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Unpacking the metrics: a critical analysis of the 2025 QS World University Rankings using Australian university data

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Despite extensive critiques of university rankings highlighting their emphasis on reputation metrics over teaching quality and equity, empirical validation remains limited. This study addresses this gap by analysing relationships between QS World University Rankings indicators and overall scores for Australian universities (2025 dataset). Using correlational analyses on publicly available data, the findings identify Academic Reputation, Employer Reputation, and Employment Outcomes as influential metrics, while Faculty-to-Student Ratio and Sustainability show limited or negative correlations. Results further suggest systemic biases favouring larger, research-intensive institutions, potentially disadvantaging smaller or specialised universities regardless of academic quality. Although focused on the Australian higher education context, this research contributes timely empirical insights relevant globally. The findings inform university leaders, policymakers, and scholars, providing evidence to critically evaluate ranking methodologies and advocating for transparent, equitable, and pedagogically inclusive approaches to assessing institutional excellence.

KEYWORDS

academic reputation, Australian universities, higher education rankings, institutional performance, QS World University Rankings

Introduction

University rankings have become increasingly influential in shaping the global higher education landscape, significantly impacting the strategies and operations of academic institutions worldwide. These rankings are extensively utilised by prospective students to inform their university choices, by policymakers and funding bodies to guide resource allocation, and by institutional leaders to benchmark performance and strategise improvements. The influence of rankings extends beyond mere comparison; they actively shape institutional reputations, drive competitive funding dynamics, and enhance or constrain international research and academic collaborations (Hazelkorn, 2018; Marope et al., 2013). As ranking outcomes directly affect universities' visibility and competitiveness, institutions often adapt their priorities and practices to align more closely with ranking criteria, reinforcing the perceived legitimacy and importance of these metrics. This profound influence underscores the necessity of critically evaluating the metrics used in rankings, their prioritisation, and their broader implications for educational quality and equity.

Key metrics and critiques

Most ranking systems emphasise academic reputation, research performance, and economic value, aligning closely with national and institutional goals for global competitiveness, funding, and prestige (Marginson, 2016). However, prioritising these factors often sidelines critical dimensions such as teaching quality and equity, essential pillars of educational integrity. Despite their widespread acceptance, global rankings face critiques regarding methodological transparency, validity, and their over-reliance on subjective, perception-based indicators (Sauder and Espeland, 2020; Shin et al., 2011). These critiques highlight structural biases inherent in rankings that disproportionately favour metrics aligned with elite research outputs and economic considerations over pedagogical effectiveness and equitable access.

The Australian context and global perspectives

In Australia, higher education is a major national export industry, heavily influenced by international enrolments. Australian universities frequently use QS World University Rankings in marketing strategies to attract international students and justify tuition fee structures (Universities Australia, 2023). With over 30 Australian universities competing globally, rankings serve both as performance benchmarks and promotional instruments, generating tension between perceived and actual educational quality. This tension is not unique to Australia and reflects broader global debates about defining academic excellence. For example, Latin American scholars and university leaders argue that global rankings impose a hegemonic Anglo-American university model, neglecting their distinct cultural, social, and developmental missions (Bernasconi, 2013; Maldonado-Maldonado and Cortés, 2016; Ordorika and Lloyd, 2013). The varied responses across different countries, some resisting rankings to pursue equity-driven reforms, others leveraging rankings to guide public investments, underscore the transnational impacts of rankings and the need for empirical studies that critically evaluate ranking frameworks within specific national contexts.

Research gap and significance

Despite extensive critiques regarding methodological limitations and structural biases inherent in university rankings (Hazelkorn, 2018; Marope et al., 2013; UNESCO, 2021), rigorous empirical examination of recent ranking data remains limited. While the literature robustly highlights how rankings often prioritise metrics disconnected from universities' fundamental educational missions, particularly teaching quality, student support, and equity (Sauder and Espeland, 2020; Shin et al., 2011), empirical validation of these critiques through recent ranking data analyses is scarce. This study aims to bridge this gap by empirically assessing the QS World University Rankings' 2025 dataset for Australian universities. Specifically, it investigates whether the established critiques of ranking methodologies remain valid and explores which factors underpin the rankings. By clarifying how metrics are organised and their effectiveness, this study provides empirically grounded insights that can inform critical reassessments of global ranking frameworks.

This study unveils how recent university ranking metrics correlate with specific institutional factors within the Australian context, providing a contemporary empirical reference for ongoing global debates about university rankings. Although the analysis is grounded in the Australian higher education landscape, its broader implications extend to global contexts, offering valuable insights into structural biases and their social consequences. Ultimately, this research advances the dialogue on fairer, more inclusive, and pedagogically responsive approaches to evaluating institutional excellence. The study underscores broader societal implications, such as the disproportionate benefits that reliance on global rankings can confer upon applicants from privileged backgrounds, as exemplified by Chile's Becas-Chile scholarship program (Perez Mejias et al., 2018). By elucidating structural consequences within the Australian context, this research provides valuable empirical evidence for universities, policymakers, and ranking agencies globally, advocating for fairer, more inclusive, and pedagogically grounded evaluation practices.

Literature review

Historical development and evolution of university rankings

The development of university rankings has evolved from national classification systems and informal reputation surveys into complex global frameworks. One of the earliest formal classification efforts was the Carnegie Classification introduced in 1970 in the United States, which categorised institutions based on research intensity. Although not a ranking per se, it laid the groundwork for later metrics-based comparisons (Altbach and Salmi, 2011). The formalisation of rankings began in 1983 with the launch of the U. S. News & World Report rankings. These rankings incorporated both subjective peer assessments and quantitative indicators such as graduation rates and faculty resources, thereby establishing a model for comprehensive institutional evaluation (U.S. News & World Report, 2024). Around the same time, European countries developed systems aligned with national priorities. For instance, France's Centre National de la Recherche Scientifique (CNRS) and Germany's Centre for Higher Education Development (CHE) introduced evaluations that emphasised institutional accountability and performance benchmarking, particularly in relation to national policy goals (Dill and Soo, 2005; Usher and Savino, 2007).

The early 2000s marked a shift toward international comparisons, driven by the growing need for global standards in higher education quality assurance. UNESCO played a key role in advocating for internationally comparable evaluation frameworks (Marginson and van der Wende, 2007, as cited in Shin et al., 2011). This global momentum culminated in the release of the Academic Ranking of World Universities (ARWU) by Shanghai Jiao Tong University in 2003. ARWU introduced a research-centric methodology that prioritised indicators such as Nobel laureates, Fields Medal recipients, and publication outputs, signalling a new era of rankings focused on elite research productivity (ShanghaiRanking, 2024).

In 2004, Times Higher Education (THE) and Quacquarelli Symonds (QS) collaborated to launch the first iteration of the THE–QS World University Rankings, combining data collected by QS with editorial oversight from THE. This partnership produced joint global rankings until 2009. In 2010, the collaboration ended, and both organisations developed independent methodologies. QS retained the original framework and data sources, continuing under the title QS World University Rankings. Meanwhile, THE partnered with Thomson Reuters (now Elsevier) to develop a new ranking methodology focused more heavily on research environment and teaching metrics (Hazelkorn, 2015; QS, 2024a; Times Higher Education, 2024).

Over time, QS has broadened its scope by introducing regional rankings, subject-specific assessments, and graduate employability indices. Recent additions include metrics for sustainability, international research collaboration, and employment outcomes, reflecting evolving global priorities in higher education (QS, 2024b). As of 2025, the QS World University Rankings remain one of the most prominent and influential systems globally. The current methodology is structured around five thematic lenses: Research and Discovery (50%), Employability and Outcomes (20%), Global Engagement (15%), Learning Experience (10%), and Sustainability (5%). These lenses are operationalised through specific indicators: Academic Reputation (30%) and Citations per Faculty (20%) fall under Research and Discovery; Employer Reputation (15%) and Employment Outcomes (5%) under Employability; and four metrics including International Faculty Ratio, International Research Network, International Student Diversity, and International Student Ratio (each 5%) comprise the Global Engagement lens. The Learning Experience lens includes the Faculty-to-Student Ratio (10%), while Sustainability is represented by a dedicated 5% indicator.

While this multifactorial QS ranking structure suggests a comprehensive approach, the dominance of reputation-based indicators and the relatively limited weight allocated to pedagogical quality and student experience have attracted increasing scrutiny from scholars (Hazelkorn, 2015; Marginson, 2014; Sauder and Espeland, 2020). Methodological criticisms, particularly regarding the reliance on reputation surveys and bibliometric data, highlight potential biases that reinforce the standing of historically prestigious institutions, often neglecting broader dimensions of educational quality such as teaching excellence, equity, and community engagement (Dill and Soo, 2005; Van Raan, 2005; Kehm and Stensaker, 2009).

The influence of university rankings in higher education

University rankings have become a dominant force in shaping higher education systems globally. A substantial body of literature demonstrates their growing influence over institutional behaviour, government strategies, and cross-border collaboration (Hazelkorn, 2018; Marope et al., 2013). At the governmental level, particularly in emerging and middle-income economies, rankings are used to prioritise funding allocations and guide reforms in curriculum, infrastructure, and research capacity. For example, national excellence initiatives in countries like China, Japan, and Russia have led to ranking improvements of up to 17 places, largely driven by targeted investment and policy coordination (Altbach and Salmi, 2011; Marope et al., 2013). Similarly, in Latin America, scholars and education leaders have raised sustained critiques of global university rankings, highlighting their methodological bias and epistemological limitations. These systems are said to impose a research university archetype rooted in Anglo-American traditions, overlooking historic regional missions of public service, social justice, and community-based pedagogy (Ordorika and Lloyd, 2013; Ordorika and Lloyd, 2013; García de Fanelli, 2019).

Rankings have also been linked to widening funding inequalities in the region, as governments increasingly channel resources into top-ranked institutions at the expense of regional universities with socially critical roles (Finardi et al., 2023). Additionally, the dominance of English-language bibliographic databases in citation indicators marginalises Spanish and Portuguese scholarship, reinforcing what some describe as "epistemological hegemony" (Darwin and Barahona, 2024). In response, regional experts have proposed alternative frameworks such as U-Multirank and context-sensitive models that better recognise mission diversity and equity (Marope et al., 2013). These perspectives resonate with broader global concerns about the homogenising effects of rankings and reinforce the rationale for a more inclusive, pedagogically grounded framework.

On the institutional level, university rankings shape enrolment strategies, brand positioning, and academic recruitment. High-ranked universities attract high-performing students who perceive rankings as indicators of academic quality and career outcomes (Hazelkorn, 2015). Institutions often respond by expanding English-language programmes, increasing international student enrolments, and prioritising faculty with high research visibility. This behaviour aligns with findings that institutions actively adapt their operational strategies to align with ranking criteria (Sauder and Espeland, 2020).

Rankings also influence employer perceptions and downstream migration pathways. Employers frequently use university rankings as proxies for graduate quality, with implications for hiring decisions and professional reputation. For example, Australia's National Innovation visa scheme prioritises PhD holders from universities ranked in the global top 100, directly linking ranking status to immigration eligibility (Department of Home Affairs, 2023). Similar policies in Canada and the UK illustrate how rankings are embedded into national talent attraction strategies (Kwak and Chankseliani, 2024).

At the global level, rankings influence academic hierarchies and geopolitical narratives. Investment-driven advancements by universities in regions such as the Gulf States, East Asia, and Latin America have resulted in these institutions entering global top tiers, challenging the traditional dominance of Anglo-American systems (Times Higher Education, 2025). This global reordering reflects a shift in power dynamics and the role of rankings in soft diplomacy and national competitiveness.

A recurring theme in the literature is the distortion of institutional missions. Empirical studies argue that rankings encourage metric-driven behaviours at the expense of broader educational values such as pedagogical quality, equity, and community engagement (Hazelkorn, 2018; Shin et al., 2011). Moreover, the pressure to perform on specific indicators can lead to superficial policy reforms or resource allocation that may not translate into genuine improvements in learning or societal outcomes. This pressure to conform to a single, dominant model of university quality is a global concern. In Mexico, rankings have been identified as powerful policy drivers, pushing institutions toward elite, STEM-focused configurations that may not align with national development needs (Estevez Nenninger et al., 2018). Moreover, a policy brief by the United Nations University warns that such rankings often incentivise universities to prioritise short-term gains, such as superficial metric improvements over meaningful investments in teaching, staff wellbeing, or community partnerships (United Nations University, 2023). These trends exemplify how rankings can distort institutional priorities even in systems with different educational missions and socio-political goals.

Collectively, the literature suggests that while rankings can incentivise improvement and visibility, their outsized influence must be critically assessed, particularly when institutional goals become narrowly aligned with ranking metrics rather than educational quality or equity outcomes. Within this global context, the Australian higher education sector exemplifies the strategic integration of rankings into institutional and national agendas. Australia is one of the world's leading destinations for international students, with international education representing a multi-billion-dollar export industry. As such, Australian universities actively leverage rankings. Particularly QS and THE rankings, in promotional campaigns, branding strategies, and international recruitment efforts (Universities Australia, 2023). The visibility of global rankings supports narratives of institutional excellence, justifies tuition frameworks, and shapes decisions about partnerships, curriculum development, and infrastructure. Rankings also play a crucial role in national education diplomacy and influence how Australian institutions position themselves within regional and global academic markets. These dynamics highlight the high-stakes environment in which Australian universities operate and the reliance on rankings as both a tool and a benchmark for institutional success (Hazelkorn, 2018; Marope et al., 2013).

Critique and empirical analysis of rankings

Despite their widespread influence, university rankings face growing scrutiny due to significant conceptual and methodological limitations. A primary concern is the over-reliance on subjective reputation-based indicators, particularly in the QS World University Rankings, where Academic and Employer Reputation together account for 45% of the total score. These survey-based metrics tend to reinforce established hierarchies rather than reflect current institutional performance (Shin et al., 2011). Critics have also highlighted the methodological opacity and questionable validity of some metrics used across ranking systems. For example, citation metrics, while popular as a proxy for research output can be highly variable across disciplines and do not necessarily reflect research impact or teaching quality (Van Raan, 2005; Bornmann and Daniel, 2008; Elsevier, 2022).

Language and regional biases have also been documented, particularly the favouring of institutions in English-speaking, high-income countries, thus marginalising universities with strong local missions in non-Anglophone contexts (Marginson and van der Wende, 2007). Additionally, university rankings often neglect pedagogical excellence, community engagement, and social inclusion, leading to a narrow conception of institutional quality (Dill and Soo, 2005; Kehm and Stensaker, 2009). This emphasis on research metrics has been linked to the marginalisation of teaching responsibilities and broader public service goals. Institutional behaviour is also influenced by rankings, with some universities adopting strategies that artificially enhance their scores. Examples include hiring highly cited researchers or Nobel laureates and forming nominal international partnerships to inflate metrics related to research reputation and global engagement (Marope et al., 2013).

Taken together, these critiques highlight the need for a more balanced, transparent, and multidimensional approach to evaluating university performance. This study contributes to this growing dialogue by offering a correlation-based analysis of QS World University Rankings indicators in the Australian context. It explores the extent to which current QS metrics align or misalign with empirically grounded indicators of educational quality, thereby informing future ranking methodologies that are more pedagogically inclusive and context sensitive.

Methodology

This study utilises publicly available data from the QS World University Rankings 2025, with a specific focus on Australian universities due to resource constraints and the feasibility of consistent institutional comparison within a single national context. The dataset was retrieved and adapted from the official QS rankings website and includes metrics such as Academic Reputation, Employer Reputation, Faculty-to-Student Ratio, Citations per Faculty, International Faculty Ratio, International Student Ratio, International Research Network, Employment Outcomes, and Sustainability (QS, 2025b). While the extracted and processed dataset used for the analysis is provided as Supplementary material, the complete dataset remains accessible through the official QS source (QS, 2025b).

During the data preparation stage, the dataset was cleaned to retain only numeric values and ensure consistency in the variable formats. Initially, records for 38 Australian universities were retrieved from the QS World University Rankings 2025 dataset. However, 7 of these institutions lacked an Overall Score and were therefore excluded from the analysis. As a result, data from 31 Australian universities were included in the final analysis.

The analysis was conducted in two stages. In the first stage, descriptive statistics and boxplots were used to examine the distribution of Overall Scores across university classifications provided by QS, specifically Size (Extra Large, Large, Medium, Small) and Focus (Fully Comprehensive, Comprehensive, Focused). These visualisations offered insights into structural patterns and institutional characteristics within the dataset.

In the second stage, Pearson correlation coefficients were computed to evaluate the strength and direction of relationships between the ranking indicators and the Overall Score. This statistical analysis was performed using Python libraries, including pandas, seaborn, and matplotlib. A correlation heatmap was generated to visualise these associations, highlighting both strong and weak correlations, including negative ones. This approach allowed for a detailed quantitative assessment of which indicators most significantly contribute to QS rankings and how they interact with one another.

It is important to clarify that this analysis of the QS ranking criteria is based on the methodology applied to the QS World University Rankings 2025 dataset. Any subsequent changes to QS's ranking methodology, such as those introduced for the 2026 rankings (published in 2025) (QS Quacquarelli Symonds, n.d.), including the adjustment where International Student Diversity became an unweighted indicator, are not reflected in this paper. This paper exclusively presents and discusses the matrix relevant to the 2025 ranking cycle.

Results and discussion

Descriptive analyses reveal observable patterns in how QS classifications based on university size and institutional focus relate to Overall Scores. According to QS (2024a), university size is categorised into four groups: Extra Large (XL), Large (L), Medium (M), and Small (S), based on student enrolment volume. Although QS does not disclose the exact student number thresholds for each category, these classifications broadly reflect institutional scale, ranging from small regional institutions to large, multi-campus universities. Meanwhile, focus refers to the breadth of academic offerings and is categorised into three levels: Fully Comprehensive (FC) institutions offer a wide and balanced range of academic disciplines, often including professional degrees, humanities, sciences, and technology; Comprehensive (CO) universities offer a broad portfolio but may emphasise specific disciplinary clusters; and Focused (FO) institutions are more specialised, concentrating on a narrower academic or professional area (e.g., education, health, or creative arts).

As shown in Figure 1, Extra Large (XL) universities recorded the highest average Overall Scores, followed by Large (L) and Medium (M) institutions. Small (S) universities exhibited the lowest mean scores. This trend aligns with broader concerns that university rankings reward scale and visibility, which often advantage larger institutions with diverse offerings and substantial resources. It is also plausible that larger universities benefit from higher Academic and Employer Reputation scores, both of which collectively account for a substantial proportion of the QS methodology. Given that reputation-based indicators are influenced by institutional recognition and branding, larger and more established institutions may be more likely to receive favourable assessments from academics and employers alike, further reinforcing their positions in global rankings.

Figure 2 illustrates the distribution of QS Overall Scores by institutional focus. Fully Comprehensive (FC) universities exhibited the highest and most consistent Overall Scores. Comprehensive (CO) universities showed more variability and generally lower scores, while Focused (FO) institutions had the lowest median scores and the greatest dispersion. These findings suggest that breadth of academic disciplines and institutional scope may positively influence perceived quality and ranking outcomes. It is plausible that QS rankings, by prioritising reputation and citation-based metrics, inherently favour institutions that are broader in focus and thus more visible across multiple academic domains. Focused institutions, despite possibly excelling in niche areas or maintaining high-quality education in specialised fields, may be disadvantaged in the current QS methodology, which tends to amplify the advantage of institutional scale, disciplinary breadth, and established global recognition.

These descriptive patterns are consistent with critiques of global rankings that highlight systemic favouritism toward large, research-intensive institutions. The implications of these structural classifications are discussed further below in relation to the performance indicators and correlation findings.

Correlation between each indicator and the overall score

The correlation analysis revealed that the Overall Score was most strongly associated with Academic Reputation, $r(29) = 0.98$, $p < 0.001$, followed by Employer Reputation, $r(29) = 0.97$, $p < 0.001$, and Employment Outcomes, $r(29) = 0.94$, $p < 0.001$ (see Figure 3). These indicators, which collectively account for 50% of the QS methodology (QS, 2024a), highlight the dominant role of perception-based metrics. While widely cited as measures of prestige, such metrics have been criticised for perpetuating historical privilege and lacking responsiveness to current institutional improvements (Hazelkorn, 2015; Marginson, 2014).

