ISBN: 978-628-96613-3-0. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2026.1.1.2378

Determinants of Scientific Productivity in Peruvian Public Research Institutes: A Multiple Case Study

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***Abstract*—Public Research Institutes (PRIs) are part of national innovation systems and perform functions that extend beyond academic research, including technological services, regulation, policy support, and technology transfer. In emerging economies, these institutions are expected to respond to scientific and productive priorities while operating under resource constraints and institutional instability. This study examines the determinants of scientific productivity in three Peruvian PRIs: the Instituto Peruano de Energía Nuclear (IPEN), the Instituto Geofísico del Perú (IGP), and the Instituto Tecnológico de la Producción (ITP). A mixed-methods multiple case study design was applied, using 15 semi-structured interviews with researchers, managers, and technical personnel, complemented by documentary analysis, thematic coding, ordinal scoring, and cross-case comparison. The qualitative evidence was organized through a 1–5 scale, interpreted as a comparative valuation of influence, and triangulated with institutional information on research outputs, projects, cooperation mechanisms, and technological activities. The evidence suggests that scientific productivity is shaped by the interaction between internal capacities and external conditions. Internally, infrastructure, qualified human resources, access to scientific information, and organizational governance affect the continuity and quality of research work. Externally, competitive funding, institutional stability, science and technology policy, and cooperation networks influence the ability of PRIs to sustain and expand research output. The study proposes an analytical framework for assessing productivity drivers in PRIs with hybrid mandates. The analysis indicates that research careers, funding continuity, governance mechanisms, and institutionalized collaboration are central to improving the performance of public research organizations in Peru.**

***Keywords*—Scientific productivity, public research institutes, research governance, research policy, Peru**

I. Introduction

Public Research Institutes (PRIs) are part of national innovation systems because they conduct research, provide technological services, support public policy, and, in some cases, perform regulatory or sectoral functions. In emerging economies, these institutions are especially relevant when private R&D investment is limited and scientific capabilities are concentrated in public organizations. In Peru, institutions such as the Instituto Peruano de Energía Nuclear (IPEN), the Instituto Geofísico del Perú (IGP), and the Instituto Tecnológico de la Producción (ITP) operate in strategic fields such as nuclear technology, geophysics, risk monitoring, industrial productivity, and technology transfer [1]–[3].

Scientific productivity is usually measured through publications, citations, patents, research projects, and participation in competitive funding schemes. However, these indicators must be interpreted according to the mission, disciplinary orientation, and public mandate of each institution [4], [5]. Unlike universities, PRIs frequently combine research with technical assistance, public service delivery, regulation, and support for government decision-making. This institutional configuration requires an analysis that considers both internal capacities and external conditions affecting research activity [6].

A recurrent problem in PRIs from developing contexts is the uneven continuity of scientific output. Previous studies have associated research productivity with qualified human resources, infrastructure, access to scientific information, organizational support, funding, and collaboration networks [7], [8]. Research collaboration and stable funding can improve scientific output by increasing access to specialized knowledge, equipment, data, and international research agendas [9]–[12]. Nevertheless, these effects depend on governance arrangements, incentive systems, leadership continuity, and the capacity of each institution to transform resources into measurable results.

Most studies on scientific productivity focus on universities, academic departments, or national science systems. Evidence on PRIs remains more limited, particularly in Latin America. This gap is relevant because PRIs differ from higher education institutions in their organizational structure, sources of legitimacy, dependence on public policy priorities, and interaction with sectoral stakeholders. Consequently, frameworks developed for universities may not fully explain productivity determinants in public research organizations [6], [13], [14].

This study analyzes the determinants of scientific productivity in three Peruvian PRIs: IPEN, IGP, and ITP. A mixed-methods multiple case study design was applied, integrating semi-structured interviews, document analysis, thematic coding, ordinal scoring, and cross-case comparison. The analysis distinguishes internal determinants, including human resources, infrastructure, access to databases, organizational governance, and technological adaptability, from external determinants, including funding, cooperation networks, institutional stability, and science and technology policy.

The paper contributes in three specific ways. First, it provides empirical evidence on PRI productivity conditions in a Latin American emerging economy. Second, it proposes an analytical classification of internal and external determinants adapted to organizations that combine research, regulation, technology transfer, and policy support. Third, it derives managerial and policy implications for research careers, funding continuity, cooperation networks, and institutional governance.

The paper is organized as follows. Section II presents the theoretical background. Section III describes the methodology and case selection. Section IV presents the empirical findings. Section V discusses the results in relation to previous literature. Section VI presents managerial and policy implications. Section VII summarizes the conclusions, limitations, and future research directions.

