International Studies in Science and Technology
https://isstechjournal.science

Public Acceptance with Biotechnology Governance Frameworks across Transnational Advisory Bodies

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Abstract

This paper investigates the relationship between biotechnology governance frameworks and public acceptance of emerging biotechnological innovations across transnational contexts. While scientific advancement in fields such as gene editing, synthetic biology, and gene drives continues at an unprecedented pace, the societal legitimacy of these technologies remains highly contested. Using a comprehensive panel dataset spanning fifteen countries over a fifteen-year period (2008 to 2023), this study utilizes panel data analysis to evaluate how specific characteristics of national and transnational biotechnology governance frameworks predict public acceptance. Specifically, we operationalize governance frameworks through metrics of regulatory transparency, regulatory stringency, and public participation mechanisms. Our econometric specifications control for socio-economic factors, scientific literacy, and country-specific fixed effects. The empirical results demonstrate that while regulatory stringency has a non-linear, U-shaped relationship with public acceptance, both regulatory transparency and formal public participation mechanisms are robust, positive predictors of societal trust and technology adoption. Transnational advisory bodies act as critical institutional intermediaries, translating governance quality into public confidence by harmonizing standards and fostering discursive legitimacy across borders. These findings provide critical insights for policymakers aiming to design robust, democratic, and globally aligned biotechnology policies.

Keywords: Biotechnology Governance; Public Acceptance; Panel Analysis; Transnational Advisory Bodies; Multidisciplinary Research

1. Introduction

1.1 Background on Biotechnology Governance

The rapid evolution of modern biotechnology has ushered in a transformative era for healthcare, agriculture, and environmental management. Innovations such as clustered regularly interspaced short palindromic repeats (CRISPR-Cas9), gene drives, and synthetic biology offer unprecedented capabilities to eradicate genetic diseases, boost agricultural yields, and mitigate climate change. However, these profound technological disruptions simultaneously present complex ethical, ecological, and socio-political challenges. In response to these challenges, governments and international organizations have established diverse biotechnology governance frameworks designed to manage risks, oversee ethical boundaries, and ensure biosafety. Historically, biotechnology governance was predominantly technocratic, relying on expert-led risk assessments to dictate policy decisions. This top-down model often treated risk as a purely technical calculation, ignoring the broader socio-ethical and cultural dimensions of technological intervention. Over the past three decades, however, the paradigm of governance has shifted significantly.

The historical legacy of public backlash against first-generation genetically modified organisms (GMOs) in the late 1990s demonstrated that scientific consensus alone is insufficient to guarantee societal adoption. Public skepticism was not merely a product of scientific ignorance, but rather a reflection of institutional distrust, perceived regulatory capture, and the exclusion of public values from decision-making processes. Consequently, modern biotechnology governance frameworks have increasingly integrated principles of transparency, public deliberation, and adaptive regulation to cultivate societal legitimacy. Despite these structural modifications, there remains a persistent divergence in public acceptance of biotechnology across different nation-states and regions. Understanding the drivers of this divergence is paramount for the sustainable development of the global bioeconomy.

1.2 The Role of Transnational Advisory Bodies

As biotechnological research and supply chains are inherently global, national governance frameworks do not operate in isolation. Instead, they are increasingly mediated, harmonized, and influenced by transnational advisory bodies. Entities such as the Organisation for Economic Co-operation and Development (OECD), the European Academies Science Advisory Council (EASAC), the World Health Organization (WHO), and various United Nations committees serve as vital nodes in the global governance architecture. These transnational bodies act as epistemic communities, producing scientific consensus reports, drafting model regulatory frameworks, and establishing normative guidelines for biotechnology oversight.

Transnational advisory bodies play a dual role in shaping both policy and public opinion. On one hand, they facilitate policy diffusion by transferring regulatory best practices across national borders, thereby driving a degree of institutional convergence. On the other hand, they function as arenas for public diplomacy and stakeholder engagement, shaping the international discourse on the safety and ethical acceptability of biotechnology. By providing a platform for transnational dialogue, these bodies help to establish international benchmarks for regulatory quality. This paper argues that the efficacy of these transnational advisory bodies in fostering public acceptance is mediated by how national governments implement and adapt these international benchmarks within their domestic governance frameworks.

