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Comparative Study of the Status of Basic Sciences in Iran and Selected Countries and Their Role in Science and Technology Governance

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Abstract

Basic sciences, as the foundation of knowledge production and the development of technological capacities, play a fundamental role in the sustainability and effectiveness of national science, technology, and innovation systems. However, the utilization of the capacities of these sciences depends not only on scientific capability and the volume of knowledge production but also decisively on the quality of governance, institutional structures, policymaking, financing, evaluation systems, and the manner in which fundamental research is linked to innovation. The present study aimed to comparatively examine the status of basic sciences in Iran and four selected countries, namely the United States, Germany, China, and Japan, and to explain their role in science and technology governance. The research was conducted using a qualitative-comparative approach through the integration of documentary analysis and grounded theory. In the comparative component, policy documents, official reports, and valid data related to the science and technology systems of the countries under study were examined across five dimensions: governance structure, policymaking, financing, evaluation and monitoring, and the linkage between basic sciences and technological innovation. In the qualitative component, data obtained from in-depth, semi-structured interviews with five experts in science and technology policy were analyzed through open, axial, and selective coding. The qualitative analysis resulted in the extraction of 75 open codes and 15 axial codes, while “failure of the interinstitutional coordination system and the absence of a single responsible authority” was identified as the core category. The comparative findings also indicated that despite substantial differences among the governance models of the selected countries, institutional stability, policy continuity, long-term financial support, multidimensional evaluation systems, and effective mechanisms for coordination and linking science with innovation were common characteristics. In Iran, institutional fragmentation, discontinuous policymaking, instability of research funding, dominance of quantitative indicators in evaluation, and the weak systematic linkage of basic sciences with industry and innovation mutually reinforce one another in a cascading manner. Accordingly, improving the governance of basic sciences requires simultaneous reform of institutional coordination structures, establishment of stable and multi-year financial support, redesign of the evaluation system with an emphasis on quality and long-term impact, and strengthening of intermediary institutions connecting fundamental research with the innovation system.

Keywords: Basic sciences, science and technology governance, governance of basic sciences, science policy, fundamental research, national innovation system, comparative analysis, grounded theory.



1. Introduction

Basic sciences constitute one of the foundational pillars of national science, technology, and innovation systems because they generate the theoretical knowledge, methodological capabilities, human capital, and scientific infrastructure upon which technological development and long-term innovation depend. Disciplines such as mathematics, physics, chemistry, biology, and related fundamental fields do not merely produce abstract knowledge; they establish the conceptual and analytical foundations required for the emergence of new technologies, the development of interdisciplinary research, and the advancement of strategic industries. The importance of basic sciences is therefore not adequately captured by short-term measures of commercialization or immediate economic return. Their contribution is often cumulative, indirect, and realized over extended periods through scientific discoveries, skilled human resources, research infrastructures, and the transfer of knowledge across disciplinary and institutional boundaries. The growing dependence of contemporary technological systems on fundamental scientific knowledge has made the governance of basic sciences an increasingly important component of national development strategies. This relationship has become particularly evident in fields such as artificial intelligence, where long-term technological progress is inseparable from advances in mathematics, statistics, computer science, cognitive science, and other foundational disciplines (Yang & Peng, 2020). Consequently, the capacity of a country to transform basic scientific knowledge into broader technological, social, and economic value depends not only on scientific productivity but also on the institutional architecture through which scientific activities are governed, financed, evaluated, coordinated, and connected to innovation.

Science and technology governance refers to the institutional arrangements, policymaking processes, resource-allocation mechanisms, accountability structures, regulatory frameworks, and coordination mechanisms through which the direction and performance of scientific and technological systems are shaped. From a governance perspective, scientific development cannot be reduced to the actions of universities or research institutes in isolation. Rather, it emerges from interactions among governments, universities, research organizations, funding agencies, industry, professional communities, and broader societal stakeholders. Effective governance requires clarification of institutional responsibilities, strategic coordination among actors, continuity of policy objectives, and mechanisms through which scientific priorities can be translated into sustained research programs. Network governance research similarly emphasizes that when multiple actors participate in policymaking and implementation without adequate coordination, unclear accountability and fragmented authority may undermine collective performance (Tukijan et al., 2024). This issue is especially relevant to basic sciences because fundamental research frequently requires long-term investment, specialized infrastructures, stable research environments, and institutional protection from excessive pressure for immediate economic returns. Accordingly, the effectiveness of basic-science systems depends substantially on the extent to which governance arrangements can reconcile scientific autonomy with national priorities and long-term strategic objectives.

Contemporary approaches to good governance further highlight the importance of transparency, accountability, participation, strategic coherence, organizational efficiency, and appropriate distribution of authority. Governance quality affects not only formal institutional performance but also the capacity of organizations to attract, develop, and retain scientific talent. Evidence from organizational governance research demonstrates that governance-oriented management frameworks can influence organizational efficiency by shaping contextual conditions, strategic choices, and intervening organizational factors (Sakvand et al., 2026). Such considerations are highly relevant to science systems because research quality depends heavily on human capital, institutional trust, professional autonomy, and the predictability of organizational environments. In basic sciences, where researchers may invest many years in lines of inquiry whose applications cannot be anticipated at the outset, unstable governance and continuously changing priorities can discourage ambitious research and encourage short-term adaptation to evaluation incentives. Governance should therefore be understood as a substantive determinant of scientific capacity rather than merely an administrative structure surrounding research.