II. Theoretical Background

A. Scientific Productivity and Its Measurement

Scientific productivity refers to the capacity of researchers and research organizations to produce, validate, and disseminate knowledge through outputs recognized by scientific, technological, or policy communities. In Public Research Institutes (PRIs), productivity should not be limited to academic publications, since these organizations usually combine research, technological services, regulation, policy support, and technology transfer [4], [6]. Consequently, productivity assessment in PRIs requires indicators that reflect both scientific output and the institutional mandate of each organization.

The most common indicators include peer-reviewed publications, citation impact, patents, externally funded projects, participation in competitive grants, and collaborative outputs [1], [2]. Bibliometric measures are useful for assessing visibility and publication performance; however, they must be interpreted according to disciplinary differences, institutional missions, and the type of knowledge produced [15]. This consideration is important for PRIs, where research performance may also be expressed through technical reports, monitoring systems, specialized services, technological development, and contributions to public decision-making.

In Latin America, scientific productivity is also affected by unequal access to funding, infrastructure, international collaboration, and scientific databases. RICYT has documented persistent differences in scientific and technological capabilities among countries and institutional types, which limits direct comparison between research organizations [16]. For this reason, bibliometric indicators should be complemented with institutional and contextual variables, particularly when PRIs operate in emerging economies.

B. Determinants of Scientific Productivity

The literature identifies determinants of scientific productivity at the individual, organizational, and systemic levels. This study groups them into internal and external factors. Internal factors include resources, capacities, and management processes mainly controlled by the institution. External factors include conditions related to funding, policy frameworks, collaboration networks, and the national innovation system.

This distinction is relevant for PRIs because their performance depends not only on internal research capacity but also on public funding stability, institutional autonomy, regulatory conditions, and access to national and international cooperation mechanisms [5], [6]. Table I summarizes the factors used in the analytical framework.

TABLE I
Internal and External Factors Affecting Scientific Productivity

Internal Factors	External Factors
Qualified human resources	Access to competitive funding
Physical and digital infrastructure	Participation in collaboration networks
Access to scientific databases and specialized software	National science, technology, and innovation policies
Organizational governance and institutional planning	Institutional stability and leadership continuity
Research incentives, career paths, and evaluation mechanisms	International cooperation and mobility mechanisms

1) Internal Factors: Human capital is a recurrent determinant of scientific productivity. The availability of qualified researchers, doctoral training, accumulated experience, and specialized technical personnel affects the capacity of an institution to formulate research questions, execute projects, publish results, and participate in collaborative networks [7], [14]. However, human capital does not operate independently. Its effect depends on working conditions, research time, incentives, career development, and organizational support [17], [18].

Infrastructure is also central to research performance, particularly in PRIs that depend on laboratories, experimental facilities, monitoring equipment, pilot plants, computational resources, and specialized software. In these organizations, equipment availability and maintenance affect both the volume and continuity of scientific and technological outputs [4], [8]. Access to scientific databases and information systems also matters because it supports literature review, benchmarking, methodological updating, and identification of publication opportunities.

Organizational governance influences productivity through planning routines, internal procedures, evaluation mechanisms, incentives, and coordination between administrative and research units. Studies on research organizations show that institutional design can facilitate or restrict scientific output depending on how resources, responsibilities, and incentives are structured [5], [19], [20]. In PRIs, this factor is especially relevant because researchers often work under public-sector administrative rules that may not be aligned with the timing, uncertainty, and technical requirements of scientific work.

2) External Factors: External factors arise from the institutional and policy environment in which PRIs operate.

Competitive funding, from national or international sources, affects the capacity to acquire equipment, finance fieldwork, hire specialized personnel, and sustain research agendas. Prior studies show that funding influences publication performance, although its effect depends on institutional capacity and incentive design [12], [21], [22]. In public research laboratories, hybrid funding mechanisms may also affect the balance between scientific output, technological services, and mission-oriented activities [23].

Collaboration networks are also associated with scientific productivity. Research collaboration can provide access to complementary knowledge, shared infrastructure, specialized data, advanced methods, and co-authorship opportunities [9], [10]. For PRIs, collaboration is particularly important because their missions often require interaction with universities, government agencies, firms, international organizations, and sectoral stakeholders. Nevertheless, collaboration improves productivity only when it is supported by stable agreements, active research groups, and institutional mechanisms that transform joint work into measurable outputs [11], [24].

Science, technology, and innovation policies provide the framework through which PRIs define priorities, obtain legitimacy, and access public resources. Evaluation systems, researcher certification schemes, national research agendas, procurement rules, and public investment mechanisms shape institutional incentives and accountability [3]. Policy discontinuity, frequent leadership changes, and fragmented governance may weaken long-term research planning and reduce the capacity of PRIs to consolidate scientific trajectories.

