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A Multidimensional Assessment of Scientific Empowerment among Women Researchers in Peru

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Abstract

Women's participation in higher education and scientific research has increased globally; however, educational attainment and research participation do not necessarily translate into equivalent levels of scientific recognition, institutional positioning, or leadership. This study examined the empirical structure of scientific empowerment among women researchers in Peru and developed a composite index based on that structure. A quantitative, non-experimental, cross-sectional study was conducted with 156 women researchers registered in Peru's National Registry of Researchers in Science, Technology and Innovation (RENACYT). Scientific trajectories were operationalized through 12 objective subdimensions covering academic capital, scientific production and impact, research participation, editorial activity, institutional positioning, leadership, recognition, and innovation. Exploratory factor analysis was performed using minimum residual extraction and oblimin rotation. The data showed adequate factorability (KMO = 0.823; Bartlett's test, $p < 0.001$). A three-factor solution was retained based on factor-retention evidence, interpretability, parsimony, loading patterns, and conceptual coherence. The resulting dimensions represented (1) participation and research trajectory, (2) scientific production and impact, and (3) scientific positioning and research capacity. These dimensions were positively associated but were not redundant. A Global Scientific Empowerment Index was subsequently constructed as the mean of their standardized scores. The findings suggest that the observable and institutionally situated dimension of scientific empowerment examined here is multidimensional and cannot be adequately represented by academic credentials or scientific output alone. The study provides an empirically informed framework for examining how participation, production, recognition, professional positioning, and research capacity are organized within a formally recognized national research system.

1 Introduction

Gender inequalities in academic science remain evident across research production, citation impact, authorship, recognition, and access to positions associated with greater scientific visibility and institutional authority [1, 2]. Although women's participation in higher education and research has expanded substantially, these gains have not translated uniformly into scientific careers or into proportional representation in positions of leadership and decision-making [3–6]. This distinction is particularly relevant when scientific careers are examined beyond participation rates and educational credentials, because advancement within research systems depends on the accumulation and activation of multiple forms of scientific, institutional, and relational resources.

The relationship between gender and scientific evaluation also requires contextual consideration. Bibliometric indicators and other formal performance measures do not operate independently of disciplinary and institutional environments, and evidence suggests that their relationship with peer assessment may vary across fields and gender groups [7]. Consequently, measures of scientific career should not be interpreted simply as neutral representations of individual merit. They are embedded within institutional systems that determine which activities become visible, which achievements receive recognition, and which forms of participation facilitate further opportunities.

These issues are particularly relevant in scientific systems where women may attain high levels of formal education and participate actively in research while remaining less represented in positions associated with institutional authority and recognition. Evidence from Latin America and other contexts of the Global South indicates that gender inequalities persist across different stages of academic and scientific careers, including access to resources, recognition, leadership, and institutional decision-making [8–10]. Thus, increasing women's educational attainment is an important component of gender equity but does not, by itself, explain how scientific careers become sustained, visible, and institutionally influential.

Peru provides a relevant setting for examining these processes. In 2023, women represented approximately 31.9% of researchers registered in the National Registry of Researchers in Science, Technology and Innovation (RENACYT), compared with 68.1% of men [11]. Gender disparities are also evident in university governance. According to the Fourth Biennial Report on the State of Higher Education in Peru, women represented 31.8% of deans or equivalent academic

coordinators and 19.7% of university rectors or presidents in 2022 [12]. These figures suggest that women's participation in higher education and research should be examined together with the forms of recognition, positioning, and institutional authority that characterize scientific careers.

Educational credentials, however, should not be interpreted as equivalent to scientific empowerment. While academic qualifications may provide resources for entering research careers, they do not necessarily determine access to research opportunities, scientific communities, recognition, leadership, or institutional visibility. This distinction is consistent with feminist conceptualizations of empowerment, which emphasize that empowerment involves transformations in the capacity to access resources, exercise agency, and achieve valued outcomes within specific structural conditions [13–15]. From this perspective, empowerment is not simply an accumulation of individual attributes. It concerns the capacity to mobilize resources and act within institutional and social structures that may facilitate or constrain the conversion of resources into outcomes.

Within academic science, this perspective can be complemented by Bourdieu's conceptualization of scientific and symbolic capital [16]. Scientific positions are shaped not only by individual qualifications but also by the distribution and recognition of different forms of capital within a structured field. Participation in scientific communities, access to research projects, publication and editorial activity, recognition, leadership, innovation, and institutional positioning may therefore represent interconnected but distinct aspects of scientific trajectory. These dimensions may develop at different rates and need not constitute interchangeable manifestations of a single underlying attribute.

