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Organizational characteristics and the social impact of UK research: disciplinary patterns from REF 2021

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Abstract

The elevation of research culture to a standalone evaluation dimension in REF 2029 reflects increasing recognition that research performance depends not only on outputs but also on the environments supporting research. However, the role of research culture relative to other organizational characteristics in relation to societal impact remains insufficiently understood. This study develops a quantitative approach to measure research culture based on narrative environment statements from REF 2021. Using five core dimensions of positive research culture, relevant textual evidence is identified and scored using a large language model to generate institution–UOA level indicators. We then examine whether these scores are associated with official environment ratings beyond conventional quantitative indicators. Building on these measures, we estimate regression models across 34 UOAs and compare standardized coefficients and their rankings to assess the relative importance of organizational characteristics. The results show clear disciplinary differences. Staff size and economic resources show stronger associations in science-based fields, while degree training is more prominent in social sciences and arts and humanities. Research culture shows a weaker but heterogeneous association across disciplines. Overall, the findings highlight substantial disciplinary variation and suggest the need for discipline-sensitive approaches to research evaluation and management.

Keywords research culture; social impact; cross-disciplinary comparison; REF2021

1 Introduction

The Research Excellence Framework (REF) is the UK's system for assessing the quality of research in higher education institutions. It evaluates not only the excellence of research outputs but also their broader effects beyond academia (Glaeser 2024) and the environment that supports high-quality research, including provisions for people and teams (REF2029 2025). In REF 2021, societal impact—defined as effects on the economy, society, culture, public policy or services, health, the environment, or quality of life—was assessed through impact case studies. The institutional environment, which included aspects of research culture, was evaluated separately through narrative statements and quantitative data.

REF 2029 marks a key change: research culture becomes a distinct element within the broader People, Culture and Environment (PCE) component, separate from the general institutional environment. This shift reflects a belief that the health of the research system depends not just on resources and outputs but also on the internal norms, values, and practices that shape how research is done and shared. A positive research culture supports innovation, integrity, collaboration, inclusivity, and career development, all of which help research produce lasting societal benefits (Liston and Fitzgerald 2024; Uttley et al. 2025).

Existing studies on how institutional features affect research impact have mostly examined external factors, such as partnerships and networks. Work on internal features—such as the research environment or organizational support—has been limited, often based on small case studies or qualitative comparisons, with few general empirical findings. This leaves a gap in understanding how core internal characteristics, including research culture, jointly shape societal impact at the institutional level.

This study addresses that gap. We use the full set of 1,826 unit-of-assessment (UOA)-level environment statements and related REF 2021 data as our main source. Guided by the REF 2029 framework for positive research culture, we identify textual evidence from the statements and apply a large language model to systematically generate research culture scores at the UOA level.

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We then combine this measure with three institutional characteristics—staff size, economic resources, and degree training—and estimate multiple regression models at the UOA level. To further assess the relative importance of these characteristics, we compare standardized regression coefficients and their ranking positions across UOAs, and aggregate the results at the disciplinary panel level. The analysis examines how these internal characteristics are associated with societal impact and whether their relative importance varies across disciplinary fields.

Our approach contributes to the literature in three ways. First, it quantifies research culture from large-scale qualitative data using a method, providing a bridge to REF 2029's emphasis on culture as a standalone dimension. Second, it offers generalizable evidence on the role of internal institutional attributes in generating societal impact, beyond what prior small-scale or external-focused studies have shown. Third, by comparing effects across disciplinary panels, it reveals field-specific patterns that can inform targeted policies for resource allocation, institutional strategy, and research management.

2 Theoretical foundation

2.1 Research culture in evaluation

A substantial body of evidence has demonstrated the significant role of research culture in either fostering or hindering a thriving scientific innovation system (THE ROYAL SOCIETY 2018 Trust 2020; BEIS 2021; Balasubramanian and Flood 2022; Cordrey et al. 2022). For instance, *The culture of scientific research* published by the Nuffield Council on Bioethics, identified factors that are detrimental to the formation of a positive research culture (Bioethics 2014). The first explicit mention of research culture in formal evaluation practice can be traced back to the expert assessment guidance document, Panel Criteria and Working Methods, for the REF2014. In Part 2C of this document, which describes the evaluation of the institutional environment, it is stated: '*Vitality of the research environment reflects the existence of a thriving, dynamic and fully participatory research culture based on a clearly articulated research strategy, displayed both within the submitting unit and in its wider contribution …*' (UKRI 2012). At this stage, research culture was primarily considered a component of the 'vitality' dimension within the broader institutional environment, rather than an independent, operationalizable evaluation dimension.

In 2023, the four UK higher education funding bodies jointly launched the Future Research Assessment Programme (FRAP) to inform the iterative development of the next Research Excellence Framework. In the initial decisions document published in June of that year, the original institutional environment section was replaced by three components: *People, Culture and Environment (PCE)*. Research culture was formally established as an independent evaluation dimension, and a more detailed, operationalizable framework for its assessment was subsequently proposed, positioning it as one of the key conditions underpinning research excellence (as shown in Fig. 1). This further demonstrates that research culture is not merely an adjunct indicator for evaluating research outputs, but a core element for measuring and promoting the overall health and sustainable development of the research system.

As the primary organizing body for the REF, UK Research and Innovation (UKRI), drawing on the definition from the Royal Society (THE ROYAL SOCIETY 2018), interprets research culture as encompassing 'the behaviours, values, expectations, attitudes and norms of our research communities. It influences researchers' career paths and determines the way that research is conducted and communicated' (UKRI 2024). Based on this understanding, UKRI developed an initial assessment framework aimed at comprehensively capturing various aspects of research culture performance and providing a consistent way to describe