C. Integrated Framework

Figure 1 presents the conceptual framework used in this study. The framework assumes that scientific productivity in PRIs results from the interaction between institutional capacities and external conditions. Internal determinants include qualified human resources, infrastructure, access to scientific information, organizational governance, and research incentives. External determinants include funding, cooperation networks, policy frameworks, institutional stability, and international cooperation.

This framework builds on bibliometric and institutional approaches to research productivity [1], [2], [15], organizational analyses of scientific performance [5], [19], [20], and studies on funding and collaboration as determinants of research output [9], [10], [12], [22]. It also incorporates the specific nature of PRIs as public research organizations with hybrid mandates, where scientific output must be interpreted in relation to research, regulation, technology transfer, and policy support functions [6]. This distinction guides the interpretation of the three Peruvian cases analyzed in the following sections.

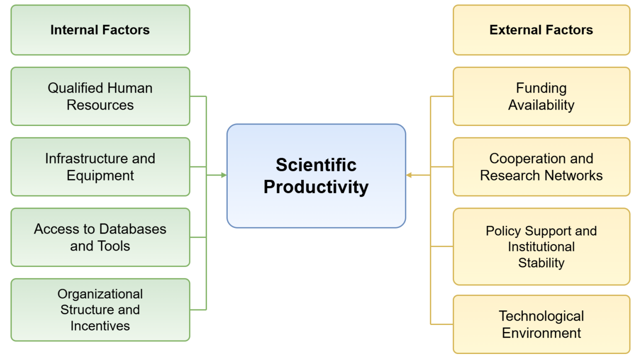

Fig. 1. Conceptual Framework of Internal and External Factors Influencing Scientific Productivity.

III. Methodology

A. Research Approach

This study used a mixed-methods multiple case study design to examine the determinants of scientific productivity in three Peruvian Public Research Institutes (PRIs). The design combines qualitative evidence from interviews and institutional documents with descriptive quantification based on an ordinal scoring procedure. This approach is suitable when the phenomenon under study depends on institutional conditions, organizational processes, and contextual factors that cannot be separated from their setting [25], [26].

The study follows a multiple case logic. Its purpose is not to estimate statistical relationships for the universe of PRIs, but to compare institutional patterns across cases with different scientific domains and public mandates. The integration of qualitative interpretation and structured numerical comparison follows mixed-methods principles, where different forms of evidence are combined to improve analytical consistency [27]. In this study, the qualitative component explains how each determinant operates, while the ordinal scores provide a comparable valuation of its relative influence across cases.

As shown in Fig. 2, the research process included case selection, documentary review, semi-structured interviews, thematic coding, ordinal scoring, cross-case comparison, and synthesis of managerial and policy implications.

B. Case Selection

The selected cases were the Instituto Peruano de Energía Nuclear (IPEN), the Instituto Geofísico del Perú (IGP), and the Instituto Tecnológico de la Producción (ITP). These institutions were selected because they are Peruvian PRIs with consolidated operational trajectories, differentiated scientific domains, and explicit functions related to research, technological development, specialized services, or policy support. The selection also permits comparison among organizations whose missions are not limited to publication activity, which is relevant in the analysis of public research organizations [4], [6]. Table II summarizes the selected cases.

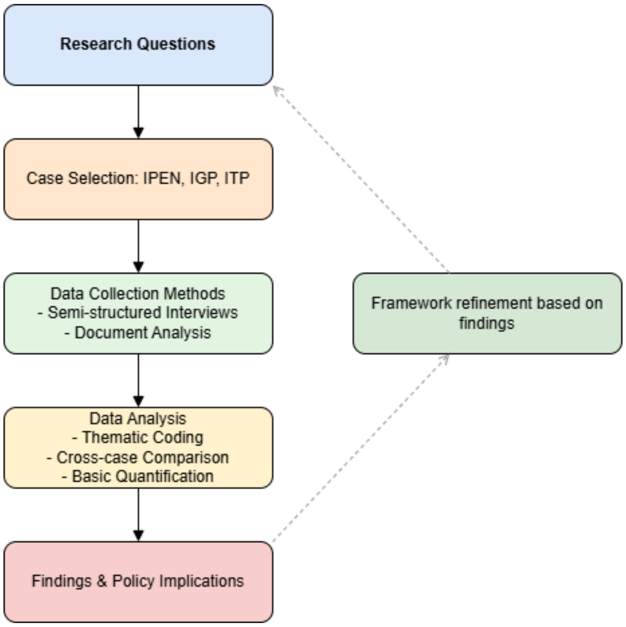

Fig. 2. Research Design: Mixed-Methods and Multiple Case Study Structure.