The concept of scientific empowerment adopted in this study therefore refers to a multidimensional configuration of resources, participation, achievements, recognition, and positioning that enables women researchers to develop and sustain scientific trajectories within an institutionalized research system. This definition is deliberately broader than publication performance. It recognizes that scientific careers involve both measurable outputs and opportunities to participate in the institutional and relational processes through which scientific activity becomes visible and valued.

The Peruvian RENACYT system provides a particularly useful institutional context for examining this configuration. The registry constitutes a formal institutional mechanism for recognizing researchers according to multiple criteria related to academic qualifications, scientific publications, intellectual property, books, funded projects, thesis supervision, and other research activities [17]. Consequently, studying women already incorporated into RENACYT makes it possible to move beyond the question of women's representation in science and examine variation in their scientific trajectories within a formally recognized research population.

The initial conceptual framework for this study was informed by the Institutionalized Research Empowerment Model (IREM), which organized scientific empowerment around active scientific visibility, operational research leadership, and institutional recognition. The model integrated the resource–agency–achievement perspective [14] with the concept of scientific capital [16] and emphasized the role of institutional structures. In the present study, however, the framework was treated as a theoretical starting point rather than an empirically established measurement structure. Its dimensions were used to guide the initial organization of the indicators, while the empirical structure was examined independently.

Despite extensive literature on gender inequalities in science, comparatively less attention has been given to the joint empirical organization of objective indicators of scientific trajectory among women who have already achieved formal recognition within a national research system. In particular, it remains unclear whether dimensions associated conceptually with academic capital, research participation, scientific production, recognition, leadership, and institutional positioning remain empirically distinct or instead form broader configurations of scientific career.

This study therefore aimed to examine the empirical structure of scientific empowerment among women researchers in Peru and to construct a composite index based on that structure. Specifically, the study sought to: (1) examine the empirical organization of objective indicators of scientific trajectory; (2) identify the resulting dimensions; (3) compare the empirical

structure with the original theoretically informed framework; and (4) construct a Global Scientific Empowerment Index (GSEI) from the empirically derived dimensions.

The study does not claim that objective indicators fully capture empowerment as theorized in feminist scholarship. Accordingly, the construct examined here should be interpreted as an institutionalized and observable dimension of scientific empowerment, reflecting the accumulation and activation of scientific, organizational, and recognition-related resources within a formal research system rather than a comprehensive measure of subjective empowerment or perceived agency.

Rather than testing a previously specified measurement model, the study adopts an exploratory approach appropriate for examining a multidimensional and institutionally situated construct. This approach allows the analysis to address an important distinction in the study of women in science: educational attainment, scientific participation, recognition, and professional positioning may be related without being equivalent. Examining how these components are empirically organized provides a more nuanced basis for understanding scientific empowerment within higher education and national research systems.

2 Methods

2.1 Study design and participants

A quantitative, non-experimental, cross-sectional design was used to examine the empirical organization of scientific empowerment among women researchers in Peru.

The study focused on women researchers registered in the RENACYT, Peru's national researcher recognition system, administered by the National Council for Science, Technology and Technological Innovation (CONCYTEC) [17].

The initial database contained 158 records. During data screening, two duplicate questionnaire records were identified and removed, resulting in a final analytical sample of 156 women researchers (N = 156). Participants were recruited through non-probability voluntary participation among eligible researchers. It was therefore analyzed as a group of women researchers with formally recognized scientific trajectories rather than as a probabilistic sample representative of all women researchers in Peru.

The analytical objective was not to compare women and men researchers, but to examine heterogeneity in scientific trajectories among women researchers who had already achieved formal recognition within the national research system RENACYT. Accordingly, the study focuses on how different forms of scientific participation, production, recognition, and institutional positioning are organized within this population.

2.2 Conceptual framework and operationalization

The conceptual framework was informed by feminist approaches and scientific capital theory [13–16]. These perspectives suggest that access to resources and the capacity to translate them into valued outcomes are shaped by institutional and relational structures rather than by individual qualifications alone.

The initial theoretical framework distinguished four dimensions:

1. academic capital and institutional positioning;
2. participation and research trajectory;
3. scientific production, impact, and innovation; and
4. recognition and incentives.

These dimensions were used to organize the initial measurement framework, and they were not treated as empirically validated latent factors. The purpose of the subsequent exploratory analysis was precisely to examine whether the theoretically organized components would remain empirically distinct or would form broader dimensions within the study population.