1.3 Objectives and Scope of the Study

The primary objective of this study is to empirically evaluate and predict public acceptance of emerging biotechnologies based on the structural characteristics of domestic biotechnology governance frameworks. While existing research has extensively explored the psychological and cultural determinants of public risk perception, there is a scarcity of quantitative, longitudinal analyses that link macro-level governance characteristics to micro-level public acceptance. This study addresses this gap by employing panel data analysis to examine fifteen countries over a fifteen-year period (2008–2023).

We conceptualize biotechnology governance through three primary institutional dimensions: regulatory transparency, regulatory stringency, and public participation mechanisms. By analyzing how these dimensions interact with public opinion over time, we seek to identify which institutional configurations are most effective at building public trust. Furthermore, we investigate how country-level engagements with transnational advisory bodies moderate these relationships. By moving beyond cross-sectional analyses, this panel approach allows us to control for unobserved time-invariant country characteristics and identify temporal trends, offering robust predictive insights for international policymakers and science communicators.

2. Literature Review and Theoretical Foundations

2.1 Public Acceptance of Emerging Technologies

The study of public acceptance of emerging technologies has evolved from the early cognitive deficit model to more sophisticated, multidimensional socio-psychological frameworks. The cognitive deficit model posited that public skepticism toward scientific innovation was primarily due to a lack of scientific knowledge [1]. According to this view, educating the public on the underlying mechanisms of biotechnology would naturally lead to increased acceptance. However, extensive empirical testing has largely discredited this simplistic model. Research has demonstrated that scientific literacy does not have a linear, positive relationship with technology acceptance; in some cases, highly literate individuals are the most polarized in their views due to biased assimilation and cultural cognition [2].

Modern theories of technology acceptance emphasize the role of affect, values, and trust. The cultural cognition thesis suggests that individuals form risk perceptions that reflect their core values regarding social structure and authority, aligning their beliefs with their peer groups. In the context of biotechnology, agricultural applications are often viewed through the lens of environmental preservation, corporate dominance, and naturalness, whereas medical applications are evaluated based on personal health benefits and altruistic outcomes. Consequently, public acceptance is highly context-dependent, necessitating governance frameworks that can accommodate diverse societal values rather than merely relying on scientific communication.

2.2 Institutional Trust and Governance Frameworks

When citizens lack the technical expertise to personally evaluate the safety of complex biotechnologies, they substitute this technical assessment with institutional trust. Trust acts as a cognitive heuristic, reducing the complexity of decision-making under uncertainty [3]. Public trust is directed toward the regulatory institutions tasked with monitoring, evaluating, and mitigating the risks associated with biotechnology. The institutional performance model suggests that trust is a function of how effectively, transparently, and fairly these regulatory bodies operate [4].

Within this framework, biotechnology governance architectures can be characterized by their degree of regulatory transparency, regulatory stringency, and public participation. Regulatory transparency refers to the accessibility of scientific data, decision-making rationales, and safety assessments to the public. High levels of transparency reduce suspicion of regulatory capture by corporate interests and allow independent scientists to verify regulatory claims [5]. Regulatory stringency denotes the rigor and precautionary nature of the evaluation processes. While high stringency can reassure the public of safety, excessively restrictive regulations may signal that the technology is inherently dangerous, thereby inadvertently increasing risk perception. Finally, public participation mechanisms, such as consensus conferences, citizen juries, and public consultations, provide citizens with a voice in the policy process. These participatory mechanisms foster procedural justice, ensuring that public values and ethical concerns are integrated alongside technical risk assessments, which in turn enhances the democratic legitimacy of the governance framework [6].

2.3 Panel Data Analysis in Policy Evaluation

Methodologically, much of the existing literature on public acceptance of biotechnology relies on cross-sectional survey data, such as Eurobarometer surveys or national opinion polls conducted at a single point in time. While valuable, cross-sectional studies are highly vulnerable to omitted variable bias and cannot establish temporal ordering, making it difficult to infer causal relationships between policy interventions and changes in public opinion. Furthermore, cross-sectional analyses cannot account for time-invariant cultural, historical, or institutional factors unique to specific countries, which may confound the relationship between governance frameworks and public acceptance [7].