Citations per Faculty also demonstrated a strong association with the Overall Score, $r(29) = 0.79$, $p < 0.001$, affirming the significance of research productivity. However, its slightly lower strength compared to reputation-based metrics indicates that empirical research performance alone does not drive rank outcomes. Notably, the correlation between Citations per Faculty and Academic Reputation was moderate, $r(29) = 0.67$, $p < 0.001$, suggesting that research reputation does not always align with measurable. This

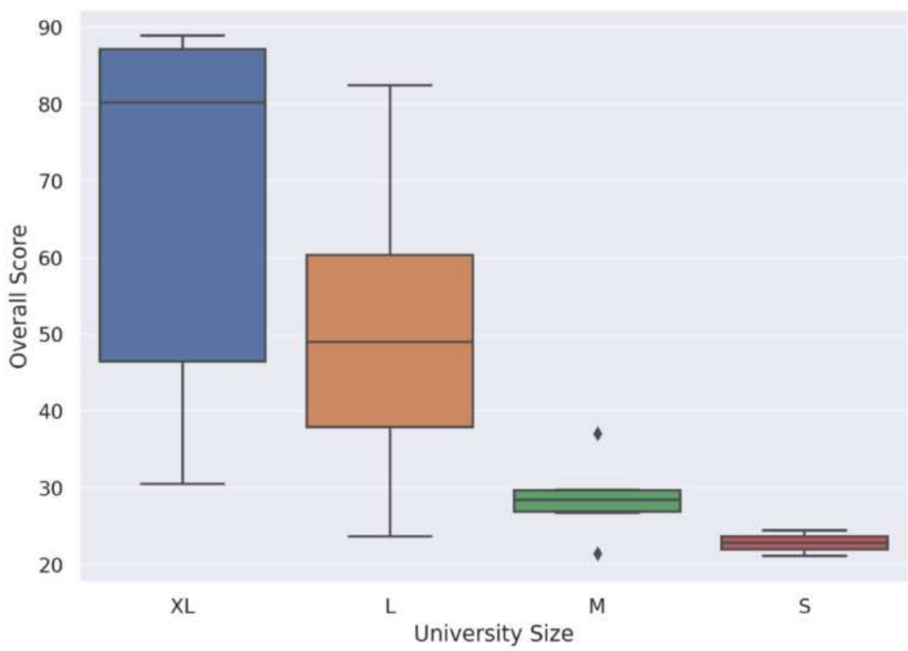

FIGURE 1
Average QS overall score by university size.

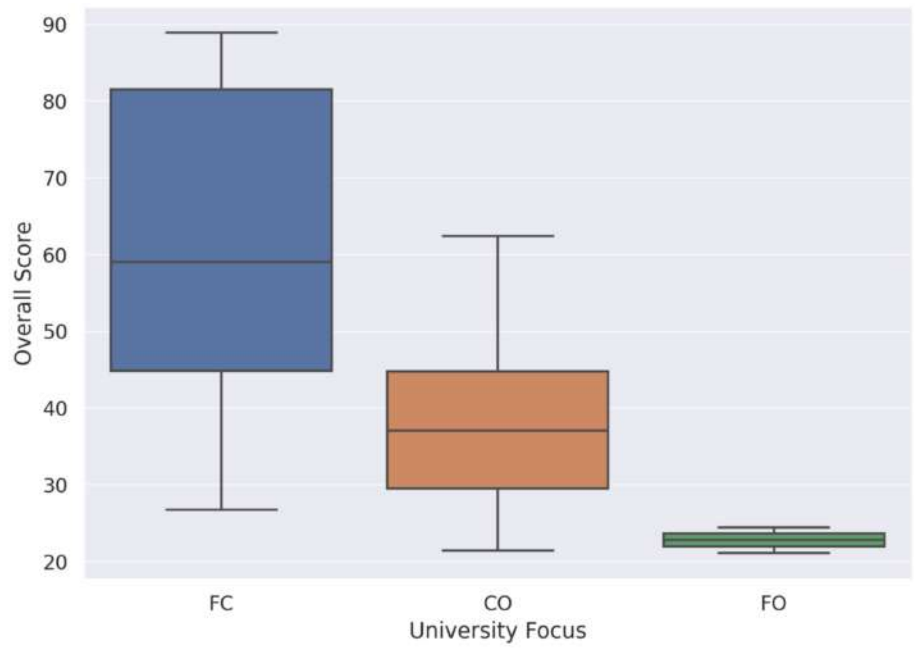

FIGURE 2
Distribution of QS overall scores by university focus.

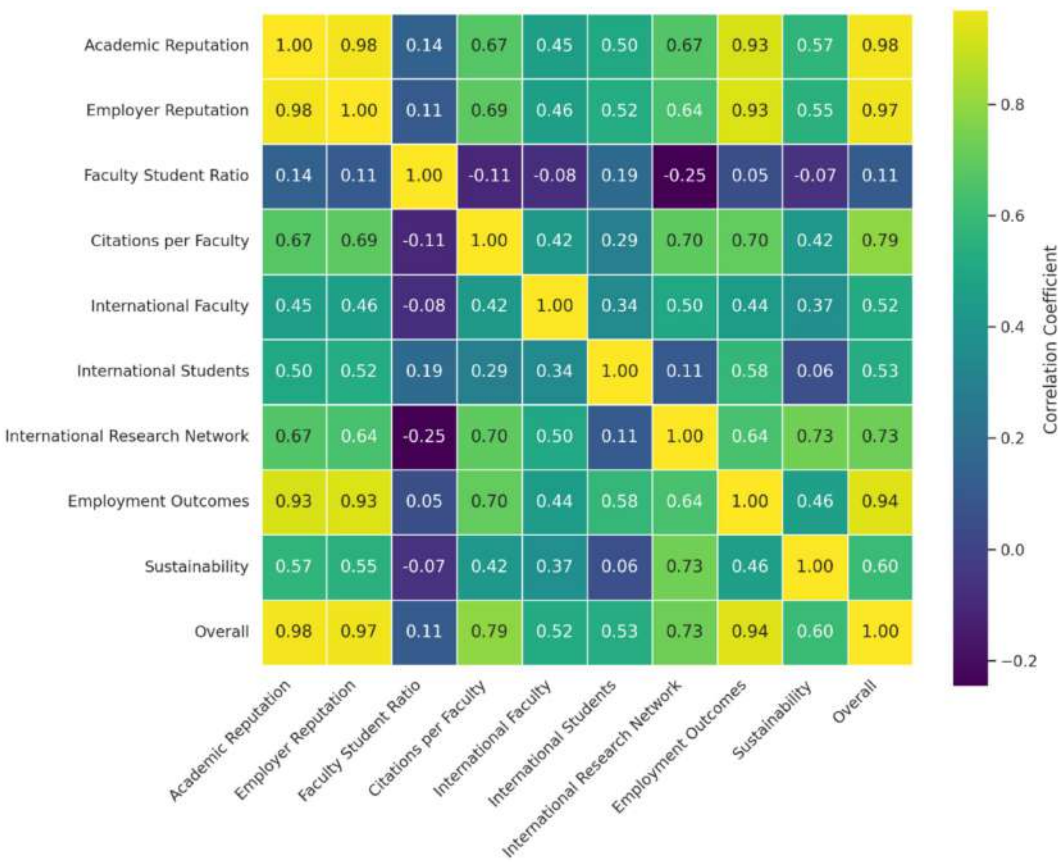

FIGURE 3
Correlation heatmap of QS 2025 ranking indicators (Australian universities).

concern has been the subject of sustained academic critique. Scholars such as Bornmann and Daniel, 2008 and Tahamtan and Bornmann (2019) have argued that reputation-based indicators often reflect historical prestige and subjective perceptions rather than current, verifiable research performance. These metrics risk reinforcing institutional hierarchies and may obscure disciplinary differences in publication and citation practices, ultimately undermining the reliability of rankings that heavily rely on reputation scores.

Faculty Student Ratio exhibited a weak correlation with the Overall Score, $r(29) = 0.11$, $p = 0.556$, and was negatively correlated with several other indicators: International Research Network, $r(29) = -0.25$, $p = 0.166$; Sustainability, $r(29) = -0.07$, $p = 0.702$. These findings indicate a misalignment between teaching-related infrastructure and the criteria valued by global rankings. Despite evidence that lower student-to-faculty ratios are linked to better student engagement and outcomes (Umbach and Wawrzynski, 2020; Shin et al., 2011), such metrics are underweighted in the QS framework. This suggests that pedagogical quality and student-centred learning environments are systematically undervalued in favour of research visibility and internationalisation, raising concerns about the extent to which rankings reflect the core educational mission of universities.

Moderate correlations were observed for International Faculty, $r(29) = 0.52$, $p = 0.003$, and International Students, $r(29) = 0.53$, $p = 0.002$, indicating some influence of internationalisation metrics. Sustainability also showed a moderate positive correlation with the Overall Score, $r(29) = 0.60$, $p < 0.001$, reflecting the increasing but still secondary weight given to institutional commitment to environmental and social responsibility.

Correlation among the ranking indicators

As shown in Figure 3, the correlation map revealed strong interconnections among reputational indicators. Academic Reputation and Employer Reputation were nearly collinear, $r(29) = 0.98$, $p < 0.001$, suggesting potential redundancy in their measurement. Employment Outcomes were also strongly correlated with both Academic Reputation, $r(29) = 0.93$, and Employer Reputation, $r(29) = 0.93$, indicating that employability rankings may be shaped more by perception than by distinct labour market data (Hazelkorn, 2015).

Citations per Faculty correlated moderately with Academic Reputation ($r(29) = 0.67$, $p < 0.001$), yet much lower with Faculty Student Ratio ($r(29) = -0.11$, $p = 0.556$), reinforcing the idea that teaching capacity and research recognition function in largely disconnected domains under the current model. Faculty Student Ratio also displayed weak or negative correlations with Employment Outcomes ($r(29) = 0.05$, $p = 0.796$), Sustainability ($r(29) = -0.07$, $p = 0.702$), and International Research Network ($r(29) = -0.25$, $p = 0.166$), further suggesting the marginal role of pedagogical investment in global performance evaluations.

Critical evaluation of the ranking metrics and its implications

The analysis reinforces the understanding that the QS World University Rankings tend to disproportionately reward institutional visibility, research output, and stakeholder perception. The prominence of Academic Reputation and Employer Reputation, both derived from large-scale surveys, reflects a heavy reliance on subjective inputs that may reinforce legacy hierarchies rather than assess contemporary institutional performance (Dill and Soo, 2005; Sauder and Espeland, 2020). Although Citations per Faculty provides a more quantifiable measure of academic output, it does not offset the dominant role played by reputational indicators. The fact that Citations per Faculty correlates more strongly with Overall Score than Faculty-to-Student Ratio highlights a methodological preference for research productivity over indicators typically associated with teaching quality. This pattern points to a systemic undervaluation of teaching infrastructure and student support within the QS methodology. Faculty-to-Student Ratio, a widely recognised proxy for academic accessibility and class size, exhibits weak or even negative correlations with several other indicators. This is notable given substantial empirical evidence linking smaller class sizes and more engaged faculty with improved student learning outcomes and satisfaction (Umbach and Wawrzynski, 2020; Shin et al., 2011). Similarly, the limited correlation between Sustainability and other core indicators suggests that institutional commitment to social responsibility is only marginally reflected in ranking outcomes. These trends mirror structural critiques from Latin America, where ranking-driven pressures have been shown to distort academic values and institutional priorities. Ordorika and Lloyd (2013) argue that global ranking systems structurally disadvantage Latin American universities by privileging indicators aligned with Anglo-American models, which emphasise research volume, citation metrics, and international prestige, while neglecting missions grounded in social equity, cultural relevance, and public service. Extending this critique, Finardi et al. (2023) observe that such pressures increasingly incentivise scholars in the region to publish in international, English-language journals, often at the cost of locally oriented research agendas and epistemic diversity. These global parallels underscore the urgency of redefining university quality in ways that better reflect institutional diversity, pedagogical excellence, and social contribution.

Furthermore, the descriptive findings indicate that large and fully comprehensive universities tend to score higher in the QS rankings. This trend implies that institutional size and breadth may confer advantages within the current framework. Larger institutions are more likely to attract global partnerships, secure higher research funding, and achieve broader visibility, all of which align with QS's weighting of reputation, international engagement and publication-based metrics. In contrast, smaller or more specialised universities, including those with strong pedagogical outcomes, may be structurally disadvantaged. Their limited scale and narrower disciplinary focus can restrict performance on visibility-driven indicators, despite their potential excellence in teaching or niche research areas. Therefore, the weighting structure appears to favour large, research-intensive institutions, raising concerns about fairness and inclusiveness in global rankings.

In essence, while QS rankings continue to serve as a high-profile reference for institutional comparison, their reliance on reputational and research-intensive measures may distort perceptions of institutional quality. A more balanced approach that incorporates teaching effectiveness, equity-focused strategies, and local impact could result in a more holistic and inclusive assessment of university performance. Such a revision would not only broaden recognition across diverse types of institutions but also promote more equitable and pedagogically meaningful evaluation frameworks in higher education.

Recommendations

Drawing on the findings and critical evaluation of the QS World University Rankings, a number of strategic recommendations are proposed to enhance the transparency, equity, and methodological robustness of global university ranking systems, ensuring they reflect and support the core missions of higher education institutions.

Stakeholders, including ranking agencies, government bodies, and academic leaders, are encouraged to undertake a careful and inclusive re-examination of ranking methodologies. Future frameworks should move beyond reliance on static, perception-based indicators by adopting pilot models that actively incorporate feedback from a diverse range of institutions. Establishing regional working groups, particularly with representation from underrepresented regions such as the Global South, could promote participatory development and mitigate systemic biases in indicator design (Hazelkorn, 2018).

National governments and policymakers have a critical role in supporting the development of locally relevant, context-sensitive metrics. These should be aligned with strategic educational goals and encourage balanced improvement in both research and teaching quality. In parallel, public agencies could play a facilitative role in encouraging ranking organisations to disclose data sources and methodological choices transparently, enabling independent verification and fostering public trust (Marope et al., 2013).

Universities, for their part, may benefit from pursuing a dual strategy. While working to enhance performance in commonly ranked indicators, such as international research networks and citation impact, they should also contribute constructively to dialogue on the refinement of ranking criteria. Engagement in ranking reform discussions can help ensure that institutional diversity, educational impact, and equity goals are appropriately valued (Sauder and Espeland, 2020).

Ranking organisations should also be urged to increase transparency in their processes. This includes publishing detailed methodological reports, providing access to raw datasets, and adopting clearer rationales for indicator weightings. Enhanced transparency is essential to reduce the perception of opacity and arbitrariness that often surrounds global ranking outputs (Bornmann and Daniel, 2008).

Finally, it is recommended that students, funding agencies, and other key stakeholders approach rankings with critical awareness. Rather than treating rankings as definitive indicators of institutional quality, users are encouraged to supplement them with other information sources, such as national performance matrices, teaching evaluations, graduate outcomes, and field-specific assessments. As Marginson (2014) suggests, a pluralistic and evidence-based understanding of institutional performance would better serve individual learners and contribute to a more holistic higher education ecosystem.

The aforementioned recommendations advocate for a more reflective and balanced approach to the use and development of global university rankings. Ensuring their future relevance and legitimacy depends on broader stakeholder participation, methodological accountability, and alignment with the diverse purposes of higher education.

Limitations

This study is subject to several limitations that should be acknowledged when interpreting the findings. First, the analysis relied solely on publicly available data from the QS World University Rankings 2025. As such, it was restricted to the core indicators reported by QS and does not include potentially influential internal metrics such as teaching evaluations, student engagement, or institutional context.

Second, the scope of the study focused exclusively on Australian universities. While this national perspective offers valuable insights into the local implications of global rankings, the results may not be generalisable to institutions in other regions where structural, policy, and cultural factors differ. Future research may extend this approach to comparative studies involving universities across multiple countries or regions.

Third, the analysis was based on Pearson correlation coefficients to identify relationships between ranking indicators and overall scores. Although correlations offer useful insights into the strength and direction of associations, they do not establish causality. Interpretations must therefore be made with caution, as correlation does not imply a direct or causal effect between variables.

Finally, the study employed a cross-sectional analysis of a single year's data. Rankings and institutional performances can vary over time, and longitudinal analysis may reveal additional patterns or shifts in factor importance. Future research could expand the temporal dimension to assess changes across multiple years and the stability of indicator influence. Despite these limitations, the study contributes meaningfully to ongoing debates about the validity, influence, and reform of global university ranking methodologies.

Conclusion

This study examined the relationships between key indicators in the QS World University Rankings and the overall institutional scores of Australian universities in the 2025 dataset. By applying descriptive and correlation analysis to publicly available data, the study identified both systemic patterns and specific metric-level relationships that shape ranking outcomes.

The findings confirm that reputation-based indicators-Academic Reputation, Employer Reputation, and Employment Outcomes-are the most influential in determining institutional rank. Conversely, indicators more directly associated with pedagogical quality and educational environment, such as Faculty-to-Student Ratio and Sustainability, demonstrated weak or negative correlations with overall score. In addition, descriptive analysis revealed that larger and more comprehensive universities generally performed better in QS rankings, suggesting structural advantages tied to institutional scale and academic breadth.

These insights raise critical questions about the validity and inclusiveness of the QS ranking framework. Institutions with focused academic profiles or smaller enrolments may be structurally disadvantaged despite strong teaching or niche research excellence. Furthermore, the dominant role of perception-based metrics potentially reinforces historical prestige rather than capturing current institutional performance.

The study is limited by its reliance on a single year of QS data and its exclusive focus on Australian universities, which may constrain generalisability to other global contexts. As the analysis is correlational and cross-sectional, causality should not be inferred. Beyond the Australian case, this study contributes to an expanding international discourse that critiques the narrow metrics underpinning global rankings. Latin American experiences show how uncritical adoption of these frameworks can marginalise universities with strong teaching profiles and community-based missions. Recognising these patterns strengthens the call for globally inclusive and socially responsive ranking reforms that prioritise equity, institutional mission, and educational quality over visibility alone (Ordorika and Lloyd, 2013; UNESCO, 2021).

Future research could build on this foundation by incorporating multi-year data, cross-country comparisons, and qualitative assessments of teaching and community engagement. A more participatory and transparent approach to constructing global ranking frameworks, one that meaningfully integrates measures of teaching quality and social contribution could offer a fairer and more accurate reflection of institutional value in higher education.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MB: Writing – original draft, Methodology, Project administration, Data curation, Visualization, Validation, Resources, Investigation, Supervision, Funding acquisition, Conceptualization, Software, Formal analysis, Writing – review & editing.

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The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Gen AI was used in the creation of this manuscript. GenAI was used for preparing the Python scripts to analyze the data.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1619897/full#supplementary-material

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Original Article

The predictability of QS ranking based on Scopus and SciVal data

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Abstract: The use of international university rankings is an internationally recognized way of evaluating higher education systems and institutions. The QS ranking is one of the best-known among them, and it ranks institutions along six indicators. This study has two objectives. We first examine how the QS ranking and the university rankings derived from the variables obtained from the Scopus/SciVal database by the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) ranking procedure relate to each other. We find that the QS ranking and the ranking obtained with the Scopus/SciVal data show strong similarity. The second goal was to test the place of the countries on the ranking. A comparison of universities from countries on the QS ranking led to the conclusion that the top-ten ranked countries were mainly smaller Western European countries as well as two city-states from the Far East. Our analysis can be considered somewhat unique as the method for calculating the data determining the QS rankings is not always available on the QS website, so the ranking cannot be repeated. In addition, the ranking results are only available once a year, so only the results of the most recent QS measurement are available between the two dates.