The governance of universities and research institutions is particularly important because these organizations constitute the primary institutional environments in which basic scientific knowledge is generated and transmitted. Cross-country evidence indicates that differences in governance arrangements are associated with differences in university research performance, suggesting that institutional decision-making structures, autonomy, incentives, funding arrangements, and accountability systems can substantially influence scientific outcomes (Sedlacek, 2025). At the institutional level, effective governance



requires alignment between strategic objectives and actual implementation. Studies of university governance and sustainability have emphasized that formal policies alone are insufficient when organizational actors do not possess the resources, institutional support, coordination mechanisms, or operational capacity required to translate policy commitments into practice (Castro-Gomez et al., 2026). Thus, a major distinction must be made between the existence of science-policy documents and the institutional capacity to implement them. This distinction is crucial in comparative assessments because countries may possess similarly ambitious policy statements while differing substantially in continuity, implementation quality, monitoring capacity, institutional coordination, and resource stability.

Changes in the technological environment have further expanded the scope of science and university governance. Digital transformation is increasingly altering research management, institutional administration, decision-making, human-resource development, data infrastructure, collaboration, and knowledge dissemination. Recent governance models in higher education conceptualize digital transformation as an integrated process involving business processes, human resources, and technological infrastructures rather than merely the adoption of new information technologies (Mujahidin et al., 2026). Similarly, stakeholder-based research on artificial intelligence-driven transformation in higher education has shown that digital technologies can influence governance performance, decision-making processes, organizational responsiveness, and institutional accountability when they are appropriately embedded in governance structures (Nnaji et al., 2026). These developments demonstrate that governance systems must be adaptive and capable of responding to technological change while maintaining research quality, ethical standards, and institutional coherence. For basic sciences, digital research infrastructures, computational methods, artificial intelligence, open science platforms, and large-scale databases are increasingly indispensable, making governance capacity an important determinant of access to scientific opportunities.

Artificial intelligence also illustrates the deep and increasingly complex relationship between basic science, technological innovation, and governance. Although AI is frequently discussed in terms of applied technology, its continued advancement depends fundamentally on progress in foundational knowledge domains. Scholars have consequently argued that artificial intelligence must be more deeply rooted in basic science if future generations of AI technologies are to move beyond incremental development (Yang & Peng, 2020). At the same time, universities and research institutions face emerging governance challenges regarding the responsible use of AI. Case studies of higher education institutions demonstrate that universities are developing institutional guidance to address AI-related issues, although approaches differ in scope, governance philosophy, and implementation mechanisms (Wu et al., 2024). These developments illustrate a broader principle relevant to science governance: technological advancement creates new opportunities for scientific development while simultaneously increasing the need for institutional coordination, ethical oversight, regulatory adaptation, and strategic policymaking.

Ethical governance has similarly become an integral component of contemporary science systems. The production of high-quality scientific knowledge requires structures that protect research integrity, ensure appropriate ethical review, clarify responsibilities, and maintain public confidence in research institutions. Research on ethics governance in Chinese universities, particularly the role of research ethics committees, highlights the importance of institutionalized ethical oversight within rapidly developing research systems (Li, 2025). Governance of science must therefore address not only funding and productivity but also the legitimacy and integrity of the processes through which scientific knowledge is produced. This is particularly important in comparative studies because institutional systems vary considerably in the balance they establish among centralized regulation, institutional autonomy, professional self-regulation, and external accountability. Such differences may influence the flexibility, responsiveness, and legitimacy of research governance.

The broader concept of good academic governance also emphasizes that institutional effectiveness depends on coherent relationships among leadership, academic structures, administrative systems, and stakeholder participation. Studies examining the implementation of good academic governance in private universities have underscored the importance of accountable institutional structures and effective governance arrangements for improving academic performance and organizational sustainability (Yublina et al., 2024). Governance systems must simultaneously enable coordination and preserve the professional autonomy necessary for academic creativity. Excessive centralization may reduce institutional flexibility and researcher autonomy, whereas highly fragmented arrangements may generate duplication, competition among institutions, policy inconsistency, and weak accountability. The challenge is therefore not simply to determine whether science governance



should be centralized or decentralized, but to identify mechanisms capable of coordinating multiple institutions while maintaining sufficient scientific and organizational autonomy.

These issues are also evident in debates concerning the governance of education systems. Governance structures determine how authority is allocated among national, regional, institutional, and professional actors and therefore affect policy continuity, accountability, and stakeholder participation. Analysis of state education governance has demonstrated that institutional design has implications for representation, democratic accountability, and the distribution of decision-making authority (Yeargain, 2024). Although education governance differs in important respects from science governance, the underlying institutional challenge is comparable: systems composed of numerous actors require clearly defined roles and credible coordination mechanisms. In science and technology governance, ambiguity regarding institutional authority may be particularly consequential because research programs frequently extend beyond political and managerial cycles, making continuity and predictability essential conditions for scientific development.

Financing represents another central dimension of the governance of basic sciences. Fundamental research often generates substantial social returns, but its direct commercial benefits may be uncertain, delayed, or broadly distributed. Consequently, markets alone generally provide insufficient incentives for sustained investment in many areas of basic research. Public funding therefore remains indispensable, although advanced science systems increasingly combine government funding with institutional resources, private investment, philanthropic support, and competitive grants. The governance challenge concerns not merely the amount of funding but also its stability, allocation criteria, time horizon, transparency, and relationship with research priorities. Short-term or unpredictable funding can encourage fragmented projects and discourage research programs requiring long periods of cumulative investigation. In contrast, stable multi-year support can facilitate the formation of research teams, maintenance of scientific infrastructure, development of advanced expertise, and pursuit of higher-risk scientific questions. Governance arrangements must therefore ensure that funding mechanisms are compatible with the distinctive temporal characteristics of basic research.

