind technological innovation. This provides theoretical support for constructing benign interaction between technology and society.

1.2 Research Objectives and Methodology

This study focuses on an in-depth analysis of the interactive mechanism between technology and society, aiming to uncover the driving forces and social value orientations underlying technological evolution. It establishes a theoretical framework and practical path for the coordinated development of technology and society through systematic analysis from a critical technological perspective. Multiple research methods are integrated in this research:

1.Literature Research Method: This study retrieves Chinese and foreign literature in the fields of philosophy of technology, Science, Technology and Society (STS), and technological ethics, covering academic journal papers, monographs and industrial research reports. It systematically sorts out research achievements concerning the social dimensions of technology and the interaction mechanism between technology and society, laying a theoretical foundation by reviewing the state-of-the-art research trends in this field.

2.Case Analysis Method: Representative technologies with extensive social impacts, including Internet technology, artificial intelligence and gene editing, are selected as research cases. In-depth multi-angle analysis identifies the functional mechanism linking technological innovation with social demands and cultural traditions.

3.Interdisciplinary Research Method: The research integrates theories and methodologies from philosophy, sociology, economics and ethics to conduct a comprehensive study on the social attributes and value dimensions of technology. The philosophical perspective primarily explores

fundamental issues such as the inherent attributes of technology, the driving forces and goals of social development; sociological theories analyze the impacts of technology on social structures, social relations and social changes. The construction of an interdisciplinary analytical framework breaks the limitations of single-discipline research and enables comprehensive and in-depth understanding of the complex interaction between technology and society.

1.3 Research Innovations and Difficulties

The innovations of this research mainly lie in the expansion of research perspectives and the construction of analytical frameworks. Different from existing studies that adopt single or limited dimensional analysis, this paper adopts multi-dimensional comprehensive analysis to examine the interaction mechanism between technology and society from economic structure, cultural tradition, ethical norms and other perspectives. It constructs an interdisciplinary analytical framework to systematically reveal the functions, values and social driving forces of science and technology in diverse social scenarios, breaking the horizon constraints of traditional research.

Furthermore, this paper conducts empirical case analysis on emerging representative technologies including artificial intelligence and gene editing. Characterized by rapid development and wide-ranging social impacts, these technologies have generated numerous social and ethical dilemmas. Focusing on real-world cases enables timely discussion of opportunities and challenges brought by technology, providing prompt and effective theoretical and practical guidance for coping with social transformations and ethical predicaments triggered by emerging technologies.

This research also faces challenges stemming from the complexity of technology-society interactions. The interplay between technology and society does not follow a simple linear relationship; instead, it involves complex subjective factors such as institutions, culture and ethics. Clarifying the intricate relationships among various factors and analyzing the deep co-construction mechanism of

technology and society require the integration of multi-disciplinary theoretical tools and dynamic systematic analysis, imposing high requirements on the scientificity of research design and the effectiveness of analytical methods.

2 Theoretical Paradigms of Mutual Influences Between Technology and Society

2.1 Technological Determinism: Core Logic and Historical Limitations

Technological determinism constitutes a pivotal theory in research on the relationship between technology and society. Its core proposition holds that technology follows an autonomous evolutionary logic and technological changes dominate social transformations. This theoretical tradition can be traced back to optimistic perceptions of technological innovation during the Industrial Revolution. Max Weber (2010) put forward the view that "technology serves as the ultimate driving force of historical development", embodying the mindset that regards technology as the core engine of social evolution.

This theoretical system comprises two forms: strong technological determinism and weak technological determinism. Strong technological determinism emphasizes that technology is the sole decisive factor of social development, completely negating the restrictive effects of social factors on technology, and arguing that technological progress inevitably guides society toward specific outcomes. Weak technological determinism acknowledges the dominant role of technology while recognizing mutual interactions between technology and society. It posits that technology operates within social environments shaped by politics, economy and culture, emerging from society and exerting counteractive influences in return. Jacques Ellul, a representative scholar of moderate technological determinism, views technology as an all-encompassing scientific methodology and self-disciplined organism that marginalizes human beings and becomes the decisive force of society, with economy, politics and culture all undergoing technologization. Distinct from strong technological

determinism, his analysis of technological determinism incorporates social influences on technology, stressing the correlations between technological systems and social political, economic and cultural factors.