Keywords: University ranking, TOPSIS, Scopus / SciVal

Introduction

Higher education plays an increasingly important role in the economic growth and social development of individual nations (OECD, 2015). Higher education institutions are increasingly prominent players in terms of knowledge production and sharing as well as innovation potential (El Gibari et al., 2018). Their activities and performance—like other industries and human activity in general—are constantly measured and monitored. The now accepted and internationally recognized form of this is the use of international university rankings. These rankings have also become the center of attention for science policy at the national level, and for governments and students facing further education choices, as well as

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the media (Johnes, 2018). At the same time, we can see how higher education institutions strive to meet the measure of "excellence" defined by these relative performance measurement tools (the institutions are compared to each other), often significantly transforming their mission and scope of activities (Daraio et al., 2015).

The three major international university rankings and their indicators

Three rankings stand out internationally, providing a strong reputational source for the universities listed. These are global rankings focusing primarily on research performance rather than education. The world's leading universities are annually scored and ranked on these global rankings, namely UK's Times Higher Education (THE) World University Rankings, Quacquarelli Symonds' (QS) World University Rankings starting in 2004, and Academic Ranking of World Universities (ARWU) starting from 2003. These rankings show slight differences in terms of the indicators they use for measuring overall academic performance.

Table 1. Indicators and Weights for QS, THE and ARWU

Num-ber	**QS World University Rankings– Methodology**		**World University Rankings (THE)– Methodology**	
	Metric	**% weigh-ting**	**Metric**	**% weigh-ting**
1	Academic Reputation	40	Teaching	30
2	Employer Reputation	10	Research	30
3	Faculty/Student Ratio	20	Citations	30
4	Citations per faculty	20	International outlook	7,5
5	International Faculty Ratio	5	Industry income	2,5
6	International Student Ratio	5		
	ShanghaiRanking's Academic Ranking of World Universities Methodology (ARWU)			
1	Alumni of institution winning Nobel Prizes and Fields Medals			10
2	Staff of an institution winning Nobel Prizes and Fields Medals			20
3	Highly Cied Researchers			20
4	Papers published in Nature and Science			20
5	Papers indexed in Science Citetion Index Expanded and Social Science Citation Index			20
6	Per capita academic performance of an institution			10

Source: QS World University Rankings – Methodology, World University Rankings 2022: methodology, https://www.shanghairanking.com/methodology/arwu/2021

Following the overview of the chosen rankings' indicators, we should compare them in order to put them in context. The most important difference between these rankings is where they gather their bibliometric data from that are related to research performance indicators. The QS and THE rankings are based on the Scopus, while the ARWU is based on the Web of Science. Marginson (2005) points out that the ARWU is the most numeric ranking using a very simplified, research performance oriented and transparent methodology. In parallel with this, the QS and THE rankings take a wider variety of aspects into account, also measuring the prestige of a given university through questionnaires, the quality of education, as well as relations with industry. Due to the methodological background, the ARWU ranking is more suitable for STEM (science, technology, engineering and mathematics) oriented universities, while the other two are good benchmarking tools for universities identifying their primary profile in the field of social sciences and arts and humanities. Nevertheless, studies found significant correlations and similarities between the ranking results (Shebatta & Mahmood, 2016; Aguillo et al., 2010).

Indicators used for measuring the impact of research in the rankings

The research pillar is a constituent element in all of the three major international rankings, however, they are presented to a varying degree and measured by using different indicators. The QS and THE rankings incorporate research pillars not only by bibliometric data but also by applying surveys or questionnaires. In the QS ranking, two of the indicators deal with the research performance: academic reputation measured by survey which accounts for 40 percent of the total score, and the citations per faculty, which is measured by the total number of citations received by all papers produced by a given institution throughout a five-year period divided by the number of faculty members at that institution. As there are significant differences regarding the number of citations among the disciplines, the QS ranking uses normalized citation numbers (QS Top Universities, 2021). The THE ranking calculates the research output within two of its pillars, namely the research accounting for 30 percent of total score and the citations pillar accounting for 30 percent of the total score. The research pillar includes the indicators of reputation survey, research income, and research productivity, while the citations pillar includes the citations indicator. The ARWU ranking is mostly centered around measuring research performance, focusing on the bibliometric data, incorporating the indicator of quality of faculty, which is based on the number of Nobel Prizes awarded and Fields Medallists faculty members, highly cited researchers, and the research output based on the number of papers published in the Nature or Science journals, and the number of papers listed in the Web of Science Citation Index-expended or the Social Sciences Citation Index. These indicators combined together account for 80 percent of the total score.

Of the three main missions: research, education, and industrial knowledge sharing (Laredo, 2007), international rankings focus primarily on research, and thus clearly promote the strengthening of the research aspect in the profile of institutions. The emphasis being put on the research pillar is also observed by Demeter (2019) who investigates academic productivity and academic capital, stating that peer-reviewed articles have become the most significant “currency of business”.

Predicting the positions in the QS World University Rankings

In our study, our aim is to investigate the QS World University Rankings from the perspective of the research output of the institutions measured.

As it has been demonstrated in the tables presenting the methodology of the rankings, in the QS ranking, academic reputation accounts for 40 percent of the total score, followed by 20 percent for the faculty/student ratio, 20 percent for citations per faculty, 10 percent for employer reputation, 5 percent for international student ratio and 5 percent for international staff ratio. This shows that a total of 60 percent is directly related to the research output of the university. Our research question was triggered by Johnes’ (2018) study, which examines the varieties of indicators used by the different national and global university rankings. He points out the difficulties of getting a consistent overview on the universities’ performance from a set of very different indicators. He builds this statement on the 10 indicators of The Complete University Guide (2018), including the entry standards, student satisfaction, research assessment, research intensity, graduate prospects, student-staff ratio, academic services spending, facilities spending, good honours and degree completion. He proves that although the majority of indicators are highly correlated, there are 12 pairs which do not correlate at a conventional level of significance. This leads to the consequence that it is important to pay attention to the indicators in which a given university stands out with high scores, because they do not necessarily reflect the good teaching or research performance of the university. According to Johnes' results, universities reaching high scores in soft indicators such as employer reputation would reach high positions in the ranking even without reaching high scores in other indicators such as citations per faculty.

As a reflection to the problem brought up by Johnes, we offer a thought experiment and an analysis closely related to it. We ask whether it is possible to carry out an analysis that is able to predict the final positions of universities in the rankings to a reliable degree even before they are officially published. If so, how accurate can it be? Our choice has fallen on the QS World University Rankings for two main reasons. The data obtained for our analysis should be identical to the dataset used by the official QS rankings in order to fulfil the requirement of comparability, even if we know that the exact calculation algorithm is not available. As we have full access to the services of Scopus/SciVal, it seemed to be the most reasonable option. The other reason is that this ranking seems to be the most promising to put Johnes' results to the test, as the QS World University Rankings contains the highest share of soft indicators. In other words, our aim is to examine how accurately the final, official ranking can be predicted, leaving soft indicators out of the equation and solely concentrating on research and citation data. Thus, our analysis deals with the publication activity and citation metrics related to the six pillars.

In the paper, we investigate several questions, most importantly whether we can predict the QS ranking based only on the data extracted from the SciVal software. Besides this, we analyze the accuracy of this prediction, as well as to what extent the accuracy of the prediction depends on the raw data or ratios. In our paper, we assume that the data obtained from the SciVal software allow us to establish the ranking of the universities. Demeter (2018) in his paper emphasizes the internationally recognized journal lists – including the Scopus and by this indirectly the SciVal being a database built upon raw data originating from the Scopus – are key influencers of the university rankings. As we made a reference to it above, the QS World University Rankings calculates its research output pillar based on the Scopus database, so universities target to reach high scholarly output indexed in this database to arrive in higher ranks. This guarantees them better chance to attract talented international students and the best performing scholars. Demeter and Tóth (2021) state that research intensive universities gain their reputational capital through their research output indexed in internationally recognized citation databases including Scopus. Considering the role of research output regarding the rankings, we assume that publishing activity and its impact may also properly approximate university rankings with the rest of the pillars not taken into account. To prove this, we use university-specific data from the already mentioned SciVal database. We only examine universities that are included in the QS 2021 list.

The ranking established from the publication data was calculated using the TOPSIS method, based on two selected six-variable databases. For the sake of comparability, we had to break down the QS ranking between universities with the same rank, for which we took these institutions into account with the average of their ranks.

After these introductory chapters, the next chapter discusses the process of database compilation. We then compare the TOPSIS rankings obtained from the two six-variable databases (raw data and the ratio) and compare the three rankings with Kendall's τ-b rank correlation. In the last part, following the analysis on the two databases, we review the positions of the countries in the ranking.

Compilation of databases

We set out to work by compiling the database. We used basic variables in the analysis, 5 of which were taken from the SciVal database, while the sixth was taken from the official websites of the examined institutions. Our variables, and our raw data show the status as it was in 2019. The basic variables extracted from SciVal are:

- number of publications (*PUBL*),
- number of citations (*CIT*),
- number of authors (*AUT*),
- the five-year Hirsch index between 2015 and 2019 (*H5-I*) and
- the Field-Weighted Citation Impact (*FWCI*).

The field-weighted impact *(FWCI)* indicator shows the citation attractiveness of the publications from researchers working at a given university in a summarized form. FWCI is suitable for measuring the citation attractiveness of publications both in similar and different discipline areas because it shows a normalized value. FWCI is only available in the Scopus and SciVal databases, a value above 1 indicates that the citation attractiveness of a given publication is higher than other publications that provide a basis for comparison. A description of the indicator can be found in studies by Elsevier (2019) and Purkayastha et al. (2019).

The sixth variable, which refers to the staff of the institutions, was extracted from the official website of the QS ranking. As the authors of the publications do not necessarily teach, or vice versa, many lecturers also do research, we also determined the number of professionals employed by a university:

- the total number of teaching and research staff (*AFS*).

We used these six variables and indicators as the starting point of our study. For further examinations, we created six ratios along the basic variables, which are as follows:

- proportion of authors to all teaching and research staff (*AUT / AFS*),
- number of publications per author (*PUBL / AUT*),
- number of citations per author (*CIT / AUT*),
- number of citations per publication (*CIT / PUBL*),
- the number of publications per lecturer or researcher (*PUBL / AFS*) and
- number of citations per lecturer or researcher (*CIT / AFS*).

The newly-introduced variables are seen as relative indicators. Three of them show the weight of the citations per researcher as well as per publications. The remaining three indicators illustrate publications for researchers and faculty. Thus, these indicators summarize the attractiveness of the citations and the proportion and effectiveness of the research staff.

Using the two databases (basic variable and ratio-based), we formed two rankings and examined how the resulting rankings related to the QS 2021 indicator. It was also necessary to determine the missing values for our analysis. Missing values were calculated using the SPSS26 program. The SPSS program offers several methods for calculating the missing value; we chose the method in which the system takes the mode of the top and bottom value of the nearest missing value. We were able to use this method because the examined institutions had already been in the ranking according to QS ranking indicators.

Comparison of the QS 2021 ranking and the rankings determined based on basic data and ratios

The TOPSIS method was used to determine the ranking based on basic data and ratios. We used the version of the TOPSIS method which determines weights endogenously from the data. In other words, this is the entropy-based method of weight determination. The methodology of the actual calculation is briefly presented below.

The TOPSIS ranking procedure first normalizes the available basic data. The purpose of normalization is to eliminate size differences between each criterion. There are several methods for normalization, for instance transforming the data to [0,1] intervals or shortening them to a circle with a unit radius, that is, the Euclidean distance with a unit radius. The normalized decision matrix is then weighted with a weight vector. In order to select the weight vector, there are three basic methods to choose from: subjective weight given exogenously, objective weight derived from the decision matrix, and finally an integrative method achieved by combining the former two methods. In our case, we chose weights by finding the objective weight. In the course of finding the objective weight, the criteria are multiplied by the weights first, then we determine the best or ideal point in the space of the criteria for each criterion in the new matrix, and the anti-ideal or nadir point. We then determine the distance from each ideal and nadir point for each decision-making unit (DMU). If a DMU is close to the ideal point, its distance from that is close to zero, while its distance from the nadir point will then be close to the distance of the two awarded points. The essence of the method is that the two distances form a quotient. If the DMU is close to one, it is considered good, whereas if the DMU quotient is close to zero, it will fall to the nadir point. close to the DMU.

In the first step, we normalize the basic data. Let us assume that the data for variable i for each university are contained in the vector $\mathbf{x}_i$. Data transformation is as follows:

$$y_{ji} = \frac{x_{ji} - x_j^{min}}{x_j^{max} - x_j^{min}}, \quad (j = 1,2,\ldots,n;\ i = 1,2,\ldots,m),$$

where the minimum and maximum values of the variable i are x_j^{min} and x_j^{max}, n is the number of universities and m is the number of variables/criteria. With this transformation, the values of each variable are converted to a [0,1] interval per university. Let $\mathbf{y}$ be the value of the new vectors.

In the *second step*, knowing the values of each variable, we use the entropy-based method to determine the weights of the variables (Zou et al., 2006). The equation for the transformation is as follows:

$$H_i = \frac{-1}{ln(n)} \cdot \sum_{j=1}^{n} \frac{y_{ji}}{\sum_{j=1}^{n} y_{ji}} \cdot ln\left(\frac{y_{ji}}{\sum_{j=1}^{n} y_{ji}}\right), \quad (i = 1,2,\ldots,m).$$

Thus, the weights are as follows:

$$w_i = \frac{1 - H_i}{n - \sum_{i=1}^{m} H_i}, \quad (i = 1,2,\ldots,m).$$

The weighted normalized values are represented by z_{ji}, which are: $z_{ji} = w_i \times y_{ji}$. The ideal and lowest points are then determined using the z_{ji} values.

Finally, in the *third step*, we determine the efficiency index based on the weighted data using the ideal (I_i) and lowest (N_i) points, which are calculated as follows:

$I_i = \max_{j=1,2,\ldots,n} z_{ji}$, $N_i = \min_{j=1,2,\ldots,n} z_{ji}$, $(i = 1,2,\ldots,m)$.

The distance of university j from the ideal and the low point is determined as follows:

$d_j^I = \sqrt{\sum_{i=1}^{n}(z_{ji} - I_i)^2}$, $d_j^N = \sqrt{\sum_{i=1}^{n}(z_{ji} - N_i)^2}$, $(j = 1,2,\ldots,n)$.

Finally, the last calculation determines the efficiency of TOPSIS E_j, which shows the ratio of the distance from the two defined points:

$E_j = \frac{d_j^N}{d_j^I + d_j^N}$, $(j = 1,2,\ldots,n)$.

After a brief description of the TOPSIS method, we present the results of the calculations performed on the data set. The detailed calculations are beyond the size limits of the present study, therefore it is not possible to discuss them in detail. Objective weights are presented in the two tables below (Tables 2 and 3).

Table 2. TOPSIS weights of the model calculated using basic data

	PUBL	*CIT*	*AUT*	*H5-I*	*FWCI*	*AFS*
Weights	0.165	0.166	0.171	0.166	0.166	0.166

Source: Our own editing based on SciVal data

Table 3. TOPSIS weights of the model determined using ratios

	AUT/AFS	*PUBL/AUT*	*CIT/AUT*	*CIT/PUBL*	*PUBL/AFS*	*CIT/AFS*
Weights	0.168	0.159	0.167	0.170	0.167	0.169

Source: Our own editing based on SciVal data

The three rankings for all the 1003 universities in the QS ranking can be found in the appendix to this study.

Our calculations are carried on by comparing the three rankings using Kendall τ-*b* correlation. This correlation measures the relationship between variables measured on the ordinal scale. The calculation process of this correlation is based on the Kemény distance. (Kemény, 1959) Kendall τ-*b* correlation between the three rankings for the 1003 universities is shown in the table below (Table 4). The QS Rankings 2021 Ties list shows the resolution of the original QS ranking, where in the case of ties, the indeterminable ranking is substituted by the average of the sum of the ordinal numbers of the tied universities. It is considered to be a proven method of ordering.

Table 4. Kendall correlation between the three rankings

Kendall τ-b correlation		**TOPSIS basic data**	**TOPSIS ratios**
QS ranking 2021 Ties	Correlation coefficient	**0.477****	**0.427****
	2-sided significance	0.000	0.000

TOPSIS basic data	Correlation coefficient		**0.677**[**]
	2-sided significance)		0.000

** 2-sided significance 1%

Source: Our own editing based on SciVal data

In Table 4, it can be observed that the correlations are greater than 0.35, which means that there is a strong correlation, in our case an association, between the three rankings. Although the level of correlation between the TOPSIS rankings obtained from the two databases is not particularly strong, it is significant enough not to be ignored. The overall result is not surprising since the ratios were determined with the data of the basic variables. Having examined the correlations, it is worth taking a look at the positions the countries achieved in each ranking to see whether a similar degree of correlation can be determined.

Positions of countries on the QS lists

Sidorenko and Gorbatova (2014) begin their study with the statement that international university rankings not only measure success but also introduce a huge challenge to higher education players and nations in the pursuit of a better rank. With these performance rankings not only higher education institutions but also entire national higher education systems become measurable, comparable and transparent. In order to establish how accurately this can be done using our method for measurement, we decided to examine the overall ranking of universities in various countries. As it was previously noted, only universities in the QS 2021 list were examined. As a consequence, only those countries were taken into consideration in this part of our analysis that represented themselves in the list by delegating universities to it. First, we examined the average of the rankings of universities in each country by comparing the averages. Our null hypothesis (H0) was that the average of the rankings of the universities of the countries is the same, that is, there is no difference between the universities of the countries. Using the Compare Means tab in the SPSS 26 software, we obtained that our null hypothesis (H0) was not satisfied, meaning that the average of the rankings of the universities of the countries in order is not equal. With this, we accepted hypothesis H1. This result made it possible to compare the means of the three rankings.

Table 5 shows which rankings are on the list. QS Rankings 2021 shows the official ranking given by QS-R. We had to resolve this for all universities because all institutions were tied on the list with other universities. This resolution is contained in the QS Rankings 2021 Ties column. The QS-RD column shows the ranking obtained with the basic data, while the QS-RE column shows the ranking obtained with the ratios. Since the chance of a tie is small with TOPSIS, the positions of the institutions in the ranking calculated with this method are clear. Table 4 also shows the average rank of universities of countries and the three rankings. The average order of the universities in each country was then put in order, which is after the three averages. Finally, we formed the average of the orders, which was then also ranked. This was placed in the last column of Table 5.