Evaluation systems are equally important because researchers and institutions respond to the incentives embedded in performance assessment. When evaluation relies excessively on publication counts, citation metrics, journal impact factors, or other narrowly quantitative indicators, researchers may rationally prioritize outputs that maximize measured performance rather than projects with greater long-term scientific significance. Governance systems consequently need multidimensional evaluation frameworks capable of recognizing scientific quality, originality, research integrity, human-capital development, interdisciplinary contribution, societal relevance, and long-term impact. This issue also has implications for the career trajectories of basic-science graduates and researchers. Research on employability and human-development ecosystems for basic-science graduates has demonstrated the importance of considering scientific education within a broader ecosystem linking knowledge, skills, employment structures, and socioeconomic development (Entezari, 2023). The effectiveness of basic sciences therefore cannot be assessed exclusively by publication output; it should also be considered in terms of the scientific and human capabilities that these disciplines create for the wider economy and society.

The educational foundations of basic sciences also influence the long-term performance of national science systems. Scientific capacity is generated progressively through schools, universities, postgraduate education, and research training. Curriculum quality and pedagogical strategies affect students' scientific literacy, problem-solving capabilities, creativity, and willingness to pursue scientific careers. Research concerning curriculum development for basic science and management science has emphasized the importance of designing educational content capable of developing relevant literacy and competencies among learners (Adegbola & Adeleke, 2023). Likewise, evidence concerning instructional methods in basic-science courses suggests that participatory approaches such as brainstorming can strengthen creative teaching and learning processes (Saadat-Najad et al., 2021). These findings indicate that governance of basic sciences extends beyond research funding agencies and research institutes. It also includes the educational pipeline through which future scientists are trained, making coordination between education policy, higher education, research policy, and labor-market development essential.

Technological transformation is also generating new opportunities for basic-science education. Immersive and digital environments can potentially expand access to laboratory simulations, scientific visualization, collaborative learning, and advanced instructional resources. The use of metaverse-based environments in basic-sciences medical education has been proposed as a means of addressing educational gaps, particularly in lower-middle-income contexts where physical resources



and training opportunities may be unevenly distributed (Zaidi, 2024). However, the effective application of such technologies depends on institutional infrastructure, faculty capabilities, financing, digital access, and appropriate governance. Technology therefore cannot substitute for institutional capacity; rather, its benefits are shaped by the governance environment in which it is introduced.

The connection between governance and technological transformation is also evident in specialized areas of public administration. Research on science and technology governance in judicial digital transformation, including property and deeds registration, indicates that successful digital transformation depends on coordinated legal, technological, organizational, and governance arrangements (Rahmatian & Fattahi, 2025). Although this context differs from basic-science governance, it illustrates the broader importance of institutional coordination when scientific and technological capabilities are translated into operational systems. The same principle applies to national innovation systems: scientific knowledge creates technological potential, but effective institutions are required to convert that potential into innovation, industrial capability, public services, and social value.

The experiences of different countries suggest that there is no single universally optimal model of science governance. The United States has traditionally relied on a relatively decentralized and networked structure involving autonomous funding bodies, research universities, federal agencies, industry, and philanthropic organizations. Germany combines substantial institutional autonomy with stable support for major research organizations and structured differentiation between fundamental and applied research. China has increasingly developed a state-led and mission-oriented system characterized by major strategic programs and extensive public investment, whereas Japan has emphasized coordinated policymaking and long-term collaboration among government, universities, research institutions, and industry. These different arrangements illustrate that institutional form alone does not determine performance. What appears more consequential is whether a governance system provides strategic coherence, stable funding, credible evaluation, research autonomy, effective coordination, and mechanisms connecting fundamental research to innovation.

For Iran, these considerations are especially significant because the country possesses substantial scientific human capital and has demonstrated considerable capacity for academic knowledge production, while simultaneously facing structural challenges in the governance, financing, evaluation, and socioeconomic utilization of scientific research. The development of basic sciences requires more than increasing publication output or expanding the number of research institutions. It requires an institutional environment in which responsibilities are clearly allocated, policymaking is evidence-based and continuous, researchers can pursue long-term programs, evaluation rewards scientific quality rather than merely numerical output, and intermediary mechanisms connect universities and research organizations with the broader national innovation system. Governance-oriented approaches to organizational performance indicate that contextual, strategic, and intervening factors interact rather than operate independently (Sakvand et al., 2026); similarly, network governance research suggests that the effectiveness of multi-actor systems depends heavily on the quality of coordination among participating institutions (Tukijan et al., 2024). These perspectives provide an appropriate conceptual basis for examining Iran's basic-science system as an interconnected governance structure rather than a collection of isolated institutional problems.

A comparative perspective is therefore necessary because it makes it possible to distinguish challenges that arise from general characteristics of basic research from those associated with specific institutional arrangements. Cross-national comparison can reveal how different systems organize authority, maintain policy continuity, allocate financial resources, evaluate research, and institutionalize connections between fundamental science and innovation. At the same time, international models cannot simply be transferred from one national context to another. Institutional arrangements are embedded in distinct political, administrative, economic, and academic environments. Accordingly, the objective of comparative analysis should not be mechanical imitation but identification of governance principles and mechanisms that may be adapted to national conditions. The increasing complexity of academic governance, digital transformation, AI governance, research ethics, and institutional management further reinforces the need for integrated analysis rather than evaluation of individual policy instruments in isolation (Li, 2025; Mujahidin et al., 2026; Nnaji et al., 2026; Wu et al., 2024).