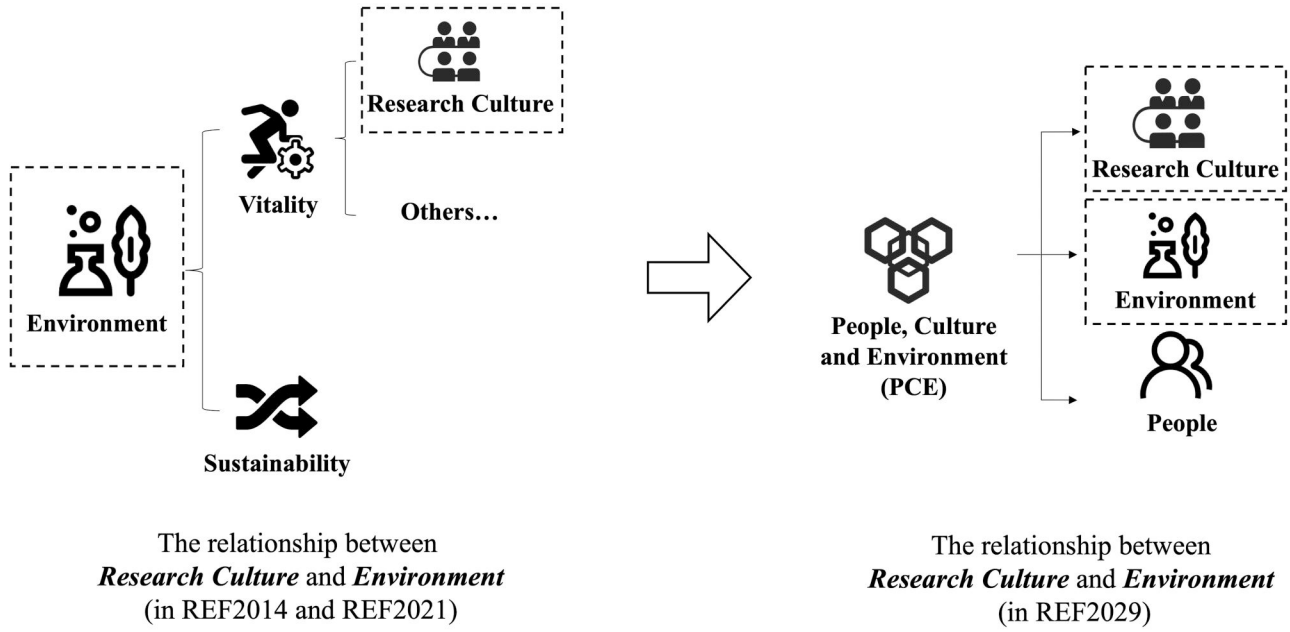


Figure 1 The Evolution of the Relationship between Research Culture and Environment. The figure shows the changing conceptual relationship between research culture and the research environment from REF2014 to REF2029.

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the values and behaviours that underpin an open, inclusive, constructive, and supportive research culture. This conceptualization is currently widely accepted within UK higher education institutions and serves as the primary definition of research culture guiding the subsequent exploration in this study.

Building on this definition, UKRI first formulated a preliminary conceptual framework for research culture, primarily involving four main overlapping areas: the ways research is managed and conducted, including aspects of governance and management, research integrity, and sustainability; how research ensures it creates value for communities, society, culture, and the economy, including open research, communication, and impact through translation and commercialization; how staff are supported, encompassing recruitment and employment, recognition and evaluation, career development, and a healthy working environment; and the ways individuals interact, including leadership and management, individual rights, and collegiality (UKRI 2024). With the commencement of a new round of pilot exercises for REF2029, the REF team, building on the aforementioned preliminary framework and incorporating feedback from the pilot work, has proposed a set of five core dimensions for describing a positive research culture (REF2029 2025). This framework serves as a crucial reference for the subsequent evaluation of institutional research culture in this study (as shown in Table 1).

2.2 Institutional characteristics and research impact

As key meso-level entities supporting the conduct of scientific research, various institutional attributes, including research income, influence the execution and dissemination of scientific work, thereby indirectly shaping the generation and diffusion of its multidimensional impacts (Arsalan et al. 2024; Ambulos et al. 2025). A growing number of scholars are attempting to explore, at the institutional level, the key attributes that influence the societal impact of research, aiming to provide new references for policy formulation and impact assessment practices. Such studies can be broadly categorized into internal and external institutional attributes. The former primarily refers to characteristics inherent to the institution itself, independent of external influences from other organizations, such as the institutional research environment (Inglis et al. 2024). The latter refers to attributes arising from interactions between the institution and external entities, such as collaborative partnerships (Hou et al. 2024; Yoo et al. 2024; Chavez et al. 2025).

This study focuses specifically on research concerning the influence of institutions' internal characteristics on research impact. For example, Laudel through a qualitative comparative analysis of the conditions under which Australian and German physicists obtain external funding, demonstrated that success in securing funding is only partially related to the quality of researchers and their proposals (Laudel 2005). Reale through three case studies on social science research projects, further emphasized the significance of organizational-level changes for understanding the societal impact of research (Reale 2022). Arsalan et al., using survey data from 630 scientists globally and employing structural equation modeling, assessed the influence of 29 factors related to researcher characteristics and institutional support, confirming that institutional support—through leadership, resources, recognition, and funding—significantly

Table 1 Enabling factors and example of positive research culture.

Factor	Definition (Semantic Anchor)	Example
Strategy	Having robust, effective, and meaningful plans to manage and enhance the vitality and sustainability of the research culture and environment	• Robust processes are in place to evaluate the effectiveness of activities to improve research culture.
Responsibility	Upholding the highest standards of research integrity and ethics, enabling transparency and accountability in all aspects of research	• Staff and research students pursue research, assessment and engagement activities responsibly, with integrity and to the highest standards
Connectivity	Enabling inter-disciplinary and cross-disciplinary approaches both within and between institutions, fostering co-creation and engagement with research users and society, and recognizing and supporting open research practices	• Research and research enabling staff and research students share research, knowledge and expertise widely both internally and externally, including through open research practices.
Inclusivity	Ensuring the research environment is accessible, inclusive, and collegial, enabling equity for under-represented and minoritized groups	• Institution/unit tackles inequities in the research system and robustly addresses equality, diversity and inclusion across all of its activities.
Development	Recognizing and valuing the breadth of activities, practices and roles involved in research, building and sustaining relevant and accessible career pathways for all staff and research students, providing effective support and people-centered line management and supervision, supporting porosity and embedding professional and career development at all levels and across all roles	• Staff and research students can access relevant and meaningful support at all career stages.

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affects research impact (Arsalan et al. 2024). Zhu et al., within a collaboration network comprising over 110,000 scholars and controlling for research diversity, further explored the relationship between team size and both research output and impact (Zhu et al. 2021). Boeren et al., based on REF2021 impact case study data, analyzed the strength of the relationship between different types of funding sources and grade point averages (Boeren 2023). Frenken et al., employing regression analysis, assessed the influence of structural factors such as university size, age, and city location on university research performance (Frenken et al. 2017).

The development of large-scale scientific databases (e.g. MAG, ResearchGate) has progressively clarified the structured interaction patterns between institutions. Consequently, discussions focusing on institutions' external attributes have increased, predominantly drawing on large-scale data as their primary empirical source (Wang et al. 2023; Chen et al. 2025; Li and Li 2025; Yang et al. 2025). In contrast, recent research examining institutions' internal attributes and their impact on research influence has been relatively scarce compared to studies on external attributes, often relying on small-scale cases and lacking broader comparative and generalizable discussions. Therefore, based on an understanding of the concept of research culture, this study incorporates it into the analytical framework of institutions' multidimensional internal characteristics, primarily addressing the following two key research questions:

RQ1: How can evidence for assessing research culture be identified from existing environment statements and subsequently evaluated?

