Unveiling a Governance Analysis Framework for Basic Research in Iran

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Abstract

Basic science, as a cornerstone of the national innovation system, has long been at the center of debates on which management approaches are most effective for this activity due to its specific nature that distinguishes it from other types of research. For example, given the long time lag between investment in basic research and the manifestation of economic and social effects from its results, many organizations, especially in the private sector, are reluctant to invest in it. However, insufficient support for basic science becomes a brake on further innovative development and creates the risk of stagnation. This article contributes to the development of these discussions. It considers key concepts of research governance with an emphasis on their application and achieved results in the Iranian context. A comprehensive theoretical framework for analyzing the processes of basic research management in Iran is developed, which can be adapted to similar contexts worldwide. Strategies for improving the alignment of needs and priorities at different funding levels, both operationally and strategically, are proposed. It is concluded that improving the governance of basic science can not only increase the economic returns from research activities, but also bring them into line with societal needs.

Keywords: research governance; fundamental/basic research; innovation system; research funding; economic and social effects; fuzzy cognitive mapping; meta-synthesis

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Introduction

Basic research plays a special role in the evolution of the human knowledge base as a basis for further development. Basic research aims for deep understanding in a subject through experimental or theoretical efforts, focusing on fundamental phenomena without immediate practical applications. It provides the foundation for long-term technological innovations and economic benefits (Nelson, 1959), though it involves challenges like ambiguity and high risk, with outcomes that are often unpredictable and knowledge that may become "caged" after discovery (Salter, Martin, 2003). Despite the lack of immediate financial returns, basic research is crucial for leadership in innovation and managing the risks of new technologies (Rosenberg, 1990). Within the comprehensive scope of research and development, which includes basic and applied research, and development activities, emphasizing basic sciences is essential. This entails fostering an ecosystem conducive to understanding and addressing challenges in knowledge-based industries and reverse engineering advanced technologies (OECD, 2015). The imposition of sanctions on Iran, limiting access to certain industrial knowledge-based necessities, has spurred domestic production of knowledge-based products, thereby enhancing economic efficiency. Such occurrences underscore the indispensable role of basic research in bolstering national capacity. Despite economic downturns and budgetary constraints, channeling resources towards effective interventions in basic research remains paramount. Additionally, with a growing recognition of the importance of foundational research in today's landscape, there is an increased emphasis on examining governance structures within this realm. Research governance requires a systemic management and oversight approach to ensure coordinated and effective research activities, characterized by shared responsibilities among all stakeholders rather than centralized control (Shaw et al., 2005).

Relyilng on literature review, the article further considers key definitions and concepts of basic research and research governance, with an emphasis on their application and achieved results in the Iranian context. Finally, conclusions are drawn regarding its findings, and recommendations for future research are provided.

The Role of Basic Research in Contemporary Innovation Systems

Corporate fundamental research

Most previous studies examining the impact of basic research on innovation have focused on increasing corporate R&D activity. The paper (Ceccagnoli et al. 2024) provides new data describing the links between fundamental research and the degree of radicality of innovations created by both in-house and external ideas in American companies. Over 5,100 manufacturing companies in the United States were studied. The results of fundamental research are usually difficult to adapt at the company level. However, it has been established that the more diversified the company itself, the easier it is to find application for these results, perhaps even in directions that are not obvious at first glance (Rosenberg, 1989; Akcigit et al., 2021).

Many researchers have noted a trend that has emerged in recent decades that large corporations may abandon fundamental research and rely on external research from universities and start-ups (Arora et al., 2019). These observations provide important theoretical implications as an information basis for guiding basic research to create innovation. The authors conclude that firms that conduct fundamental research are more likely to launch more radical innovations. In turn, companies that abandon fundamental research, even though they exploit the capabilities of established technologies, lose the potential for creative destruction, become bogged down at best in incremental innovations, and become path dependent. Thus, fundamental research proves to be an important complement to applied research, maintaining a company's overall high potential for renewal and adaptation (Akcigit et al., 2021; Pavitt, 1991; Rosenberg, 1990). However, this benefit may vary depending on the extent to which a company is able to exploit the results of basic research. Diversified companies are more likely to generate radical innovations when conducting such research, as they master the diversity of product areas and develop the ability to see unexpected solutions. This is determined by the very nature of basic research, since it also generates knowledge that is less tied to established company practices.

In the last few decades, companies have shifted their focus to external knowledge acquisition (Arora et al., 2019; Chesbrough, 2003; Lariviere et al., 2018), curtailing their own activities in basic research. At the same time, a number of researchers express concerns that such an imbalance will also lead to a decrease in the company's potential for creating radical innovations (Arora, Gambardella, 1994; Cohen, Levinthal, 1989), which may negatively affect the company's development in the long term. It is also noted that radical innovations are not always better than incremental innovations, as the literature shows that significant social (and private) benefits for well-being are often created on the basis of incremental innovations (Pisano, 2015; Rosenberg, 1982). The final conclusion of the authors is that companies need to maintain a balance between the use of internal and external resources to create innovations, between fundamental and applied research, between radical and incremental innovations. At the same time, the more diversified the company, the easier it is for it to assimilate knowledge from different sources and find a "profitable" application for them, maintain the potential for renewal and adaptation.

Public Fundamental Research

The results of basic research in China are presented in the paper (Hu et al., 2023) also confirm the thesis that the results of fundamental research play an important role in promoting strategic and radical innovations. China's investment in basic research has continued to increase in recent years, with state investment totaling 181.7 billion yuan in 2021, up 23.9% year-on-year. However, China's impressive basic research results have not been effectively translated into practical technologies to drive technological revolution and industrial change. The authors come to the valuable conclusion that fundamental research, which is predominantly privately funded, has a higher potential to develop into breakthrough innovations that will contribute to the long-term competitiveness of both the company and the economy as a whole.