Table 5. Positions occupied by the countries in the ranking

Countries	QS-R		QS-RD		QS-RE		Average	Rank	Number of universities
Netherlands	168.385	2	189.77	2	143.92	4	2.67	1	13
Denmark	197.000	6	134.40	1	130.40	2	3.00	2	5
Switzerland	195.950	5	215.60	6	136.60	3	4.67	3	10
Sweden	193.000	4	214.88	5	168.75	5	4.67	4	8
Singapore	180.500	3	209.67	4	231.00	10	5.67	5	3
Hong Kong SAR	150.857	1	306.00	9	218.86	9	6.33	6	7
Norway	271.500	8	206.50	3	237.25	12	7.67	7	4
Belgium	298.667	10	280.44	7	186.56	7	8.00	8	9
Australia	372.319	13	351.69	13	235.97	11	12.33	9	36
Finland	357.944	12	390.89	16	270.11	13	13.67	10	9
Cyprus	479.500	24	431.00	18	100.00	1	14.33	11	1
United States	434.745	21	291.87	8	305.88	15	14.67	12	151
Qatar	245.000	7	463.00	24	271.00	14	15.00	13	1
Germany	414.678	18	322.53	10	342.47	17	15.00	14	45
Canada	389.231	15	347.08	12	362.35	18	15.00	15	26
New Zealand	279.063	9	477.00	27	385.63	19	18.33	16	8
Israel	405.750	17	450.00	22	416.00	23	20.67	17	6
Italy	626.681	47	338.31	11	211.64	8	22.00	18	36
France	483.929	26	437.96	20	390.68	20	22.00	19	28
United Kingdom	443.905	23	440.86	21	411.55	22	22.00	20	84
Macau SAR	548.000	33	497.00	29	180.50	6	22.67	21	2
Portugal	523.357	29	413.29	17	446.86	25	23.67	22	7
Austria	391.125	16	540.88	30	475.63	27	24.33	23	8
China (Mainland)	497.422	27	367.78	15	559.53	31	24.33	24	51
Ireland	424.188	20	479.50	28	459.63	26	24.67	25	8
Georgia	628.000	49	365.00	14	338.00	16	26.33	26	1
South Africa	556.786	35	454.00	23	443.57	24	27.33	27	7
Spain	523.558	30	474.12	26	527.27	29	28.33	28	26
South Korea	439.483	22	586.48	33	543.93	30	28.33	29	29
Brunei	302.750	11	685.50	44	618.00	38	31.00	30	2
Greece	719.833	61	466.83	25	391.17	21	35.67	31	6
Taiwan	419.594	19	699.38	48	632.81	40	35.67	32	16
Saudi Arabia	573.400	37	614.70	35	608.10	36	36.00	33	10
Iran. Islamic Republic of	603.200	40	693.40	46	483.20	28	38.00	34	5
Estonia	622.333	45	636.00	36	603.33	35	38.67	35	3
Belarus	610.250	41	655.50	38	631.50	39	39.33	36	2
Japan	528.598	31	696.22	47	689.88	44	40.67	37	41
Slovenia	765.500	64	563.50	31	595.00	32	42.33	38	2
Lebanon	602.563	39	656.75	39	715.13	49	42.33	39	8

Countries	QS-R		QS-RD		QS-RE		Average	Rank	Number of universities
Oman	375.500	14	800.00	65	757.00	51	43.33	40	1
Bulgaria	628.000	48	685.00	43	636.00	41	44.00	41	1
Turkey	704.944	59	654.56	37	613.33	37	44.33	42	9
India	584.405	38	764.95	63	600.90	33	44.67	43	21
Brazil	653.679	51	591.14	34	775.07	53	46.00	44	14
United Arab Emirates	536.000	32	764.13	61	691.38	46	46.33	45	8
Russia	481.036	25	745.46	58	791.21	56	46.33	46	28
Malta	903.000	77	581.00	32	601.00	34	47.67	47	1
Egypt	696.125	58	434.25	19	837.75	66	47.67	48	4
Chile	668.150	53	721.30	49	689.60	43	48.33	49	10
Czech Republic	621.300	44	743.80	57	709.90	48	49.67	50	10
Pakistan	653.214	50	741.43	55	690.00	45	50.00	51	7
Malaysia	551.200	34	759.55	60	807.70	59	51.00	52	20
Jordan	778.250	65	671.50	40	726.00	50	51.67	53	4
Peru	688.667	55	738.33	53	771.33	52	53.33	54	3
Argentina	616.346	43	743.54	56	826.46	61	53.33	55	13
Hungary	744.000	63	735.75	52	708.88	47	54.00	56	8
Philippines	707.625	60	674.00	41	831.75	62	54.33	57	4
Mexico	673.958	54	687.83	45	837.42	65	54.67	58	12
Poland	800.133	68	751.00	59	689.60	42	56.33	59	15
Ecuador	861.500	71	740.67	54	786.00	55	60.00	60	3
Croatia	903.000	74	684.50	42	868.00	67	61.00	61	2
Thailand	658.375	52	764.25	62	880.88	70	61.33	62	8
Cuba	517.000	28	957.00	79	981.00	78	61.67	63	2
Lithuania	727.125	62	826.75	68	792.25	57	62.33	64	4
Indonesia	565.125	36	860.63	74	977.38	77	62.33	65	8
Slovakia	803.500	69	822.00	67	777.25	54	63.33	66	4
Colombia	625.364	46	856.73	73	907.36	73	64.00	67	11
Costa Rica	794.000	67	783.00	64	836.33	64	65.00	68	3
Kazakhstan	614.800	42	907.20	77	972.70	76	65.00	69	10
Uruguay	690.250	56	846.00	71	877.00	69	65.33	70	4
Latvia	845.000	70	812.00	66	833.67	63	66.33	71	3
Vietnam	903.000	80	721.50	50	905.50	71	67.00	72	2
Ukraine	691.250	57	848.67	72	939.00	75	68.00	73	6
Iraq	903.000	75	729.00	51	987.00	79	68.33	74	2
Romania	903.000	79	829.00	69	799.00	58	68.67	75	2
Kuwait	903.000	76	887.33	76	824.33	60	70.67	76	3
Bahrain	791.000	66	969.50	80	873.00	68	71.33	77	2
Bangladesh	903.000	73	838.50	70	922.50	74	72.33	78	2
Venezuela	871.875	72	887.00	75	906.25	72	73.00	79	4
Panama	903.000	78	931.00	78	997.00	80	78.67	80	1

Source: Our own editing based on SciVal data

Contrary to the expectation that the United States and the United Kingdom would be in the top ten countries in the list, the sequenced ranking showed that the top 10 of the 80 countries included eight Western European countries as well as two Far Eastern city-states, namely Hong Kong and Singapore. The bottom 10 positions are shared by Middle Eastern (3 countries), Eastern European (3 countries), Latin American (2 countries), and South Asian (2 countries) states.

It is also observable that most of the larger, economically developed states reached positions from 11th to 20th such as the United States, the United Kingdom, Germany, France and Italy. Interestingly, the positions of the BRIC states show a much wider variation: China ranks 24th, South Africa 27th, India 43rd, Brazil 44th, and Russia is placed 46th.

Summary

Numerous works in the international literature have already addressed the indicator systems of international university rankings and their relation to each other as well as to the final ranking of institutions. In these works, as described in the introduction, the indicators were basically divided into several pillars. One group included indicators of the university's researcher reputation and citations while the other group included indicators of employer appreciation, the ratio of domestic and foreign students and the number of foreign workers.

The authors found significant relationships between the indicators of the former group, which also shape the final rank for each university. Beyond this, our present study tested how accurately the position of a given institution in the QS ranking can be predicted using only the indicators of research potential and performance.

In our analyses, we determined the alternative rankings for this question with the TOPSIS ranking method, using the basic variables collected from the SciVal database and, in the case of one variable, from the official websites of the universities and the ratios derived from them. Then, the values of these variables were compared with the official QS ranking. We concluded that both rankings were close to the ranking that was obtained by resolving the ties in the QS ranking. The "goodness" of the rankings was determined by Kendall τ-b correlation based on Kemény distance. Our results also show that universities focusing on research excellence are more likely to have a good position in the QS university ranking.

In addition to the QS ranking, further research may focus on whether a similar conclusion can be drawn in the case of the other two major university rankings, THE and ARWU. In essence, the question is whether, and how accurately, the research and publication data obtained from the Scopus and SciVal databases can be used to predict the content of the official rankings.

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Relationship between bibliometric indicators and university ranking positions

Péter Szluka[1], Edit Csajbók[1,2] & Balázs Győrffy[3,4]✉

A growing interest for demonstrating prestige and status of higher education institutions has spurred the establishment of several international ranking systems. A major percentage of these rankings include parameters related to scientific productivity. Here, we examined the differences between diverse rankings as well as correlation with bibliometric parameters and disciplines for the top universities. We investigated the top 300 universities from four international rankings, the Times Higher Education World University Ranking (THE), the QS World University Rankings (QS) the ShanghaiRanking-Academic Ranking of World Universities (ARWU) and the U.S.News Best Global Universities Ranking (USNews). The assessed parameters include ranking positions, size related and bibliometrics-related indicators of each selected ranking. The weight of scientometric parameters ranges between 20% (QS) and 75% (USNews). The most important parameters defining ranking positions include citations, international reputation, and the number of researchers, but the correlation strength varies among ranking systems. The absolute number of publications and citations are particularly important in ARWU and USNews rankings, and scientific category normalized (field weighted) citation impact is central in THE and USNews rankings. Our results confirm that universities having outstanding results in rankings using size-independent indicators (QS and THE) compared to others have significantly lower number of students. High impact research can improve position in ARWU and USNews ranking lists. Regarding to different disciplines, the main results show that outstanding universities in THE ranking have higher publication activity in social sciences and universities which perform better in USNews and QS ranking have more publications in science, technology, and medicine fields and lower score in social sciences. In brief, here we present a comprehensive analysis of the correlation between scientometric parameters and university ranking positions, as well as the performance of outstanding universities and their correlation with different disciplines, to help decision makers select parameters for strengthening and to attract the interest of prospective students and their parents via a better understanding of the functions of different ranks.

Abbreviations

THE	Times Higher Education World University Ranking
QS	QS World University Rankings
ARWU	ShanghaiRanking-Academic Ranking of World Universities
USNews	USNews Best Global Universities Ranking
WUR	World University Ranking
FTE	Full Time Equivalent

Success of a higher education establishment can be measured by different metrics, like by the academic results of the admitted students, by the employment characteristics of graduates, by the participation of industry, or by the research output. In the case of universities, there are several metrics enabling qualitative assessment, including the oversubscribed proportion of the admissions, the admission score, the proportion of international students, the ratio of students to lecturers, the number of lecturers with PhDs, etc. In this field, before the publication of university rankings, the reputation of the university was the decisive argument for the choice. Expanding globalization created a widespread demand for higher university reputation[1]. Reputation, however, did not

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always prove to be appropriate, because it takes many, many years to gain and establish it. On the other hand, it is not so easy for a university with a history of hundreds of years to lose it either. According to several authors, a university's reputation is a decisive factor that increases the number of international students[2].

As early as 1863, a research was published with the purpose to compare and analyze the German polytechnic schools—Hanover, Karlsruhe, and Zurich—for the upcoming reorganization of the Technical College in Prague[3]. Hundred years later, in 1986, the US News and Report US Colleges Ranking was published, which was the first national level comparison of universities. The first truly global international university ranking, the Shanghai Jiao Tong University's Academic Ranking of World Universities, was published in 2003. Since then, more and more university rankings have appeared, some of which have a long history and became recognized, while some others have lost attention over time.

The purpose of university rankings is to compare universities based on their merit and performance. There are as many methodologies as there are rankings, and their data collection can be based on data submitted by universities and data extracted from other sources and databases. Using these data, ranking systems aim to provide a common definition of value[4]. The range of indicators used is wide, there are metrics that depend on or are independent of the size of the university, and there are rankings where the reputation of the university is part of the method, which is assessed with the help of questionnaires. Despite their different methodologies, there are reasonable similarities between the rankings[5], and a common feature of rankings is the use of bibliometric indicators.

Studies have been conducted to assess the effect of university rankings on the selection preferences of prospective students. A study mapped Chinese students' knowledge of university rankings using a survey of more than 900 students and found that thirty percent of the students was aware of ranking positions[6]. On the other hand, progress achieved in ranking lists had little or no effect on the students' choice of university[2]. According to others, the university rankings had an impact on the choice of university and among the indicators of the rankings, students consider those universities that refer to mentoring, faculty infrastructure, and general satisfaction of students as the most important aspects, while the characteristics that are aimed at research are less relevant to them[7]. Other studies have also shown that prospective students and their parents rely on university rankings when making decisions about higher education[8]. Based on data from a medium-sized German university, the university's place in the rankings had high importance for both international and national students, similarly to other determinants of reputation and quality[9]. A study using Google trends and QS World University Rankings found positive and significant relationship between QS ranking results and Google Search volumes for universities in the top 500[10]. Nevertheless, international students are mostly concentrated at large universities[11].

For the determination of scientific output, a new branch of science, scientometrics, has emerged, the purpose of which is to provide an objective, qualitative picture of research output with the help of mostly quantitative indicators. The analysis of scientometric performance, an easily quantifiable output, is a key feature in each ranking. The aim of our study was to investigate the possible correlations between different scientometric variables and the results achieved by a university in each ranking and to find the common scientometric and discipline characteristics of universities that have achieved outstanding results in one ranking compared to other rankings. We also aimed to compare the importance of different parameters when determining ranking outcome. It's important to emphasize that universities should avoid prioritizing rankings as their only objective. Instead, their focus should include enhancing teaching quality, advancing scientific research, and elevating the standard of their services. In this aspect, ranking is one of the tools at hand for monitoring relative output.

Results

Setting up a matched ranking for top universities. The ranking presented by the Times Higher Education (THE) magazine performs its own data collection for the included universities. It had common roots with QS ranking between 2004–2009, but in 2010 it switched to a different methodology. THE is based on 13 performance indicators grouped into five areas: teaching (30%), research (30%), citations (30%), knowledge transfer (2.5%), and international outlook (7.5%). All together 13 indicators are used, and out of these the total weight of bibliometric indicators is 38.5%. All indicators are normalized to university size or scientific area. Elsevier's SciVal (based on Scopus data) is used as publication and citations source.

The QS—World University Ranking is published by the Quacquarelli Symonds (QS) company. Universities are ranked based on six key metrics in the ranking: academic reputation (40%), employer reputation (10%), faculty/student ratio (20%), citations per faculty (20%), international faculty ratio (5%), and international student ratio (5%). There is only one bibliometric indicator (citations per faculty—20%) which is normalized to the scientific area, and self-citations are excluded. Elsevier's SciVal (based on Scopus data) is used as publication and citations source.

The Academic Ranking of World Universities (ARWU, also called ShanghaiRanking) was first published in 2003. Since 2009 the ARWU has been published by ShanghaiRanking Consultancy, which is a fully independent organization. It ranks the first 1000 universities, using six indicators, including quality of education (10%), quality of faculty (40%), research output (40%), and per capita performance (10%). The two normalized bibliometric indicators have a total weight of 40%, and one bibliometric related (number of highly cited researchers) indicator weights 20%. Clarivate's InCites database (based on Web of Science Core Collection data) is used as publication and citations source.

The U.S.News Best Global Universities Ranking was launched by U.S.News & World Report in 2014. It ranks universities based on thirteen indicators, including global research reputation (12.5%), regional research reputation (12.5%), and eleven bibliometric indicators (75%). It contains size-dependent indicators, but some indicators are normalized. Clarivate's InCites database (based on Web of Science Core Collection data) is used as publication and citations source.

After analyzing all four rankings, we got a common list with 470 universities included in at least one ranking among the top 300 universities. Of these, nine universities were found in one ranking only, 25 universities were found in two rankings, 48 universities were missing from one ranking, and 388 institutions were found in all four rankings.

Ranking positions vs. determined parameters. First, we compared the ranking positions to the selected scientometric parameters, the number of students, and enrollment. All together 105 correlations were computed, and in 98 cases there were correlations ($p < 0.05$) between ranking positions and the determined parameter. The high proportion of significant correlations between ranking indicators and rank positions of the universities in most cases proves that bibliometrics related indicators play an important role in each of the examined rankings. The correlations were stronger with a particular ranking's own indicators. We observed lower correlation in four cases: USNews international collaboration (relative) (corr.coeff = 0.24, p = 1.25e−07), USNews conferences (corr.coeff = 0.31, p = 5.86e−12), THE international outlook (corr.coeff = −0.41, p = 1.61e−19), and QS citations per faculty (corr.coeff = −0.44, p = 1.78e−22), Of these, the first three represent indicators with low weight, but the last one gives 20% weight of the entire ranking. University sizes shows medium correlation with ARWU and USNews ranking results, but there is no correlation with THE and QS rankings. The highest positive correlation coefficients were present for citations and percentage of papers in the top 1%, while the strongest negative correlations were present for two non-ranked parameters, the number of highly cited researchers and publications in Nature and Science. The complete results are presented in Fig. 1.

Differences in ranking positions vs. determined parameters. Next, we investigated the correlation between the ranking position differences and the determined scientometric parameters. In this analysis, high correlation values mean high importance for this parameter and low correlations mean small importance in determining ranking differences between the four investigated rankings. All together 126 correlations were evaluated, and in 99 cases we found significant correlations ($p < 0.05$).

The most significant correlations were observed in case of the THE citations and the USNews normalized citation impact indicators. Although both of these indicators represent the citation impact of publications relative to their scientific discipline, but they use two different data sources, Web of Science and Scopus. The two indicators show higher correlation in THE–QS and in THE–ARWU pairs proving that universities with higher discipline-specific citation reach better ranking in THE compared to QS or ARWU. Albeit with lower correlation values, these universities also have better ranks in USNews. When comparing THE and USNews, THE has a positive value also linked to the higher weight of citation in THE (30%).

In case of THE–QS and of the ARWU–USNews pairs, the differences do not show correlation with university size while in case of the QS/ARWU vs THE/USNews pairs the differences show high correlation values. These results support the notion that QS and THE rankings are better for small universities with high impact while larger universities can reach better scores in ARWU and USNews rankings.

The detailed analysis results are shown in Fig. 2.

Comparing all determined parameters to each other. We also correlated all the investigated parameters to each other across all included universities. In this, 441 associations were checked, 399 of which had a significant correlation ($p < 0.05$).

Particularly high correlations can be observed for USNews scientometric parameters including the number of publications in the top 10% and top 1%, and citations in the top 10% and top 1%. These results provide evidence that the overall impact of these parameters is amplified by their influence on the other parameters. Of note, the percentage of top 10% and top 1% are also positively correlated.

Similarly, significant correlations can be observed between the size-dependent parameters of ARWU and USNews. The complete results for all parameters are depicted in Fig. 3.

Outstanding universities. A particularly interesting analysis involves the "outstanding universities", which have excellent position in one ranking but mediocre position in another. All together twelve outstanding university groups were compared with the control groups (which include all non-outstanding universities) for the 22 determined parameters. The analysis includes universities outstanding in THE vs. the three other rankings (Fig. 4A), universities outstanding in QS vs. the three other rankings (Fig. 4B), universities outstanding in ARWU compared to the other universities (Fig. 4C), and universities outstanding in USNews compared to other rankings (Fig. 4D). Note that because outstanding universities have better positions (lower number), the ranking difference is negative for almost each parameter.

We also studied the typical disciplines of the universities selected with this method. We examined the differences of OpenAlex root level concepts scores (19 concepts and three concept groups) between outstanding university groups and control groups. In this analysis, we found significant differences (Mann–Whitney $p < 0.01$, two-tailed) in case of 98 outstanding groups (see result in Fig. 5A–D). The main results show that outstanding universities in THE ranking have higher score in social sciences and universities which perform better in USNews and QS ranking have higher score in science, technology, and medicine fields and lower score in social sciences.

The university size parameter was also examined when comparing outstanding and control university groups. Results show that universities outstanding in QS and THE compared to ARWU and USNews have significantly differed with lower number of students (Mann–Whitney $p < 0.01$ two-tailed) and conversely, universities outstanding in ARWU and USNews compared to THE and QS had higher median of number of students (Fig. 6).