TABLE II
OVERVIEW OF SELECTED PUBLIC RESEARCH INSTITUTES

Institute	Scientific Domain	Main Functions
IPEN	Nuclear technology	Nuclear research, radiation applications, regulation, technical services, and radioisotope production
IGP	Geophysics	Seismology, geodynamics, atmospheric studies, natural hazard monitoring, and public alerts
ITP	Industrial technology	Productive innovation, technological services, applied research, technology transfer, and support to CITE networks

As shown in Table II, the cases differ in scientific specialization, stakeholder interaction, infrastructure requirements, and relationship with public policy. These differences allow the identification of both common determinants and institution-specific conditions affecting scientific productivity.

C. Data Collection

Two sources of evidence were used: semi-structured interviews and institutional documents. The 15 interviews were distributed across the three institutions and included researchers, managers, and technical personnel involved in research, technical management, institutional planning, or scientific coordination. The interviewees had direct knowledge of research activities and institutional constraints. This selection was intentional and based on the relevance of each participant to the study variables.

The interview protocol was organized around the determinants identified in the theoretical framework: human resources, infrastructure, access to scientific information, organizational governance, technological adaptability, funding, cooperation networks, and science and technology policy. Institutional documents were reviewed to contrast interview evidence with formal information on research activities, projects, organizational functions, cooperation mechanisms, and technological services. Table III presents the evidence sources used, and Table IV summarizes the dimensions explored in the interviews.

TABLE III
DATA SOURCES USED IN THE STUDY

Source	Information Collected	Use in the Analysis
Semi-structured interviews	Perceptions on determinants, institutional constraints, research practices, and enabling conditions	Identification of internal and external factors and construction of qualitative evidence
Institutional documents	Strategic plans, reports, regulations, project information, cooperation records, and organizational descriptions	Triangulation of interview evidence and contextualization of each case
Productivity-related records	Information on publications, projects, technological activities, cooperation mechanisms, and institutional outputs	Complementary evidence for interpreting scientific productivity beyond self-reported assessments

TABLE IV
KEY DIMENSIONS EXPLORED IN SEMI-STRUCTURED INTERVIEWS

Dimension	Examples of Guiding Topics
Human resources	Researcher profiles, specialization, training, incentives, retention, and incorporation of new talent
Infrastructure and equipment	Laboratories, specialized equipment, software, supplies, maintenance, and operational continuity
Access to scientific information	Databases, bibliographic resources, information systems, and access to specialized tools
Organizational governance	Procedures, planning, evaluation mechanisms, research management, and administrative coordination
Funding and budget	Public budget, external funding, competitive grants, international resources, and financial sustainability
Collaboration networks	Scientific networks, interinstitutional agreements, joint projects, mobility, and international cooperation
Science and technology policy	Regulatory framework, institutional stability, national priorities, and public support mechanisms

D. Operationalization of the Scoring Procedure

To compare the cases, qualitative evidence was transformed into an ordinal valuation scale from 1 to 5. The score does not represent a statistical measurement of productivity; rather, it summarizes the perceived and documented influence of each determinant on scientific productivity in each PRI. The score assigned to each factor was based on the convergence between interview statements, documentary evidence, and consistency across respondents. Table V defines the scale used in the analysis.

TABLE V
ORDINAL SCALE USED TO ASSESS THE INFLUENCE OF EACH DETERMINANT

Score	Level of Influence	Operational Interpretation
1	Very low	The factor is present only marginally or shows no clear influence on research activity
2	Low	The factor has limited influence and appears as a secondary condition in the evidence
3	Moderate	The factor influences productivity, but its effect is irregular or depends on other conditions
4	High	The factor is consistently reported as relevant and is supported by institutional evidence
5	Very high	The factor is central to research activity and repeatedly appears as a decisive determinant across evidence sources

The average score for each determinant was calculated from the valuations assigned to its corresponding subdimensions. These averages were used only for descriptive comparison among cases and were interpreted together with the qualitative evidence to avoid a purely numerical reading of institutional performance.

E. Data Analysis Strategy

The analysis followed four steps. First, interviews and documents were reviewed using deductive categories derived from the theoretical framework. These categories corresponded to internal and external determinants of productivity. Second, inductive themes were identified when participants described conditions not fully captured by the initial categories, such as administrative rigidity, delays in procurement, leadership continuity, or mismatch between scientific work and public-sector procedures.

To improve coding consistency, the coding matrix was reviewed against the theoretical framework and documentary evidence before cross-case comparison.

Third, each determinant was assessed using the ordinal scale described in Table V. The scoring process considered the frequency of references, the strength of the statements, and the degree of support found in institutional documents. Fourth, a cross-case comparison was conducted to identify common patterns, differences among institutes, and factors with higher relative influence.