This difference between the public and private sectors is explained by the fact that companies have a smaller resource base than the state, and they are forced to manage it more efficiently, which leads to a higher level of conversion of the results of fundamental research into innovative products in demand by the market. Effective integration of basic and applied research has been shown to result from a combination of private investment, responsible management, and a comprehensive assessment of the implementation of university research results into corporate practice (Wiesbaden, 2015).

Data from 23 OECD countries show that significant effects of investments in basic research on economic development only appear in the long term and have a positive effect on the economic complexity index of countries (Laverde-Rojas, Correa, 2019) .

Another important topic discussed in the literature is the role of intellectual property rights protection in generating breakthrough innovations. Authors (Nelson, 1959; Arrow, 1962) point to positive effects of this mechanism for which it was conceived. However, more recent studies have noted the negative consequences of the abuse of this mechanism, showing that the purchase of intellectual property rights is used by individual companies as a restraining mechanism that hinders the innovative activity of competitors, and thereby slows down the overall pace of innovative development and reduces the prospects for economic renewal.

Basic fundamental research has its own specific features that serve as the basis for arguments in favor of more active state participation in its support. Among these features are a long development cycle, the need for specialized laboratories and precise research equipment, which requires significant capital investment. The topic of the balance of support for fundamental research from public and private sources is developed by the authors of the study (Marchiori, Minelli, 2023). It is shown that if the task of supporting fundamental research is assigned primarily to the state (which has more resources for this activity than companies), then the risks of inefficient distribution of funds between performers and the creation of a distorted system of incentives for them increase. As a result, such researchers lose motivation to generate useful and breakthrough results, in particular for reasons of the "safety and reliability" of the topic. Such attitudes negatively affect the overall potential for converting fundamental science into practice.

The authors (Gersbach et al., 2023) reveal the influence fundamental research on the general economy, and public investments are also analyzed with a view to achieving a balance in the provision of resources for fundamental research between the private and public sectors. The main motive for national investment in basic research is to support private innovation in the domestic economy. The costs and benefits of these investments depend critically on the country's integration into the world economy. On the one hand, innovative domestic firms benefit from supplying their products to the world market. On the other hand, domestic consumers benefit from importing foreign innovations, which allows countries to free ride on investment in basic research. On the other hand, innovation combines the ideas and insights of basic research with industry-specific know-how. The more complex and diverse the domestic economy, the greater its potential for innovation and, consequently, the greater the domestic benefits from investment in basic research. The authors conclude that the costs and benefits associated with public basic research in a given country are critically dependent on the global economy: first, in a globalized world, national benefits from basic research ideas are determined by the cost of their commercialization in global markets. The authors show that positive effects dominate when basic research is at least as skill-intensive as manufacturing, implying that more advanced countries invest a higher share of their GDP in basic research. Moreover, due to their broad industrial base, these countries benefit more from knowledge spillovers from the rest of the world and are thus highly innovative. Their high levels of innovation allow these countries to capture a disproportionate share of global profits.

It has been found that a coordinated policy of fundamental research will lead to an improvement in welfare in three dimensions. The first is a more even distribution of investments in fundamental research among performers. In reality, developing countries are insufficiently effective in fundamental research because, due to the general inefficiency of the economic system, they become "victims" of the process of knowledge spillover. This is expressed in the fact that, on the one hand, they do not receive enough external knowledge, and on the other, they suffer from the leakage of internal knowledge. In developing the thesis about the unequal distribution of resources between the performers of fundamental research, the authors (Gersbach et al., 2023) provide data on the distribution of investments in basic research by country. In developing countries, the underdevelopment of basic science may be due to the temptation to use a simpler management model and focus on exploiting and trading the existing resource base in order to extract immediate benefits, without bothering with costly investments in the long term, for which the results of basic research are designed. This leads to a lock-in in such patterns as "raw material orientation", the "middle income trap", etc.

The thesis is put forward that the main volumes of investment, due to imperfect evaluation systems and for other reasons, may be allocated to ineffective performers. At the same time, other recipients of such investments, which have a much higher potential for breakthrough R&D , may remain underfunded. Because of this, the overall effectiveness of fundamental science falls. Improvement of evaluation systems and improvement of mechanisms for coordinating the distribution of funds "from above" are proposed as general measures to correct this imbalance.

As for the state's support for fundamental research, it is stated that the state can "compulsorily" offer individual enterprises and industries to use the results generated by fundamental science. However, such a measure is not effective. It is more correct to increase the ability of the companies themselves to assimilate new knowledge and diversify, so that it is the companies that select for themselves the fundamental knowledge that has the greatest potential for commercial implementation.

The findings presented in this paper contribute to a better understanding of effective approaches to coordinating basic research policies at the international level.

Research Background

Numerous researchers have explored governance in basic research. Salo and Liesio (2006) emphasized prioritization and its implementation, linking these to achieving economic and social goals through both top-down and bottom-up strategies. Similarly, Hellström et al. (2017) studied institutional support mechanisms, advocating for an integration of governance levels, emphasizing the critical role of organizational capabilities. Gassler et al. (2007) identified policy and operational levels as key for supporting basic research, stressing the effectiveness of bottom-up feedback processes. Building on these ideas, Hicks (2012) suggested a model linking financial support with performance assessment to enhance government aid for research. He highlighted the importance of aligning research interests with cost evaluations and accountability. Guida (2018) also stressed the need for aligning financial support with research quality and national priorities. Shokatian and Ghazinoory (2020) argued for an effective prioritization process to optimize resource allocation and impact, proposing a hybrid prioritization approach that considers inputs from various levels. Shokatian and Ghazinoory (2019) also described a policy framework for basic research that includes prioritization, funding allocation, and research evaluation, advocating for a governance structure that combines top-down and bottom-up processes.

In summary, the literature underscores a governance division between policy and operational levels, with prioritization, funding, and evaluation as core functions. This study aims to clarify these functions, their interactions, and their implications for governance enhancement in Iran.