	THE calculated rank	QS calculated rank	ARWU calculated rank	USNews rank	Best Rank
Continuous indicators (scores)					
THE FTE of Students	-0.02 n=440	0.04 n=421	**-0.39** n=406	**-0.36** n=423	**-0.18** n=440
USNews Enroll (# of Students)	0.03 n=290	0.07 n=285	**-0.34** n=282	**-0.27** n=293	**-0.16** n=293
QS citations per faculty	**-0.52** n=421	**-0.44** n=433	**-0.40** n=403	**-0.46** n=421	**-0.49** n=433
THE citation	**-0.70** n=440	**-0.29** n=421	**-0.41** n=406	**-0.59** n=423	**-0.43** n=440
THE research	**-0.85** n=440	**-0.76** n=421	**-0.66** n=406	**-0.69** n=423	**-0.78** n=440
THE international outlook	**-0.41** n=440	**-0.42** n=421	-0.08 n=406	**-0.25** n=423	**-0.25** n=440
ARWU # highly cited researchers	**-0.60** n=406	**-0.45** n=403	**-0.82** n=431	**-0.75** n=423	**-0.67** n=431
ARWU Nature and Science	**-0.67** n=406	**-0.55** n=403	**-0.83** n=431	**-0.78** n=423	**-0.71** n=431
ARWU publications	**-0.48** n=406	**-0.48** n=403	**-0.79** n=431	**-0.70** n=423	**-0.64** n=431
ARWU per capita performance	**-0.64** n=406	**-0.58** n=403	**-0.62** n=431	**-0.62** n=423	**-0.63** n=431
Ranked indicators					
USNews publications	**0.56** n=423	**0.53** n=421	**0.82** n=423	**0.78** n=451	**0.70** n=451
USNews books	**0.65** n=423	**0.52** n=421	**0.56** n=423	**0.67** n=451	**0.57** n=451
USNews conferences	**0.19** n=423	**0.39** n=421	**0.40** n=423	**0.31** n=451	**0.39** n=451
USNews normalized citation impact	**0.63** n=423	**0.26** n=421	**0.39** n=423	**0.61** n=451	**0.40** n=451
USNews total citations	**0.67** n=423	**0.55** n=421	**0.86** n=423	**0.88** n=451	**0.75** n=451
USNews # top 10% cited	**0.66** n=423	**0.53** n=421	**0.87** n=423	**0.89** n=451	**0.74** n=451
USNews % top 10% cited	**0.64** n=423	**0.32** n=421	**0.48** n=423	**0.66** n=451	**0.46** n=451
USNews international collaboration (relative)	**0.12** n=423	**0.18** n=421	**0.22** n=423	**0.24** n=451	**0.21** n=451
USNews # top 1% cited	**0.70** n=423	**0.54** n=421	**0.86** n=423	**0.92** n=451	**0.75** n=451
USNews % top 1% cited	**0.60** n=423	**0.30** n=421	**0.46** n=423	**0.64** n=451	**0.43** n=451

Figure 1. Spearman rank correlation of ranking positions and selected indicator values/ranks. High correlations show that the given indicator/rank affects the rank position in different rankings. Continuous indicators are scores, where higher values mean better positions, while USNews indicators are ranks, where the lower value means a better position. Best rank was computed by using the best positions across all four ranking for each university and reflects the power of each feature in predicting the best position of a university. Significant differences ($p < 0.05$) are marked with bold correlation coefficients. (The colors show the distance from the zero. Green to Yellow < 0; Yellow to Red 0 <).

Discussion

Here, we have determined the effects of scientometric parameters in four international ranking systems. Our results confirm previous observations that there are reasonable similarities between the rankings[5]. Of course, this does not mean that all universities perform equally in each ranking—we can also confirm the size dependence, which lead to better result for larger universities[14]. Our results clearly show that smaller universities have better results in size independent rankings including the THE and QS, while bigger universities can perform better in USNews and ARWU rankings which both have size-dependent indicators. Overall, large universities can

	RankDiff THE-QS	RankDiff THE-ARWU	RankDiff THE-USNews	RankDiff QS-ARWU	RankDiff QS-USNews	RankDiff ARWU-USNews
Continuous indicators						
THE FTE of Students	-0.07 n=421	**0.49** n=406	**0.50** n=423	**0.49** n=393	**0.47** n=409	**-0.16** n=400
USNews Enroll (# of Students)	-0.06 n=284	**0.48** n=280	**0.48** n=290	**0.45** n=275	**0.44** n=285	**-0.17** n=282
QS citations per faculty	-0.03 n=421	**-0.12** n=393	**-0.14** n=409	-0.07 n=403	-0.04 n=421	0.05 n=398
THE citation	**-0.52** n=421	**-0.34** n=406	**-0.28** n=423	**0.11** n=393	**0.27** n=409	**0.29** n=400
THE research	-0.07 n=421	**-0.21** n=406	**-0.30** n=423	**-0.14** n=393	**-0.14** n=409	-0.04 n=400
THE international outlook	0.07 n=421	**-0.45** n=406	**-0.35** n=423	**-0.38** n=393	**-0.29** n=409	**0.30** n=400
ARWU # highly cited researchers	**-0.13** n=393	**0.23** n=406	**0.13** n=400	**0.36** n=403	**0.26** n=398	**-0.22** n=423
ARWU Nature and Science	**-0.13** n=393	**0.20** n=406	0.06 n=400	**0.26** n=403	**0.17** n=398	**-0.21** n=423
ARWU publications	0.07 n=393	**0.39** n=406	**0.30** n=400	**0.32** n=403	**0.23** n=398	**-0.24** n=423
ARWU per capita performance	-0.07 n=393	-0.01 n=406	**-0.13** n=400	0.05 n=403	0.00 n=398	**-0.10** n=423
Ranked indicators						
USNews publications	-0.03 n=409	**-0.34** n=400	**-0.30** n=423	**-0.30** n=398	**-0.26** n=421	**0.20** n=423
USNews books	**0.15** n=409	0.05 n=400	-0.01 n=423	-0.05 n=398	**-0.14** n=421	**-0.09** n=423
USNews conferences	**-0.32** n=409	**-0.25** n=400	**-0.26** n=423	-0.01 n=398	0.08 n=421	**0.15** n=423
USNews normalized citation impact	**0.45** n=409	**0.28** n=400	**0.16** n=423	**-0.13** n=398	**-0.32** n=421	**-0.33** n=423
USNews total citations	**0.09** n=409	**-0.25** n=400	**-0.25** n=423	**-0.32** n=398	**-0.33** n=421	**0.09** n=423
USNews # top 10% cited	**0.09** n=409	**-0.25** n=400	**-0.25** n=423	**-0.34** n=398	**-0.35** n=421	**0.10** n=423
USNews % top 10% cited	**0.38** n=409	**0.19** n=400	0.08 n=423	**-0.18** n=398	**-0.32** n=421	**-0.23** n=423
USNews international collaboration (relative)	-0.06 n=409	**-0.11** n=400	**-0.16** n=423	-0.05 n=398	-0.05 n=421	0.00 n=423
USNews # top 1% cited	**0.14** n=409	**-0.21** n=400	**-0.23** n=423	**-0.33** n=398	**-0.36** n=421	0.03 n=423
USNews % top 1% cited	**0.37** n=409	**0.18** n=400	0.06 n=423	**-0.18** n=398	**-0.32** n=421	**-0.25** n=423

Figure 2. Spearman rank correlation between ranking position differences and the investigated scientometric parameters. High correlation values mean high importance of this parameter in determining the ranking-specific positions. Low correlation values mean small importance in determining ranking differences between the four investigated rankings. RankDiffs are the ranking position differences of a university between two rankings (ranked place of first ranking minus ranked place in the second ranking). RankDiff value is low (negative) if the university is ranked higher in the first ranking than in the second, and high (positive) if it is ranked higher in the second ranking. Significant differences ($p < 0.05$) are marked with bold correlation coefficients. (The colors show the distance from the zero. Green to Yellow < 0; Yellow to Red 0 <).

emphasize size and/or quality parameters, while smaller universities can reach better positions in staff normalized rankings.

We have determined the effect of scientometric indicators on ranking positions. Previously, it has been shown that ranking scores correlate with the publication output and citations of a university[15]. It was also established and extended that broader field coverage is also an advantage in rankings[16]. Our results confirmed that scientometric indicators play a major role in rankings. We have found significant correlations between almost all bibliometric-related indicators and positions in each examined ranking. Our results also show that the absolute number of publications and citations are particularly important in ARWU and USNews rankings, and scientific category normalized (field weighted) citation impact is important in THE and USNews rankings.

Each ranking uses different indicators to measure the performance of universities, which vary from one ranking to another. Remarkably, many of these different parameters used for the rankings are not truly independent and we found strong correlations between examined parameters in some cases. These similarities can be divided to two groups: first, the correlation is actually high because of the natural phenomenon that the indicators can be similar in different rankings, e.g., ARWU publications and USNews publications or THE citation and USNews normalized citation impact show similar data from different sources which have significant

	USNews Enroll (# of Students)	QS citations per faculty	THE citation	THE research	THE international outlook	ARWU # highly cited researchers	ARWU Nature and Science	ARWU publications	ARWU per capita performance	USNews publications	USNews books	USNews conferences	USNews normalized citation impact	USNews total citations	USNews # top 10% cited	USNews % top 10% cited	USNews international collaboration	USNews # top 1% cited	USNews % top 1% cited
Continuous indicators																			
THE FTE of Students	**0.97** n=290	-0.03 n=421	**-0.11** n=440	**0.11** n=440	**-0.27** n=440	**0.31** n=406	**0.23** n=406	**0.60** n=406	-0.07 n=406	**-0.59** n=423	**-0.33** n=423	**-0.45** n=423	**0.14** n=423	**-0.53** n=423	**-0.53** n=423	**0.08** n=423	-0.04 n=423	**-0.48** n=423	0.08 n=423
USNews Enroll (# of Students)		-0.08 n=285	**-0.12** n=290	0.03 n=290	**-0.33** n=290	**0.25** n=282	**0.18** n=282	**0.56** n=282	-0.09 n=282	**-0.52** n=293	**-0.24** n=293	**-0.40** n=293	**0.16** n=293	**-0.45** n=293	**-0.45** n=293	**0.11** n=293	-0.07 n=293	**-0.40** n=293	0.09 n=293
QS citations per faculty			**0.33** n=421	**0.54** n=421	**0.23** n=421	**0.41** n=403	**0.36** n=403	**0.32** n=403	**0.50** n=403	**-0.35** n=421	**-0.26** n=421	**-0.36** n=421	**-0.25** n=421	**-0.39** n=421	**-0.43** n=421	**-0.41** n=421	**-0.22** n=421	**-0.41** n=421	**-0.29** n=421
THE citation				**0.31** n=440	**0.37** n=440	**0.48** n=406	**0.43** n=406	**0.20** n=406	**0.52** n=406	**-0.22** n=423	**-0.45** n=423	**0.18** n=423	**-0.88** n=423	**-0.40** n=423	**-0.40** n=423	**-0.78** n=423	-0.04 n=423	**-0.49** n=423	**-0.81** n=423
THE research					**0.24** n=440	**0.51** n=406	**0.62** n=406	**0.57** n=406	**0.55** n=406	**-0.64** n=423	**-0.58** n=423	**-0.42** n=423	**-0.28** n=423	**-0.65** n=423	**-0.65** n=423	**-0.36** n=423	**-0.18** n=423	**-0.63** n=423	**-0.27** n=423
THE international outlook						**0.14** n=406	**0.12** n=406	**-0.11** n=406	**0.36** n=406	0.05 n=423	**-0.37** n=423	**0.13** n=423	**-0.40** n=423	-0.06 n=423	-0.05 n=423	**-0.35** n=423	**0.11** n=423	**-0.11** n=423	**-0.35** n=423
ARWU # highly cited researchers							**0.64** n=431	**0.64** n=431	**0.50** n=431	**-0.64** n=423	**-0.44** n=423	**-0.30** n=423	**-0.45** n=423	**-0.71** n=423	**-0.74** n=423	**-0.57** n=423	**-0.18** n=423	**-0.77** n=423	**-0.56** n=423
ARWU Nature and Science								**0.57** n=431	**0.56** n=431	**-0.63** n=423	**-0.56** n=423	**-0.25** n=423	**-0.45** n=423	**-0.71** n=423	**-0.71** n=423	**-0.52** n=423	**-0.23** n=423	**-0.72** n=423	**-0.50** n=423
ARWU publications									**0.35** n=431	**-0.96** n=423	**-0.47** n=423	**-0.57** n=423	**-0.09** n=423	**-0.91** n=423	**-0.90** n=423	**-0.19** n=423	**-0.15** n=423	**-0.84** n=423	**-0.15** n=423
ARWU per capita performance										**-0.38** n=423	**-0.43** n=423	-0.05 n=423	**-0.53** n=423	**-0.47** n=423	**-0.46** n=423	**-0.55** n=423	**-0.19** n=423	**-0.50** n=423	**-0.52** n=423
Ranked indicators																			
USNews publications											**0.53** n=451	**0.56** n=451	**0.14** n=451	**0.97** n=451	**0.96** n=451	**0.23** n=451	**0.13** n=451	**0.91** n=451	**0.22** n=451
USNews books												**0.23** n=451	**0.40** n=451	**0.60** n=451	**0.59** n=451	**0.38** n=451	-0.04 n=451	**0.58** n=451	**0.33** n=451
USNews conferences													**-0.31** n=451	**0.45** n=451	**0.47** n=451	**-0.16** n=451	**0.26** n=451	**0.38** n=451	**-0.22** n=451
USNews normalized citation impact														**0.36** n=451	**0.36** n=451	**0.88** n=451	0.06 n=451	**0.46** n=451	**0.90** n=451
USNews total citations															**0.99** n=451	**0.43** n=451	**0.13** n=451	**0.98** n=451	**0.42** n=451
USNews # top 10% cited																**0.46** n=451	**0.15** n=451	**0.98** n=451	**0.43** n=451
USNews % top 10% cited																	**0.17** n=451	**0.54** n=451	**0.89** n=451
USNews international collaboration (relative)																		**0.16** n=451	**0.16** n=451
USNews # top 1% cited																			**0.56** n=451

Figure 3. Spearman rank correlations between all the investigated parameters across all included universities. High correlations show that the given indicator/rank affects the other indicator/rank. Significant differences ($p<0.05$) are marked with bold correlation coefficients. "n" means the number of universities where both indicator/rank data were available. (The colors show the distance from the zero. Green to Yellow < 0; Yellow to Red 0 <).

overlap (e.g., data from Web of Science or Scopus). The second group involves indicators correlated to each other within one ranking. We found that indicators measuring absolute values in USNews ranking are highly correlated with each other. For example, universities performing well in the publications indicator also rank well in the citation's indicator, similar to the #top 1% cited and #top 10% cited indicators.

We have to mention several criticisms of university rankings formulated by different research groups. Vernon et al. summarized several doubts about the rankings, suggesting that the significance of the reputation questionnaire should be kept below 10%[12]. QS has the highest weight of reputation indicator (50%) of all the rankings we examined, followed by THE (33%) and USNews (25%). Daraio et al. abridged the main criticisms of the rankings into following four issues: monodimensionality, i.e. the rankings focus mainly on research among the education, research, and third missions of universities; statistical robustness, i.e. statistical problems of the individual indicators; dependence on university size and subject mix; and lack of consideration of the input–output structure[13]. As our results show, that ARWU and USNews rankings have high correlation with university size, while THE and QS rankings use normalized parameters.

We have to note a limitation of our study: the university ranking websites usually do not provide detailed information on the indicators, so approximations had to be used in some cases. In the THE ranking, the "Research" and "International Outlook" pillars, whose values are publicly available, were calculated by combining bibliometric and other indicators, so the effect of bibliometric parameters can be distorted in the correlation calculations. In the USNews ranking, the order of each indicator was available instead of the score values, and this contains less information. The exact ranking position in the ARWU list can only be calculated as an approximation, which also causes some bias. A second limitation is the use of different university names. In some ranking sites the English name only while in other sites the local language versions are used. We tried to identify each university in each list precisely, but we cannot completely exclude the possibility of a mismatch. Notably, as we found strong correlation between number-related parameters, it seems that at least for the THE, USNews, and QS rankings this potential bias is negligible. Finally, although we aimed to make all data openly available, the copyright of the original data sources prohibited this goal.

Unfortunately, in our study it was not possible to give a perfect guide, as one of the limitations of our project is that we only looked at bibliometric indicators (and the university's size). However, each ranking attempts to find the best universities by weighting different indicators. In our study, we found that, even when using the most objective bibliometric indicators, significant differences in the performance of several universities in each ranking can be detected when using certain types of indicators, and that publication differences in the disciplines

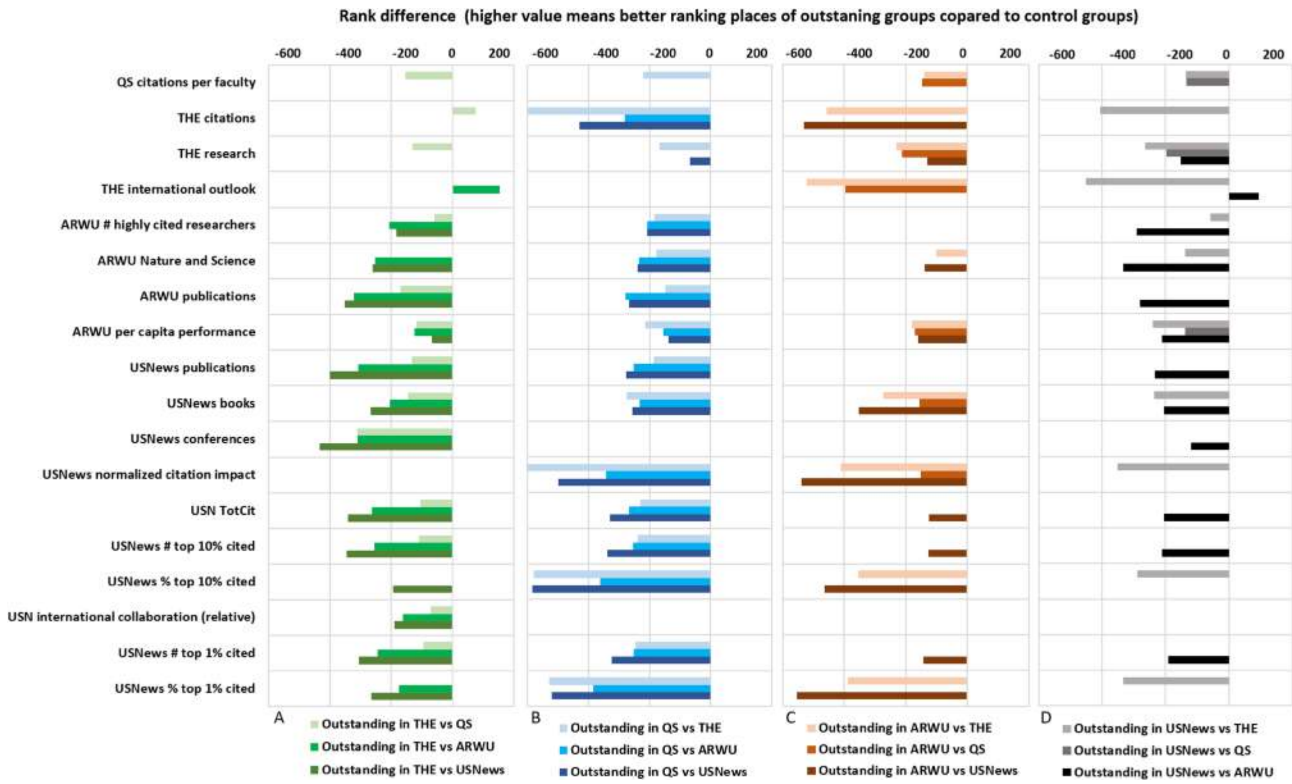

Figure 4. Differences of medians of indicator ranks between outstanding university groups compared to control groups comprising all non-outstanding universities in the given pair. Outstanding universities were those which had a ranking advantage of at least 100 positions compared to position in the other ranking. Outstanding universities and control groups were compared using the Mann–Whitney two-sample rank-sum test. Only those median differences are shown where the two group significantly differed ($p < 0.01$).

also affect the performance in each ranking. Based on these considerations, it is likely that the use of discipline-specific rankings would be more effective than overall rankings for the study of education, research and services.

University ranking systems are on the rise and influence the perceived prestige of a university. Here, we have determined the effects of scientometric parameters on university ranking positions. Notably, there are also other reasons why one group of universities have significantly different results in rankings, e.g., diversified territorial and educational contexts can cause structural biases[17]. In this study we have identified factors significantly related to the outstanding status. Overall, strong publication activity is an important factor in each ranking, but significant differences in ranking places depend on both the selected indicators used by the ranking and the publication and citation characteristics of the universities.

Methods

Setting up a matched ranking for top universities. We selected four internationally recognized rankings from three continents, Europe, North-America and Asia. A common characteristic of these rankings was the availability of detailed ranking data. We used the most recent version of the four chosen rankings including the Times Higher Education World University Ranking 2022 edition (THE), the QS World University Rankings 2022 edition (QS) the ShanghaiRanking—Academic Ranking of World Universities 2021 edition (ARWU), and the U.S.News Best Global Universities Ranking 2022 edition (USNews).

Recomputing ranking scores for scientometric indicators. Because most ranking websites do not publish exact ranking results, only bins, we had to calculate the ranking positions of the universities according to the ranking's published methodology. For example, in ARWU, the total scores were available only for the first 100 universities, for the other universities the total scores could not be derived from the public data, so we used estimation of the total score based on the values of each indicator using their methodology.