Triangulation was used to reduce dependence on self-reported information. Interview evidence was contrasted with documents and productivity-related records whenever available. This procedure also helped identify discrepancies between formal institutional arrangements and the experience reported by researchers or managers. The analysis therefore combines interpretation, comparison, and descriptive quantification, without treating the scores as independent statistical indicators.

F. Methodological Scope and Limitations

The study provides an institutional comparison of three Peruvian PRIs and offers analytical evidence on the determinants that shape their scientific productivity. However, the findings should be interpreted within the scope of a multiple case study. The results are not intended to be statistically generalizable to all PRIs, but analytically transferable to organizations with similar public research mandates.

A further limitation is that part of the evidence comes from interviews and may reflect institutional perceptions. To address this issue, documentary review, cross-case comparison, and productivity-related information were used as complementary sources. Future research could extend this design by incorporating longitudinal bibliometric data, patent records, project funding series, and regression or correlation analysis between institutional determinants and objective productivity indicators.

IV. RESULTS

A. Internal Factors

The cross-case analysis indicates that scientific productivity in the three PRIs is conditioned by institutional capacities that affect the continuity, quality, and scope of research activity. The ordinal scores reported in this section are interpreted as comparative valuations of influence, based on interview evidence and documentary triangulation, not as direct measurements of productivity.

Among the internal factors, **infrastructure and equipment** obtained the highest average score (4.47/5). This factor includes laboratories, specialized equipment, computing resources, software, supplies, and facilities required for experimental and applied research. Its relevance is consistent with the technical nature of IPEN, IGP, and ITP, whose research activities depend on specialized physical and digital capacities. Infrastructure therefore acts not only as a support condition but also as a restriction when equipment renewal, maintenance, or access to specialized tools is delayed. This pattern is consistent with studies showing that the performance of public research organizations depends on the availability and management of research infrastructure [4], [5].

Qualified human resources also obtained a high average score (4.23/5). The evidence indicates that scientific productivity depends on specialized researchers, accumulated technical experience, and personnel capable of formulating projects, operating equipment, publishing results, and participating in research networks. However, the cases also reveal weaknesses in career development, incentives, training, and mechanisms for incorporating new researchers. Thus, human resources influence productivity not only through academic credentials but also through institutional conditions that allow researchers to sustain scientific work over time [17], [18].

Organizational governance obtained an average score of 4.00/5. Procedures, planning routines, evaluation mechanisms, and coordination between research and administrative units affect the capacity of PRIs to transform resources into scientific outputs. Rigid administrative procedures and weak links between productivity and career progression were identified as constraints. This result is relevant for PRIs because their mandates combine research, regulation, technological services, and policy support, which requires organizational arrangements different from those of universities [6].

Finally, **access to scientific databases and specialized tools** obtained the lowest internal average score (3.97/5), although it remained within the range of high influence. The three cases reported the relevance of bibliographic databases, scientific information systems, statistical software, and specialized computational tools. Limited access to these resources restricts international comparison, methodological updating, and identification of publication opportunities.

B. External Factors

External factors also influenced scientific productivity across the three cases. These factors are not fully controlled by each institution, but they affect resource availability, collaboration opportunities, and continuity of research agendas.

Access to funding obtained an average score of 4.40/5. Funding was reported as necessary for equipment acquisition, fieldwork, laboratory operation, staff training, and participation in research projects. External funding is especially relevant when ordinary public budgets are insufficient or when research activities require specialized inputs. This observation is supported by studies showing that funding mechanisms affect publication performance and research capacity, although their effects depend on institutional conditions and incentive design [12], [22].

Cooperation networks obtained a similar average score (4.37/5). Collaboration with universities, public agencies, international organizations, and specialized research networks facilitates access to data, equipment, methods, and co-produced outputs. For PRIs, cooperation is relevant because their scientific work is linked to public problems, sectoral needs, and technological services. This interpretation aligns with evidence showing that collaboration can increase scientific productivity when it is supported by stable institutional arrangements and active research groups [9]–[11].

National policy support obtained an average score of 4.13/5. The cases show that science and technology policies, researcher evaluation systems, public funding instruments, and institutional stability influence research continuity. IGP appears to benefit from stronger alignment with national disaster risk management priorities, while IPEN and ITP report greater exposure to changing mandates, administrative discontinuity, and uneven resource flows. These differences suggest that policy coherence and leadership continuity affect the capacity of PRIs to sustain research agendas.

Technological adaptability obtained an average score of 4.03/5. This factor refers to the capacity of each institution to respond to scientific and technological change through updated equipment, methods, information systems, and technical capabilities. The evidence indicates that technological change creates research opportunities, but these opportunities are not immediate. They require financial resources, specialized personnel, acquisition processes, and organizational readiness.