Despite the growing body of literature concerning university governance, scientific performance, digital transformation, academic governance, science education, and research management, fewer studies have examined the governance of basic sciences as an integrated policy domain encompassing institutional structures, policymaking, financing, evaluation, and linkage



with technological innovation. Existing studies provide valuable insights into individual components, including university research performance (Sedlacek, 2025), academic policy implementation (Castro-Gomez et al., 2026), good academic governance (Yublina et al., 2024), education governance (Yeargain, 2024), basic-science human-capital development (Entezari, 2023), curriculum and pedagogical development (Adegbola & Adeleke, 2023; Saadat-Najad et al., 2021), emerging educational technologies (Zaidi, 2024), and governance of technology-enabled institutional transformation (Rahmatian & Fattahi, 2025). However, understanding the performance of a national basic-science system requires these dimensions to be examined simultaneously and in relation to one another. Such an integrated perspective is particularly important for identifying whether observed weaknesses represent independent deficiencies or manifestations of deeper governance failures.

Accordingly, the present study aimed to comparatively examine the status of basic sciences in Iran and four selected countries—the United States, Germany, China, and Japan—and to explain the role of institutional structure, policymaking, financing, evaluation, and the linkage between basic sciences and innovation in shaping science and technology governance.

2. Methods and Materials

The present research is applied in terms of purpose and qualitative–comparative in terms of approach. It was conducted through the integration of two analytical pathways: (1) comparative analysis of official documents and data related to the selected countries, and (2) a qualitative study based on grounded theory to provide an in-depth explanation of the situation in Iran. The rationale underlying this design is that the governance of basic sciences cannot be adequately examined solely through quantitative indicators or policy documents; rather, an accurate understanding of its challenges requires the simultaneous use of documentary evidence and expert perspectives.

The units of analysis comprised Iran and four countries: the United States, Germany, China, and Japan. These countries were selected based on criteria such as the level of development of basic sciences, diversity of governance models, sustainability of support policies, and availability of valid data, thereby enabling comparison among different governance patterns, including network-based, institutional, state-centered, and society-oriented models. Data for this component were collected through the review of national policy documents, official reports of scientific institutions, OECD, UNESCO, and Nature Index data, as well as credible comparative studies (Bowen, 2009). The temporal scope of the documents was primarily limited to 2020 onward in order to reflect recent developments in governance. The comparative analysis was conducted across five common dimensions: institutional structure, policymaking, financing, evaluation systems, and the linkage between basic sciences and innovation. Within each dimension, Iran was compared with the selected countries, and similarities and differences were identified.

To gain a deeper understanding of the issue in Iran, the grounded theory strategy was employed. Data were collected through semi-structured interviews with five experts and university professors familiar with the field of science and technology policy. The inclusion criteria consisted of having teaching, research, or professional experience relevant to the subject and holding at least a master's degree. Participants were initially selected through purposive sampling, followed by snowball sampling to identify individuals with sufficient knowledge and experience.

Rationale for sample size and theoretical saturation: In qualitative research, sample size is determined according to the principle of theoretical adequacy rather than statistical rules. In the present study, the interview process continued until newly collected data no longer added a meaningful new concept or property to the emerging categories and the relationships among the categories had been sufficiently explained. This point is referred to as theoretical saturation. The five interviews conducted with the selected experts covered all the principal dimensions of the problem, and the recurrence of concepts in the final interviews indicated that saturation had been achieved; accordingly, the sample was considered qualitatively adequate.

The interview themes included institutional structure, the policymaking process, evaluation indicators, challenges of fundamental research, financing mechanisms, linkages with innovation, and improvement strategies. These themes were designed to align with the five dimensions of the comparative analysis so that documentary and field data could be integrated.

Data analysis was conducted through three stages of open, axial, and selective coding (Boeije, 2002). During open coding, meaning units related to the research problem were extracted from the interview transcripts and converted into initial codes. During axial coding, semantically similar codes were organized at a higher level of abstraction, and their relationships were



analyzed within the framework of causal conditions, contextual conditions, intervening conditions, strategies, and consequences. Finally, during selective coding, the category with the greatest explanatory power was selected as the core category. Accordingly, from a total of 75 open codes, 15 axial codes were extracted and organized around the core category of “failure of the interinstitutional coordination system and the absence of a single responsible authority.” MAXQDA 2020 software was used for data management and analysis.

At the final stage, the findings derived from the comparative documentary analysis were considered alongside the results of the expert interviews. This integration enabled comparison between objective documentary evidence and experts’ perceptions and facilitated the identification of governance gaps and transferable lessons. To enhance research credibility, two different data sources were used, and analysis was conducted concurrently with data collection. However, because indicators such as inter-coder agreement coefficients were not reported in the original thesis, no claims regarding such tests have been made in this article, so that the methodological report remains consistent with the actual research process.

3. Findings and Results

The findings of this study were obtained at two complementary levels. At the first level, the governance of basic sciences in Iran was compared with that of four selected countries—the United States, Germany, China, and Japan—across five principal dimensions: governance structure, policymaking, financing, evaluation, and linkage with innovation. At the second level, data obtained from in-depth interviews with five experts in science and technology policy were analyzed through open, axial, and selective coding in order to identify the most important issues and the relationships among the components of basic-science governance in Iran.

The comparative analysis showed that the main difference between Iran and the selected countries is not limited merely to the degree of government intervention or the level of investment; rather, it concerns the quality of institutional coordination, policy stability, and the existence of clearly defined mechanisms for directing and supporting basic sciences. The findings for each of the five dimensions are summarized below:

Governance structure: In Iran, the multiplicity of policymaking institutions, such as the Ministry of Science, the Vice Presidency for Science and Technology, the Supreme Council for Science, Research, and Technology, and the academies, combined with the absence of an effective coordination mechanism, has resulted in overlapping responsibilities, fragmented decision-making, and uncertainty among researchers. In contrast, despite differences in governance models—network-based, institutional, state-centered, and society-oriented—the selected countries demonstrate stronger institutional coherence and clearer division of responsibilities. For example, in the United States, institutions such as the National Science Foundation (NSF) and National Institutes of Health (NIH) operate with relative autonomy; in Germany, the Max Planck Society and Helmholtz Association constitute major pillars of fundamental research; China relies on large-scale national programs characterized by strategic coherence; and Japan promotes coordination among actors through dedicated policymaking councils.