RQ2: How are internal institutional characteristics associated with societal impact across disciplinary panels, and how do their relative importance rankings differ across fields?

3 Research design

3.1 Approach

We obtained the 1,833 UOA-level environment statements from the official REF 2021 website through an external interface (https://results2021.ref.ac.uk/swagger/index.html). These statements were converted from PDF to machine-readable text files using custom scripts. UOA-level statements describe the research environment within specific disciplinary units inside each institution and are typically around 10,000 characters long, making them more focused than institution-wide statements. In the following analysis, each institution–UOA unit is consistently referred to as an '*organization*.'

The study has two main phases: *indicator calculation* and *heterogeneity analysis* (as shown in Fig. 2).

The indicator calculation phase includes three steps. First, we extract text segments from the environment statements that provide evidence of research culture and use a large language model to score them in multiple independent rounds. Second, we compute the other required indicators from the quantitative REF 2021 submission data. Third, we test whether the research culture scores explain additional variation in the official REF environment ratings beyond the quantitative indicators, confirming their validity.

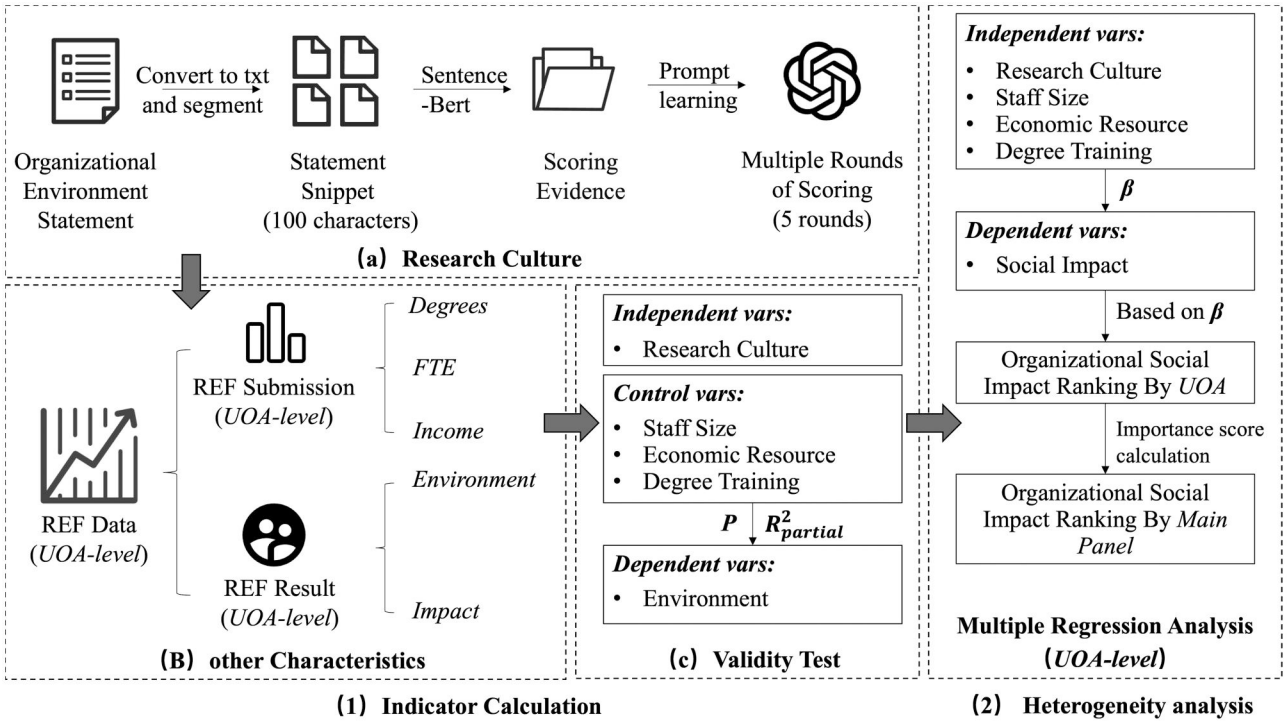


Figure 2 Research Approach Diagram. This figure shows the two key research stages of this study: indicator calculation and heterogeneity analysis.

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The heterogeneity analysis phase groups the data by the four REF 2021 main panels. Within each panel, we treat the four organizational characteristics *(staff size, economic resource, degree training, and research culture*) as independent variables and the societal impact of research (average impact case study rating) as the dependent variable. We estimate regression models separately for each UOA to examine the associations between organizational characteristics and societal impact, and assess their relative importance by comparing standardized coefficients and their rankings across UOAs and disciplinary fields.

3.2 Indicator calculation

3.2.1 Organizational environment score

During the implementation of the REF, on a disciplinary basis, assessment is conducted at the UOA level. Each sub-panel is required to manually evaluate submissions based on the narrative environment statements submitted by institutions, along with quantitative data including research income, across two dimensions: the vitality and sustainability of the environment. The publicly available REF results tables provide the distribution of ratings from panel members for each institution's performance within different UOAs. These ratings are classified into five quality levels, ranging from world-leading to unclassified: 4, 3, 2, 1, and Unclassified. This study first calculates an initial environment score for each individual institution within each specific UOA, denoted as Env_{i,UOA_j}.

$$Env_{i,UOA_j} = 4 \cdot p^{4*}_{i,UOA_j} + 3 \cdot p^{3*}_{i,UOA_j} + 2 \cdot p^{2*}_{i,UOA_j} + 1 \cdot p^{1*}_{i,UOA_j} + 0 \cdot p^{Unclassified*}_{i,UOA_j},$$

Where p^{k*}_{i,UOA_j} represents the proportion of 4*, 3*, 2*, 1* and Unclassified ratings received by institution *i* for its environment score within UOA_j.

3.2.2 Organizational research social impact score

Following the same approach used for calculating the organizational environment score, during the implementation of the REF, each sub-panel is required to evaluate the societal impact of the impact case studies submitted by institutions, based on the impact descriptions and corresponding supporting evidence provided. This study adopts the definition of societal impact as outlined in the REF 2021 framework: 'impact *is defined as the effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia'* (UKRI 2022).

Consistent with the calculation method for the organizational overall environment score, this study calculates the initial societal impact score for research conducted by institution *i* within a specific UOA_j based on the distribution of star ratings assigned by the sub-panel for research societal impact $Impact_{i,UOA_j}$.

3.2.3 Organizational characteristics

Based on the official publicly available environment statement from REF2021, we constructed four organizational characteristic variables: *staff size*, *economic resource*, *degree training* and *research culture* (as shown in Fig. 3). Among these, the first three characteristics are measured primarily using quantitative indicators from the REF2021 submission data.