The original questionnaire comprised fields covering academic qualifications, research production, scientific visibility, participation in scientific events, institutional leadership, research projects, recognition, and incentives. During data preparation, redundant dichotomous indicators were excluded when an equivalent frequency measure was available, while open-ended fields and categorical variables not incorporated into the analytical model were also excluded.

The retained indicators were organized into 12 analytical subdimensions: academic capital, scientific impact, scientific production, editorial activity, participation in scientific events, academic production, competitive research projects, institutional research projects, scientific recognition, institutional hierarchy, research leadership, and innovation. For each subdimension, the corresponding indicators were coded consistently and combined using an arithmetic mean. A summary of their operationalization and correspondence with the empirical factor structure is provided in Supplementary Table S1. The complete item-level traceability file, including questionnaire fields, coding procedures, indicator retention, exclusions, and aggregation details, is available from the corresponding author upon reasonable request.

The resulting subdimensions constituted the analytical variables submitted to exploratory factor analysis. This level of aggregation was selected because the original indicators represented conceptually related manifestations of broader domains of scientific activity and were measured on heterogeneous scales. Aggregating them into theoretically defined subdimensions before factor extraction therefore provided a consistent analytical unit while retaining the multidimensional character of the construct.

2.3 Data screening and preparation

Data screening included a review of categorical and count variables to identify coding inconsistencies and redundant indicators. The resulting analytical matrix contained complete data for all variables included in the exploratory factor analysis.

2.4 Exploratory factor analysis

An exploratory factor analysis (EFA) was conducted to examine the empirical organization of the 12 analytical subdimensions. EFA was preferred over principal component analysis (PCA) because the objective was to examine the empirical organization of broader dimensions of scientific trajectory rather than to derive components optimized primarily for data reduction. Factorability was assessed using the Kaiser–Meyer–Olkin (KMO) measure, Bartlett's test of sphericity, and individual measures of sampling adequacy. Factor extraction was performed using minimum residual (MINRES) estimation with oblimin rotation, given the expectation that the resulting dimensions would be related.

Alternative factor-retention approaches were considered, including parallel analysis, eigenvalue-based criteria, and fixed-factor solutions. The theoretically specified four-factor structure was examined as a fixed-factor solution, while three-factor solutions were also evaluated in greater detail. Factor retention was determined from the convergence of factor-retention evidence, loading patterns, factor correlations, interpretability, conceptual coherence, and parsimony rather than from a single statistical criterion.

2.5 Construction of empirical dimensions

Composite scores were calculated for each retained empirical dimension by averaging the subdimensions assigned to that factor. Primary loadings were used to define the empirical dimensions, while secondary loadings were considered when evaluating factor coherence.

The resulting empirical structure differed from the original four-dimensional framework.

2.6 Correspondence between theoretical and empirical structures

Pearson and Spearman correlations were used to examine correspondence between the theoretical and empirical composite dimensions. Because both constructions shared component indicators, the resulting correlations were interpreted descriptively rather than as independent evidence of construct validity.

2.7 Global Scientific Empowerment Index

A Global Scientific Empowerment Index (GSEI) was constructed from the three empirically derived dimensions. Each dimension was standardized using a z-score, and the GSEI was calculated as the arithmetic mean of the three standardized dimension scores:

$$GSEI = \frac{Z_{F1} + Z_{F2} + Z_{F3}}{3}$$

Equal weighting was adopted because the three empirical dimensions were considered conceptually important components of scientific empowerment and no theoretical or empirical justification existed for assigning greater importance to any individual dimension.

This distinction is important because the three dimensions represent differentiated aspects of scientific trajectory and were constructed from objective indicators. Internal consistency was consequently not used as a criterion for retaining or removing dimensions.

2.8 Ethical considerations

Participation was voluntary, and the information collected was treated confidentially and used exclusively for research purposes.

3 Results

3.1 Descriptive characteristics

All 12 subdimensions had complete data for the 156 participants. Descriptive statistics for the three empirical dimensions are reported after the factor structure has been established.

3.2 Suitability for exploratory factor analysis

The 12-subdimension correlation matrix showed adequate factorability (KMO = 0.823). Bartlett's test of sphericity was significant, $\chi^2(66) = 496.0$, $p < .001$, and individual measures of sampling adequacy ranged from 0.719 to 0.899. These results supported proceeding with EFA. Results are shown in Table 1.

3.3 Comparison of factor-retention solutions

Alternative factor-retention procedures were examined before selecting the final empirical structure, including parallel analysis, eigenvalue-based criteria, and fixed-factor solutions. Particular attention was given to three- and four-factor solutions.