C. Cross-Case Summary

Table VI summarizes the average influence of the eight factors analyzed across IPEN, IGP, and ITP. The highest average values correspond to infrastructure, funding, and cooperation networks. The evidence indicates that scientific productivity in PRIs depends on the interaction between internal research capacity and external support conditions.

TABLE VI
CROSS-CASE ANALYSIS OF FACTORS INFLUENCING SCIENTIFIC PRODUCTIVITY

Factor	**IPEN**	**IGP**	**ITP**	**Avg.**
Qualified human resources	4.50	4.00	4.20	4.23
Infrastructure and equipment	4.70	4.20	4.50	4.47
Access to databases and tools	3.80	4.10	4.00	3.97
Organizational governance	3.90	4.00	4.10	4.00
Access to funding	4.30	4.50	4.40	4.40
Cooperation networks	4.20	4.60	4.30	4.37
National policy support	4.00	4.30	4.10	4.13
Technological adaptability	3.90	4.20	4.00	4.03

Figure 3 provides a graphical representation of the cross-case comparison. The radar chart shows that IPEN has a higher valuation in infrastructure, IGP in cooperation networks and policy support, and ITP a more balanced profile across the analyzed factors.

V. DISCUSSION

The evidence indicates that scientific productivity in PRIs cannot be explained only by the availability of researchers or by publication incentives. The three cases show that productivity depends on the combined effect of internal capacities and external conditions. Infrastructure, human resources, governance, funding, cooperation networks, and policy stability operate together and affect the capacity of each institution to sustain research activity.

The relevance of infrastructure reflects the technical nature of the analyzed PRIs. IPEN, IGP, and ITP require laboratories, equipment, software, monitoring systems, and specialized inputs to produce scientific or technological outputs. This result differs from studies focused mainly on universities, where publication activity may depend more directly on individual academic incentives. In PRIs, the absence or deterioration of

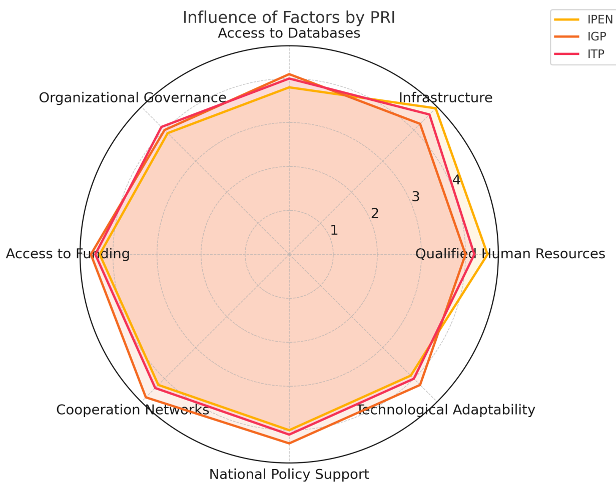

Fig. 3. Radar chart showing the average influence of internal and external factors across IPEN, IGP, and ITP.

equipment can interrupt research processes, limit experimentation, and reduce the generation of publishable results. This interpretation is consistent with research on public laboratories and research organizations, where infrastructure and organizational conditions influence scientific performance [4], [5].

Human resources also appear as a central determinant, but their effect is mediated by institutional conditions. Specialized researchers are necessary, but productivity is reduced when incentives are weak, career paths are limited, training is insufficient, or recruitment of new talent is difficult. This finding supports previous studies that associate research output with both individual capacity and organizational context [17], [18], [20]. Therefore, strengthening scientific productivity requires not only hiring qualified personnel but also creating conditions for researchers to remain, collaborate, and develop long-term research agendas.

The cases also show that external funding is not merely complementary. In the three cases, funding influences equipment acquisition, project continuity, collaboration, and access to specialized resources. This is particularly important in public research organizations with limited ordinary budgets. However, the effect of funding depends on the institutional capacity to formulate projects, manage resources, comply with administrative requirements, and convert financial support into measurable outputs. This finding is consistent with evidence that funding can improve research productivity when it interacts with adequate organizational capabilities [12], [22].

Cooperation networks constitute another relevant determinant. The cases suggest that collaboration expands access to knowledge, data, methods, infrastructure, and publication opportunities. Nevertheless, cooperation does not automatically translate into productivity. Its effect depends on formal agreements, active research groups, continuity of relationships, and internal capacity to participate in joint projects. This is aligned with studies indicating that collaboration contributes to scientific productivity when it is embedded in stable research practices and institutional arrangements [9]–[11].