A brief overview of the Iranian context

The management of basic research in Iran faces significant challenges, primarily due to reliance on government funding, weak priority-setting, and misalignment between policies and national needs. One major challenge is assessing the benefits and effectiveness of basic research, given its long-term nature and lack of immediate practical applications. This makes it difficult for policymakers to measure return on investment (Shokatian, Ghazinoory, 2019). In Iran, basic research is predominantly funded by the government. However, the prioritization process is fragmented and lacks coordination among key bodies, such as the Ministry of Science and the Ministry of Health. This fragmentation leads to inefficient resource allocation, as projects are funded without sufficient alignment with the country's strategic needs (Ghazinoory, Shokatian, 2021). The absence of intermediary institutions to regulate and coordinate research priorities exacerbates this inefficiency. In contrast to developed countries, where independent scientific foundations guide research agendas and funding distribution, institutions like the National Elites Foundation and the Iran Science Fund have limited influence in shaping scientific directions (Ghazinoory, Safari, 2022). Additionally, weak governance and the lack of robust monitoring and evaluation systems contribute to these inefficiencies. Vague evaluation criteria and ineffective oversight mechanisms hinder the effective management of basic research. Global experiences suggest that multi-layered assessment frameworks, addressing economic, technological, and social impacts, can significantly improve research governance (Karimmian et al., 2021). While these governance challenges are common globally, their impact in Iran's state-driven research ecosystem presents unique dynamics. The Iranian government plays a central role in funding and prioritizing basic research, given the resource-dependent economy and the structure of the national innovation system (Karimmian et al., 2019). National funding schemes are controlled by bodies such as the National Science Foundation of Iran, which prioritizes state-driven development goals over scientific curiosity. This contrasts with more decentralized research systems in some Western countries, where research priorities are less influenced by government intervention (Shokatian, Ghazinoory, 2019). A key challenge in Iran is balancing applied and fundamental research. Policymakers often prioritize research that yields immediate economic benefits, despite acknowledging the long-term importance of fundamental science. Bureaucratic hurdles, fragmented funding structures, and an overemphasis on short-term outcomes have hindered the development of a coherent strategy for basic research (Shokatian, Ghazinoory, 2020). Despite increasing research output, there are inadequate mechanisms for technology transfer and industrial collaboration, leading to the underutilization of scientific advancements (Ghazinoory, Aghaei, 2021). Unlike countries with stable research ecosystems, Iran's funding patterns are volatile, heavily dependent on fluctuating state budgets. A shift toward a more diversified funding model, including private sector involvement and international collaboration, could mitigate current constraints and strengthen the research system (Ghazinoory, Safari, 2022).

While the governance challenges of basic research in Iran are shared globally, their manifestation within the country's unique policy environment requires tailored solutions. Integrating insights from Iranian policy literature and empirical studies, this analysis provides a contextually grounded discussion of the governance of basic research in Iran, offering a comprehensive view of the situation. The study is based on publicly available national statistics on fundamental research funding, but detailed data on specific research fields or publication activity is not accessible in Iran due to the generalized nature of the available statistics.

Figure 1 presents the number of research projects, categorized by type of research. The rapid increase in the total number of publications is evident particularly after 2010, when it reached over 180,000 publications by 2021. This reflects a significant surge in research activity across all fields. While fundamental research also shows growth, it remains much lower compared to the overall total. The number of fundamental research publications starts at 3,420 in 1996 and increases steadily to around 40,000 in 2021, though the growth rate is more gradual compared to total research. The gap between total research and fundamental research widens notably after 2010, suggesting that while total research activity has exploded, fundamental research has not experienced the same level of exponential growth. This could be due to various factors, such as a shift towards applied research or more targeted government funding in certain areas. A notable jump in both categories can be seen from 2019 to 2021, likely reflecting a combination of increased government investment, research policy changes, and possibly the growing international focus on scientific advancements in Iran. This graph illustrates the overall growth in scientific output, but the slow growth of fundamental research in relation to overall research activity points to a key challenge: despite significant investment, much of the funding has not been directed toward fundamental research. This discrepancy may reflect weaknesses in governance and structural factors that have hindered the allocation of resources to the fundamental research domain.

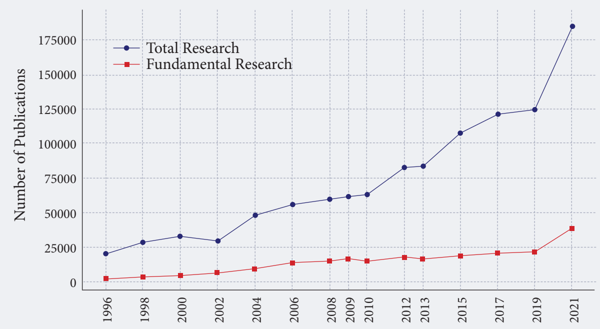
According to the Iranian legislation, all executive bodies are required to allocate at least 1% of their operational budget (excluding non-operational expenses) to research and technological development[1] . This funding is in addition to the annual research budget assigned to these organizations in the national budget laws. The High Council for Science, Research, and Technology (ATF) and the Statistical Center of Iran are responsible for monitoring and reporting the performance of research expenditures.

As shown in tables 1 & 2, Investment in basic research remains minimal, as only 6% of total research projects and the overall research budget are allocated to this area, indicating weak support for foundational scientific studies. Additionally, there is a significant gap between budget allocation and actual spending. While 81,158 million IRR was allocated for basic research, only 76% of this amount was ultimately spent. In contrast, developmental research not only received its full budget but exceeded the estimated allocation, receiving 140% of the planned amount. Meanwhile, developmental research, despite making up only 6% of research projects, secured 21% of the total research budget. This imbalance further reinforces the preference for practical research over fundamental scientific exploration.