Regarding staff size, this study does not measure the overall size of an institution, but rather characterizes the size of research staff submitted for assessment within a specific UOA. Under the REF framework, Full-Time Equivalent (FTE) refers to the number of research staff submitted by an institution at the disciplinary unit level; their research outputs and activities constitute the formal objects of assessment, thus more accurately reflecting the scale of research capacity within that disciplinary unit. FTE is commonly used to measure the size of research staff in a research institution or university, and is regarded as an important indicator for assessing research capacity and research

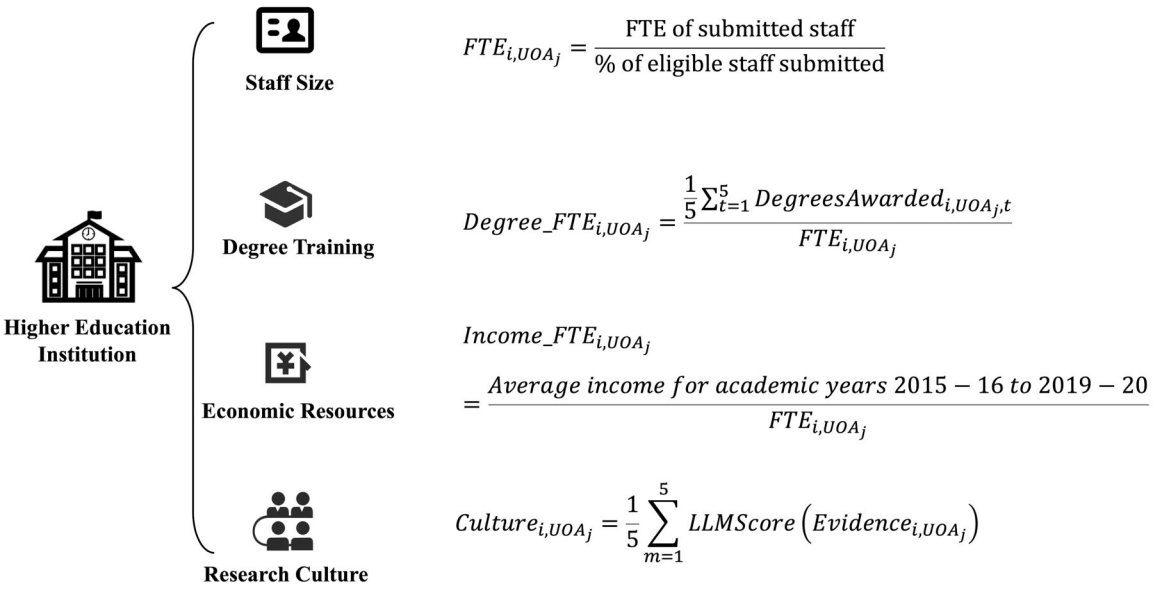


Figure 3 Organizational Characteristics and their Definitions. This figure shows how the organizational characteristic indicators in this study are calculated.

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productivity (Lepori et al. 2023; Stock et al. 2023). In this study, it is primarily used to represent the *staff size* of a specific institution within a specific disciplinary field. Operationally, we selected two variables from REF2021 for a given UOA: '*FTE of submitted staff*' and '*% of eligible staff submitted*'. The former reflects the absolute size of research staff, while the latter indicates the proportion of eligible staff submitted under the same assessment framework. By combining these two variables, we calculate FTE_{i,UOA_j}.

The SIAMPI evaluative theory model suggests that the societal impact of scientific research is primarily generated and disseminated through productive interactions among participating actors (de Jong et al. 2014; Boshoff and Sefatsa 2019; Smit et al. 2024). Higher education institutions can promote the real-world application of scientific research by training research talents and supplying them to various sectors of society, thereby exerting significant societal influence. To enhance comparability across different organizations, we standardize the number of degrees awarded within the assessment period by organizational size, thereby calculating the *degree training rate* $Degree_FTE_{i,\ UOA_j}$, which is used to measure the degree training level exhibited by a specific institution within a specific disciplinary field.', which is used to measure the educational level exhibited by an organization.

Existing research has shown that research income per capita is an important factor influencing research output and impact (Hussinger and Carvalho 2022; Thelwall et al. 2023). In this study, we use the data indicator '*average research income for the academic years 2015–16 to 2019–20*' from REF2021, which reflects sustained resource capacity through a five-year average rather than short-term fluctuations. To enable comparability across different disciplines and institutions, we standardize total income by FTE_{i,UOA_j}, obtaining the research income capacity per researcher, denoted as $Income_FTE_{i,UOA_j}$. This indicator reflects the level of *economic resources* available to an organization to support research activities, including infrastructure development, doctoral training, and communication activities related to research application, all of which may further promote the societal impact of research.

Unlike the first three types of indicators, which can be directly assessed based on quantitative data, the *research culture* of higher education institutions is primarily reflected in the environment statements submitted by institutions. Within the REF2021 assessment framework, research culture was mainly evaluated as a component of the broader research environment. Based on this hierarchical relationship, the assessment of organizational research culture in this study is conducted in two main parts: *evidence extraction* and *model scoring* (as shown in Fig. 4).

First, this phase draws on the five key dimensions of the latest positive research culture framework (as shown in Table 1), using their corresponding definitions as standard semantic anchors. Considering both computational cost and semantic completeness, each UOA-level TXT version of the environment statements is segmented into evidence snippets of 100 characters in length. Subsequently, both the semantic anchors and the evidence snippets are input into a unified Sentence-BERT model (all-MiniLM-L6-v2) to generate semantic embeddings in a shared vector space. Within this space, the *cosine* similarity between each evidence snippet and each semantic anchor is computed sequentially to measure their semantic similarity. For each dimension, only those evidence snippets with a cosine similarity >0.5 with the corresponding semantic anchor are retained as supporting evidence for that dimension (as shown in Table 2).

Subsequently, all extracted evidence segments are used as input for scoring with a large language model (GPT-4o-mini).