Nevertheless, technological determinism bears notable limitations. It overstates the role of technology in social development by treating it as the sole or decisive factor, while overlooking other social elements including politics, culture and history. Moreover, the theory fails to fully recognize the reverse constraints imposed by society on technology. Technological development is not an isolated process; instead, it is guided and regulated by multiple social factors such as social demands, resource allocation and policy orientations.

2.2 Co-evolution Theory: An Analytical Framework of Dynamic Co-construction

Co-evolution theory advocates that the relationship between technology and society is not a unidirectional deterministic or constructive one, but a dynamically correlated joint evolution formed through mutual interactions. It conceptualizes technology and society as a tightly coupled system, emphasizing that the two continuously influence, adapt to and evolve alongside each other through sustained interactions. Its core lies in revealing the two-way driving mechanism between technological innovation and social transformation.

The core value of co-evolution theory resides in highlighting the dynamic sustainability of technology-society interactions. The two parties undergo adaptive adjustments through a spiraling co-construction process. This theoretical perspective transcends the one-sided limitations of technological determinism and social constructivism, integrating the internal logic of technological development and external constraints of the social environment via systematic thinking. It depicts a more realistic comprehensive and dynamic picture of the mutual influences and co-evolution of technology and society, providing an analytical framework balancing comprehensiveness and dynamism for understanding technology-society relations.

3 Dual Analysis of Social Effects of Technology

3.1 Positive Impacts

3.1.1 Economic Development and Industrial Transformation

The central role of technology in economic development and industrial transformation is fully demonstrated through historical processes and contemporary practices. Taking the Industrial Revolution as a landmark technological transformation, the invention and popularization of steam engines drove the shift of human production modes from manual labor to mechanized mass production. As a power source applied across textile, mining, transportation and other sectors, steam engines exponentially boosted production efficiency. Meanwhile, the emergence of steam locomotives and steamships reconstructed global transportation networks, strengthened regional economic linkages and promoted trade prosperity. Data shows that during the Industrial Revolution, the output of Britain's cotton textile industry multiplied over decades, and surging export volumes established Britain as a global economic leader, highlighting the decisive impact of technology on economic patterns.

As a pivotal node of technology-driven economic and industrial transformation, the Information Revolution has systematically restructured economic operation modes and industrial structures through rapid advances in the Internet, computers and communication technologies. The instant and efficient communication features of the Internet break traditional temporal and spatial barriers, directly spawning emerging formats including e-commerce and the digital economy. Enterprises leverage Internet platforms to realize global resource allocation and market expansion, reducing transaction costs and improving operational efficiency. A typical case is e-commerce platforms such as Alibaba, which subvert traditional trading models, enabling consumers to purchase global commodities online and merchants to sell products worldwide via platforms. The evolution of the digital economy has further given rise to emerging industries including big data, cloud computing, artificial intelligence and the Internet of Things,

whose innovative and high-value-added characteristics render them new growth engines for the economy. Data from the China Academy of Information and Communications Technology indicates that China's digital economy reached 59.6 trillion RMB in 2023, accounting for 47.5% of GDP, with its contribution rate to economic growth maintaining an upward trend.

In terms of industrial structural evolution, technological development continuously drives the transformation and upgrading of traditional industries as well as the innovation of emerging formats. Manufacturing industries apply automation and intelligent technologies to realize intelligent control, management optimization and quality improvement of production processes, effectively cutting costs and enhancing competitiveness. Meanwhile, technological integration accelerates the dissolution of industrial boundaries. For instance, the deep integration of the Internet and traditional finance has spawned Internet finance, providing users with convenient and diversified financial services, demonstrating the key role of technology in breaking industrial barriers and creating new economic growth points.

3.1.2 Improvement of Quality of Life

Rapid technological advancement has significantly improved human quality of life and delivered unprecedented convenience across multiple dimensions. The widespread popularization of Internet technology stands as a typical epitome of this process. The rise of e-commerce platforms such as Taobao and JD.com has reconstructed consumption patterns. Consumers browse commodity information and place orders via electronic devices, with sophisticated logistics systems delivering goods globally. Statistics show that China's online retail sales hit 15.4 trillion RMB in 2023, representing a year-on-year growth of 11.0%. The prevalence of online shopping has brought disruptive changes to offline consumption models.