Figures 2 and 3 show the trends in proposals received, approved projects, and allocated budgets by scientific field in basic research from 2014 to 2024 according to Iran National Science Foundation[2]. A key takeaway is that basic sciences consistently received the highest number of proposals and the largest share of the allocated budget, highlighting that foundational research continues to dominate in both attention and funding. However, this dominance of basic sciences also reveals a significant gap: basic research in applied fields like engineering sciences and agriculture has not been adequately recognized or funded, despite the growing interest in these areas. The National Science Foundation in Iran appears to have struggled in effectively bridging the gap between basic research and its applications in these practical fields. The foundation has been more focused on well-established research in basic sciences, leading to an imbalance in support for applied research. This is reflected in the data where, despite increasing proposals in engineering sciences and agriculture, the approval rates and allocated budgets in these fields were lower for many years. This suggests that the foundation has not fully identified and supported the necessary basic research needed to drive innovation in applied areas. However, there is a positive shift in recent years, particularly from 2023 onwards, where we see an increase in the allocated budgets for engineering sciences and agriculture, signaling a recognition of the need for basic research in these ap-

[1] Article 65 of the «Law on Adding Certain Articles to the Law on Regulating Part of Government Financial Regulations», as well as «Article 56 of the Sixth Development Plan». (https://www.fao.org/faolex/results/details/en/c/LEX-FAOC182369/, accessed 16.01.2025).

Figure 1. **Number of Research Projects by Type of Research**



Source: Iran Statistical Center. https://amar.org.ir/statistical-information/statid/21820, accessed 19.02.2025.

plied sectors. This gradual decrease in the proportion of funding allocated to basic sciences and the increase in funding for engineering sciences and agriculture reflect a growing understanding that the development of applied fields depends on solid foundational research. The relatively low funding for environment and health throughout the years indicates that despite the societal importance of these sectors, the funding and proposal approval have not kept pace with the growing challenges in these fields. This area, like engineering sciences and agriculture, requires more attention in terms of basic research funding to address environmental and health crises.

Thus, while the basic sciences field continues to be prioritized, the shift towards recognizing and funding basic research in applied fields is a positive development. However, the slow pace of this shift and the ongoing underfunding of critical areas like Environment and Health underscore the need for Iran NSF to strengthen its role in linking basic research with real-world applications. By doing so, it can better address national priorities and global challenges.

Research Methodology and Data Description

In our present study, employing a systematic literature review method, specifically meta-synthesis, and drawing upon documents and credible sources accessible via the Web of Science database, we identified a total of 422 pertinent documents. These documents were sourced from a diverse collection of primary articles, covering the period from 1940 to 2022. Subsequently, we scrutinized the selected documents, using the *Bibliometrix* package within the R software primarily focusing on fundamental research, and derived a classification of significant and noteworthy dimensions

Notably, "innovation" emerged as the most frequently occurring keyword followed by "research and development", "science policy", and "economic development". The combined assessment of development degree and relationship degree suggests that science policy and applied research are key areas of interest within this domain. Moreover, within scholarly documents focused on exploring fundamental research and its associated definitions and concepts, "applied research" ranks as the second most common keyword. This underscores the intrinsic connection between fundamental and applied research, where the latter often builds upon the findings of the former.

The studies also identified three distinct literature streams within the field of fundamental research: one concentrating on conceptualizations and definitions, another focusing on theoretical frameworks, and a third emphasizing the social and economic dividends of fundamental research. By analyzing time intervals, two primary periods were delineated. The first, spanning from 1934 to 1994, spotlighted concepts such as benefits, research, investment, system, development, fundamental, science, and indicators. In contrast, the second interval, from 1995 to 2021, saw an emergence of research on fundamental concepts, policy implications, economic considerations, applied research, and various influencing factors within the field. Finally, qualitative analysis using the meta-analysis method involved a thorough examination and discussion of the texts extracted from the identified articles, along with the concepts comprising the knowledge base encompassing 422 cases. Among these, 40 articles were found fitting for final coding. Through meta-synthesis studies, we identified three primary themes: inputs, processes, and outputs (table 3). These were catego-

Table 1. **Approved Research Projects by Type**

Type of Research	Number of Projects	Percentage of Total Projects
Basic Research	182	6
Applied Research	1418	88
Developmental Research	62	6
Total	**1655**	**100**

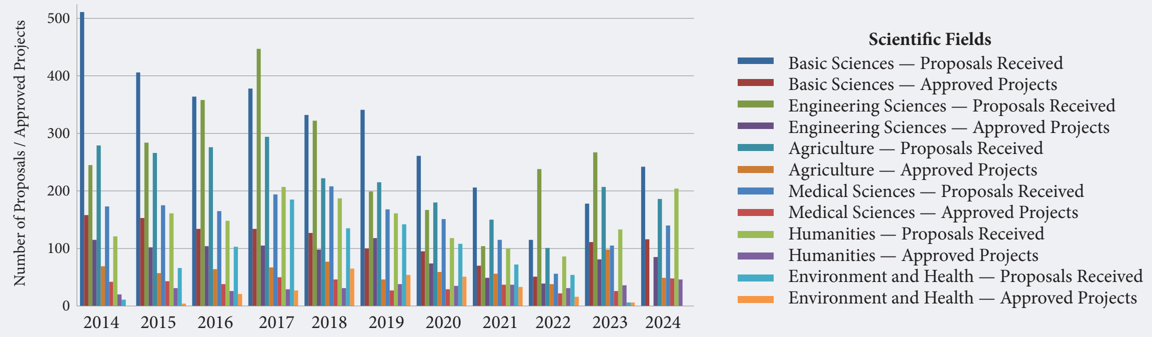
Source: Iran Statistical Center. https://amar.org.ir/statistical-information/statid/21820, accessed 19.02.2025.