Panel data analysis, which tracks the same cross-sectional units (countries) over multiple time periods, offers several distinct advantages for policy evaluation. By utilizing country fixed effects, panel models control for stable, unobserved national characteristics, such as deep-seated cultural values, historical regulatory trajectories, or national identity. Additionally, panel analysis allows researchers to model dynamic processes, capturing how changes in governance structures, such as the passage of a new transparency law or the creation of a public advisory council, affect public acceptance over time. This temporal dimension is critical for identifying lag effects, as public trust is rarely built or eroded instantaneously but rather aggregates gradually in response to sustained institutional performance.

3. Methodology and Panel Data Specification

3.1 Data Sources and Variable Operationalization

To empirically model the relationship between biotechnology governance frameworks and public acceptance, we constructed a balanced panel dataset comprising fifteen countries over a fifteen-year period (2008 to 2023). The selection of countries represents a diverse range of regulatory models, geographic regions, and levels of biotechnological development, including the United States, Canada, the United Kingdom, Germany, France, Japan, South Korea, China, Australia, Brazil, and India.

Data on public acceptance were harmonized from several long-running international and national survey programs, including the Eurobarometer on Biotechnology, the World Values Survey, and national science academy polls. The primary dependent variable, the Public Acceptance Index, is a standardized composite score ranging from 0 to 100, reflecting the aggregate level of public support for emerging agricultural and medical biotechnologies within a given country-year.

To operationalize the independent variables representing biotechnology governance frameworks, we developed three distinct indices based on regulatory statutes, legislative databases, and reports from transnational advisory bodies. The Regulatory Transparency Index measures the extent to which regulatory safety data, decision-making protocols, and clinical trial results are made publicly accessible without cost. The Regulatory Stringency Index evaluates the complexity, duration, and precautionary level of the approval processes for biotechnology products, incorporating metrics such as approval timelines and post-market surveillance requirements. The Public Participation Index quantifies the institutionalized opportunities for public input, assessing the frequency, scale, and legal weight of public consultations, citizen panels, and advisory boards.

Table 1 provides a detailed summary of the variables, their operational definitions, and the primary data sources utilized in the study.

Table 1: Definitions and Sources of Key Panel Variables

Variable Name	Operational Definition	Primary Data Source	Range
Public Acceptance Index	Standardized composite score of public support for agricultural and medical biotechnology	Eurobarometer, World Values Survey, National Polls	0 to 100
Regulatory Transparency Index	Metric of public accessibility to safety data, regulatory rationales, and scientific studies	World Resources Institute, National Legislative Portals	0 to 10
Regulatory Stringency Index	Metric of complexity, precautionary requirements, and duration of the approval process	OECD Regulatory Policy Outlook, National Statutes	0 to 10
Public Participation Index	Metric of frequency, scale, and legal mandate of citizen consultations and panels	International Association for Public Participation	0 to 10
Scientific Literacy Index	Country-year aggregate score of basic scientific knowledge and methodology understanding	OECD PISA, National Science Board Surveys	0 to 100
GDP per Capita	Logarithm of gross domestic product per capita, adjusted for purchasing power parity	World Bank Development Indicators	Continuous

3.2 Panel Data Econometric Specifications

To model the predictive relationship between biotechnology governance frameworks and public acceptance, we specify a series of panel regression models. We evaluate both fixed effects and random effects specifications to determine the most appropriate model for our panel structure. The general formulation of the panel model assumes that public acceptance is a function of our primary governance indices, a set of time-varying country-level control variables, and unobserved country and time effects.

The fixed effects model controls for all time-invariant, country-specific characteristics that might influence public acceptance, such as deep-seated cultural skepticism toward biotechnology or historical regulatory paths. The model is specified such that the Public Acceptance Index for country i at time t is determined by the country-specific intercept, the coefficients of the three governance indices, the coefficients of the control variables, a country-specific fixed effect, a time-specific fixed effect, and the idiosyncratic error term. To capture potential non-linearities in the effect of regulatory stringency, we also include a quadratic term for the Regulatory Stringency Index in subsequent specifications.

The random effects model assumes that the country-specific unobserved effects are uncorrelated with the independent variables. This specification allows for the inclusion of time-invariant country-level variables, though it may suffer from inconsistency if the independence assumption is violated. We employ the Hausman specification test to formally choose between the fixed effects and random effects models. A statistically significant Hausman test statistic indicates that the country fixed effects are correlated with the regressors, rendering the random effects estimates inconsistent, and thereby necessitating the use of the fixed effects model.