We selected bibliometrics-related indicator values from the four rankings, which were available on the webpage of the rankings. This includes altogether twenty indicators (one indicator from QS, three indicators from THE, four indicators from ARWU, and 12 indicators from USNews) which are described in detail in Table 1. Notably, the total weight of scientometric parameters is 60% in THE, 60% in ARWU, 20% in QS, and 75% in USNews.

We also collected available data on university sizes, which was the "Number of Students" parameter from THE and "Enrollment" value from USNews. These two parameters were the same for most universities, but they originate from different data collection processes.

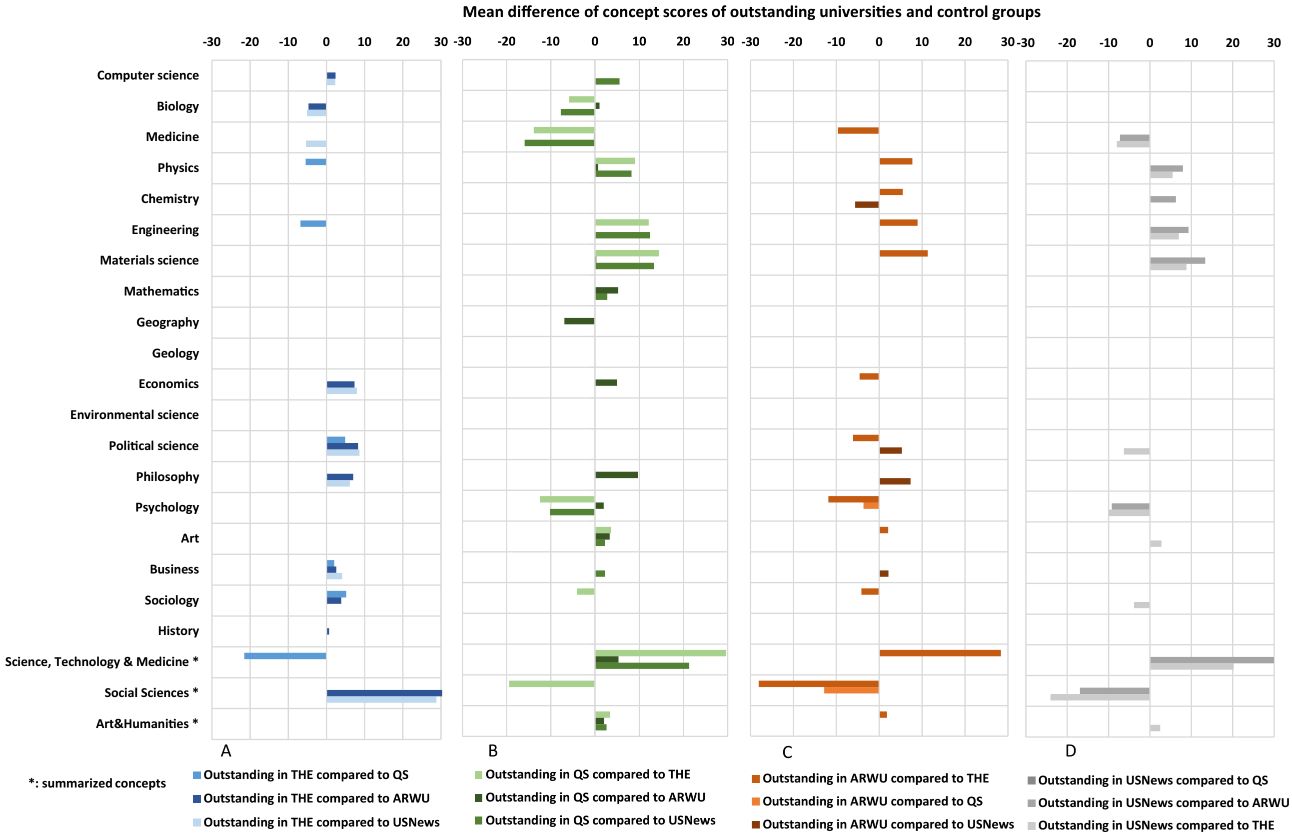

Figure 5. Differences of means of score values of root level concepts between outstanding university group compared to control groups comprising all non-outstanding universities in the given pair. Outstanding universities were those which had a ranking advantage of at least 100 positions compared to position in the other ranking. Outstanding universities and control groups were compared using the Mann–Whitney two-sample rank-sum test. Only those mean differences are shown where the two group significantly differed ($p < 0.01$).

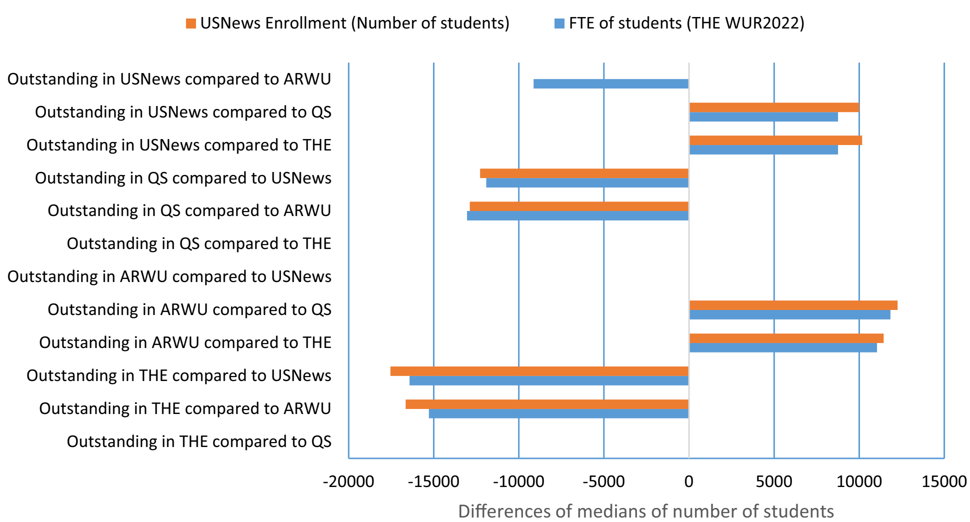

Figure 6. Differences of medians of university size parameters between outstanding university groups compared to control groups comprising all non-outstanding universities in the given pair. Outstanding universities were those which had a ranking advantage of at least 100 positions compared to the other ranking. Outstanding universities and control groups were compared using the Mann–Whitney two-sample rank-sum test. Only those median differences are shown where the two group significantly differed ($p < 0.01$).

Indicator abbreviation	Ranking	Indicator original name	% of overall	size dependent	Definition	Indicator origin (database)	Indicator type
THE citation	THE	Citations	30%	no	Citation ratio compared to average in same field, area, type and year	Scopus	Citation
THE research	THE	Research (Includes research productivity)	30% (6%)	no	Number of publications (article, review)/number of staff FTE	Scopus	Publication
THE international outlook	THE	International Outlook (Includes collaboration)	7.5% (2.50%)	no	% of articles	Scopus	Publication
QS citations per faculty	QS	Citations per faculty	20%	yes	The total number of citations received by all papers produced by an institution across a five-year period by the number of faculty members at that institution	Scopus	Citation
USNews publications	USNews	Publications	10%	yes	The total number of scholarly papers—reviews, articles and notes	Web of Science	Publication
USNews books	USNews	Books	2.50%	yes	The total number of books	Web of Science	Publication
USNews conferences	USNews	Conferences	2.50%	yes	The total number of conference abstracts, proceeding papers	Web of Science	Publication
USNews normalized citation impact	USNews	Normalized citation impact	10%	yes	The total number of citations per paper	Web of Science	Citation
USNews total citations	USNews	Total citations	7.50%	yes	The total number of citations	Web of Science	Citation
USNews # top 10% cited	USNews	Number of publications that are among the 10% most cited	12.50%	yes	The number of papers that have been assigned as being in the top 10% of the most highly cited papers in the world for their respective fields	Web of Science	Publication
USNews % top 10% cited	USNews	Percentage of total publications that are among the 10% most cited	10%	no	The percentage of a university's total papers that are among the top 10% of the most highly cited papers in the world—per field and publication year	Web of Science	Publication
USNews # top 1% cited	USNews	Number of highly cited papers that are among the top 1% most cited in their respective field	5%	yes	Number of highly cited papers that are among the top 1% most cited in their respective field based on the Clarivate's Essential Science Indicators™	Web of Science	Publication
USNews % top 1% cited	USNews	Percentage of total publications that are among the top 1% most highly cited papers	5%	no	The number of highly cited papers for a university divided by the total number of documents it produces	Web of Science	Publication
USNews international collaboration (relative)	USNews	International collaboration—relative to country	5%	no	The proportion of the institution's total papers that contain international co-authors divided by the proportion of internationally co-authored papers for the country that the university is in	Web of Science	Publication
ARWU Nature and Science	ARWU	N&S—Papers published in Nature and Science	20%	yes	The number of papers published in Nature and Science between 2016 and 2020. To distinguish the order of author affiliation, a weight of 100% is assigned for corresponding author affiliation, 50% for first author affiliation (second author affiliation if the first author affiliation is the same as corresponding author affiliation), 25% for the next author affiliation, and 10% for other author affiliations	Web of Science	Publication
Continued							

Indicator abbreviation	Ranking	Indicator original name	% of overall	size dependent	Definition	Indicator origin (database)	Indicator type
ARWU publications	ARWU	PUB—Papers indexed in Science Citation Index-Expanded and Social Science Citation Index	20%	yes	Total number of papers indexed in Science Citation Index-Expanded and Social Science Citation Index in 2020. Only publications of 'Article' type are considered	Web of Science	Publication
ARWU per capita performance	ARWU	PCP—Per Capita Performance	10%	no	The weighted scores of the five indicators divided by the number of full-time equivalent academic staff give PCP scores. If the number of academic staff for institutions of a country cannot be obtained, the weighted scores of the above five indicators are used	Web of Science	Publication
ARWU # highly cited researchers	ARWU	HiCi—Highly Cited Researchers	20%	yes	Number of researchers in "highly cited researchers" list by Clarivate	Web of Science	Special

Table 1. Summary of examined scientometric indicators.

Notably, in the THE ranking, the value of the Research productivity and International collaboration indicators are not published, only the aggregated value of these combined with other indicators (Research and International Outlook). As USNews ranking did not publish the scores of different indicators, only by the rank by the indicator values, we calculated the ranking positions for each used indicator in order to make these indicators easily comparable where this was reasonable.

Creating merged ranking of universities listed among the top 300 in at least one ranking. A unified ranking of universities was created by merging universities which were among the top 300 in any of selected four rankings. Different university names in different rankings have been manually identified and merged (e.g., in some cases a local name was used in one ranking and English name in another). For each university in the merged list, we collected the ranking positions and indicator scores and/or ranking position values from all four selected rankings even in case the university was not listed in the other rankings. If the university was not listed at all in a ranking, the ranking place and the determined parameter indicators were left empty. In each case, we tried to identify the reason for being excluded from a particular ranking. In some cases, we found that QS did not list some universities because they are specialized in one specific field. Some institutions were listed as a part of a larger institution in one ranking, and separately in other rankings (e.g., Indian Institute of Technology).

Determining typical disciplines of universities. To identify the most typical scientific fields of each university we used OpenAlex database concepts which classifies scientific works using an automated algorithm[18]. OpenAlex has 19 root level concepts, and concepts score values are aggregated at the university level. We have collected the score values of root level concepts of all universities, and we summarized score values of concepts to three categories, including (1) Science, Technology, and Medicine which contains the following concepts: Computer science, Biology, Medicine, Physics, Chemistry, Engineering, Materials science, Mathematics, Geography, Geology, and Environmental science; (2) Social Sciences, which contain Economics, Political science, Philosophy, Psychology, Business, and Sociology; and (3) Arts & Humanities, including Art and History.

Statistical analysis. We used Spearman's rank correlation coefficient to evaluate the correlation between ranking positions and determined parameters in order to assess the overall weight of the investigated parameters. Also, Spearman's rank correlation was computed to correlate the positions in different rankings vs. the parameters, and between the determined parameters.

In a separate analysis, for each ranking pair (THE-QS, THE-USNews, THE-ARWU, QS-USNews, QS-ARWU, USNews-ARWU, and their reverse complementary pairs) universities for which the difference in ranking positions exceeded 100 were classified as "outstanding universities" in the given pair of rankings. Parameters and score values of OpenAlex concepts of outstanding groups and control groups were compared using the Mann–Whitney two-sample rank-sum test. Statistical significance was set at $p < 0.01$ in the study.

Data availability

THE World University Ranking (WUR) Ranking 2022: https://www.timeshighereducation.com/world-university-rankings/2022/world-ranking; QS WUR Ranking 2022: https://www.topuniversities.com/university-rankings/world-university-rankings/2022; Shanghai_ARWU Ranking 2021: https://www.shanghairanking.com/rankings/arwu/2021. The other datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Author contributions

P.S. and B.G. conception of the work; P.S. and B.G. design of the work; P.S. and E.C. design of data; E.C. acquisition of data; P.S. and E.C. clean of data; P.S. and B.G. interpretation of data; P.S., E.C. and B.G. wrote the manuscript; All the authors contributed to revision of the manuscript.

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Competing interests

The authors declare no competing interests.

Additional information

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RESEARCH ARTICLE

Systemic Analysis of the QS International Research Network Indicator Using Big Data: Regional Inequalities and Recommendations for Improved University Rankings

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ABSTRACT The International Research Network (IRN) indicator, introduced in the QS (Quacquarelli Symonds) World University Rankings 2024, has generated notable volatility and regional disparities in global university standings. This paper presents a systemic analysis of the IRN indicator across three ranking cycles (2023–2025) using big data methodologies, including descriptive statistics, scatter plots, university size analysis, a case study of South Korean universities in Social Sciences & Management, correlation, and regression analysis. The results reveal pronounced instability in IRN scores, with sharp year-to-year fluctuations and a marked concentration of top-ranked institutions in English-speaking and European regions-98 of the top 100 and 85% of the top 500 IRN-ranked universities originate from these areas. In addition to identifying structural and regional biases, this study examines how effectively IRN functions as a ranking metric, particularly in its ability to predict overall QS performance. Findings from regression analysis show that the contribution of IRN to the overall QS score is minimal, with its predictive power diminishing significantly in the 2025 ranking year. The South Korean case study highlights methodological inconsistencies, showing that the IRN formula disadvantages institutions with multiple partnerships in the same region. These observations are reinforced by correlation and regression analyses, which further confirm that IRN's explanatory power for overall QS scores weakened in the 2025 ranking year. These findings underscore the need to refine the IRN indicator to enhance transparency, consistency, and inclusivity, thereby supporting a more equitable evaluation of global research networks.

INDEX TERMS Big data analytics, higher education, international research network, international research network (IRN), QS world university rankings, regional inequality, research evaluation, university rankings.

I. INTRODUCTION

The human inclination to categorize and rank has profoundly shaped the landscape of higher education, where global university rankings now play a central role in defining academic quality, research impact, and institutional reputation [1], [2]. Prominent ranking systems—including the QS (Quacquarelli Symonds) World University Rankings (QS WUR), Times Higher Education World University Rankings (THE WUR), Academic Ranking of World Universities (ARWU), and U.S. News & World Report Global University Rankings—have become influential benchmarks for universities and stakeholders worldwide. Among these, QS WUR has gained particular traction in Asia and the Middle East, in part due to its inclusive reputation surveys and mechanisms for direct institutional participation, which have enabled universities from diverse regions to elevate their global profiles [3].

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Historically, QS WUR evaluated institutions using six core indicators: Academic Reputation, Employer Reputation, Faculty-Student Ratio, Citations per Faculty (CPF), International Faculty Ratio (IFR), and International Student Ratio (ISR). In the 2024 ranking cycle (release in June 2023), QS introduced three new metrics—Sustainability, Employment Outcomes, and the International Research Network (IRN) indicator—while adjusting the weightings of existing metrics, notably reducing Academic Reputation from 40% to 30% and increasing Employer Reputation from 10% to 15%. The IRN indicator, designed to assess the breadth of international research partnerships, was first piloted in regional rankings before its formal integration into QS WUR 2024 (released in June 2023).

The implementation of the IRN indicator has been marked by pronounced volatility and controversy. IRN scores were first disclosed in QS WUR 2023 (released in June 2022) but were not used in the published rankings. When IRN was formally included in the 2024 ranking cycle, its impact was particularly dramatic for South Korean universities. Among the top 30 South Korean institutions, 28 experienced a drop in their overall world university ranking, one was a new entrant with no prior ranking for comparison, and only one institution improved its position. All of these universities, however, saw their IRN scores drop precipitously—for example, KAIST's IRN score fell from 65.2 to 10.6, POSTECH from 30.9 to 1.3, UNIST from 31.7 to 1.2, and GIST from 34.5 to 1.3. This widespread decline led to a coordinated response from 52 Korean universities, who publicly challenged the transparency and reliability of the IRN metric [4], [5]. In response to these concerns, QS recalibrated the indicator for the 2025 ranking cycle (released in June 2024), resulting in a sharp rebound in IRN scores and partial recovery in the rankings for many affected institutions. However, this rapid adjustment also exposed significant inconsistencies in the calculation and application of the metric, as illustrated by the scatter plots and correlation heatmaps (Figures 2 and 4), which reveal persistent volatility and regional disparities in IRN performance [6].

A detailed analysis of QS WUR 2025 data reveals a persistent geographical imbalance in the IRN rankings: 98% of the top 100, 94.5% of the top 200, and 85% of the top 500 IRN-ranked universities are located in English-speaking or European countries. This concentration is further illustrated in Figure 1, which shows the overwhelming representation of institutions from the United Kingdom, United States, France, Australia, and Germany among the IRN elite, with only limited participation from regions such as the Middle East and Latin America.

As illustrated in Figure 1, the skewed distribution of IRN scores suggests that institutions from dominant regions may disproportionately benefit from this metric. This raises critical questions about whether the IRN indicator effectively captures global research collaboration or merely reinforces existing advantages for institutions in well-connected regions. In comparison, the Citations per Faculty (CPF) indicator shows a more balanced representation, with only 70% of the top 500 CPF institutions located in English-speaking or European countries. These disparities, coupled with the volatility of IRN scores, highlight the need for a comprehensive review to ensure the IRN metric provides a fair and transparent measure of international research collaboration.

Moreover, the limited variation in IRN scores among top-ranked universities raises concerns about the indicator's ability to meaningfully differentiate institutions with diverse levels of international engagement. For instance, in the 2025 ranking year, the university ranked 700th for IRN still had a score of 54.7, indicating minimal differentiation despite substantial differences in partnership networks. Such compression of scores, coupled with year-to-year volatility, challenges the reliability and interpretability of the IRN metric.

This study undertakes a comprehensive evaluation of the IRN indicator, employing big data methodologies that include descriptive statistics, scatter plot analysis, university size stratification, a focused case study of South Korean universities in the Social Sciences & Management field, as well as correlation and regression analyses. By critically examining the IRN's methodological framework, score distributions, and regional imbalances, this research aims to illuminate the constraints of the current metric and propose pathways for improving its transparency, consistency, and fairness. The findings contribute to ongoing debates about the role of global rankings in higher education and underscore the need for more robust and equitable measures of international research collaboration, supporting sustainability in university evaluation practices.

II. MATERIALS AND METHODS

A. DEFINITION AND SCOPE OF THE QS INTERNATIONAL RESEARCH NETWORK (IRN) INDICATOR

The International Research Network (IRN) Index is a bibliometric tool designed to evaluate the diversity and robustness of an institution's global research collaborations. Derived from the Margalef Index, which is traditionally used in environmental sciences to measure species diversity, the IRN Index has been adapted to assess international research partnerships. To qualify as a sustainable partnership, institutions must co-author at least three research papers with collaborators from different countries over a five-year period, with each paper receiving at least one citation [3], [4], [5], [6], [7].

The IRN Index contributes 5% to the overall QS World University Rankings score, emphasizing its role in measuring global engagement. In regional rankings such as the QS Asia Rankings, its weight increases to 10%, reflecting the growing importance of international collaboration in specific geographic contexts [3], [7]. By focusing on sustained partnerships and geographic diversity, the IRN Index provides insights into how universities establish and maintain meaningful global research networks.