The four-factor solution showed strong statistical adequacy, $\chi^2(24) = 23.7$, $p = .480$, RMSEA = 0.00, 90% CI [0.00, 0.064], and TLI = 1.00. However, its substantive structure was fragmented. Scientific production showed an exceptionally high loading on one factor (0.996), while editorial activity largely defined another factor (0.868). A fourth factor combined institutional hierarchy, research leadership, and academic capital, together with a negative loading for scientific impact. This factor showed weak correlations with the other three factors (r = .098, − .138, and − .028), limiting its conceptual breadth and interpretability.

The three-factor solution provided a broader and more coherent organization of the 12 subdimensions. It accounted for 41.6% of the common variance, with F1 accounting for 16.8%, F2 for 13.7%, and F3 for 11.1%. The factors were positively correlated: r = .448 between F1 and F2, r = .455 between F1 and F3, and r = .164 between F2 and F3.

The proportion of explained common variance was moderate, consistent with the multidimensional nature of the indicators, which represented distinct aspects of scientific trajectories rather than highly homogeneous manifestations of a single construct.

The three-factor solution was therefore retained on the basis of the combined evidence from factor-retention procedures, loading patterns, factor correlations, interpretability, conceptual coherence, and parsimony rather than on the basis of a single statistical criterion.

Table 1
Adequacy of the data for exploratory factor analysis

Measure	Result
Sample size	156
Number of subdimensions	12
Overall KMO	0.823
Bartlett's χ^2	496.0
df	66
p	< .001
Extraction	MINRES
Rotation	Oblimin

Note. KMO = Kaiser–Meyer–Olkin measure of sampling adequacy; MINRES = minimum residuals.

3.4 Empirical three-factor structure

The retained solution reorganized the 12 subdimensions into three empirically interpretable domains.

F1. Participation and research trajectory was defined by institutional research projects (loading = .645), competitive research projects (.571), scientific recognition (.568), academic production (.519), and participation in scientific events (.444).

F2. Scientific production and impact was defined primarily by scientific impact (.872), scientific production (.615), and editorial activity (.419).

F3. Scientific positioning and research capacity was defined by institutional hierarchy (.490), research leadership (.466), innovation (.398), and academic capital (.397).

Although some loadings within F3 were moderate, the indicators formed a conceptually coherent domain centered on institutional positioning, research leadership, innovation, and accumulated academic capital. For this reason, the factor was retained despite the heterogeneous nature of its constituent indicators.

Some subdimensions also presented secondary loadings, particularly scientific production, editorial activity, and research leadership (Table 2). These cross-loadings were retained because the primary loading remained interpretable and the overall factor structure showed sufficient conceptual coherence.

3.5 Correspondence between theoretical and empirical structures

The correspondence between the original theoretical dimensions and the three-factor empirical solution was examined using Pearson and Spearman correlations between the corresponding composite scores. These coefficients were used to describe the degree of alignment between the conceptual and empirical structures rather than as an independent test of construct validity, because the theoretical and empirical composites were derived from overlapping subdimensions.

The strongest correspondence was observed between academic capital and institutional positioning (D1) and the third empirical dimension, scientific positioning and research capacity (F3; Pearson r = .893; Spearman ρ = .896). The second theoretical dimension, participation and research trajectory (D2), showed a particularly strong correspondence with F1 (r = .968; ρ = .953). Similarly, the third theoretical dimension, scientific production, impact and innovation (D3), was most closely associated with F2 (r = .939; ρ = .926).

The fourth theoretical dimension, recognition and incentives (D4), did not show a comparable correspondence with a distinct empirical factor. Its strongest association was with F1 (r = .583; ρ = .556), where scientific recognition was incorporated alongside research projects, academic production, and participation in scientific events.

Table 2
Exploratory factor loadings of the 12 subdimensions

Subdimension	F1	F2	F3	Uniqueness
Institutional research projects	.645	—	—	.593
Competitive research projects	.571	—	—	.631
Scientific recognition	.568	—	—	.599
Academic production	.519	—	—	.562
Scientific events	.444	—	—	.493
Scientific impact	—	.872	—	.182
Scientific production	—	.615	**.320**	.527
Editorial activity	—	.419	**.348**	.536
Institutional hierarchy	—	—	.490	.660
Research leadership	**.303**	—	.466	.588
Innovation	—	—	.398	.822
Academic capital	—	—	.397	.814

Note. Extraction method: minimum residuals (MINRES); rotation: oblimin.