Remote work and online education spawned by Internet technology are reshaping human social

activity patterns. Driven by advances in Internet and communication technologies, an increasing number of enterprises adopt remote work systems, allowing employees to complete work tasks from home or alternative locations and optimize the balance between work and life. Survey data collected during the 2022 pandemic reveals that numerous global enterprises gradually promoted remote work, with the proportion exceeding 50% in some countries.

In the medical field, technological innovations enhance quality of life through dual breakthroughs in diagnostic accuracy and therapeutic efficacy. Magnetic Resonance Imaging (MRI) technology presents high-definition images of human organ structures and pathological lesions, providing precise foundations for early disease screening. Minimally invasive surgery revolutionizes traditional surgical modes with advantages of minor trauma, fewer complications and shortened recovery cycles. Genetic testing technology analyzes hereditary information to realize precise diagnosis of genetic diseases and personalized therapeutic regimens, systematically advancing the medical sector toward precision and minimal invasiveness.

3.1.3 Knowledge Dissemination and Educational Innovation

Technological progress exerts profound impacts on knowledge dissemination, educational innovation and the redistribution of educational resources. The popularization of the Internet breaks temporal and spatial restrictions on knowledge transmission. Students access global information resources in real time via networked devices including computers, mobile phones and tablets, forming a new communication ecosystem of a "digital knowledge repository".

Technology reshapes the allocation of educational resources by breaking the traditional uneven distribution pattern of educational resources. In conventional education systems, high-quality resources are disproportionately concentrated in large cities and developed regions, leading to educational inequity. The rise of online education platforms, however, enables students in remote areas

to access high-quality curricula and instruction from elite teachers in first-tier cities through live streaming and recorded courses, substantially advancing educational equity and demonstrating technology's critical function in mitigating regional disparities in knowledge access.

3.2 Negative Impacts

3.2.1 Environmental Crises

While delivering convenience and progress, rapid technological development has triggered severe environmental problems that threaten ecosystems and human survival, among which pollution and resource scarcity stand out as prominent issues. Chemical pollution from industrial production serves as a typical case: wastewater, waste gas and solid residues discharged by chemical production contain heavy metals and organic pollutants that continuously damage soil, water sources and air. Electronic waste pollution has intensified alongside accelerated replacement cycles of electronic products. Hazardous substances including lead, mercury, cadmium and brominated flame retardants contained in waste electronics contaminate the environment through unregulated disposal such as open-air incineration and acid leaching by informal workshops, releasing toxic fumes and seeping heavy metals into soil and groundwater to expand the scope of environmental damage.

Energy overconsumption constitutes a striking dimension of resource scarcity. Driven by global economic expansion and population growth, demand for energy keeps rising. Fossil fuels including coal, petroleum and natural gas remain dominant energy sources yet are non-renewable with limited reserves. Their over-extraction and utilization exacerbate resource depletion risks. The International Energy Agency (IEA) predicts that under existing consumption patterns, global petroleum reserves will face depletion risks within decades. Environmental hazards stemming from excessive energy consumption cannot be overlooked either: rising emissions of carbon dioxide and other greenhouse gases accelerate global warming, triggering

cascading consequences including glacial melting, sea level rise and frequent extreme weather events.

Water scarcity induced by technological development also poses severe challenges. Growing water demand from industrial production, agricultural irrigation and urban domestic consumption, coupled with aggravated water pollution, renders global water shortage increasingly prominent. Massive volumes of untreated industrial wastewater discharged by industrialized regions contaminate rivers and lakes, drastically reducing available freshwater resources for human use. Water waste caused by backward irrigation technologies further intensifies supply-demand imbalances. United Nations data indicates that approximately 2 billion people worldwide live in regions facing severe water scarcity, which has become a core bottleneck restricting economic development and improvements in human quality of life.

3.2.2 Widening Social Inequality

While propelling social progress, technological development simultaneously exacerbates social inequality, manifested prominently through expanding digital divides and widening wealth gaps. The digital divide essentially refers to information disparities and wealth differentiation arising from gaps in information technology access, application capabilities and innovation levels among populations, regions and industries. Urban areas enjoy priority access to advanced information technology services supported by sound infrastructure and economic advantages, while remote impoverished rural regions suffer from inadequate network coverage and unstable signals. Rural populations face significant disadvantages in information acquisition, access to educational resources and market competition, leading to social stratification.