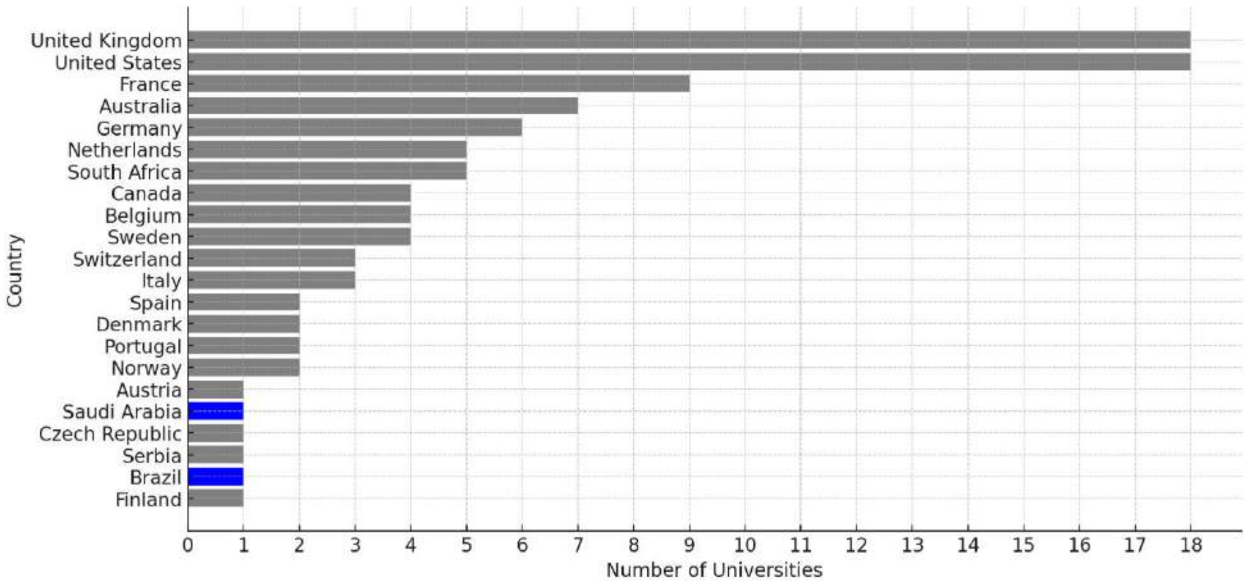

FIGURE 1. Number of universities by country in the top 100 IRN rankings.

B. IRN CALCULATION METHODOLOGY

The calculation of the IRN Index involves assessing the geographical diversity of an institution's research collaborations. The formula used is:

$$IRN\ Index = \frac{L}{\ln(P)} \tag{1}$$

where L represents the number of distinct international locations appearing in relevant publications and P denotes the number of distinct international partner institutions associated with those locations [6]. This approach ensures that institutions are evaluated based on both the breadth of their global reach and the effort required to establish diverse partnerships. To ensure meaningful collaborations are included, QS considers only sustained partnerships resulting in at least three co-authored publications during the evaluation period. Furthermore, specific types of publications are included in the calculation, and a QS affiliation cap is applied to prevent overrepresentation by large research groups where contributions may be uneven [3], [6].

The final IRN score is normalized across five major faculty areas - Arts & Humanities, Engineering & Technology, Life Sciences & Medicine, Natural Sciences, and Social Sciences & Management. Each faculty-specific IRN value is scaled individually, averaged, and adjusted to ensure consistency before publication [8]. This normalization accounts for differences in publishing cultures across disciplines while maintaining fairness in evaluating global research collaboration.

It is important to note that the formula's logarithmic denominator means that partnerships in different locations are valued more highly than multiple partnerships within the same location. For example, one partnership each in five different countries would yield a higher score than five partnerships within a single country, even if the total number of collaborating institutions is the same. This emphasis on geographical dispersion has significant implications for how institutions develop their international research strategies.

C. METHODOLOGY FOR CORRELATION ANALYSIS BETWEEN IRN AND QS WORLD UNIVERSITY RANKINGS INDICATORS

1) PEARSON CORRELATION COEFFICIENT

The Pearson correlation coefficient (r) quantifies the strength and direction of linear relationships between continuous variables. For this study, it measures associations between IRN scores and other QS WUR indicators. The coefficient is calculated as:

$$r = \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum (X_i - \bar{X})^2}\sqrt{\sum (YX_i - \bar{Y})^2}} \tag{2}$$

where Xi and Yi represent the values of two QS WUR indicators for a given institution, and $\bar{X}$ *and* $\bar{Y}$ are their respective means. The numerator measures covariance between variables, while the denominator normalizes these values to produce a coefficient ranging from -1 to 1. This approach provides a robust framework for analyzing how IRN scores relate to other indicators such as Academic Reputation or Citations per Faculty [9], [10].

2) INTERPRETATION OF CORRELATION VALUES

Correlation coefficients are interpreted according to established thresholds in statistical literature: values of 1.0 or -1.0 indicate perfect positive or negative correlations, respectively; coefficients between 0.7 and 1.0 (or -0.7 and -1.0) represent strong correlations; values between 0.3 and

0.7 (or −0.3 and −0.7) indicate moderate correlations; and coefficients between 0.0 and 0.3 (or 0.0 and −0.3) suggest weak correlations. This consistent classification framework enhances clarity when interpreting relationships between variables across different regional contexts and ranking years [11].

3) STATISTICAL SIGNIFICANCE

To determine whether observed correlations represent meaningful relationships rather than random variation, we employ a two-tailed t-test using the formula:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \tag{3}$$

where r is the Pearson correlation coefficient and n is the sample size. The resulting p-value, derived from the t-distribution, is evaluated with significance set at $p < 0.05$ [12]. This threshold ensures that only statistically significant correlations inform our conclusions about relationships between IRN and other ranking indicators.

4) DATA SELECTION AND PROCESSING

Our dataset comprises IRN scores and other QS World University Rankings (WUR) indicators for over 1,400 global universities included in the QS 2023, 2024 and 2025 rankings. While IRN scores for 2024 and 2025 were directly accessible from the official QS website, scores for the 2023 cycle were obtained from the QS 2023 Results Excel file, which is available upon request from the QS Reports & Whitepapers portal [13]. All indicator scores, including IRN, are normalized by QS on a scale from 1 to 100, ensuring comparability across metrics and institutions. In the small number of cases where indicator data are missing for a university, a value of 1—the minimum possible score—is assigned, in line with QS methodology. As a result, the dataset contains no extreme values or statistical outliers, and all variables are directly comparable without the need for additional standardization or outlier filtering. Data integrity was verified through consistency checks across multiple sources.

To facilitate regional comparisons, universities were classified based on their country of origin into either (1) English-speaking or countries located in Europe, or (2) non-English-speaking and non-European. The English-speaking group includes countries where English is a primary or official medium of higher education, while the European group includes all countries geographically situated in the European continent, regardless of EU membership. A full list of countries and the number of universities per group is provided in Appendix.

Additionally, for the QS WUR 2024 dataset, 23 out of 1,497 ranked universities lacked classification for institutional size and were excluded from analyses involving university size. For the 2023 and 2025 rankings, university size classifications were complete with no missing values. This classification framework supports both Pearson correlation analysis and university size-based subgroup analysis, allowing for systematic investigation into how IRN relates to other QS indicators across different regional and institutional dimensions.

D. REGRESSION ANALYSIS METHODOLOGY BETWEEN IRN AND QS WUR INDICATORS

1) REGRESSION MODEL SPECIFICATION

To evaluate the influence of the IRN indicator on QS World University Rankings metrics, we employ multiple linear regression analysis. This approach quantifies relationships between IRN and other ranking factors while controlling for potential confounding variables. The regression model is defined as:. The formula used is:

$$Y = \beta_0 + \beta_1(IRN) + \beta_2(X_2) + \beta_3(X_3) + \ldots + \beta_n(X_n) + \varepsilon \tag{4}$$

where Y represents the dependent variable(typically the Overall QS Score), IRN is the independent variable of primary interest, X_2 through X_n denote control variables (other QS WUR indicators). β is the intercept, β_1 through β_n are the regression coefficients, and ε represents the error term capturing unobserved factors. This model isolates IRN's effect while accounting for other influential variables such as Academic Reputation or Citations per Faculty.

2) VARIABLE SELECTION AND DATA PREPARATION

The dependent variable in the regression analysis is the Overall QS Score, reflecting its central role in institutional rankings. Independent variables include IRN scores and other QS World University Rankings (WUR) indicators, all of which are normalized by QS on a scale from 1 to 100, ensuring direct comparability across metrics and institutions. For the small number of cases with missing indicator values, a score of 1—the minimum possible value—is assigned, consistent with QS methodology for handling non-reported data.

Given this normalization, no additional standardization or outlier removal is required, as all variables are bounded within the 1–100 range and extreme values are not present. To ensure the robustness of the regression model, we assessed multicollinearity among independent variables using the Variance Inflation Factor (VIF), removing predictors with VIF values greater than 5. This approach prevents estimation bias and ensures the stability and interpretability of regression coefficients. By retaining the complete institutional sample from the QS 2024 and 2025 ranking cycles, our analysis provides a comprehensive evaluation of the relationships between IRN and other ranking indicators across the global university landscape.

3) MODEL ESTIMATION AND STATISTICAL SIGNIFICANCE

The model is estimated using Ordinary Least Squares (OLS), which minimizes the sum of squared residuals. The statistical significance of coefficients is tested via a t-test:

$$t = \frac{\hat{\beta}}{SE(\hat{\beta})} \quad (5)$$

where $\hat{\beta}$ is the estimated coefficient and SE($\hat{\beta}$) is its standard error. Coefficients with p-values < 0.05 were considered statistically significant, indicating meaningful relationships between IRN and the dependent variable.

4) INTERPRETATION OF REGRESSION RESULTS

Key metrics for interpretation include coefficients signs and magnitudes, which reflect IRN's directional impact on rankings. R^2 values, which indicate the proportion of variance explained by the model; adjusted R^2, which accounts for model complexity to prevent overfitting; and residual diagnostics, including tests for heteroscedasticity (Breusch-Pagan test) and normality of errors (Shapiro-Wilk test). For example, a positive and significant β_1 coefficient for IRN suggests that stronger international collaboration correlates with higher rankings, holding other factors constant. This comprehensive analysis framework enables nuanced understanding of how the IRN indicator contributes to overall university rankings, with implications for institutional strategies toward sustainable international research engagement.

III. ANALYSIS AND RESULTS

This section evaluates trends in International Research Network (IRN) scores across three QS World University Rankings (WUR) cycles (2023–2025), focusing on methodological inconsistencies, institutional impacts, and regional disparities. The analysis begins with a statistical overview of IRN score distributions and ranking cutoff thresholds to quantify volatility. Scatter plot visualizations explore relationships between IRN and other QS indicators, while university size analysis assesses how institutional scale influences IRN performance. A case study of South Korean universities in the Social Sciences & Management faculty highlights flaws in IRN's methodology. Finally, correlation and regression analyses evaluate IRN's predictive significance in overall rankings.

A. IRN SCORE ANALYSIS

This section presents a detailed analysis of International Research Network (IRN) scores, including their statistical characteristics, ranking cutoffs, and methodological considerations.

1) STATISTICAL SUMMARY OF IRN SCORES FOR QS WUR 2023, 2024, AND 2025

A statistical overview of International Research Network (IRN) scores from the QS World University Rankings (WUR) for the ranking years 2023 to 2025 offers valuable insights into the distribution and variability of these scores across different ranking cycles. This analysis incorporates key descriptive statistics, including the mean, standard deviation, minimum, various percentiles (25th, median, 75th), and maximum values, to highlight trends and variations in IRN performance over time. The data for this summary were obtained from the official QS World University Rankings dataset [13], [14], [15].

As shown in Table 1, the International Research Network (IRN) scores exhibited substantial volatility across the 2023, 2024, and 2025 QS World University Rankings cycles. It is important to note that the "2023 ranking year" corresponds to rankings published in 2022, the "2024 ranking year" to rankings published in 2023, and so forth. In the 2023 ranking year, IRN scores demonstrated moderate dispersion, with a mean of 49.13 and a median of 46.8. The 75th percentile (77.38) and standard deviation (30.42) reflect considerable variability in institutional performance, indicating diverse levels of global research collaboration. In the 2024 ranking year, a sharp methodological recalibration led to a marked decline in IRN scores, with the mean dropping to 23.92 and the median to 6.70. The 25th percentile fell to 1.2, suggesting that a significant proportion of institutions scored near the minimum, which points to a systemic redistribution of scores. By the 2025 ranking year, IRN scores rebounded to levels similar to the 2023 ranking year, with a mean of 50.10 and a median of 51.10. Nevertheless, the standard deviation remained high (29.88), and the clustering of scores near the upper end indicates reduced differentiation among universities. This pattern suggests that the metric's ability to distinguish between institutions was compromised, raising concerns about the effectiveness and reliability of the IRN indicator in capturing genuine differences in international research collaboration.

2) IRN SCORE CUTOFFS BY RANK

Table 2 highlights the volatility of IRN score cutoffs at the 100th, 200th, 300th, 400th, 500th, and 600th ranks across the 2023, 2024, and 2025 ranking years. The 2024 ranking year experienced a significant decline in scores across all thresholds, with the 200th rank dropping from 87.8 in the 2023 ranking year to 69.3, and the 600th rank plummeting from 57.7 to 15.1. This sharp decrease reflects a major redistribution of scores, likely due to methodological revisions. By the 2025 ranking year, IRN scores rebounded at all cutoff points, often exceeding their 2023 levels. Notably, the 100th and 200th ranks in the 2025 ranking year returned to values comparable to those in the 2023 ranking year, indicating a re-stabilization in IRN score calculation and distribution following the 2024 drop. However, the clustering of scores near the upper end in the 2025 ranking year suggests diminished discriminative power, as universities with varying degrees of international research engagement receive similar IRN scores, limiting the metric's effectiveness in distinguishing institutional performance.

3) METHODOLOGICAL CRITIQUE AND IMPLICATIONS

The International Research Network (IRN) indicator has demonstrated pronounced volatility, primarily due to

TABLE 1. Statistical summary of IRN scores (2023-2025).

Ranking Year	# of Ranked Universities	mean	std	min	25th Percentile Score	Median Score	75th Percentile Score	max
2023	1422	49.13	30.42	1	21.20	46.80	77.38	100
2024	1497	23.92	30.36	1	1.20	6.70	40.30	100
2025	1503	50.10	29.88	1	22.70	51.10	77.10	100

TABLE 2. IRN Score Cutoffs for the 100th, 200th, and 600th Ranks (2023-2025).

Ranking Year	100th	200th	300th	400th	500th	600th
2023	93.4	87.8	81.2	74.9	66.5	57.7
2024	87.2	69.3	52.1	37.2	24.8	15.1
2025	93.9	87.8	81.4	75.4	68.8	62.3

significant methodological changes that have led to major fluctuations in university rankings. Although the underlying dataset remained largely consistent across the 2023, 2024, and 2025 ranking cycles, QS introduced substantial modifications to the calculation and normalization of IRN scores, resulting in reduced transparency and consistency [3]. One of the most consequential changes was the shift from a university-level IRN calculation in the 2023 ranking year (published in 2022) to a faculty-based approach in the 2024 ranking year (published in 2023). Under this revised methodology, the IRN score is now computed separately for each of the five broad faculty areas and then averaged to produce the final institutional score [16]. This adjustment disproportionately penalized universities with strong international research networks concentrated in specific faculties, while favoring institutions with more evenly distributed international collaborations. The lack of prior communication and explanation regarding this change led to confusion among universities attempting to interpret their ranking performance.

Additionally, the normalization procedures for IRN scores varied between the 2023 and 2024 ranking years, further amplifying score instability. The introduction of the new faculty-based calculation and normalization in the 2024 ranking year resulted in a marked decrease in IRN scores for many institutions, as indicated by significant drops in median and percentile values. In response to widespread concerns, QS revised its methodology again for the 2025 ranking year, which led to a dramatic increase in IRN scores across universities. However, this surge caused many scores to cluster at the upper end of the scale, reducing the metric's ability to differentiate meaningfully between institutions and raising questions about its effectiveness as a measure of international research engagement.

The ongoing and opaque methodological adjustments to the IRN indicator raise concerns regarding the reliability and transparency of the QS ranking system. Institutions seeking to improve their IRN performance face challenges in developing long-term strategies due to the unpredictable nature of these changes. For the IRN to remain a valuable metric, it is essential that QS ensures greater methodological consistency, transparency in its calculations, and clear justification for any modifications to avoid destabilizing global university rankings [16], [17].

B. SCATTER PLOT ANALYSIS OF IRN SCORES AND QS WUR INDICATORS

This section presents a visual analysis of the relationship between International Research Network (IRN) scores and other key indicators in the QS World University Rankings (WUR) for the 2024 and 2025 ranking years. The analysis examines how IRN scores relate to Academic Reputation (AR), Employer Reputation (ER), Faculty-Student Ratio (FSR), Citations per Faculty (CPF), International Faculty Ratio (IFR), International Student Ratio (ISR), Employment Outcome (EO), Sustainability, and the Overall Score.

1) VISUAL INTERPRETATION OF SCATTER PLOTS

Scatter plots serve as visual exploratory tools that display the distribution of data points across two variables, allowing researchers to identify patterns, clusters, and potential relationships [18]. In this analysis, scatter plots provide a mechanism to observe how universities perform on IRN scores in relation to other QS indicators, revealing both typical and atypical institutional profiles.

The scatter plots in Figure 2 reveal several noteworthy patterns across both ranking years. For perception-based indicators such as Academic Reputation (AR) and Employer Reputation (ER), universities exhibit a wide range of IRN scores regardless of their reputational standing. This dispersion suggests that institutional reputation does not necessarily align with international research collaboration intensity. Similarly, for Faculty-Student Ratio (FSR), which primarily reflects teaching resources, universities demonstrate

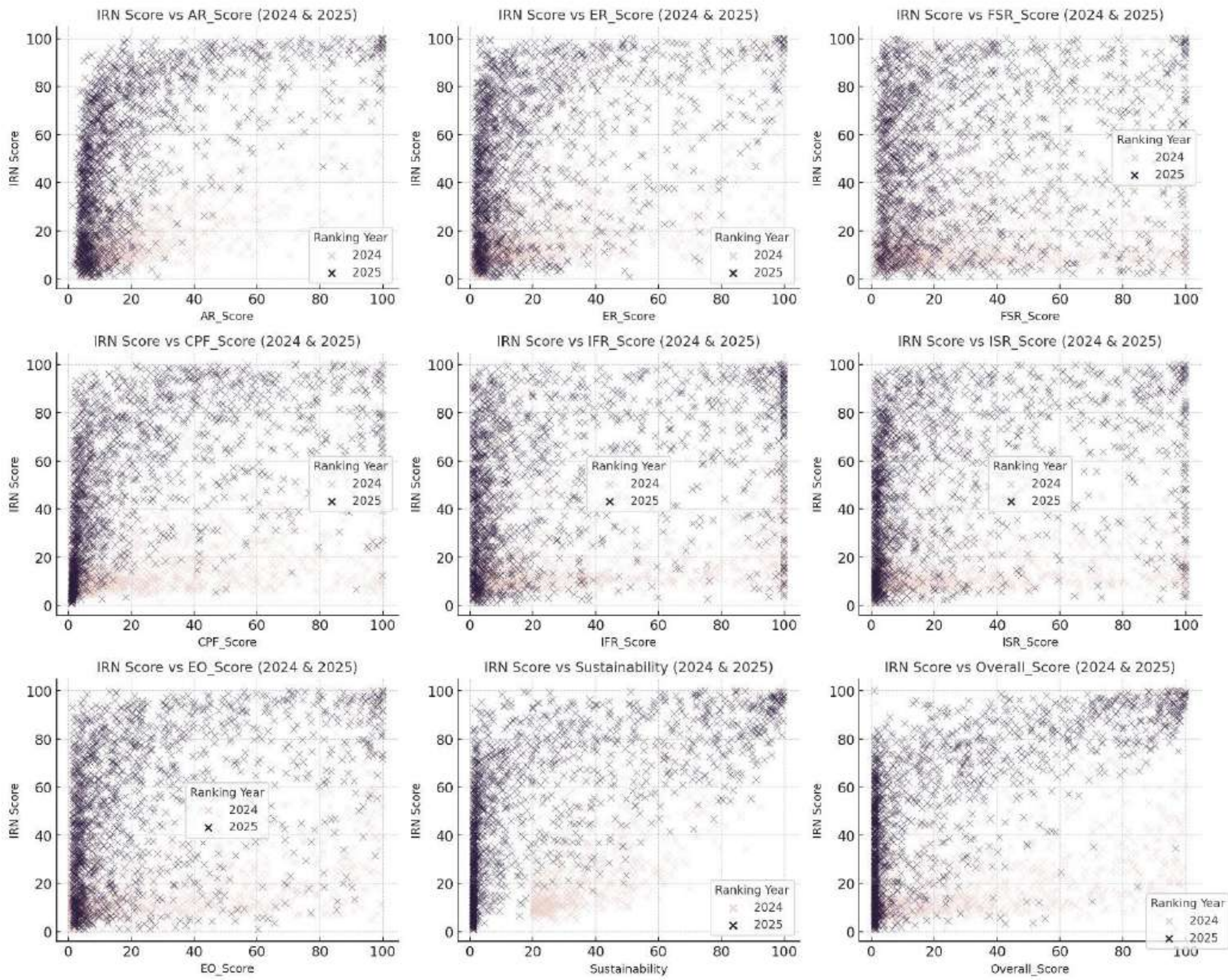

FIGURE 2. **IRN scatter plot comparison of IRN score vs other QS indicators for QS WUR 2024 and 2025.**

varied IRN performance across the spectrum, indicating that teaching-focused institutions may have diverse approaches to international research engagement.