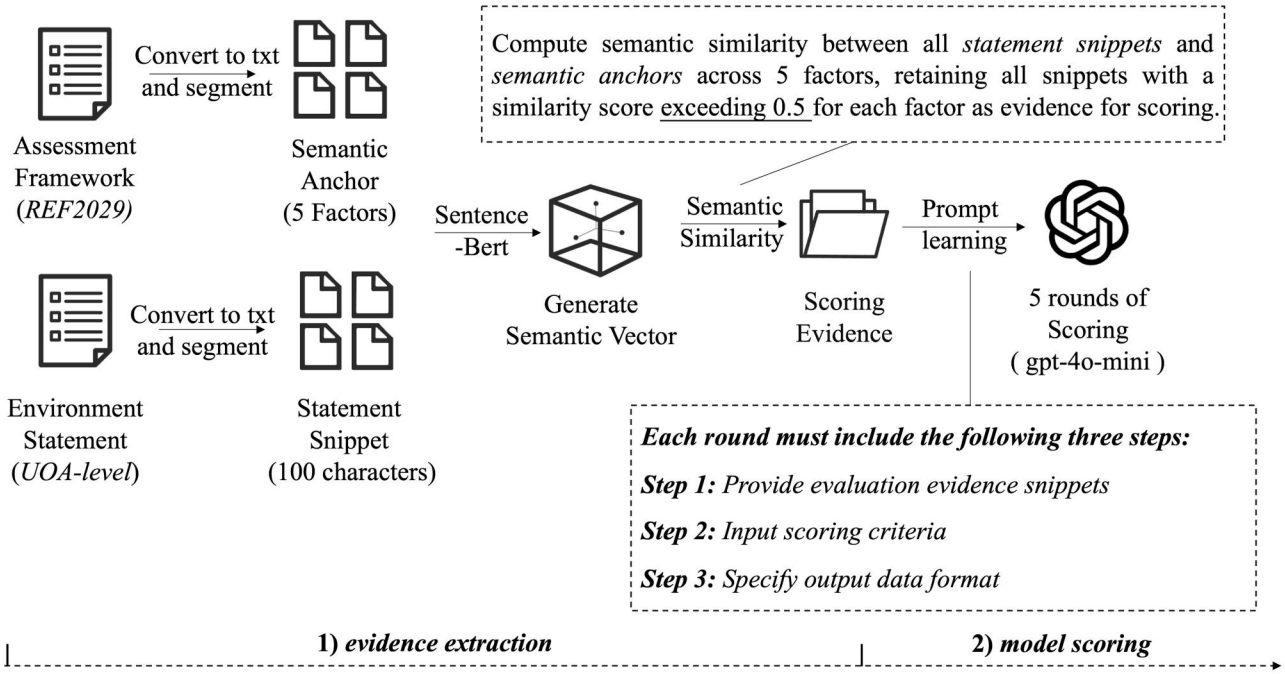


Figure 4 Scoring Process for Research Culture Based on a Large Language Model. This figure shows how we use large language models to assess research culture at the organizational level.

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Table 2 Results of organizational research culture evidence extraction (examples).

UKPRN	UOA	Institution Name	Criterion	Similarity	Evidence Text
1000xxxx	4	University of xxxx	Development	0.5178	to help them establish an independent research career. They are given reduced teaching loads in thei
1000xxxx	5	University of xxxx	Connectivity	0.5032	1 and 2) Research in Biosciences is vibrant, collaborative, and interdisciplinary, enabling the hig

Step 1: Provide evaluation evidence snippets

Below are all available evidence fragments from the institution's environment statement for this UoA.Please read and retain all evidence below. Do not score yet.

----------EVIDENCE ----------

Strategy:{self.format_evidence("Strategy", evidence_dict.get("Strategy", []))} …other 4 factors…

Step 2: Input scoring criteria

Now apply the following Positive Research Culture framework and REF star-level scoring definitions.

----------POSITIVE RESEARCH CULTURE FRAMEWORK----------

Positive Research Culture is understood through the following five enabling factors.

Strategy: Having robust, effective and meaningful plans to manage and enhance the vitality and sustainability of the research culture and environment.

…other 4 factors…

----------REF STAR-LEVEL SCORING DEFINITIONS----------

4★ (World-leading):Robust evidence of a culture and environment enabling world-leading research quality and outstanding engagement and impact, in terms of vitality, sustainability and rigour.

…other levels…

Step 3: Specify output data format

Based on the full conversation above, assign a single overall star score (0-4) for Positive Research Culture and indicate which evidence fragments support your judgement.

TASK

1) Assign a single overall star score (0–4) for Positive Research Culture. 2) Indicate which evidence fragments support your judgement.

INSTRUCTIONS

1)Produce ONE overall star score (0–4). 2)Do NOT assign or report separate scores for individual enabling factors.3)Assess Positive Research Culture holistically across all five enabling factors together. 4)When listing evidence_used, refer to evidence by ID only (e.g. Strategy-1, Connectivity-2). 5)If a factor has no evidence, do not cite its placeholder line. 6)Output only the JSON object specified below.

OUTPUT FORMAT

Return your assessment strictly in the following JSON format: {score": <integer from 0 to 4>,"evidence_used": ["<evidence ID>","<evidence ID>"]}

Figure 5 Prompt Content for a Single Round. This figure specifically shows the prompt text we provided to the large language model.

Considering the input limitations of large language models, the interaction in each scoring round is structured into three sequential steps: *providing evaluation evidence snippets, input scoring criteria*, and *specify output data format* (as shown in Fig. 5).

To ensure that the model bases its evaluation strictly on the provided evidence, it is required not only to assign scores but also to return the corresponding *evidence IDs* for each score. For example, an output such as 'Strategy-1' indicates that the score is based on the top-ranked (Top 1) evidence segment with the highest semantic similarity within the strategy dimension.

By designing specific prompt instructions, the model is guided to systematically evaluate and score the organizational research culture based on the provided evidence. To mitigate the impact of randomness in the large language model's output on the stability of the scores, this study adopts a multi-round independent scoring strategy. Five independent scoring processes are conducted by resetting the dialogue context, and the arithmetic mean of these five scores is ultimately taken as the organizational final research culture score.

4 Empirical analysis

4.1 Disciplinary differences in organizational characteristics: non-parametric analysis

After excluding cases with missing values for key characteristics (e.g. staff size), this study ultimately retained 1,826 cases with complete characteristic data. To demonstrate the necessity of conducting analyses within a disciplinary context, the Kruskal–Wallis test was applied to examine differences across UOAs for all organizational characteristics. The results indicate that all variables exhibit statistically significant differences at the UOA level (as shown in Table 3).

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Table 3 Kruskal–Wallis test results for organizational characteristics across UOAs.

Variable	Groups_included	H_statistic
Research Culture	34	88.76**
Staff Size	34	448.34**
Degree Training	34	364.58**
Economic Resource	34	776.32**

Note.
** Indicates $P < 0.001$.

Specifically, the research culture indicator shows significant variation across disciplines ($H = 88.76$, $P < 0.001$), indicating that evaluation outcomes differ systematically between UOAs and suggesting that disciplinary context plays an important role in shaping performance.