Overall, the results indicate substantial correspondence alongside empirical reorganization, while also showing that the original four-domain organization was reorganized into three related empirical dimensions. In particular, recognition and incentives did not remain empirically distinct, whereas academic capital became integrated with institutional positioning, research leadership, and innovation.

The magnitude of these correlations should be interpreted in light of the shared indicator composition of the theoretical and empirical composites. Consequently, they primarily reflect structural overlap between alternative composite constructions rather than independent evidence of construct validity.

Table 3 shows the correspondence between theoretical and empirical composite dimensions.

3.6 Composite empirical dimensions

Composite scores for the three empirical dimensions were calculated as the arithmetic mean of their respective subdimensions.

F1 had a mean of 1.05 (median = 0.99, SD = 0.48), with scores ranging from 0.20 to 2.57. F2 had a mean of 0.88 (median = 0.83, SD = 0.41), with scores ranging from 0.19 to 2.42. F3 had a mean of 0.53 (median = 0.53, SD = 0.22), with scores ranging from 0.00 to 1.31.

Table 3
Correspondence between theoretical and empirical composite dimensions

Theoretical dimension	F1	F2	F3
D1. Academic capital and institutional positioning	.346	.177	.893
D2. Participation and research trajectory	.968	.464	.537
D3. Production, impact and innovation	.663	.939	.399
D4. Recognition and incentives	.583	.425	.244

Note. Values are Pearson correlations. All reported correlations were statistically significant at p < .05. Spearman correlations showed the same overall pattern: D1–F3 = .896, D2–F1 = .953, D3–F2 = .926, and D4–F1 = .556. Because the theoretical and empirical composites share component indicators, these correlations represent correspondence between composite constructions and should not be interpreted as independent validation coefficients.

The three empirical dimensions were positively associated. Pearson correlations were .509 between F1 and F2, .472 between F1 and F3, and .276 between F2 and F3 (all p < .001). Spearman correlations were .447, .405, and .230, respectively, with the latter association remaining statistically significant (p = .004). The pattern indicates that the three dimensions were related while retaining empirical differentiation.

The descriptive results are shown in Table 4.

3.7 Global Scientific Empowerment Index

For the 156 researchers, the GSEI had a mean of approximately zero (M = 0.000), a median of − 0.105, and an SD of 0.783. Scores ranged from − 1.51 to 2.99. The distribution showed moderate positive skewness (0.982) and kurtosis (1.78).

The standard deviation below one is consistent with averaging three standardized but correlated dimensions rather than standardizing the resulting composite again.

The GSEI was strongly associated with each of its component dimensions: r = .844 with F1, r = .760 with F2, and r = .744 with F3 (all p < .001). These correlations are expected because the GSEI is mathematically derived from the three component dimensions and therefore do not constitute independent evidence of construct validity.

Descriptive statistics of the Global Scientific Empowerment Index are shown in Table 5.

Table 4
Descriptive statistics of the empirical dimensions

Dimension	M	Median	SD	Min	Max
F1. Participation and research trajectory	1.05	0.99	0.48	0.20	2.57
F2. Scientific production and impact	0.88	0.83	0.41	0.19	2.42
F3. Scientific positioning and research capacity	0.53	0.53	0.22	0.00	1.31

Table 5
Descriptive statistics of the Global Scientific Empowerment Index

Statistic	GSEI
N	156
Mean	0.000
Median	−0.105
SD	0.783
Minimum	−1.51
Maximum	2.99
Skewness	0.982
Kurtosis	1.78

3.8 Supplementary internal consistency analysis

As a supplementary analysis, Cronbach's alpha and McDonald's omega were calculated. Cronbach's alpha was 0.658 and McDonald's omega was 0.715. These coefficients were not used as criteria for removing any dimension. The relatively modest alpha coefficient was considered in light of the multidimensional and objective nature of the index: the three empirical components represent differentiated aspects of scientific trajectory and were not designed as interchangeable reflective indicators of a single latent trait. The three-factor structure was therefore retained on the basis of its empirical organization, conceptual coherence, and parsimony rather than on the basis of maximizing internal consistency.

4 Discussion

This study examined the empirical organization of scientific empowerment among women researchers formally recognized within Peru's national research system. Rather than testing a previously established measurement model, the analysis explored how objective indicators of scientific trajectories were organized among 156 women researchers registered in RENACYT. The main finding was that the initial four-domain conceptual framework was reorganized into three related empirical dimensions: participation and research trajectory, scientific production and impact, and scientific positioning and research capacity. The correspondence between the theoretical and empirical structures was substantial, but recognition did not remain as a separate domain and academic capital did not emerge independently from institutional positioning and research capacity.