Policy support and institutional stability help explain differences among cases. IGP appears to benefit from a clearer connection with national disaster risk management priorities, which gives its research activity greater public relevance and continuity. By contrast, IPEN and ITP face more visible constraints related to changing priorities, administrative discontinuity, and fragmented institutional support. This suggests that PRI productivity is affected by policy coherence and by the degree to which national science and technology frameworks provide stable incentives, resources, and legitimacy.

Overall, the results support an integrated interpretation of PRI productivity. Internal factors determine the capacity to conduct research, while external factors define the conditions under which research agendas can be financed, connected, and sustained. Improvements in scientific productivity should therefore not be limited to publication incentives. They should include research career systems, equipment renewal, access to scientific information, stable funding instruments, cooperation mechanisms, and governance arrangements adapted to the specific mandates of PRIs.

From a managerial and policy perspective, four implications arise from the analysis. First, PRIs require career and incentive systems that recognize scientific production, technological development, and policy-oriented outputs. Second, infrastructure and equipment investment should be linked to long-term research agendas rather than isolated procurement decisions. Third, cooperation networks should be managed institutionally, not only through individual researchers. Fourth, national science and technology policy should reduce discontinuity in funding, leadership, and administrative rules that affect research continuity.

These findings contribute to the analysis of public research organizations in emerging economies by showing that scientific productivity depends on institutional capacity and systemic stability. The Peruvian cases suggest that PRIs require governance mechanisms suited to hybrid mandates, where research, technological services, regulation, and public policy support coexist within the same organization.

VI. Managerial and Policy Implications

The evidence suggests that PRI productivity depends on conditions located at two levels. Some are managed within each institution, such as infrastructure, qualified personnel, governance, and access to scientific information. Others depend on the science and technology system, including funding instruments, cooperation networks, public policy priorities, and institutional stability. For this reason, improvement measures require both internal management decisions and policy instruments adapted to public research organizations.

A. Implications for PRI Managers

PRI managers should prioritize the conditions that sustain research activity over time. The cross-case analysis indicates that infrastructure and equipment obtained the highest internal valuation, which is consistent with the technical profile of IPEN, IGP, and ITP. In these institutions, laboratories, monitoring systems, specialized equipment, software, and supplies are not auxiliary inputs; they constitute the operational base of scientific work. Investment decisions should therefore be linked to research agendas, maintenance plans, and expected scientific or technological outputs, rather than to isolated procurement processes [4], [5].

Human resources require the same level of attention. Specialized researchers and technical personnel are necessary for project formulation, experimentation, publication, and participation in cooperation networks. However, the cases also show weaknesses in incentives, training, career development, and recruitment of new researchers. PRI managers should strengthen career paths, establish transparent promotion criteria, and recognize different forms of output, including indexed publications, patents, technological services, research projects, technical reports, and policy-oriented contributions [17], [18].

The results also indicate that cooperation networks should be managed as institutional assets, not only as individual initiatives. Agreements with universities, public agencies, firms, and international research centers can improve access to data, equipment, methods, and co-authored outputs. Nevertheless, collaboration contributes to productivity only when it is supported by active research groups, formal coordination mechanisms, and monitoring of joint results [9]–[11]. Table VII summarizes the main institutional and policy actions derived from the analysis.

B. Implications for Policymakers

At the policy level, the analysis supports the need for stable funding instruments adapted to the operational conditions of PRIs. Short-term grants and irregular budget flows limit the continuity of research agendas, especially in institutions that require specialized equipment, fieldwork, laboratory inputs, and highly qualified personnel. Prior studies indicate that the effect of funding on productivity depends on continuity, incentive design, and the capacity of organizations to transform resources into outputs [12], [22].

Public policy should also recognize the hybrid mandate of PRIs. Unlike universities, these organizations combine scientific research with regulation, technological services, monitoring systems, technology transfer, and policy support. Evaluation frameworks should therefore include bibliometric indicators but also consider technological, institutional, and public-service outputs [6]. A narrow focus on publications may underestimate the contribution of PRIs to national innovation systems.

Policy support is also needed to reduce institutional discontinuity. Frequent leadership changes, fragmented mandates, and unstable public priorities affect the capacity of PRIs to consolidate research programs. National science and technology policy should establish mechanisms for leadership continuity, medium-term research programming, and predictable resource allocation. These measures are consistent with broader recommendations on public-sector performance and institutional capacity in science and innovation systems [28], [29].