In terms of staff size, the test statistic is relatively large ($H = 448.34$, $P < 0.001$), demonstrating substantial variation in organizational scale across disciplines, with some UOAs characterized by significantly larger organizations than others. Similarly, degree training also shows significant differences ($H = 364.58$, $P < 0.001$), indicating notable imbalances in educational capacity across disciplines. The most pronounced disparity is observed in economic resources, with the highest test statistic ($H = 776.32$, $P < 0.001$), suggesting a high degree of inequality in resource allocation, with certain disciplines possessing clear resource advantages.

Overall, the Kruskal–Wallis test results reveal significant structural differences across disciplines in terms of all organizational Characteristics. These findings further support the necessity of controlling for or stratifying by disciplinary differences in subsequent analyses.

4.2 Validity test

This study ultimately extracted 71,460 evidence snippets to support the evaluation of research culture across different organizations. After obtaining the research culture scores for each organization, all variables were first standardized within each UOA using *z-score normalization* to control for disciplinary effects. To test the validity of the scores derived in this study, a multiple linear regression model was then constructed with the standardized organizational environment score (*Envz*) as the dependent variable.

This validity test is essential because it examines whether the research culture scores generated through large language model analysis capture meaningful variance beyond what can be explained by traditional quantitative indicators readily available in the REF submission data. Quantitative characteristic indicators, including staff size (*FTEz*), economic resources (*Income_FTEz*), and degree training (*Degree_FTEz*), were included as control variables in the baseline model, as these represent the organizational characteristics commonly employed in research evaluation and scientometrics studies.

The specific model is as follows:

$$Envz_{i,UOA_j} = \beta_{(0)} + \beta_{(1)} Income_FTEz_{i,UOA_j} + \beta_{(2)} FTEz_{i,UOA_j} + \beta_{(3)} Degree_FTEz_{i,UOA_j} + \beta_{(4)} Culturez_{i,UOA_j} + \varepsilon_i$$

To further measure the independent explanatory power of the research culture score obtained based on GPT-4o-mini after controlling for other variables, this study employs the partial coefficient of determination $R^2_{partial}$ for evaluation. This statistic is particularly appropriate for our purposes as it isolates the unique contribution of the research culture variable by quantifying the proportion of variance in the dependent variable that can be attributed to this predictor alone, after accounting for all other predictors in the model. Its calculation formula is as follows:

$$R^{(2)}_{partial} = \frac{R^{(2)}_{full} - R^{(2)}_{reduced}}{\left(1\right) - R^{(2)}_{reduced}}$$

Where R^2_{full} represents the coefficient of determination of the full model including the research culture score variable, and $R^2_{reduced}$ represents the coefficient of determination of the baseline model containing only the control variables.

The test results indicate that in the model containing only the control variables, the coefficient of determination was $R^2_{reduced} = 0.5176$. This baseline value demonstrates that the traditional quantitative indicators alone explain a substantial portion (46.06%) of the variance in institutional environment scores, confirming their relevance as predictors. After adding the research culture score, the model's coefficient of determination increased to $R^2_{full} = 0.5356$ Further calculation yielded a partial coefficient of determination for the research culture score of $R^2_{partial} = 0.0374$. This suggests that, after controlling for other three characteristics, the research culture score derived from the large language model can explain an additional ∼3.42% of the variance in environment scores. While this incremental explanatory power may appear modest in absolute terms, it is notable given that the baseline model already captures nearly half of the variance, and that research culture represents just one of many qualitative dimensions considered by REF panelists during evaluation. Examining the standardized regression coefficient β, the coefficient for the research culture score was $\beta_4 = 0.1377$, which was statistically significant ($P < 0.001$). This positive and significant coefficient indicates a meaningful relationship between the research culture score obtained in the earlier phase of this study and the official environment evaluation results. Furthermore, the fact that research culture provides explanatory power beyond the three quantitative indicators validates our methodological approach and supports its use in the subsequent heterogeneity analysis across disciplinary panels.

4.3 Heterogeneity analysis based on main panels

4.3.1 Characteristics importance measurement based on *UOA-level* standardized coefficients and *panel-level* aggregation

To characterize the relative importance of different organizational characteristics in the process of knowledge generating

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societal impact across various disciplinary fields, and to mitigate the effects of differences in disciplinary sample sizes and instability in regression estimates, this paper introduces a feature importance measurement approach based on ranking and cumulative scoring, building upon subgroup regression analysis. This method first performs estimation at the *UOA level*, and then aggregates the results to the *Main Panel level*, thereby enabling cross-disciplinary comparative analysis.

First, within each discipline (UOA), a regression model is constructed to estimate the influence of various organizational characteristics on the dependent variable $Impactz_{i,UOA_j}$, based on standardized variables. Since all variables have been standardized, the regression coefficients can be compared horizontally within the same model, thereby reflecting the relative influence strength of different variables. On this basis, the explanatory variables within each discipline are ranked according to the magnitude of their *standardized regression coefficients*. In the ranking process, the *absolute values* of the standardized regression coefficients are used to compare the relative importance of characteristics, thereby capturing the magnitude of their effects regardless of direction.

Suppose there are a total of K organizational characteristics (K=4 in this paper) within a given UOA, and let the rank of characteristic j in this discipline be r, where $r = 1$ indicates that the organizational characteristic has the greatest influence in that discipline. To further aggregate the importance of variables at the disciplinary panel level, this paper introduces a rank-based scoring mechanism. Specifically, decreasing weights are assigned to different ranks, and the score corresponding to the r^{th} rank is defined as:

$$w_r = K - r + (1)$$

Under the framework of this paper, the first, second, third, and fourth ranks are assigned scores of 4, 3, 2, and 1.

Subsequently, within the same disciplinary panel, the scores of characteristic j across all UOAs in that panel are summed to obtain the overall *importance score* of that variable in the *main panel*:

$$Importance_{g,j} = \sum_{d \in g} w_{r_{d,j}}$$

Here, $d \in g$ denotes all UOAs belonging to panel g. This step achieves the aggregation from local estimates at the *UOA* level to an overall summary at the *Main Panel* level, enabling unified comparison of feature importance across different disciplines at a higher level.

The importance score reflects the frequency and extent to which a variable rank highly within the disciplinary panel. A higher score indicates that the variable has greater importance across more disciplines, thus playing a more prominent role in explaining the dependent variable overall. Compared with directly comparing the magnitudes of regression coefficients across disciplines, this method introduces a ranking and cumulative scoring mechanism, effectively mitigating the influence of extreme coefficient values and small-sample fluctuations on the results, thereby providing a more robust measure of feature importance at the disciplinary panel level.

4.3.2 Importance score-based cross-disciplinary panel heterogeneity analysis

4.3.2.1 Medicine, Health and Life Sciences

Table 4 presents the ranking distribution of organizational characteristics in the Medicine, Health and Life Sciences panel. The results indicate a dual-pattern structure in which both organizational scale and resource endowment exhibit relatively higher levels of importance in relation to societal impact.