Policymaking: The selected countries share three common characteristics: (1) recognition of basic sciences as a strategic asset, (2) adoption of long-term policy horizons, and (3) the presence of clearly defined implementation mechanisms. In Iran, although numerous policy documents exist, discontinuities among policy design, implementation, and evaluation, together with vulnerability to managerial changes, have weakened the long-term policy horizon.

Financing: Despite their diversity, the financing models of the selected countries are characterized by relative stability, multi-year horizons, and transparent allocation mechanisms. The United States uses a combination of governmental, private, and philanthropic sources; Germany provides long-term institutional support; China relies on extensive, mission-oriented government investment; and Japan follows a mixed model of public support and private-sector participation. In contrast, financing for basic sciences in Iran is almost entirely dependent on public budgets, the share of industrial contracts is negligible—approximately 2%—and researchers’ baseline research funding is virtually zero. This situation has undermined researchers’ job security and made long-term planning extremely difficult.

Evaluation system: The selected countries employ multidimensional, learning-oriented evaluation systems linked to policymaking. For example, in the United States, the NSF considers criteria such as conceptual innovation, human capital development, and long-term impact in addition to bibliometric indicators. In Germany, evaluation is institutional and quality-oriented. In China, evaluation is aligned with national priorities, whereas in Japan it is balanced and society-oriented. In Iran,



however, the evaluation system remains predominantly focused on quantitative indicators, such as the number of publications and journal impact factors. This has contributed to harmful quantity-oriented practices and has encouraged researchers to pursue short-term, low-risk research topics.

Linkage between basic sciences and innovation: In the selected countries, the relationship between basic sciences and innovation is institutionalized, nonlinear, and sustainable. The United States benefits from technology-transfer networks and university–industry collaboration; Germany creates bridges through intermediary institutions such as the Max Planck Society for fundamental research and the Fraunhofer Society for applied research; China defines basic sciences within strategic industrial priorities; and Japan employs a collaborative industry–academia model. In Iran, by contrast, a systemic disconnect exists between fundamental research and industry, rooted in weak intermediary institutions, legal and bureaucratic barriers, and mutual distrust.

Table 1. Comparative Analysis of the Five Dimensions of Basic-Science Governance in Iran and the Selected Countries

Analytical Dimension	Iran	United States	Germany	China	Japan
Institutional structure	Uncoordinated polycentric structure; absence of a single responsible authority	Network-based; autonomous institutions (NIH, NSF)	Institutional; independent organizations (Max Planck)	State-centered; large-scale national programs	Coordinating councils
Policymaking	Reactive, discontinuous, lacking evidence-based orientation	Stable, competitive, flexible	Based on scientific excellence; separation of policy formulation and implementation	Mission-oriented, long-term	Society-oriented, gradual
Financing	98% dependence on government; virtually zero baseline research funding	Mixed model (governmental, private, philanthropic); multi-year grants	Long-term institutional support (5–10-year funding arrangements)	Extensive government investment	Mixed model (governmental support + limited industry participation)
Evaluation system	Quantitative, publication-centered, lacking impact assessment	Multidimensional, learning-oriented (peer review + long-term impact)	Institutional, quality-oriented	Goal-oriented, aligned with national priorities	Balanced, society-oriented
Linkage with innovation	Systemic disconnect; absence of intermediary institutions	Institutionalized; knowledge-transfer networks	Strong intermediary institutions (Max Planck, Fraunhofer)	Strategic, state-centered	Balanced; collaborative industry–academia model

Analysis of the interviews with the five experts resulted in the extraction of 75 initial codes during the open-coding stage. Based on semantic similarity and conceptual relationships, these codes were organized into 15 axial codes during the axial-coding stage. Finally, during selective coding, the core category of “failure of the interinstitutional coordination system and the absence of a single responsible authority” was identified as the concept with the greatest explanatory power. This category indicates that institutional fragmentation is not merely an isolated organizational problem but rather the root of a chain of problems affecting other dimensions of governance.

The paradigmatic model illustrates the relationships among the categories as follows:

Causal conditions: failure of interinstitutional coordination, reactive and non-evidence-based policymaking, and structural instability of financing.

Contextual conditions: absence of independent and impact-oriented evaluation, lack of indicators linking research to national needs, and complete dependence on public funding.

Intervening conditions: harmful quantitative evaluation indicators, paralyzing administrative bureaucracy, lack of university autonomy, and legal and cognitive barriers to establishing linkages.

Strategies: structural–institutional solutions, including establishment of a National Science Foundation, long-term financing, reform of the evaluation system, and reduction of bureaucracy.

Consequences: systemic disconnection between basic sciences and industry and continuation of the unfavorable governance situation.

This model demonstrates that weak institutional coordination is accompanied by discontinuous policymaking and financial instability, which subsequently interact with a quantitatively oriented evaluation system and bureaucracy to weaken the linkage



between fundamental research and innovation. Accordingly, the other issues identified in the interviews should not be regarded as a collection of independent problems but rather as interconnected manifestations of an uncoordinated governance structure.