Table 2. **Comparison of Estimated vs. Allocated Budget for Research Projects (Million IRR)**

Type of Research	Estimated Budget	Allocated Budget	Ratio of Allocated to Estimated
Basic Research	81 158	61 888	76%
Applied Research	1 652 651	868 618	53%
Developmental Research	611 566	858 556	140%
Total	**2 515 126**	**1 215 626**	**58%**

Source: Iran Statistical Center. https://amar.org.ir/statistical-information/statid/21820, accessed 19.02.2025.

Figure 2. **Proposals Received and Approved Projects by Year for Each Scientific Field (2014-2024)**



Source: Iran Statistical Center. https://amar.org.ir/statistical-information/statid/21820, accessed 19.02.2025.

rized under the title of dimensions and components of governance in fundamental research.

Based on the articles' focus on combining functions at both operational and strategic levels, along with the findings by (Shokatian, Ghazinoory, 2019; Ghazinoory, Shokatian, 2021) and these two levels were used to analyze Iran's fundamental research system. To ensure the validity, experts were interviewed that were selected using a snowball sampling method.[3] Based on the findings, a conceptual framework (Figure 4) was developed, outlining the various institutions involved in science and research governance in Iran. Their distribution by levels with a description of their composition is shown in Table 4.

Through literature review and the application of document analysis method, and finally interviewing experts in the field of fundamental research, 14 fundamental influential factors, including functions and role players of the fundamental research domain, were identified and presented in a conceptual framework. This set of factors and the conceptual framework formed the basis for designing questionnaires with a fuzzy cognitive mapping approach and generating primary research data. A cognitive map consists of two main elements: concepts and relationships. Concepts represent the variables of the model, variables that cause a change, known as cause variables, and those affected by the change are called effect variables. Nodes or concepts typically represent features, characteristics, qualities, variables, and states of a system, and each concept represents one of the key factors of the modeled system. In fact, cognitive mapping simplifies the information of a complex system and reduces it to a knowledge map, which is presented as a visual overview. Therefore, cognitive mapping can model any system with any level of complexity and with an infinite number of concepts, links, and feedback. The concepts represented in a map are connected to each other through causal and effect relationships, known as cause-effect or means-end relationships. Concepts that represent causes are located at the beginning of the arrow, and those representing effects are located at the arrowhead (Timulak, 2009). One of the topics discussed in cognitive mapping is related to the decomposition and analysis of concepts and calculating the impact of each concept in the mapping structure. One of the most important measures is centrality, which is based on the "research purpose and hypothesis" using one or a combination of these measures and concepts. Centrality has a broad concept that is used to identify and determine the most important actors or connections in a network. The most important and practical centralities are degree and betweenness. The simplest type of centrality is degree, which indicates the number of neighbors of each point; the higher the degree of a point, the more access it has to resources and the more central it is considered (Faust, Wasserman, 1994).

After the conceptual framework was determined in the form of a co-occurrence matrix and preliminary analyses were conducted, fuzzy cognitive maps were drawn and related indices were calculated using social network analysis software. The present study uses UCINET software for social network analysis. Therefore, the definition of the most important analysis criteria in this method is as follows:

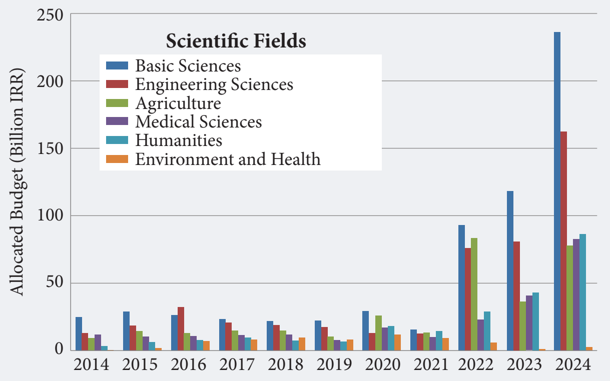
a) Degree centrality: Measures the number of direct links to a node and indicates the most connected node in the group.

b) Closeness centrality: Measures the degree of proximity of a node to the rest of the network, reflecting the

[2] https://insf.org/en, accessed 10.02.2025.

[3] Including faculty members from the Institute for Research in Fundamental Sciences and researchers from the International Center for Theoretical Physics, Abdusalam, the head of the Center for Development and Coordination of Research, Deputy of Research and Technology of the Ministry of Health, former and current presidents of the National Science Foundation, the deputy head of the National Science Foundation, a specialist in science and research funding, a faculty member from the National Center for Research on Science Policy (NRISP), an expert in research funding, and a policy expert on fundamental research.

Figure 3. **Allocated Budget by Year for Each Scientific Field (2014-2024)**



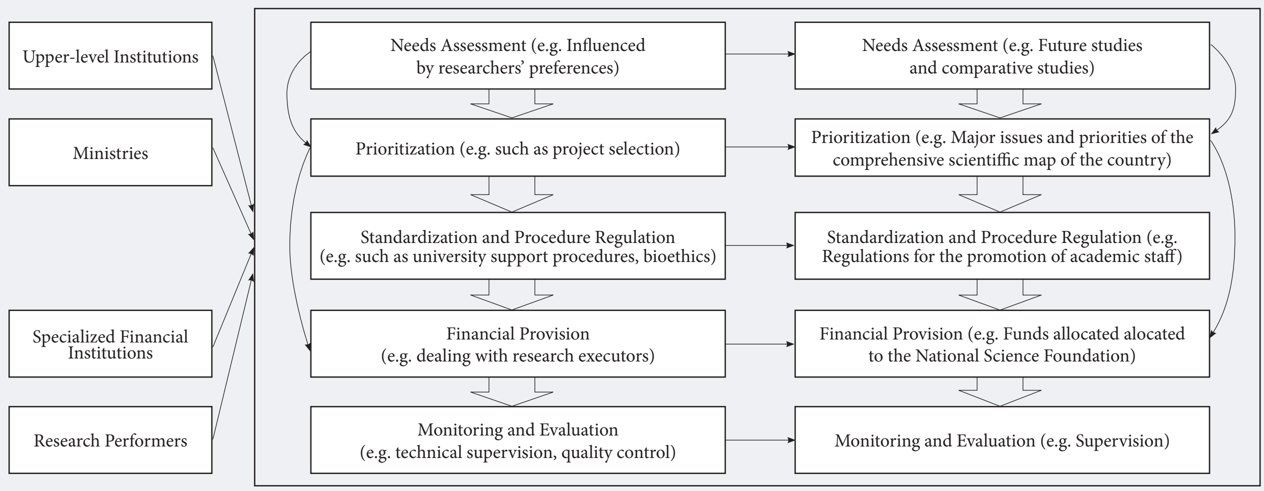
Source: Iran Statistical Center. https://amar.org.ir/statistical-information/statid/21820, accessed 19.02.2025.