Among all variables, Staff Size ranks first most frequently (three times) and achieves the highest importance score (17), suggesting that organizational scale is consistently more strongly associated with societal impact in this panel. Economic Resources also rank first three times and obtain a comparable importance score (16), indicating that financial capacity is likewise strongly associated with societal impact, although its relative importance appears slightly less stable than that of staff size. In contrast, Degree Training and Research Culture show more moderate and dispersed ranking patterns, with importance scores of 14 and 13, respectively. Degree training tends to cluster around intermediate rankings, while research culture exhibits a relatively lower and more variable association across UOAs.

Overall, the results suggest that societal impact in this panel is more strongly associated with organizational scale and resource capacity, while educational and cultural characteristics show comparatively weaker and more heterogeneous associations.

4.3.2.2 Physical Sciences, Engineering and Mathematics

Table 5 presents the ranking distribution of organizational characteristics in the Physical Sciences, Engineering, and Mathematics panel. The results indicate a relatively uneven pattern of importance, with certain characteristics showing stronger associations with social impact than others.

Among all variables, Economic Resources rank first most frequently (four times) and achieve the highest importance score (20), suggesting that financial capacity is most consistently and strongly associated with societal impact in this panel. Staff Size ranks second most frequently (three times) and has an importance score of 16, indicating a relatively stable and notable

Table 4 Ranking distribution of organizational characteristics in *Medicine, Health and Life Sciences*.

Characteristic	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Importance score
Staff Size	3	0	2	1	17
Economic Resources	3	0	1	2	16
Degree Training	0	3	2	1	14
Research Culture	0	3	1	2	13

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Table 5 Ranking distribution of organizational characteristics in *Physical sciences, Engineering, and Mathematics*.

Characteristic	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Importance score
Economic Resources	4	1	0	1	20
Staff Size	1	3	1	1	16
Research Culture	0	2	3	1	13
Degree Training	1	0	2	3	11

Table 6 Ranking distribution of organizational characteristics in *Social science*.

Characteristic	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Importance score
Degree Training	5	5	0	2	37
Staff Size	2	5	4	1	32
Economic Resources	5	0	4	3	31
Research Culture	0	2	4	6	20

association with societal impact, although its relative importance appears lower than that of economic resources.

In contrast, Research Culture exhibits a more dispersed distribution across ranking positions and achieves an importance score of 13, suggesting a moderate but less consistent association across UOAs. Degree Training shows the lowest importance score (11) and appears more frequently in lower ranking positions, indicating a comparatively weaker and more variable association with societal impact in this disciplinary context.

Overall, the results suggest that societal impact in this panel is more strongly associated with economic resources and, to a lesser extent, staff size, while research culture and degree training display comparatively weaker and more heterogeneous associations.

4.3.2.3 Social Science

Table 6 presents the ranking distribution of organizational characteristics in the Social Science panel. The results indicate a relatively balanced pattern of importance, with multiple characteristics showing substantial associations with societal impact.

Among all variables, Degree Training ranks first most frequently (five times) and appears consistently in higher ranking positions, achieving the highest importance score (37). This suggests that educational capacity shows the strongest and most stable association with societal impact in this panel. Staff Size follows with an importance score of 32 and appears frequently in the second ranking position, indicating a relatively stable and notable association across UOAs.

Economic Resources also rank first five times and achieve a comparable importance score (31), although their distribution across ranking positions is more uneven, suggesting that their association with societal impact is relatively strong but less consistent than that of degree training. In contrast, Research Culture shows a more dispersed distribution and the lowest importance score (20), indicating a comparatively weaker and more variable association across UOAs.

Overall, the results suggest that societal impact in the Social Science panel is associated with a multi-dimensional structure, where degree training, staff size, and economic resources all exhibit substantial but varying levels of importance, while research culture shows comparatively weaker and more heterogeneous associations.

4.3.2.4 Arts and Humanities

Table 7 presents the ranking distribution of organizational characteristics in the Arts and Humanities panel. The results indicate a relatively balanced pattern of importance, with no single characteristic overwhelmingly dominating across UOAs.

Among all variables, Degree Training ranks first most frequently (four times) and achieves the highest importance score (29), suggesting that educational capacity shows the strongest association with societal impact in this panel, although its advantage over other characteristics is less pronounced compared to the Social Science panel. Both Staff Size and Economic Resources obtain similar importance scores (26) and display relatively even distributions across ranking positions, indicating that these two characteristics are comparably associated with societal impact and contribute in a more balanced manner.

In contrast, Research Culture shows a more dispersed ranking pattern and the lowest importance score (19), suggesting a comparatively weaker and more variable association across UOAs.

Overall, the results suggest that societal impact in the Arts and Humanities panel is associated with a relatively balanced structure, where degree training, staff size, and economic resources all demonstrate meaningful but comparable levels of association, while research culture shows a weaker and more heterogeneous relationship.

5 Conclusion

5.1 Research summary

The elevation of research culture to a standalone evaluation dimension in REF 2029 marks one of the most important changes from the REF 2021 framework. It reflects the rising recognition that organizational research culture is a core attribute of research quality and performance.

This study developed a method to measure research culture from the narrative environment statements submitted for REF

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Table 7 Ranking distribution of organizational characteristics in *Arts and Humanities*.

Characteristic	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Importance score
Degree Training	4	3	1	2	29
Staff Size	3	2	3	2	26
Economic Resources	2	3	4	1	26
Research Culture	1	2	2	5	19

2021. Using the five core dimensions of positive research culture defined in the REF 2029 guidelines, we identified the most relevant text segments in each statement and applied large language models to generate research culture scores at the organization level. These scores were designed to mimic the qualitative judgments made by REF sub-panels. We tested their validity by examining whether they explained additional variation in the official REF environment ratings beyond what could be accounted for by quantitative indicators alone. The results showed that the culture scores added statistically significant independent explanatory power.

Using these validated scores, together with measures of *staff size*, *economic resources*, and d*egree training* we estimated multiple linear regression models within each of the 34 UOAs. The dependent variable was the average star rating of impact case studies, a direct measure of social impact.

The analysis revealed clear differences across disciplinary fields. While the regression results provide estimates of the marginal associations of each characteristic, we further examined their relative importance by comparing the magnitudes of coefficients and their ranking positions across UOAs within each panel.

In the Medicine, Health and Life Sciences panel, both organization size and economic resources show relatively strong and consistent associations with societal impact, often appearing in higher ranking positions, while degree training and research culture exhibit comparatively weaker and more variable associations. In the Physical Sciences, Engineering and Mathematics panel, economic resources show the strongest and most stable association, followed by organization size. Research culture and degree training display comparatively weaker and less consistent associations across UOAs.