The application of science and technology also widens wealth gaps across social strata. The development of automation and artificial intelligence expands income disparities between high-skilled and low-skilled laborers. Uneven wealth distribution stemming from technological innovation becomes increasingly salient: enterprises and individuals who

participated in early technological innovation and investment, such as founders of Internet giants, rapidly accumulate enormous wealth through developing and operating technological platforms. In contrast, ordinary laborers, especially those in traditional industries, struggle to share technological dividends and experience slow income growth. This distribution pattern widens social wealth gaps and intensifies class solidification, bringing latent risks to social stability and development.

3.2.3 Ethical and Moral Dilemmas

Rapid advances in high technologies including gene editing and artificial intelligence have spawned a series of moral predicaments alongside technological progress. While gene editing biotechnology brings promising treatments for hereditary diseases, it has sparked extensive ethical debates, with the most heated controversy revolving around "designer babies". The practice of parents modifying fetal genes to pursue ideal intelligence, appearance and other traits triggers discussions on the ethics of the human gene pool. Worse still, it may further exacerbate social inequality: economically privileged groups can afford costly genetic enhancement to eliminate unfavorable genes, creating a virtuous cycle, while low-income populations face increasing marginalization and even elimination by society, potentially forming a new social hierarchy based on genetic superiority and inferiority. Additionally, the challenges posed by gene editing to human dignity and natural order cannot be ignored. Artificial genetic modification is regarded as interference with natural laws, which may undermine the uniqueness and sanctity of life.

Big data privacy and security constitute another non-negligible ethical issue in modern technological development. Artificial intelligence systems rely on massive datasets for operation, which often contain personal private information such as names, addresses and consumption habits. Data leakage or abuse poses severe threats to personal privacy security. For instance, illegal actors may leverage artificial intelligence to collect and analyze user data for targeted fraud and harassment. Beyond data privacy, the division of liability when artificial

intelligence systems malfunction or cause harm represents another ethical dilemma. Taking autonomous vehicles as an example, liability allocation remains undefined when accidents occur under autonomous driving modes, creating ambiguous legal frameworks for accident accountability among design engineers, manufacturers and vehicle occupants.

4 Social Construction Mechanisms of Technology

4.1 Social Demands Drive Technological Development

Social demand constitutes the core driving force of technological progress, a truth observable throughout human civilization, particularly evident in technological iterations within the transportation sector. In ancient times, the expansion of human activity spheres and frequent material exchanges generated growing demand for convenient transportation, directly facilitating the invention of carriages as efficient transport tools. Later, urban expansion and population surges exacerbated traffic congestion, creating urgent social demand for innovative urban transportation technologies. Against this backdrop, the world's first subway line opened in London in the 1860s, rapidly emerging as a vital component of modern urban transportation globally due to its speed and convenience.

Entering the 20th century, breakthroughs in internal combustion engine technology fulfilled humanity's desire for motorized travel and fueled the rise of the automobile industry, drastically transforming travel patterns. Subsequent acceleration of globalization raised demand for rapid long-distance cross-regional transportation, driving the rapid development of aviation technology. In the contemporary era, accelerated urbanization and prominent environmental challenges have generated demand for green intelligent transportation technologies, positioning electric vehicles as a new direction for industrial transformation due to their environmental benefits.

The trajectory of technological innovation spanning carriages to electric vehicles and trams to

aviation clearly demonstrates that social demand forms the underlying logic of technological advancement. As society evolves and living standards rise, demands continue to upgrade, guiding technological innovation toward greater convenience, efficiency and sustainability.