Table 3. **Output of the Meta-synthesis Method**

Relevant Issue/Topic	Themes
Inputs	Capital, human resources, universities, laboratories, and government institutions
Processes	Financial provision, research needs identification (needs assessment), prioritization, monitoring and evaluation, and standardization and procedure regulation
Outputs	Economic growth in the form of productivity growth, efficiency, and profitability, technology development in the form of product innovation, knowledge dissemination through knowledge transfer in the form of publications, knowledge overflow, patents, social welfare, commercialization

Source: authors.

Figure 4. **Conceptual Framework of Research***



* Derived from Empirical Background and International Studies and Validated by Experts.

Source: authors.

Table 4. **Institutions Involved into Governance of Fundamental Research in Iran**

Category	Items
Upper-level institutions	Supreme Council of Cultural Revolution, the Parliament, the Cabinet, and the Organization of Budget and Planning.
Ministries	Ministries of Health, Defense, Deputy for Science, Technology, and Knowledge-based Economy and its Councils.
Specialized financial institutions	National Science Fund and the Supreme Council of Science, Research and Technology (ATF) Fun, etc.
Research performers	Research institutes, universities, government laboratories, individual researchers, and the private sector (Royan Institute, Institute for Research in Fundamental Sciences, Academic Center for Education, Culture and Research (ACECR), universities, etc.

Source: authors.

node's ability to access other nodes in the network. It is calculated as the inverse of the sum of the distances between a node and other nodes in the network.

c) Betweenness centrality: A measure indicating the frequency of a node's presence in the shortest path connecting two other nodes. Betweenness centrality is calculated based on the position of actors in the network and their placement in the shortest path between pairs of other actors. Therefore, a point with the highest betweenness centrality is located between many other pairs of points, and pathways from other points pass through it. Betweenness centrality measures the number of times a point needs to pass through intermediary points to connect with other points along the shortest path. Essentially, betweenness centrality measures the likelihood of an actor being positioned along the path of communication between other actors.

Finally, consensus centrality aggregates these three centralities based on the simple unweighted average and enables the causal analysis of the governance framework (Karimmian et al., 2021). In this study also, consensus centrality has been calculated and serves as the basis for the analyses.

The identified factors and conceptual framework laid the groundwork for crafting the questionnaire and gathering primary research data. We constructed a two-way matrix, where rows and columns represented the various functions, organizations, and institutions within the fundamental research domain. Following the conceptual framework, this matrix evaluated how upper-level institutions, ministries, specialized funding bodies, and research entities influenced both operational and strategic functions. It delved into the interplay between operational and strategic functions, assessing how operational needs assessment impacted operational prioritization, how prioritization affected operational funding, how strategic needs assessment influenced strategic prioritization, and how prioritization shaped strategic funding. Ultimately, we examined the collective impact of these factors on the structure of governance in basic research.

A resulting matrix was generated, honing in solely on these aspects, where the cell values depicted the degree of influence of the row factor on the column factor. A value of zero signified no influence. To distill causal maps from expert insights, causal relationships between structural and performance criteria were gleaned through interviews. These relationships and their implications were then integrated into fuzzy adjacency matrices and scrutinized using specialized software to sketch out cognitive maps of the experts. In this study, a consensus centrality index was employed to dissect the cognitive maps. The outcomes were fed into UCINET software for quantitative analysis, and the findings derived from the software outputs were subsequently presented. Finally, the qualitative analyses stemming from theoretical literature reviews, comparative studies, and amalgamated quantitative analyses unfolded.

Results

Summarizing calculations are represented at Table 5. As evident from the table, the factor that has the greatest impact on the governance of basic research in Iran is predominantly the specialized funding agencies and ministries. According to the experts' opinions, in the first category, the National Foundation for the Support of Researchers and Technologists has a major share of this impact, while in the second category, the Ministries of Health, Defense, and the Vice Presidency for Science and Technology bear the brunt of this influence. This aligns with the structural conformity observed in leading countries supporting basic research, such as the United States and China, where leading ministries and specialized funding agencies have the most significant influence. This trend can be preserved and strengthened in Iran as well. This assertion is also in line with the experts' views regarding the necessity of strengthening the National Foundation for the Support of Researchers and Technologists. On the other hand, the least consensus centrality (and hence causal weight) is attributed to operational needs assessment. The reason for this, according to experts, could be the general neglect of needs assessment for research at the operational level. As evident from the experts' opinions, due to the distant nature of basic research from the economy and the strong preferences of researchers in selecting research topics, this needs assessment has been overlooked more than in other areas. In other words, these national needs or specific financial resource needs for research do not necessarily drive researchers towards a particular field of activity, but rather their backgrounds, interests, and skills determine the direction of needs assessment.

Furthermore, it can be observed that all operational-level functions are weaker causally compared to strategic-level functions, indicating a top-down and non-collaborative approach in the governance of basic research. Although this approach is somewhat predominant in Iran, it is particularly noticeable in the field of basic research, where private sector actors are absent, and researchers are often more immersed in their activities and distant from decision-making processes than other researchers. According to experts, the failure to materialize what is referred to in the literature as the "scientific community" exacerbates this issue. Although relying on international experiences (especially in China and the United States), this trend can be partially justified in some functions such as standardization, funding, and evaluation, the lack of influence of research performers in the functions of needs assessment and prioritization is unacceptable.