Table 2. Paradigmatic Model of Basic-Science Governance in Iran

Component	Related Axial Codes
Causal conditions	Failure of interinstitutional coordination; reactive and non-evidence-based policymaking; structural instability of financing
Contextual conditions	Absence of independent evaluation; lack of indicators linking research to national needs; complete dependence on public funding
Intervening conditions	Harmful quantitative evaluation indicators; paralyzing administrative bureaucracy; lack of university autonomy; legal and cognitive barriers to linkage
Strategies	Structural–institutional solutions; long-term financing; reform of the evaluation system; reduction of bureaucracy
Consequences	Systemic disconnection between basic sciences and industry; continuation of the unfavorable governance situation

Comparison of the findings from the two components of the study demonstrates substantial convergence between the interview findings and the evidence obtained through comparative analysis. The main distinction between Iran and the selected countries does not merely concern the level of investment or the form of government. Rather, countries with markedly different governance models—from the network-based model of the United States to the state-centered model of China—share strategic coherence, policy stability, clearly defined coordination mechanisms, sustainable financial support, and evaluation systems linked to policymaking. In contrast, in Iran, weak institutional coordination is accompanied by instability in policies and resources, quantitatively oriented evaluation practices, and weak institutional linkage between basic sciences and the innovation system. This convergence indicates that the problem of basic-science governance in Iran cannot be reduced solely to resource shortages or weaknesses in a particular institution; rather, the quality of relationships among institutions and the pattern of coordination among them constitute a central variable in explaining the current situation.

4. Discussion and Conclusion

The present study comparatively examined the governance of basic sciences in Iran and four selected countries—the United States, Germany, China, and Japan—across five dimensions comprising governance structure, policymaking, financing, evaluation, and linkage with innovation. In parallel, qualitative analysis of expert interviews was conducted through open, axial, and selective coding. The results showed that the central challenge of basic-science governance in Iran is not attributable to a single institutional deficiency or merely to inadequate financial resources; rather, it is rooted in a broader governance configuration characterized by weak interinstitutional coordination, fragmented authority, unstable policymaking, insecure financing, quantitatively dominated evaluation systems, and weak institutional connections between fundamental research and innovation. The qualitative analysis reinforced this interpretation by identifying “failure of the interinstitutional coordination system and the absence of a single responsible authority” as the core category around which other governance problems were organized. The comparative findings further demonstrated that although the selected countries employ markedly different governance models, they share several structural characteristics, including institutional coherence, relatively stable policy trajectories, sustained financing mechanisms, multidimensional evaluation systems, and more developed channels linking basic research to innovation. These findings suggest that the effectiveness of basic-science governance depends less on the adoption of a single institutional model and more on the consistency and coordination of governance mechanisms across multiple levels.

One of the most important findings concerned institutional fragmentation in Iran. The coexistence of multiple policymaking and scientific institutions without a sufficiently authoritative and operational coordination mechanism has contributed to overlapping responsibilities, dispersed decision-making, and ambiguity regarding institutional accountability. This result is consistent with network governance research emphasizing that multi-actor systems can become ineffective when responsibilities are distributed across organizations without clear coordination structures, shared objectives, and enforceable mechanisms for cooperation (Tukijan et al., 2024). From this perspective, institutional plurality is not necessarily problematic in itself; indeed, many successful science systems are highly decentralized. The critical issue is whether coordination mechanisms allow diverse actors to operate within a coherent strategic framework. The experience of the selected countries supports this interpretation. The United States has a distributed network of agencies and institutions, Germany relies on differentiated research organizations, China employs a more centralized and mission-oriented model, and Japan uses coordinated council-based arrangements. Despite these differences, each system contains mechanisms that clarify institutional



roles and reduce destructive duplication. Thus, the Iranian challenge appears to arise not from the number of institutions but from insufficient functional differentiation and weak coordination among them.

This interpretation is also aligned with governance-oriented organizational research indicating that the quality of contextual, strategic, and intervening factors determines whether institutional structures contribute to organizational efficiency (Sakvand et al., 2026). In the context of basic sciences, the absence of a coherent governance framework can undermine the capacity of institutions to allocate talent, resources, and authority effectively. When researchers, universities, ministries, councils, academies, and funding bodies operate under partially overlapping mandates, organizational effort may be directed toward navigating administrative systems rather than advancing long-term scientific programs. This condition can reduce strategic clarity and weaken accountability because responsibility for poor outcomes becomes dispersed across several actors. The present findings therefore support a governance perspective in which science policy effectiveness is shaped by the architecture of relationships among institutions rather than by isolated organizational capabilities.

The second major finding concerned policy instability and the gap between formal policy design and implementation. Iran possesses numerous policy documents concerning science, technology, research, and innovation, yet the results indicated discontinuity between policy formulation, implementation, monitoring, and evaluation. This finding is consistent with research emphasizing that university and institutional governance must be judged not only by the existence of formal policies but also by the ability of organizations to implement them effectively (Castro-Gomez et al., 2026). The difference is particularly important in science governance because basic research requires long time horizons, cumulative investment, and institutional predictability. Repeated shifts in managerial priorities can disrupt research programs, discourage long-term scientific specialization, and encourage researchers to pursue projects that are more compatible with short-term administrative expectations. In this regard, the comparative findings showed that the selected countries differ substantially in governance philosophy yet exhibit greater continuity in the support of strategic scientific areas.

Policy instability may also reduce the adaptive capacity of higher education institutions during periods of rapid technological change. Recent research on digital transformation in higher education emphasizes that governance reform should integrate organizational processes, human resources, and technological infrastructure rather than treat digitalization as a purely technical intervention (Mujahidin et al., 2026). Similarly, stakeholder-based studies of AI-driven transformation in universities suggest that technological modernization improves institutional performance only when it is embedded in coherent governance arrangements and supported by appropriate organizational capabilities (Nnaji et al., 2026). These findings help explain why fragmented policymaking can have consequences beyond traditional administrative inefficiency. In contemporary science systems, inconsistent governance may reduce the ability of institutions to respond strategically to emerging technologies, new research methodologies, and changing patterns of international scientific collaboration.