To address issues of heteroskedasticity and serial correlation common in cross-country panel data, all models are estimated using Huber-White cluster-robust standard errors clustered at the country level.

3.3 Control Variables and Robustness Measures

To isolate the impact of biotechnology governance on public acceptance, we incorporate several critical country-level control variables. The Scientific Literacy Index is included to account for variations in foundational scientific education across countries and over time, controlling for the traditional deficit model of public understanding. We control for economic development using the logarithm of GDP per capita, as wealthier nations may exhibit different patterns of post-materialist values and risk tolerance. Additionally, we control for the level of trust in government more broadly, utilizing data from the World Values Survey, to ensure that our governance indices are capturing trust specific to the biotechnology regulatory apparatus rather than general civic trust.

To illustrate the conceptual pathway through which governance frameworks and transnational advisory bodies influence public acceptance, Figure 1 outlines the theoretical framework guiding our empirical analysis.

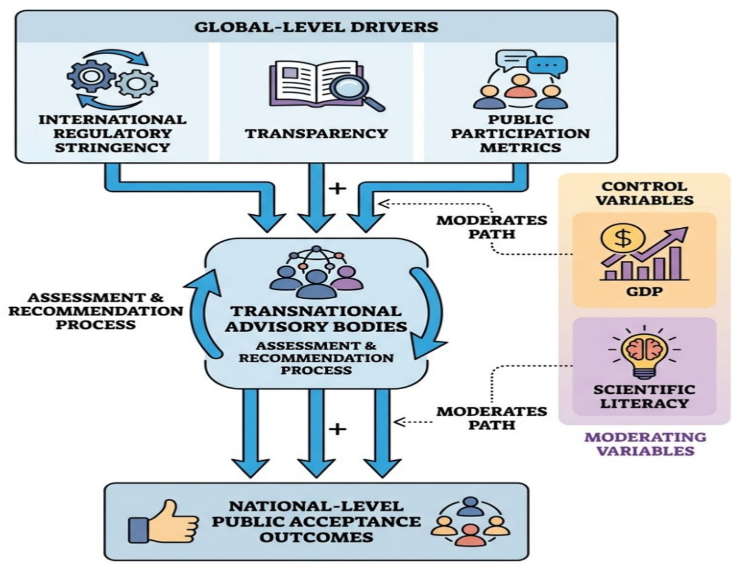

Figure 1: Theoretical Framework of Governance Impact on Public Acceptance

For robustness, we perform several auxiliary analyses. First, we test for potential endogeneity and reverse causality. It is plausible that high public acceptance leads to more relaxed or participatory governance, rather than governance quality driving acceptance. To address this, we re-estimate our models using lagged independent variables, where the governance indices at time t-1 are used to predict public acceptance at time t. Second, we perform a sensitivity analysis by sequentially excluding major biotechnology-producing nations, such as the United States and China, to ensure that our global estimates are not driven by outlier nations with highly idiosyncratic regulatory climates. Finally, we implement panel unit root tests, such as the Im-Pesaran-Shin test, to confirm that all variables in our regression models are stationary, preventing the risk of spurious regressions.

4. Empirical Results and Discussion

4.1 Descriptive Statistics and Preliminary Findings

The analysis of the descriptive statistics reveals substantial temporal and geographic variation in both public acceptance and governance structures. Over the 2008–2023 period, the global mean of the Public Acceptance Index rose from 48.2 to 56.4, driven primarily by a steady increase in the acceptance of medical biotechnologies such as gene therapies and mRNA vaccines. In contrast, public acceptance of agricultural biotechnology remained highly polarized and experienced slower growth, reflecting persistent societal concerns regarding food safety and ecological impacts.

Regionally, North American countries exhibited the highest average levels of acceptance, paired with high regulatory transparency but lower formal public participation scores. European nations displayed lower overall acceptance levels but scored significantly higher on the Public Participation Index, reflecting the institutionalization of the precautionary principle and deliberative democracy models within the European Union [8]. East Asian nations, particularly China and South Korea, showed rapid increases in regulatory stringency and transparency over the study period, accompanied by a steady upward trajectory in public acceptance.