This pattern is relevant because the study does not examine entry into science or differences between women and men. All participants had already crossed institutional thresholds associated with formal recognition as researchers. The analysis therefore captures heterogeneity within an already recognized population. In this context, scientific empowerment is better understood as a multidimensional configuration of resources, participation, achievements, recognition, and positioning rather than as a single attribute that increases uniformly with educational attainment or scientific productivity.

4.1 From academic credentials to scientific positioning

The integration of academic capital with institutional hierarchy, research leadership, and innovation in the third empirical dimension is one of the most important findings. Academic capital was strongly associated with this dimension, but it did not constitute an independent empirical domain. This suggests that qualifications and academic credentials form part of a broader configuration of scientific positioning rather than representing, on their own, a sufficient expression of empowerment.

This interpretation is consistent with feminist approaches that distinguish resources from their effective conversion into agency and achievements. Kabeer's [13] framework emphasizes that access to resources does not automatically determine the ability to exercise agency or obtain valued outcomes. From a Bourdieusian perspective, academic credentials can function as forms of capital whose value depends partly on their position within a structured field and on the processes through which that capital is recognized [16]. The present findings do not demonstrate these mechanisms directly, but they are compatible with an interpretation in which academic qualifications acquire meaning within broader institutional and scientific trajectories.

This distinction is particularly relevant for women researchers because educational expansion does not necessarily produce proportional representation in positions of authority, recognition, or institutional decision-making. Previous research has documented persistent gender differences in academic recognition, authorship, visibility, and leadership [3–6]. In the Peruvian context, the coexistence of substantial female participation in higher education with lower representation in some senior academic positions provides a broader institutional context for interpreting these patterns [7, 8]. The present analysis adds a different perspective: among women who have already obtained formal research recognition, academic capital appears to be empirically connected with institutional positioning and research capacity rather than functioning as an isolated dimension.

The finding should not be interpreted as evidence that doctoral education or academic qualifications are unimportant. Rather, the results suggest that credentials represent one component of a broader scientific trajectory. For research policy, this distinction matters because interventions focused exclusively on increasing educational attainment may address an important prerequisite while leaving other dimensions of scientific positioning insufficiently examined.

The moderate factor loadings observed within this dimension are consistent with the expectation that institutional positioning and research capacity represent complex configurations that are not fully captured through any single observable indicator.

4.2 Participation, trajectory and recognition

The first empirical dimension was defined primarily by institutional and competitive research projects, scientific recognition, academic production, and participation in scientific events. Its strong correspondence with the original theoretical dimension of participation and research trajectory indicates that this component of the conceptual framework was largely preserved after empirical reorganization.

The fact that recognition and incentives did not emerge as an independent factor should not be interpreted as evidence that participation causes recognition, or that recognition necessarily results from participation. Rather, within this cohort, these indicators formed a related empirical configuration.

This pattern is compatible with approaches that conceptualize empowerment as involving the capacity to act within institutional and social structures rather than simply possessing individual resources [13, 9]. Participation in research projects, scientific events, academic production, and related activities represents observable forms of engagement with scientific communities and research processes. These activities take place within institutional environments where access to resources, collaboration, networks, mentorship, and opportunities for visibility may vary across researchers.

Previous studies have documented gender differences in scientific participation, recognition, and career progression, although their magnitude and proposed mechanisms vary across disciplines and institutional contexts [3–6]. The contribution of the present study is more specific: among women researchers who had already attained formal recognition within RENACYT, participation, trajectory, and recognition were empirically organized more closely together than anticipated by the original four-dimensional framework.

The characteristics of the study population are relevant to interpreting this result. RENACYT constitutes a formal institutional mechanism through which researchers are evaluated and classified according to criteria that include academic

qualifications and research-related achievements. Thus, the present sample represents women who had already reached a threshold of institutional recognition. Within such a population, recognition may provide less information as an independent dimension than when studying researchers at different stages of entry, development, and consolidation.

The findings also caution against treating institutional recognition as synonymous with scientific empowerment. Formal recognition reflects specific criteria established by an evaluation system, whereas the broader construct examined here encompasses participation, production, research leadership, institutional positioning, and research capacity. Recognition is therefore better interpreted as one observable component of a broader scientific trajectory rather than as a comprehensive proxy for empowerment.