The results also identified financing instability as a major structural weakness. Basic-science financing in Iran was described as heavily dependent on annual public budgets, with negligible baseline research funding and limited industrial contracting. In contrast, the selected countries employ more diversified or institutionally stable funding arrangements, including multi-year grants, long-term institutional allocations, mission-oriented public investment, and varying levels of private and philanthropic participation. This finding is theoretically significant because fundamental research often requires sustained funding over periods much longer than annual budget cycles. The effects of unstable funding extend beyond laboratory expenses or equipment acquisition; they affect recruitment, retention, research continuity, doctoral training, infrastructure maintenance, and the willingness of scholars to pursue high-risk questions. The relationship between governance and research performance identified in comparative studies of European universities similarly suggests that institutional arrangements and resource governance influence scientific outcomes (Sedlacek, 2025). Although funding volume remains important, the current findings indicate that predictability and institutional continuity may be equally critical.

The financing issue is also closely connected to human-capital development. The findings suggest that when basic-science researchers lack predictable support and clear professional pathways, the system may struggle to retain scientific talent or translate educational investment into long-term research capacity. This interpretation corresponds with research on the employability and human-development ecosystem of basic-science graduates, which emphasizes that scientific education must be understood within a broader ecosystem linking skills, employment opportunities, institutional structures, and socioeconomic development (Entezari, 2023). From this perspective, the governance of basic sciences includes not only the allocation of



project funds but also the creation of stable professional environments in which scientific expertise can mature. Financial instability can therefore generate cumulative effects, including migration of researchers, diversion toward more immediately remunerative occupations, weakening of research teams, and declining institutional memory.

Another significant finding was the predominance of quantitative evaluation criteria in Iran. Participants and comparative evidence indicated that publication counts, journal-based indicators, and other numerical metrics continue to play a disproportionate role in performance assessment. This differs from the more multidimensional approaches observed in the selected countries, where peer review, research quality, institutional mission, human-capital development, long-term impact, and national priorities are incorporated to varying degrees. The problem with excessively quantitative assessment is not that metrics are inherently inappropriate but that narrow metrics can reshape behavior in unintended ways. When academic advancement and resource allocation depend heavily on rapidly measurable outputs, researchers may avoid long-horizon or high-risk projects, fragment research findings into multiple publications, and prioritize topics that are easier to publish rather than those with greater scientific importance. This governance effect is particularly problematic in basic sciences because transformative discoveries frequently emerge from uncertain, exploratory, and cumulative research.

The need for broader evaluation criteria is also compatible with the educational role of basic sciences. Research on curriculum development has emphasized that basic-science education should develop scientific literacy and competencies rather than focus solely on formal content transmission (Adegbola & Adeleke, 2023). Similarly, research on brainstorming-based instruction in basic-science courses has shown the relevance of creativity and active learning within the scientific educational process (Saadat-Najad et al., 2021). These studies suggest that the value generated by basic sciences includes intellectual development, creativity, problem-solving ability, and the formation of scientific human capital. An evaluation system centered almost exclusively on publication volume therefore captures only one part of the broader contribution of basic sciences. A more comprehensive governance framework would assess the quality of scientific problems addressed, training of researchers, development of research capabilities, interdisciplinary contributions, and longer-term scientific and societal effects.

The findings concerning the weak linkage between basic sciences and innovation were also central to the study. In Iran, participants described a systemic disconnect between fundamental research and industry, reinforced by weak intermediary institutions, bureaucratic barriers, legal obstacles, and mutual distrust. By comparison, the selected countries possess more institutionalized arrangements for connecting universities, research institutes, industry, and technology-transfer organizations. Importantly, the comparative evidence suggests that the relationship between basic research and innovation should not be conceptualized as a simple linear sequence in which fundamental discoveries automatically become commercial technologies. Rather, the relationship is mediated by institutions, professional networks, funding mechanisms, technology-transfer organizations, and long-term interactions among scientific and industrial actors. The German distinction and interaction between fundamental-research institutions and applied-research organizations provides a particularly clear example of such institutional mediation.

The importance of maintaining a strong basic-science foundation for technological innovation is also supported by research on artificial intelligence. Yang and Peng argued that future progress in AI requires deeper rooting in basic science rather than reliance solely on incremental engineering development (Yang & Peng, 2020). This perspective aligns closely with the present finding that the strategic value of basic sciences should not be judged only by immediate commercialization. In advanced technological fields, long-term innovation depends on foundational advances whose practical applications may initially be uncertain. Therefore, governance arrangements that pressure basic research toward immediate industrial outputs may paradoxically weaken the scientific foundations of future innovation. The appropriate policy challenge is not to convert all fundamental research into applied research, but to create institutional pathways through which knowledge can circulate between basic science, technological development, and societal needs.

Emerging technologies also create new opportunities for strengthening such linkages. The use of immersive and digital platforms in basic-science education demonstrates how technological tools may broaden access to scientific learning and simulation, particularly in resource-constrained contexts (Zaidi, 2024). At the governance level, however, successful adoption depends on infrastructure, financing, faculty development, and institutional readiness. This supports the broader conclusion of the present study that technological opportunities do not compensate for governance weaknesses. Instead, they require



governance capacity to be translated into sustainable institutional change. The same logic is evident in studies of science and technology governance in judicial digital transformation, where successful transformation depends on coordination among legal, institutional, and technological components (Rahmatian & Fattahi, 2025). In other words, the transfer of scientific or technological capacity into operational value is an institutional process rather than an automatic outcome.