An initial bivariate correlation analysis indicates that regulatory transparency is strongly and positively correlated with public acceptance, suggesting that accessible scientific information is a foundational requirement for public confidence [9]. Conversely, the simple linear correlation between regulatory stringency and public acceptance was found to be weak and statistically insignificant, hinting at a more complex, non-linear relationship that requires multivariate modeling to unpack.

4.2 Panel Regression Results

The main empirical results from our panel regression models are presented in Table 2, which contrasts the fixed effects and random effects specifications.

Table 2: Fixed Effects and Random Effects Panel Regression Estimates

Independent Variables	Model 1: Fixed Effects	Model 2: Random Effects	Model 3: Fixed Effects (Lagged)
Regulatory Transparency Index	1.84 (0.42)	1.62 (0.38)	1.55 (0.40)
Regulatory Stringency Index	-2.15 (0.75)	-1.90 (0.68)	-1.88 (0.72)
Regulatory Stringency Index (Squared)	0.22 (0.07)	0.19 (0.06)	0.18 (0.06)
Public Participation Index	2.31 (0.51)	2.05 (0.48)	1.98 (0.49)
Scientific Literacy Index	0.15 (0.08)	0.18 (0.07)	0.12 (0.08)
Log GDP per Capita	1.12 (0.45)	0.95 (0.41)	1.05 (0.43)
General Trust in Government	0.34 (0.12)	0.38 (0.11)	0.31 (0.12)
Constant	18.45 (5.12)	20.12 (4.85)	19.80 (5.02)
Number of Observations	225	225	210
R-squared (Within)	0.68	0.65	0.61
Hausman Test Statistic (p-value)	24.36 (0.001)	N/A	N/A

Standard errors are presented in parentheses. In Model 1 and Model 3, the Hausman test rejects the null hypothesis at the 1 percent level, confirming that the fixed effects specification is the most appropriate and consistent model for our analysis.

The coefficient for the Regulatory Transparency Index is positive and highly statistically significant across all specifications. A one-unit increase in the transparency index is associated with an approximate 1.84-point increase in the Public Acceptance Index, holding all other factors constant. This finding strongly supports the hypothesis that open governance and accessible risk-benefit data cultivate public confidence.

Interestingly, the Regulatory Stringency Index displays a statistically significant U-shaped relationship with public acceptance, as evidenced by the negative linear term and the positive quadratic term. This indicates that at very low levels of regulatory stringency, public acceptance is low, likely because the public perceives the regulatory system as inadequate to protect them from environmental or health hazards. As stringency increases to a moderate level, acceptance initially dips further, which may reflect heightened public anxiety caused by the perceived danger that necessitated such regulations. However, once regulatory stringency passes a critical threshold (calculated at approximately 4.9 on our 0-to-10 scale), it begins to exert a positive effect on acceptance. High levels of institutional oversight, comprehensive testing, and strict safety protocols ultimately serve as a powerful signal of safety, mitigating risk perceptions [10].

The Public Participation Index emerged as the strongest predictor of public acceptance, with a coefficient of 2.31 in the fixed effects model. This suggests that the quality of democratic engagement is a primary determinant of technology legitimacy. Giving citizens a structured, meaningful voice in biotechnology decision-making processes shifts the public perception of technology from an imposed risk to a collectively deliberated societal choice [11].

Among the control variables, the Scientific Literacy Index has a positive but relatively small and marginally significant coefficient. This confirms that while basic scientific education is helpful, it is not a primary driver of technology acceptance, further undermining the traditional deficit model [12]. General trust in government and economic development (Log GDP per capita) both exert positive and statistically significant effects, indicating that broader institutional and macroeconomic conditions also play a role in shaping societal trust in technology.

4.3 Discussion and Policy Implications

The empirical findings offer several profound insights for the academic study and practical governance of emerging biotechnologies. The robust positive effect of regulatory transparency suggests that regulatory agencies must move beyond simply releasing executive summaries of safety decisions. True transparency requires the active dissemination of raw clinical trial data, environmental impact assessments, and conflict-of-interest disclosures in accessible formats. This level of openness is critical for satisfying the scrutiny of independent civil society organizations and scientific watchdogs, who act as trusted intermediaries for the general public [13].