This distinction provides a conceptual bridge between feminist empowerment perspectives and research evaluation: institutional recognition can constitute an important achievement while representing only one part of a researcher's capacity to participate, develop a trajectory, and position herself within the scientific field.

4.3 Scientific production and impact constitute a distinct domain

Scientific production and impact formed a relatively coherent second dimension, with particularly strong loading for scientific impact and substantial contributions from scientific production and editorial activity. Its strong correspondence with the theoretical production–impact–innovation domain indicates that the empirical analysis preserved an important component of the original framework, although innovation itself moved to the third dimension.

The distinction between production and impact is relevant because scientific output is not equivalent to scientific influence. Bibliometric indicators capture particular dimensions of research activity, but their interpretation may vary according to disciplinary practices, institutional context, collaboration patterns, and evaluation systems [10, 7]. Previous research has also shown that bibliometric evaluation can contain gender-, institutional-, and disciplinary-related biases [11]. Consequently, production and impact should be interpreted as important components of scientific trajectory without assuming that they provide a complete measure of scientific empowerment.

The present results support this multidimensional interpretation. Scientific production and impact were positively correlated with participation and research trajectory and, to a lesser extent, with scientific positioning and research capacity. Thus, researchers with stronger production and impact profiles tended, in this sample, also to show stronger participation and positioning profiles. However, the correlations were not so high as to suggest that the dimensions were interchangeable. This distinction supports the decision to construct the Global Scientific Empowerment Index from several empirical domains rather than reducing the construct to publication or citation performance.

4.4 Scientific empowerment as a multidimensional configuration

The notion of scientific empowerment adopted in this study should be understood as an institutional manifestation of empowerment. Consequently, the empirical dimensions identified reflect observable forms of participation, recognition, production, leadership, and positioning rather than subjective experiences of agency or autonomy.

The final structure is consistent with the theoretical premise that empowerment involves more than the accumulation of individual resources [1, 9]. It also resonates with Bourdieu's view of academic and scientific fields, in which forms of capital acquire meaning and value through their relationships with institutional structures and recognition processes [2]. Importantly, however, these theoretical perspectives were not empirically tested as causal mechanisms in the present study. Rather, they provide a framework for interpreting why different resources, activities, achievements, and forms of positioning may be empirically related.

The findings support a distinction between academic capital, participation, recognition, production, and institutional positioning rather than treating them as successive synonyms for a single phenomenon. A researcher may possess substantial academic capital without occupying a senior institutional position; may have high scientific production without

extensive institutional leadership; or may have formal recognition while showing different levels of participation and research capacity. The empirical structure is consistent with this heterogeneity while also showing that these domains are related rather than completely independent.

This multidimensional perspective may be particularly useful in higher education research because research careers are often represented through individual indicators of academic achievement. An integrated framework can provide a broader view of scientific trajectories while retaining observable indicators that can be documented and compared. In the present study, the empirical reorganization did not discard the original theoretical framework; rather, it consolidated four conceptual domains into three related empirical dimensions: participation and trajectory, scientific production and impact, and scientific positioning and research capacity.

The resulting Global Scientific Empowerment Index should therefore be understood as an exploratory composite measure of relative positioning across these three empirical domains, not as a psychological scale or a definitive measure of empowerment. Its value at this stage lies in providing a transparent way of summarizing multidimensional observable characteristics within the study population. Further research using independent samples, longitudinal designs, and external criteria would be required to evaluate its stability, construct validity, and potential applicability beyond the present cohort.

4.5 Implications for higher education and research policy

The findings have several implications for institutions and research policy. First, initiatives designed to support women researchers may benefit from moving beyond interventions focused exclusively on formal qualifications. Doctoral training and academic credentials remain important, but opportunities to participate in research projects, develop scientific networks, lead research activities, publish, obtain recognition, and access institutional positions represent additional components of scientific trajectories.

Second, research evaluation systems may benefit from recognizing the distinction between productivity and positioning. Publication and impact indicators are important, but they do not fully capture leadership, participation, innovation, or institutional capacity. A broader monitoring framework could therefore complement conventional research-performance indicators with measures of participation, leadership, project involvement, and institutional positioning.

Third, the results suggest that policies aimed at strengthening women's scientific careers should consider multiple pathways rather than assuming a single progression from education to productivity and then to leadership. This is particularly relevant in contexts where women have achieved increasing levels of educational participation but remain less represented in some positions of institutional authority [11, 12].

These implications should be understood as policy considerations derived from the observed multidimensional structure, not as evidence that any particular intervention would produce greater empowerment. Testing such effects would require longitudinal or quasi-experimental designs capable of examining changes in trajectories over time.