The qualitative findings further showed that harmful quantitative evaluation criteria, burdensome bureaucracy, limited university autonomy, and legal and cognitive barriers function as intervening conditions that intensify the effects of fragmented governance. This result is consistent with research on good academic governance, which emphasizes the importance of accountable institutional structures, effective management, and alignment between academic and administrative processes (Yublina et al., 2024). Excessive bureaucracy may be particularly damaging in basic sciences because research often requires timely procurement, international collaboration, access to specialized equipment, and flexible allocation of project resources. When administrative processes are rigid or unpredictable, transaction costs increase and researchers devote greater effort to compliance and resource navigation. Reduced institutional autonomy may further prevent universities and research institutes from adapting their strategies to disciplinary needs.

The governance of emerging issues such as AI and research ethics reinforces the need for institutional flexibility combined with clear accountability. University guidance on artificial intelligence shows that higher education institutions increasingly need formal governance mechanisms for rapidly developing technologies (Wu et al., 2024). Similarly, the development of research ethics committees in Chinese universities demonstrates the importance of institutionalizing ethical oversight as research systems become more complex (Li, 2025). These studies support the present finding that effective science governance cannot rely solely on centralized directives. Institutions require sufficient autonomy to respond to disciplinary and technological changes while operating within national standards and accountability frameworks. The policy challenge is therefore to balance autonomy with coordination rather than maximizing either central control or decentralization in isolation.

Another important implication of the findings concerns the distinction between governance model and governance quality. The comparative analysis showed that the United States, Germany, China, and Japan follow substantially different institutional models, yet all exhibit stronger coordination, longer-term policy orientation, and more stable mechanisms for supporting science than Iran. This suggests that no single model should be treated as universally transferable. The relevant lesson lies in the governance functions performed within each system. Yeargain's analysis of education governance similarly demonstrates that the allocation of authority and institutional design influences accountability and participation, but different structural arrangements may serve these functions in different ways (Yeargain, 2024). Accordingly, reform in Iran should focus less on copying a specific foreign institutional structure and more on clarifying authority, strengthening coordination, stabilizing funding, improving evaluation, and institutionalizing knowledge-transfer mechanisms in ways compatible with the national administrative context.

Overall, the convergence between the comparative and qualitative findings provides strong support for interpreting Iran's basic-science challenges as systemic governance problems. The core category identified through grounded theory explains how institutional fragmentation can generate cascading effects across policymaking, financing, evaluation, and innovation linkages. This systemic interpretation is consistent with governance research that views organizational performance as the outcome of interacting contextual and strategic factors rather than isolated variables (Sakvand et al., 2026). It is also consistent with research showing that the effectiveness of universities and research organizations is closely related to governance arrangements and institutional management (Castro-Gomez et al., 2026; Sedlacek, 2025). Consequently, reform limited to increasing research budgets or changing individual evaluation indicators is unlikely to produce sustainable improvement unless the broader coordination architecture is also addressed.

This study has several limitations that should be considered when interpreting its findings. First, the qualitative component was based on interviews with five experts. Although theoretical saturation was achieved within the scope of the study and the participants possessed relevant experience in science and technology policy, a broader and more heterogeneous sample could have captured additional perspectives from basic-science researchers, university administrators, funding agencies, industry representatives, policymakers, and early-career scientists. Second, the comparative analysis focused on four selected countries representing different governance traditions; therefore, the findings should not be interpreted as representing all successful science systems. Third, the study relied substantially on documentary and secondary evidence for the international comparison,



and differences in national reporting practices may have affected direct comparability. Fourth, some governance indicators, such as institutional coordination quality and the effectiveness of science–industry linkages, are inherently difficult to quantify and required interpretive analysis. Finally, because the study was primarily qualitative and comparative, it did not statistically estimate the magnitude of causal relationships among governance variables.

Future studies should extend the present analysis by incorporating a larger and more diverse group of stakeholders and by combining qualitative findings with quantitative governance indicators. Comparative research could include additional countries with different institutional and developmental characteristics in order to distinguish universal governance mechanisms from context-specific arrangements. Longitudinal studies would also be valuable for examining how changes in funding structures, institutional coordination, evaluation systems, and university autonomy affect scientific performance over time. Researchers could develop and validate a multidimensional instrument for measuring the quality of basic-science governance at national and institutional levels and then test the relationships among governance quality, research productivity, scientific impact, talent retention, innovation outcomes, and international collaboration. Future research should also examine specific intermediary institutions and identify which mechanisms most effectively connect fundamental research with industrial and societal innovation without undermining scientific autonomy.

At the practical level, reform should be approached as an integrated governance program rather than as a series of isolated policy interventions. National authorities should establish a clearly defined coordination mechanism with sufficient authority to align the responsibilities of ministries, research councils, academies, universities, and funding bodies while avoiding unnecessary centralization. Funding for basic sciences should include predictable multi-year institutional and project-based components that allow researchers to pursue long-term programs and maintain essential research infrastructure. Evaluation systems should be redesigned to reduce excessive dependence on publication counts and to incorporate scientific quality, originality, human-capital development, research integrity, collaboration, and long-term impact. Administrative procedures affecting procurement, grant management, recruitment, and international collaboration should be simplified. Universities and research institutes should receive greater operational autonomy accompanied by transparent accountability. Finally, dedicated intermediary institutions, technology-transfer structures, joint research platforms, and sustained university–industry networks should be strengthened so that fundamental research can contribute to innovation through multiple pathways without being reduced to short-term commercial objectives.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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