TABLE VII
RECOMMENDATIONS FOR INSTITUTIONAL AND POLICY ACTION

PRI Managers	Policymakers
Link infrastructure and equipment investment to long-term research agendas	Establish stable and multiannual R&D funding instruments
Strengthen research career paths, incentives, training, and retention mechanisms	Create national frameworks for research careers in public research organizations
Manage cooperation networks through formal mechanisms and measurable outputs	Promote international cooperation, scientific mobility, and science diplomacy instruments
Ensure access to scientific databases, specialized software, and computational tools	Finance shared access to databases, laboratories, and digital research infrastructure
Align internal governance with the timing and uncertainty of scientific work	Reduce policy discontinuity and strengthen medium-term research planning

C. Link to Sustainable Development Goals and Innovation Agendas

The productivity of PRIs contributes to national development through applied research, technological services, monitoring systems, and policy-relevant knowledge, not only through publications. In Peru, strengthening PRIs is related to the National Policy on Science, Technology, and Technological Innovation, particularly in institutional capacity, research quality, technology transfer, and coordination within the national innovation system [30].

These implications are also consistent with the United Nations 2030 Agenda for Sustainable Development. Depending on their sectoral mandate, PRIs can contribute to quality education, industrial innovation, resilient infrastructure, risk reduction, and stronger institutions. This contribution requires stable financing, qualified personnel, institutional continuity, and mechanisms that connect scientific outputs with social, productive, and policy needs [29], [31].

VII. Conclusion and Future Work

A. Main Contributions

This study examined the internal and external determinants of scientific productivity in three Peruvian Public Research

Institutes: IPEN, IGP, and ITP. The research applied a mixed-methods multiple case study design that combined semi-structured interviews, documentary analysis, thematic coding, ordinal scoring, and cross-case comparison.

The analysis suggests that scientific productivity in PRIs is shaped by the interaction between institutional capacities and external conditions. Internally, infrastructure and equipment, qualified human resources, organizational governance, and access to scientific information affect the continuity and quality of research activity. Externally, funding, cooperation networks, policy support, institutional stability, and technological adaptability influence the capacity of PRIs to sustain and expand scientific output.

The study contributes to the literature in three ways. First, it provides empirical evidence on public research organizations in a Latin American emerging economy, a context still less represented in studies on scientific productivity. Second, it proposes an analytical classification of internal and external determinants adapted to PRIs with hybrid mandates. Third, it derives managerial and policy implications for research careers, funding continuity, cooperation networks, and governance mechanisms in public research organizations [4]–[6].

B. Limitations

The study has limitations that should be considered when interpreting the results. First, the analysis is based on three Peruvian PRIs, which limits statistical generalization. The cases were selected because of their relevance, differentiated scientific domains, and public research mandates; therefore, the findings are analytically transferable rather than statistically representative.

Second, the scoring procedure is ordinal and descriptive. The scores summarize the perceived and documented influence of each determinant, but they do not measure productivity directly. For this reason, the numerical results were interpreted together with interview evidence and institutional documents.

Third, part of the evidence comes from interviews with researchers, managers, and technical personnel. Although documentary triangulation was used to reduce self-reporting bias, institutional perceptions may still affect the assessment of some factors. Finally, the study provides a cross-sectional view of institutional conditions and does not capture long-term changes in productivity, funding, governance, or research trajectories.

C. Future Research Directions

Future research should extend the analysis in four directions. First, longitudinal studies could examine how institutional reforms, leadership changes, funding cycles, and research policies affect PRI productivity over time. Second, cross-country comparisons could determine whether the patterns identified in Peru are also observed in other Latin American or emerging economies.

Third, future studies should incorporate objective productivity indicators, including indexed publications, citations, patents, research grants, technological services, technical reports, and policy outputs. These indicators would allow a more precise analysis of the relationship between institutional determinants and measurable results. Fourth, quantitative models could be developed using bibliometric databases, budgetary information, human resource indicators, and collaboration data to test associations between determinants and outputs. Table VIII summarizes these future research directions.

TABLE VIII
SUGGESTED DIRECTIONS FOR FUTURE RESEARCH

Research Direction	**Expected Contribution**
Longitudinal analysis	Evaluate the effect of institutional reforms, leadership continuity, and funding cycles on scientific productivity
Cross-country comparison	Identify whether PRI productivity determinants are context-specific or common across emerging economies
Objective output indicators	Complement perception-based analysis with publications, citations, patents, grants, technical reports, and technological outputs
Quantitative modeling	Estimate associations between productivity determinants and measurable research outputs using bibliometric, budgetary, and HR data
Policy evaluation	Assess the effectiveness of funding instruments, researcher evaluation systems, and cooperation programs for PRIs

Overall, the evidence indicates that improving PRI productivity requires more than publication incentives. It requires institutional arrangements that support research careers, sustained infrastructure investment, access to scientific information, stable funding, cooperation networks, and policy frameworks adapted to the hybrid functions of public research organizations.

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