The discovery of a non-linear relationship between regulatory stringency and public acceptance resolves a long-standing debate in policy design. Many industry advocates argue that strict regulations stifle innovation and breed public fear by implying that biotechnologies are uniquely hazardous. Conversely, consumer protection groups argue that lax regulations cause panic. Our U-shaped curve demonstrates that both arguments contain partial truths but fail to capture the complete picture. Weak, highly permissive regulatory frameworks undermine institutional credibility, leaving the public feeling exposed to unregulated risks. Meanwhile, moderate regulations can inadvertently heighten risk salience without providing sufficient safety guarantees. To maximize public trust, governments must transition toward highly rigorous, clear, and consistent regulatory regimes that prioritize safety while remaining agile enough to accommodate scientific progress.

Most importantly, our results highlight the vital role of public participation mechanisms in securing the social license to operate for emerging technologies. In an era marked by rising populism and institutional skepticism, technocratic expert-led governance is increasingly insufficient to achieve societal consensus. Formal public participation mechanisms, when designed with genuine democratic intent rather than as mere public relations exercises, foster procedural justice. By allowing citizens to deliberate on the ethical boundaries, societal values, and distribution of benefits associated with biotechnology, these platforms transform public opposition into constructive, deliberative oversight [14].

In this context, transnational advisory bodies are uniquely positioned to act as standard-setters and capacity-builders. Since many developing nations lack the institutional resources to design and implement highly sophisticated public participation and transparency infrastructures, transnational bodies can provide model guidelines, training, and resources to help harmonize governance quality globally. By elevating the baseline of global regulatory transparency and public engagement, these international institutions can mitigate cross-border regulatory fragmentation and promote a more unified, trusting global bioeconomy.

5. Conclusion and Future Directions

5.1 Summary of Key Findings

This study has utilized panel data analysis to investigate the relationship between domestic biotechnology governance frameworks and public acceptance, mediated by the influence of transnational advisory bodies. Analyzing a unique panel dataset of fifteen countries over a fifteen-year period (2008–2023), our empirical models yield three key findings. First, regulatory transparency is a powerful and robust predictor of public acceptance, underscoring the absolute necessity of open data and accessible decision-making. Second, regulatory stringency has a non-linear, U-shaped relationship with public acceptance, indicating that while weak oversight erodes trust, highly rigorous and clear regulatory frameworks eventually serve as a strong signal of safety and institutional competence. Third, formal public participation mechanisms are the most influential predictor of technology acceptance, confirming that procedural justice and democratic deliberation are crucial for establishing societal legitimacy.

These results suggest that public trust in biotechnology is not merely a reflection of scientific literacy or raw economic development. Instead, it is an actively constructed product of institutional design. By prioritizing transparency, rigor, and democratic inclusion, governments can foster a resilient regulatory environment that accommodates rapid technological acceleration while maintaining deep societal trust.

5.2 Policy Recommendations and Limitations

Based on our empirical findings, we propose several concrete recommendations for international policymakers, regulatory agencies, and transnational advisory bodies. First, governments should establish centralized, publicly accessible registries for all biotechnology research, safety trials, and regulatory approvals to maximize transparency. Second, regulatory agencies must avoid the trap of deregulation as a means to encourage public acceptance; instead, they should maintain rigorous, predictable, and scientific oversight standards that reassure the public of institutional vigilance. Third, policymakers must institutionalize robust public deliberation mechanisms, such as citizen assemblies and consensus conferences, at the early stages of technology development rather than after regulatory policies have already been drafted. Transnational advisory bodies should play an active role in this process by developing global standards for public engagement and fostering cross-border harmonisation [15].

Despite the robustness of our panel analysis, several limitations remain. First, our dataset is primarily composed of high-income and major emerging economies due to data availability constraints, which may limit the generalizability of our findings to low-income, developing nations. Future research should make a concerted effort to gather longitudinal data on public opinion and regulatory quality in these regions. Second, while we controlled for scientific literacy and general trust in government, cultural nuances and religious values remain difficult to quantify and track dynamically in a panel dataset. Finally, as biotechnological innovations continue to converge with artificial intelligence and digital agriculture, future studies must explore how the governance of these hybrid technologies affects public risk perceptions and acceptance patterns.

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