In the broader scope of strategic functions, prioritization emerges as the key driver influencing the governance of basic research in Iran. Experts highlight that while aligning with global trends and channeling limited resources towards genuine priorities and societal needs is justifiable, Iran has deviated from this path. The experiences drawn from the Nano Council un-

Table 5. **Consensus Centrality in the Network of Actors and Functions of the Basic Research Area, by Factor type**

Factor	The degree of consensus centrality index	Causal weight
Actors		
Specialized Financial Institutions	12.51	1
Ministeries	12.51	1
Resrarch Performers	10.57	0.355482
Upper-Level Institutions	9.98	0.159468
Strategic-level		
Prioritization	10.14	0.212625
Needs Assessment	9.89	0.129568
Financial Provision	9.70	0.066445
Standardization and Procedure Regulation	9.64	0.046512
Monitoring and Evaluation	9.64	0.046512
Operational-level		
Prioritization	9.62	0.039867
Financial Provision	9.62	0.039867
Standardization and Procedure Regulation	9.61	0.036545
Monitoring and Evaluation	9.61	0.036545
Needs Assessment	9.50	0

Source: authors.

derscore this point, where financial allocations have been directed towards numerous high-quality research projects with minimal relevance—a glaring example of misalignment with strategic priorities.

Based on our findings, we can pinpoint the primary pathways that significantly influence the governance of fundamental research in Iran, and propose policy interventions accordingly. Here are some examples.

Pathway 1 (Most impactful): This pathway originates from ministries and specialized financial institutions. It plays a pivotal role in enhancing the governance of fundamental research by shaping operational prioritization, which subsequently influences strategic prioritization. Given its considerable causal impact, as supported by theoretical literature, comparative studies, and expert opinions, bolstering this pathway could yield positive outcomes for governance in this realm. Strengthening institutions like the National Fund for Researchers and Technologists, particularly in guiding strategic and operational priorities, and fostering closer alignment between these priorities can enhance governance performance in this domain.

Pathway 2: This pathway originates from research performers and holds substantial potential to shape the overall governance performance of fundamental research. It does so by influencing operational prioritization, thereby indirectly impacting strategic prioritization. Experts corroborate this pathway, emphasizing the dynamic interplay between strategic and operational prioritization. Notably, operational prioritization tends to be more influenced by researchers' awareness of the relevance of their field of activity rather than their personal interests, highlighting the intricate nature of this relationship.

Pathway 3 (Least Impactful): This pathway initiates from upper-level institutions and operates through strategic oversight and the evaluation of overall governance performance. Presently, these upper-level institutions, particularly in their role of monitoring and evaluating Iran's fundamental research status, are not optimally positioned. According to experts, this lack of comprehensive oversight results in excessive dispersion of resources, wastage, and ultimately diminishes Iran's standing compared to leading nations in a manner that may soon become irreparable. Hence, intervention is imperative. Drawing from international best practices and expert insights, enhancing the capacity and awareness of these institutions concerning the scientific and authoritative priorities of fundamental research in Iran, alongside designing evaluation and oversight mechanisms akin to successful models in other countries, can revitalize this pathway. Consequently, incorporating strategic evaluation criteria such as assessing the impact of basic research on advancements in various economic sectors and addressing societal challenges like aging can be instrumental. These criteria can be formulated and implemented by upper-level institutions, akin to the role played by the National Science Foundation in the United States.

Discussion

The proposed governance framework for basic research in Iran offers several advantages, particularly in enhancing the coordination between strategic and operational levels, strengthening the role of intermediary institutions like the National Science Foundation, and aligning fundamental research with broader societal and economic priorities. However, despite these strengths, several challenges and potential limitations must be acknowledged to provide a more balanced perspective. One of the key benefits of this framework is the enhanced coordination it promotes across governance levels. By reinforcing the role of intermediary institutions, the framework fosters better alignment between strategic priorities set by upper-level institutions and operational needs assessed by research performers. This can lead to more efficient resource allocation and improved responsiveness to national challenges. Furthermore, the integration of research networks as a tool can further enhance the exchange of data and collaboration between research institutions (Caminati, 2009; Al-Mawali et al., 2020). These networks help overcome some of the isolation that often characterizes basic research activities (Broekel, Graf, 2010). By introducing collaborative networks at national and international levels, the innovation cycle is accelerated, creating a more dynamic and interconnected research environment (Plucknett, Smith, 2005). The framework also stands out for its deliberate effort to integrate economic growth imperatives with fundamental societal concerns, such as air pollution and aging. This integration ensures that basic research remains relevant and impactful beyond academic circles (Dooly, O'Driscoll, 2022). A key element of this approach is the impact-driven prioritization, which assesses the societal and economic benefits of research. It helps align funding with national needs, addressing critical issues like climate change, healthcare, and sustainability (Chubb, Reed, 2018). Such an approach not only makes research more impactful but also ensures it is more responsive to society's evolving needs. Another notable strength is the increased strategic direction and prioritization introduced by the framework. By implementing a structured prioritization mechanism, both at strategic and operational levels, the framework helps steer research investments toward areas of high impact. This approach mitigates the risks associated with fragmented and uncoordinated funding distribution. Moreover, prioritizing based on social and economic outcomes, rather than solely academic achievements, enhances the relevance of research in addressing pressing national issues (Mulligan, Conteh, 2016; Shokatian et al., 2024; Bozeman, Youtie, 2017).