In the Social Science panel, the results indicate a more balanced pattern of association, where degree training, organization size, and economic resources all exhibit substantial and relatively comparable importance, although their ranking positions vary across UOAs. Research culture shows a weaker and more heterogeneous association. In the Arts and Humanities panel, the results suggest a relatively balanced structure, in which degree training shows the strongest association, while staff size and economic resources display similar and moderate levels of importance. Research culture again exhibits a comparatively weaker and more variable association.

Taken together, the results show that organizational characteristics are systematically associated with societal impact, but their relative importance varies across disciplines. staff size remains an important and relatively stable characteristic across all panels, while the roles of economic resources, degree training, and research culture differ substantially. STEM-related panels show stronger associations with resource-related characteristics, the Social Sciences panel reflects a more multidimensional pattern, and the Arts and Humanities panel exhibits a more balanced distribution of associations.

These patterns suggest that the ways in which organizations are associated with societal impact differ across fields and highlight the importance of discipline-specific approaches in research management, resource allocation, and institutional development, rather than uniform policies applied across all areas.

5.2 Practical implications

This study identifies substantial differences across disciplinary fields in the organizational characteristics associated with the societal impact of institutional research. These findings suggest that a uniform governance model may not be appropriate. Instead, differentiated development pathways tailored to disciplinary contexts are likely to be more effective in enhancing the efficiency of research resource allocation and the realization of societal value. Based on the empirical results across different disciplinary panels, the following practical implications are proposed from the perspective of institutional governance and research management:

First, organizational scale appears to be a consistently important structural characteristic across disciplines. The results show that staff size is frequently associated with higher relative importance in multiple panels, suggesting that well-developed organizational structures and a certain level of scale may be conducive to supporting broader societal engagement. Therefore, universities and research institutions may benefit from optimizing organizational systems and management structures, for example by strengthening cross-departmental collaboration, improving research platform integration, and enhancing institutional coordination capacity.

Second, resource conditions should be considered in relation to disciplinary differences. The stronger association between economic resources and societal impact observed in the Medicine, Health and Life Sciences and in the Physical Sciences, Engineering and Mathematics panels suggests that resource-intensive disciplines tend to rely more heavily on funding, infrastructure, and technical facilities. Accordingly, research investment strategies may need to account for these differences by providing more targeted support to disciplines with higher resource demands, particularly in areas involving experimental and technology-driven research.

Third, the role of educational capacity should receive greater attention in certain fields. In the Social Sciences panel, degree training shows a relatively strong and stable association with societal impact, while in the Arts and Humanities panel it also appears as one of the more important characteristics. This suggests that in these fields, talent development, knowledge

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transmission, and engagement with broader audiences may be closely linked to the realization of societal value. Therefore, institutions may consider strengthening the integration of teaching and research, as well as promoting public engagement and knowledge dissemination activities.

Finally, research culture may play a complementary and context-dependent role. Although its relative importance is generally lower compared to other characteristics, research culture still shows meaningful associations in certain disciplines, particularly in the Social Sciences. This suggests that fostering an open, collaborative, and socially engaged research environment may support the alignment between academic outputs and societal needs. Institutions may therefore benefit from encouraging interdisciplinary collaboration, strengthening socially oriented research agendas, and enhancing academic exchange networks.

5.3 Limitations and future directions

Although this paper takes an important step by incorporating '*research culture*' as a key organizational attribute into the analysis of the societal impact of research, several limitations remain that warrant further investigation and refinement in future studies.

First, limitations regarding causal identification and the temporal dimension. This paper conducts an empirical analysis based on cross-sectional data from the REF2021 assessment cycle. The relationships identified among variables primarily reflect statistical correlations and cannot support rigorous causal inference. There may be bidirectional relationships among organizational size, resource allocation, and societal impact, or these variables may be jointly influenced by unobserved factors (such as disciplinary structure or institutional development stage), raising potential endogeneity concerns. Future research could introduce causal inference methods, including propensity score matching (PSM), to obtain more rigorous causal conclusions. Furthermore, organizational characteristics such as research culture, economic resource, and degree training exhibit significant dynamic evolution, while the social impact of research often has a lagged effect, emerging gradually over a longer time horizon. Therefore, subsequent studies could incorporate follow-up assessment data, such as REF2029, construct longitudinal datasets across time points, and employ panel data models to examine the dynamic relationships and lagged effects more systematically between organizational characteristics and social impact.

Second, limitations of the indicator construction method. The research culture indicator in this study is derived from large language model (LLM)-based scoring of extracted evidence snippets, using prompts designed in accordance with the REF official assessment guidelines. While this approach offers substantial efficiency advantages in processing large-scale textual data, it is subject to several limitations inherent to AI-assisted methods. Specifically, LLM-generated evaluations may be influenced by prompt design, variations in textual expression, and potential model errors such as hallucination or inconsistency. In addition, the results may be sensitive to model version changes (i.e. version drift), which could affect the stability and reproducibility of the measurement. Furthermore, this study does not incorporate independent human validation of the scoring results, which may limit the extent to which the indicator fully captures the underlying research culture. Future research could incorporate human-annotated benchmarks, alternative model specifications (e.g. full-text input), and systematic robustness checks to further improve the reliability and explanatory power of the method.

Third, limitations of the text processing strategy. This paper adopts a heuristic method based on fixed-length segmentation and semantic similarity filtering to extract evidence related to research culture. While this approach improves computational efficiency, it may compromise the complete retention of key semantic information, thereby introducing potential bias into the measurement of research culture. Future research could explore more refined evidence processing strategies to accommodate complex information scenarios, such as embedded charts and figures.

Fourth, limitations at the conclusion level. Although this paper identifies significant structural differences across the four main panels, there may still be considerable subfield heterogeneity within each panel. For example, important differences in research patterns and impact pathways may exist among different medical subfields or among different social science subfields. Future research could integrate more diverse and specific case data and conduct analyses at a finer-grained disciplinary level to enhance the explanatory depth of the conclusions.

In summary, future research can be extended in several directions: first, by introducing longitudinal data and dynamic models to deepen the understanding of causal relationships and temporal mechanisms; second, by improving variable measurement and expanding data sources to enhance analytical precision; third, by incorporating human validation and robustness checks to strengthen methodological reliability; and fourth, by integrating external environmental factors and sub disciplinary analyses to construct a more comprehensive explanatory framework. These directions will help further elucidate how multidimensional organizational characteristics (including research culture) are associated with the societal impact of research, and provide more targeted theoretical and practical guidance for enhancing the societal value of research.

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Conflicts of interest

The authors declare that there are no competing interests, whether financial or non-financial, that could influence or be perceived to influence the work reported in this manuscript.

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