4.6 Strengths and limitations

The study has several strengths. It focuses on a population that is often difficult to examine empirically: women researchers who have already achieved formal recognition within a national research system. It also uses objective and count-based indicators of scientific career rather than relying exclusively on self-reported perceptions. In addition, the exploratory factor analysis allowed the empirical structure to be examined without imposing the original four-dimensional framework.

Several limitations should nevertheless be considered. First, the non-probabilistic sample limits statistical generalization to women researchers in Peru as a whole. Second, the cross-sectional design does not permit conclusions about causal relationships or changes in scientific trajectories over time. Third, because all participants were RENACYT researchers, the findings describe variation within a formally recognized cohort and should not be generalized to women who have not entered or been recognized by the national research system.

Fourth, the empirical dimensions were constructed from objective indicators with different substantive meanings and distributions. Consequently, the Global Scientific Empowerment Index is a formative-type composite of distinct domains rather than a reflective psychometric scale whose indicators are expected to be interchangeable. The supplementary alpha and omega coefficients should therefore not be interpreted as evidence for or against a single latent trait. Finally, the correspondence analyses between theoretical and empirical dimensions share component indicators and consequently should not be interpreted as independent construct-validation coefficients.

Future research should examine whether the three-dimensional structure can be replicated in larger and more diverse samples, including researchers from different disciplinary fields, career stages, institutional types, and geographic regions. Longitudinal studies would be particularly valuable for examining how participation, production, recognition, and institutional role evolve over research careers. Comparative studies involving women and men could also determine whether the same empirical structure characterizes scientific trajectories across genders or whether some dimensions are differently organized. Such research would provide a stronger basis for assessing the stability and external validity of the proposed index.

Additionally, empowerment was operationalized through objective indicators of scientific trajectory and therefore did not include subjective dimensions such as perceived agency, autonomy, or self-efficacy.

5 Conclusions

This study examined the empirical structure of scientific empowerment among 156 women researchers registered in Peru's RENACYT system. The exploratory factor analysis did not reproduce the original four-dimensional conceptual framework as four independent empirical domains. Instead, the indicators were reorganized into three related dimensions: participation and research trajectory, scientific production and impact, and scientific positioning and research capacity. Academic capital was integrated with institutional hierarchy, research leadership, and innovation rather than emerging as an independent empirical dimension.

The Global Scientific Empowerment Index developed from the three empirical dimensions should be interpreted within the boundaries of the study design and the formative, multidimensional nature of the indicators.

The main contribution of the study is therefore not the establishment of a definitive universal scale of scientific empowerment, but the provision of an empirically informed framework for examining women's scientific trajectories within a formally structured national research system. The three-domain structure offers a basis for future validation, longitudinal research, and comparative analyses across researchers and institutional contexts. For higher education and research policy, the findings suggest that strengthening women's scientific careers requires attention not only to academic qualifications and scientific output, but also to sustained participation, recognition, leadership, innovation, and institutional positioning.

Declarations

Ethics approval and consent to participate

This study involved human participants and was conducted in accordance with applicable ethical principles for research involving human participants. Participation was voluntary, and informed consent was obtained from the participants before data collection. The study procedures and informed consent process were reviewed and approved by the Research Ethics Committee of Universidad Privada San Juan Bautista. All participants provided informed consent before data collection. All procedures were conducted in accordance with the ethical standards of the institutional research committee and with the principles of the Declaration of Helsinki and its subsequent amendments.

Consent for publication

Not applicable. The study does not contain identifiable individual data or individual-level information that could identify the participants.

Competing interests

The authors declare that they have no competing financial or non-financial interests that could have influenced the work reported in this manuscript.

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Author Contribution

All authors contributed to the conception and design of the study. J.A.F., D.F.G., and I.M.V. developed the measurement framework and coordinated data collection. J.A.F., D.F.G., I.M.V. and W.G.G. conducted the data preparation and statistical analyses. V.P.C. and J.A.F. interpreted the results and drafted the manuscript. All authors critically reviewed the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

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Data Availability

The processed and anonymized data generated and/or analyzed during the current study are available from the corresponding author upon reasonable request, subject to applicable ethical and institutional restrictions. The data are not publicly deposited because they derive from individual research trajectories and contain information that may facilitate participant identification within a relatively small national research population.

Availability of materials

The measurement framework and analytical procedures are described in sufficient detail in the manuscript to facilitate replication. Additional methodological information may be made available from the corresponding author upon reasonable request.

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