This helps ensure that resources are not wasted, maximizing the potential for research to deliver tangible societal benefits. Inspired by successful models in research-intensive countries such as the United States and China, the framework emphasizes the role of national science funding bodies in guiding and overseeing research priorities. The lessons drawn from these systems underscore the importance of integrating open innovation models, where public and private sectors collaborate to leverage external knowledge and push the boundaries of basic research (Ito, Nagano, 2011; Meissner, 2019). By adapting these best practices, Iran can establish a more sustainable and globally competitive research system. However, the framework also faces several challenges that must be addressed to fully realize its potential. One major challenge is the complexity of implementing the proposed governance framework within Iran's existing bureaucratic and institutional structures. Resistance from established research institutions and government agencies may slow the adoption of new governance mechanisms. The integration of open data policies could alleviate some of these challenges by enhancing transparency and accountability (Mayernik, 2017), allowing for easier tracking of progress and greater buy-in from stakeholders (Budin-Ljøsne et al., 2023). Nevertheless, overcoming institutional inertia will require significant policy shifts and investments in capacity building. While strengthening intermediary institutions can enhance coordination, it may also add layers of bureaucracy that could delay decision-making processes (Heitmann et al., 2019). Striking a balance between oversight and administrative efficiency is crucial to avoid excessive red tape. In this regard, involving multiple stakeholders in the decision-making process can help reduce bureaucratic inefficiencies, ensuring that decisions are made more inclusively and swiftly (Vignola et al., 2013).

Another challenge is the potential constraint on researcher autonomy. The push to align basic research with economic and societal needs, although beneficial for national development, may limit researchers' freedom to pursue curiosity-driven inquiries (Brown, 1985). A rigid prioritization system could restrict the exploration of unconventional, yet potentially groundbreaking scientific ideas. Social impact assessment models (Bornmann, 2013) offer a solution here by evaluating both the short-term societal benefits and the long-term potential of fundamental research. These models ensure that even unconventional or niche research areas are not overlooked due to their lack of immediate societal returns.

The financial sustainability of the proposed framework also presents a challenge. It relies heavily on increased financial commitment from specialized funding institutions. Given Iran's economic challenges, securing sustained funding for fundamental research remains a concern. The feasibility of long-term investments in basic research must be carefully considered, especially in the context of potential economic downturns. Here, private sector engagement is critical (Robson, 1993; Rosenberg, 2010), thus, introducing policy measures that incentivize private sector participation in funding basic research could help mitigate this limitation, attracting alternative funding sources and increasing the commercialization potential of research outcomes. In Iran, unlike applied research, which often attracts industry collaboration, basic research remains primarily government-funded. This lack of private sector involvement limits alternative funding sources and reduces opportunities for knowledge transfer and commercialization (Rosenberg, 2010). Adopting open innovation models could incentivize industry partners to invest in fundamental research, thereby bridging the gap between academic and commercial research (Beck et al., 2022; Akcigit et al., 2021).

Finally, the challenge of evaluating the performance of governance reforms in basic research is an ongoing issue. Given the long gestation periods between research investments and tangible outcomes, measuring effectiveness is inherently difficult. Developing robust evaluation metrics that can accurately capture the impact of research governance reforms is essential for assessing success (Hao et al., 2023). The use of social impact assessment models could provide a framework to evaluate the broader societal and economic effects of basic research, going beyond traditional academic metrics (Soler-Gallart, Flecha, 2022; Shi et al., 2022; Jiang et al., 2024).

Summary and Conclusion

Fundamental research, as a cornerstone of national innovation systems, has long been a subject of debate regarding government intervention in its policy and governance structures. However, it is recognized that government engagement with fundamental research differs significantly from other types of research due to inherent uncertainties, challenges in assessing its economic and social benefits, substantial time lags between research and application, and other unique factors. In recent decades, theories advocating unconditional support for fundamental research or relying solely on the internal logic of science and researchers' interests have been deemed flawed, just as complete government funding allocation. Similarly, the push to increase private sector involvement with arguments akin to those for technology development and applied research has its shortcomings.

This article aims to identify functions tailored to these differences in the governance system and analyze the entire governance structure of fundamental research in Iran while offering recommendations. At higher levels of the governance system, policies determine funding mechanisms and budget allocations for fundamental research. Prioritization, occurring at both strategic and operational levels, is influenced by these policies and needs assessments. Macro-level policies set perspectives within defined timeframes, guiding strategic prioritization, which is then implemented by ministries, research institutions, scientific foundations, and universities. National needs assessments draw on international and domestic studies, foresight analyses, and strategic objectives. Additionally, local assessments at research centers and universities inform operational prioritization through a bottom-up approach. Prioritization aligns with strategic goals and drives resource allocation to priority areas, enhancing research relevance to long-term socio-economic objectives. It should ideally engage stakeholders in defining and implementing priorities, employing a bidirectional approach.

Evaluation is another critical aspect, complicated by the time lag between supporting fundamental research and its impacts. Questions arise regarding the timeframe for assessing success, the relevance of academic outputs versus tangible societal impacts, and the role of capacity-building evaluations. Key institutions responsible for these functions include upper-level specialized bodies like the Supreme Council of the Cultural Revolution, ministries such as the Ministry of Health, specialized financial institutions like the Research Support Fund, and research performers such as individual researchers.

Drawing from the preceding analysis, the following recommendations are suggested:

1. Empower institutions like the Research and Technology Fund, particularly in strategic and operational prioritization, and foster closer alignment between these levels of prioritization.

2. Heighten awareness among researchers to align their research interests with overarching priorities, recognizing the significance of researchers' contributions in fundamental research.

3. Enhance the capacity of higher-level institutions to comprehend and incorporate the scientific and authoritative priorities of fundamental research in Iran.

4. Develop strategic evaluation and monitoring mechanisms akin to those employed by leading nations, encompassing assessments of basic research impact across various economic sectors, as well as its contribution to improving quality of life and addressing societal challenges such as aging.

These recommendations are geared towards amplifying the effectiveness and impact of fundamental research within the broader spectrum of innovation governance.

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