4.2 Cultural Values Shape Technology Selection and Application

Cultural concepts represent deep-seated social consciousness that subtly yet profoundly influences the selection and application of technology. Such influences manifest through values, thinking habits and behavioral norms embedded in diverse cultures, leading to divergent developmental paths for technology during introduction, popularization and utilization. Transgenic technology serves as an illustrative case reflecting the role of cultural values, with starkly divergent societal attitudes across Western regions. Certain European countries adopt cautious or resistant stances toward this technology because their cultural traditions uphold natural order and prioritize preserving traditional lifestyles, viewing artificial genetic modification as a disruption of natural laws and a threat to conventional agricultural models. In contrast, the United States widely applies transgenic technology amid persistent social controversies. American cultural emphasis on innovation motivates enterprises and research institutions to advance technological research for improved production efficiency, while consumer and environmental organizations advocate strengthened supervision and mandatory labeling of transgenic food over concerns regarding food safety, biodiversity and ethics. This dynamic exemplifies the game between technological application and cultural values.

This case reveals that cultural values shape public perceptions and acceptance of technology, determining its general developmental trajectory and regulating specific application practices. Amid the global dissemination of technology today, clarifying the relationship between cultural concepts and technology enables technology selection to align with value demands of diverse cultures and fosters harmonious coexistence between technology and

culture.

5 A Critical Thinking Framework for Technological Ethics

Critical thinking refers to a rational and comprehensive mode of thought and value orientation. It requires objective and prudent evaluation of technology, avoiding blind overstatement of technological benefits or one-sided negation of technological value. Instead, it advocates critical reflection on the essence, developmental processes and application outcomes of technology to uncover hidden social, economic, cultural and ethical factors behind technology, as well as its complex impacts on human society and natural environments.

Its core advocates questioning and reflective spirit, encouraging inquiry into prevailing perceptions, practical modes and implicit assumptions of technology rather than passive acceptance of superficial technological phenomena. Taking artificial intelligence as an example, individuals equipped with critical thinking recognize not only its positive outcomes including improved production efficiency and convenient daily life, but also conduct in-depth analysis of underlying risks such as restructured employment landscapes, privacy security vulnerabilities and algorithmic bias.

Critical thinking further emphasizes multi-dimensional comprehensive examination of technology. Beyond technological attributes per se, it fully accounts for interactions between technology and social, cultural and ethical environments. Amid rapid technological iteration, this mindset helps avoid cognitive misconceptions of technological determinism and technological utopianism. Technological determinism regards technology as the sole driving force of social transformation while ignoring social constraints on technology, whereas technological utopianism treats science and technology as a universal solution to all social problems and disregards potential technological risks. Adopting a critical perspective clarifies the interactive logic of technology and society: technological development is guided by social demands, cultural norms and policy frameworks,

while simultaneously reshaping social structures and value systems. It enables objective assessment of the applicable scope of technology, maximizing its advantages while effectively addressing accompanying challenges.

In practical technological governance, critical thinking lays an ethical foundation for balancing diverse interest demands. For example, when potential conflicts emerge between economic benefits and social value during technological research and application, critical reasoning prompts relevant stakeholders to conduct ethical reviews and social assessments throughout the full lifecycle of technological development and implementation. It drives technological progress to align with overall human interests and long-term needs, guiding technology toward safe, reliable and sustainable development through rational normative measures and preventing irreversible harm to society and the environment caused by technological abuse.

6 Conclusion and Prospect

This study adopts co-evolution theory to analyze the relationship between technology and society, integrating the strengths of technological determinism and social constructivism to systematically examine mutual interactions between technology and society. The research finds that technology can drive economic growth yet may simultaneously trigger environmental crises, exacerbate social stratification and spark ethical controversies. In turn, social demands, institutional policies and cultural values shape the developmental trajectory of technology through demand guidance, institutional constraints and value screening.

Critical thinking stands as the key to realizing coordinated development between technology and society. Simply put, it requires rational and comprehensive evaluation of technology: acknowledging the transformative role of technological innovation in social progress while remaining vigilant of potential risks and ethical dilemmas. Taking artificial intelligence applications

in medical care and transportation as an example, despite its capacity to boost medical efficiency and alleviate traffic congestion, it introduces challenges including data privacy leakage, algorithmic unfairness and ambiguous liability definitions. Cultivating critical thinking requires multi-pronged efforts: educational systems should strengthen training in critical reasoning; societies should cultivate open forums for discussions on technological ethics; individuals need to enhance technological literacy and reflective capabilities. Multi-agent collaborative mechanisms enable social stakeholders to make rational judgments and scientific decisions throughout technological innovation processes.

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