Citations per Faculty (CPF), a direct measure of research output and impact, shows a more complex distribution pattern. Universities with both high and low citation rates display the full range of IRN scores, suggesting that research productivity and international collaboration may operate as distinct dimensions of institutional performance. The internationalization indicators (IFR and ISR) similarly show no clear visual pattern with IRN scores, despite their conceptual connection to global engagement, highlighting the specific nature of research collaboration compared to broader international presence.

Employment Outcome (EO), which assesses graduate employability and career success, displays a distribution similar to other indicators, with IRN scores spanning the entire range regardless of employment outcomes. This pattern reinforces the distinction between educational outcomes and research collaboration priorities. The Sustainability indicator, introduced more recently to the QS framework, likewise shows no distinctive visual pattern with IRN, though this may evolve as sustainability-focused research partnerships develop over time

2) OBSERVED TRENDS AND ANOMALIES

The most striking feature across all scatter plots is the heavy concentration of universities with low QS indicator scores (clustered near zero on the x-axis) yet widely distributed IRN scores ranging from 0 to 100. This distinctive pattern appears consistently across all nine indicators examined. The distribution raises important questions about the IRN metric's calibration relative to other ranking components. A score of 20 in indicators such as Academic Reputation or Employer Reputation corresponds to ranks around 441 and 454, respectively, in the 2024 ranking year. In contrast, the same score in IRN corresponds to rank 554. However, in the 2025 ranking year, this shifts dramatically—an IRN score of 20 places an institution around rank 1,159, despite other indicators showing similar rank stability. This change reveals a steep inflation of IRN scores and a compression of rank differentiation.

A comparison of the 2024 and 2025 data points reveals substantive changes in the distribution patterns. The 2025 ranking shows a notable upward shift in IRN scores across the board, with fewer institutions receiving low IRN scores compared to 2024. This shift suggests a significant recalibration in how IRN was calculated between these ranking cycles, resulting in less differentiation among universities on this dimension.

The dense clustering of data points along the lower end of QS indicator values, combined with the full-range dispersion of IRN scores, creates visualization patterns that appear disconnected from what might be expected if the metrics were measuring related aspects of university performance. This unusual distribution pattern warrants further investigation into the IRN calculation methodology and its relationship to other ranking components.

3) ANALYSIS RESULTS

The scatter plot analysis provides valuable insights into the distribution patterns of IRN scores in relation to other QS indicators. The visualizations reveal that IRN scores appear to operate somewhat independently from other ranking metrics, with substantial shifts in score distribution between the 2024 and 2025 ranking cycles. The score of 20 serves as a reference point that demonstrates this inconsistency: in the 2024 ranking year, it places a university around mid-tier in IRN, but in the 2025 ranking year, the same score drops the institution to the bottom quartile. This distortion highlights how recalibration may have inflated IRN scores for a large number of universities. The observed patterns suggest that QS's recalibration of the IRN methodology between these years may have inflated scores, particularly for institutions with lower values in other indicators. As a result, IRN in the 2025 ranking year fails to provide adequate discriminatory power among institutions with differing levels of international engagement, undermining its utility as a reliable ranking metric.

These findings highlight the importance of methodological transparency in university rankings. While visual analysis alone cannot determine the appropriateness of the IRN indicator, it raises important questions about measurement consistency and the ability of the metric to meaningfully differentiate between institutions based on their international research collaboration profiles.

C. RELATIONSHIP BETWEEN IRN SCORES AND UNIVERSITY SIZE

Understanding the relationship between university size and International Research Network (IRN) scores is essential for interpreting patterns of global research collaboration. In the QS World University Rankings (WUR), institutions are classified by student enrollment as Small (S: fewer than 5,000 students), Medium (M: 5,000–12,000 students), Large (L: 12,000–30,000 students), and Extra Large (XL: more than 30,000 students), as shown in Table 3. These categories facilitate analysis of how institutional scale influences the capacity for international research engagement [19].

TABLE 3. QS institutional size categories based on student enrollment.

Size Category	Student Enrollment
Small (S)	Fewer than 5,000 students
Medium (M)	5,000 to 12,000 students
Large (L)	12,000 to 30,000 students
Extra Large (XL)	More than 30,000 students

1) DISTRIBUTION OF IRN SCORES BY UNIVERSITY SIZE (RANKING YEAR 2023, 2024, AND 2025)

A comparative analysis of IRN scores across the 2023, 2024, and 2025 ranking cycles reveals pronounced differences by institutional size. As summarized in Table 4, Large and Extra-Large universities consistently achieve higher median and upper-quartile IRN scores than Small and Medium institutions. This trend reflects the broader disciplinary scope, greater faculty diversity, and enhanced funding capacity of larger universities, which collectively facilitate more extensive international research networks. In contrast, smaller universities tend to exhibit lower medians and greater variability in IRN scores, indicating both structural challenges and disparate success in building global partnerships.

2) INTERPRETATION OF IRN SCORE TRENDS

The data indicate that the IRN indicator structurally benefits larger universities, as its methodology averages scores across five major faculty areas. Institutions with a broad disciplinary scope and substantial resources are more likely to achieve higher IRN scores, reinforcing their dominance in global rankings. Smaller universities, even those with strong international collaborations in select fields, are disadvantaged if their partnerships do not span all faculty areas included in the IRN calculation.

Moreover, the IRN score does not account for the quality or depth of international collaborations. A large university with numerous low-impact partnerships may outscore a smaller institution with fewer but more meaningful collaborations, reducing the reliability of IRN as a true measure of global research engagement. The instability in IRN scores observed between the 2023 and 2025 ranking cycles—particularly the sharp decline in the 2024 ranking year and subsequent recovery in the 2025 ranking year—further highlights methodological inconsistencies and raises concerns about the transparency and predictability of the QS ranking system.

Analysis of the score distributions shows that Large and Extra Large universities not only have higher medians but also narrower interquartile ranges, reflecting more consistent performance in international research engagement.

In contrast, Small and Medium institutions exhibit greater variability, with some achieving high IRN scores while others remain at the lower end of the spectrum. The wider whisker range for Small universities suggests pronounced disparities in international collaboration within this group.

The 2024 ranking year saw a significant decline in IRN scores across all size categories, attributable to methodological changes in the QS rankings. The subsequent rebound in the 2025 ranking was more pronounced among larger institutions, indicating their greater capacity to adapt to revised scoring methodologies. Nevertheless, some small and medium universities demonstrated strong IRN performance, illustrating that targeted institutional strategies and research priorities can overcome structural limitations imposed by size.

3) VISUALIZATION OF IRN SCORES BY UNIVERSITY SIZE

Figure 3 illustrates the distribution of IRN scores for different university sizes across ranking years. The central line in each box represents the median IRN score, while the upper and lower edges represent the interquartile range (25th and 75th percentiles). The whiskers extend to the lowest and highest values within 1.5 times the interquartile range, with outliers plotted individually.

4) ANALYSIS RESULTS

This analysis demonstrates that larger universities generally hold an advantage in international research engagement as measured by the IRN indicator, largely due to structural and methodological factors. However, the presence of small and medium universities with strong IRN performance underscores the role of institutional strategies and research priorities in fostering global research networks. These findings highlight the need for methodological refinement in global university rankings to ensure a fair and meaningful assessment of international research collaboration across diverse institutional contexts.

D. IRN SCORES OF 17 SOUTH KOREAN UNIVERSITIES IN THE SOCIAL SCIENCE & MANAGEMENT FIELD

The International Research Network (IRN) Index in QS rankings is measured across five broad faculty areas: Arts & Humanities, Engineering & Technology, Life Sciences & Medicine, Natural Sciences, and Social Sciences & Management. For this study, the QS 2025 rankings were analyzed specifically for the Social Sciences & Management field, where methodological inconsistencies are particularly evident.

The IRN score calculation methodology combines the number of distinct international locations (L) divided by the natural logarithm of the number of distinct international partners (P), where partners refer to universities with which an institution has co-authored at least three papers within a five-year period. Each paper must receive at least one citation to be counted. Importantly, locations are defined geographically, with the United States counted as a single location despite having over 2,500 universities, while Mainland China, Macau, Hong Kong, and Taiwan are considered four separate locations [3].

1) OVERVIEW OF IRN SCORES IN SOUTH KOREAN UNIVERSITIES

This section examines the IRN scores of 17 South Korean universities in the Social Sciences & Management field, highlighting inconsistencies and biases in the QS IRN calculation methodology. While the IRN metric is intended to reflect the strength and diversity of international research collaborations, closer analysis reveals that the methodology disproportionately favors institutions with partnerships distributed across many locations rather than those with multiple partners in the same region (Table 5).

2) FINDINGS AND INCONSISTENCIES IN IRN SCORES

Analysis of the data reveals that to maximize IRN scores, institutions benefit from having a higher number of distinct locations with a limited number of partners per location. This creates a counterintuitive situation where geographical diversity is prioritized over the depth and intensity of international collaborations. For example, Hallym University has established partnerships with 11 institutions across 2 locations, while DGIST has only 2 partners across 2 locations. Despite Hallym's more extensive collaborative network, its IRN score (3.85) is significantly lower than DGIST's (18.47) [4], [5]. This pattern suggests that the QS methodology structurally favors institutions with one partner per location rather than those with multiple partners in the same country or region.

Similarly, the comparison between KAIST and GIST further illustrates this methodological bias. Despite KAIST's substantially larger research network spanning 20 locations with 92 partners and higher scholarly output (380 publications), it received an IRN score of 29.43. In contrast, GIST, with fewer locations (15) and significantly fewer partners (21), achieved a higher IRN score of 33.02. This counterintuitive result demonstrates how the logarithmic denominator in the IRN formula systematically undervalues extensive research networks, particularly when they include multiple partnerships within the same locations. The formula effectively penalizes institutions that develop deep collaborative relationships with multiple partners in key research regions rather than seeking geographic diversity for its own sake.

3) CRITIQUE OF QS IRN METHODOLOGY

The case of South Korean universities in the Social Sciences & Management field exposes several significant flaws in the QS IRN indicator methodology. First, the current formula creates a structural disincentive for establishing multiple partnerships within the same country. As demonstrated by the University World News report, Korean universities have argued that it is illogical that collaborating with many institutions in a single country—such as the United

TABLE 4. IRN score statistics by university size (Ranking year 2023, 2024, and 2025).

Ranking Year	Size	Count	min	Lower Whisker	25%	50%	75%	Upper Whisker	max
2023	S	83	1	1	6.8	18.3	34.7	73.0	73.0
	M	338	1	1	11.3	26.3	50.2	96.1	96.1
	L	663	1	1	26.1	56.6	79.6	100.0	100.0
	XL	338	1	1	42.2	71.9	90.8	100.0	100.0
2024	S	90	1	1	1.0	1.1	2.6	4.9	40.3
	M	349	1	1	1.0	1.5	7.4	17.0	94.3
	L	688	1	1	1.6	12.2	45.2	100.0	100.0
	XL	347	1	1	4.4	27.1	75.9	100.0	100.0
2025	S	88	1	1	9.2	18.5	35.5	74.8	78.8
	M	372	1	1	12.4	28.7	50.2	96.0	96.0
	L	691	1.2	1.2	29.4	59.1	78.9	100.0	100.0
	XL	352	3.7	3.7	47.0	70.4	90.6	99.9	99.9

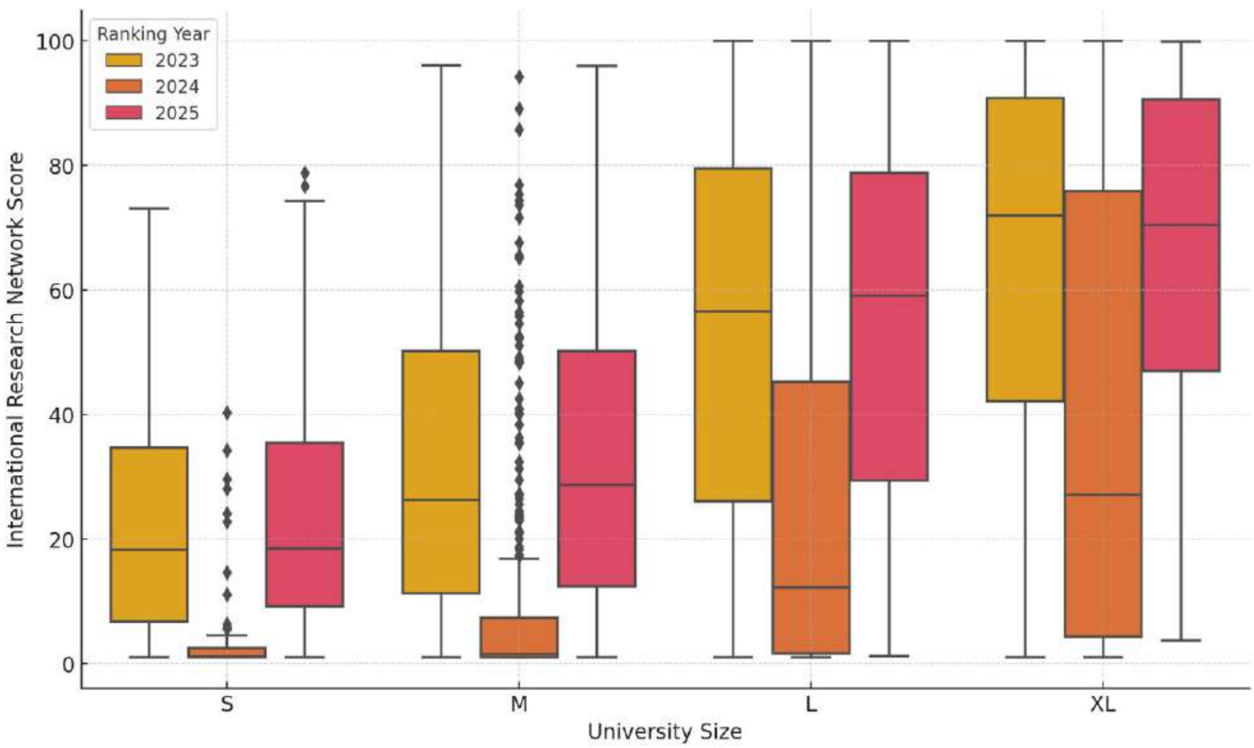

FIGURE 3. IRN score distribution by university size for QS WUR 2023, 2024 and 2025.

States—is interpreted as not being globally engaged [4], [5]. This has particularly affected Asian institutions that historically maintained strong research ties with leading US universities.

Second, the formula produces unrealistic score inflation for institutions with minimal but geographically dispersed partnerships. For instance, DGIST's score of 18.47 appears disproportionately high given its limited research output (6 papers) and partnerships (2). This suggests that geographical breadth is weighted more heavily than the depth, quality, or impact of collaborations.

Third, the calculation lacks transparency, particularly regarding how the non-scaled IRN index (L/ln(P)) is transformed into the final IRN score. As noted by the University Rankings Forum of Korea (URFK), institutions have requested more detailed explanations of how these indices are calculated but have received insufficient clarification. The dramatic shifts in ranking positions—with some Korean

TABLE 5. IRN Scores of 17 South Korean Universities in the Social Sciences & Management Field [20].

QS metric	IRN Scholarly Output (QS)	Locations (QS)	Partners (QS)	Non-Scaled International Research Network (IRN) Index (QS)	International Research Network (IRN) Index (QS)
Yeungnam University	249	17	85	3.83	25.18
Hanllym University	34	2	11	0.83	3.85
University of Ulsan	36	7	9	3.19	20.61
Chungbuk National University	39	6	11	2.5	15.74
Ajou University	90	11	21	3.56	23.27
UNIST	125	16	32	4.62	30.81
KAIST	380	20	92	4.42	29.43
POSTECH	86	9	24	2.83	18.09
GIST	64	15	21	4.93	33.02
Hankuk University of Foreign Studies	120	9	31	2.6	16.41
Dankook University	44	8	15	2.95	18.96
Soonchunhyang University	12	3	3	2.73	17.37
Sungshin Women's University	14	1	4	0.72	3.05
DGIST	6	2	2	2.89	18.47
Seoul Tech	59	8	14	3.03	19.51
Youngsan University	21	4	4	2.89	18.47
Catholic University of Korea	30	3	7	1.54	8.89

universities dropping 200-300 places—underscore the significant impact of these methodological choices on institutional standings.

4) ANALYSIS RESULTS

The analysis of South Korean universities' IRN scores in the Social Sciences & Management field reveals fundamental inconsistencies in the QS methodology. The findings demonstrate that the current IRN calculation favors universities with single collaborations in multiple regions rather than institutions that cultivate strong, multi-partner research networks in specific locations. This approach disadvantages universities in countries like South Korea that have historically developed intensive research collaborations with institutions in a limited number of locations, particularly the United States.

For more meaningful assessment of international research networks, QS should consider methodological refinements that recognize both the breadth and depth of international collaborations. Given the increasing emphasis on international research cooperation for addressing global sustainability challenges, ranking systems should encourage rather than disincentivize robust research networks, regardless of their geographical distribution. The current methodology not only misrepresents the global engagement of universities but may also subtly shape institutional behavior in ways that do not necessarily advance meaningful international research collaboration.

E. CORRELATION BETWEEN IRN AND QS WUR INDICATORS

This section explores the relationship between International Research Network (IRN) scores and other major QS World University Rankings (WUR) indicators, focusing on the 2024 and 2025 ranking years. The analysis distinguishes between universities located in Europe or English-speaking countries (including the UK, Canada, Australia, New Zealand, and South Africa) and those in non-European and non-English-speaking countries, to examine potential regional disparities in how international research collaboration is reflected in the rankings.

1) OVERVIEW AND METHODOLOGY

Correlation analysis provides valuable insight into the relationships between IRN scores and other key ranking indicators. Building on the Pearson correlation methodology described in Section II, this analysis examines how IRN relates to eight key QS indicators: Academic Reputation (AR), Employer Reputation (ER), Faculty-Student Ratio (FSR), Citations per Faculty (CPF), International Faculty Ratio (IFR), International Student Ratio (ISR), Employment Outcome (EO), and Sustainability. In this context, ''Sustainability'' refers specifically to the QS Sustainability Ranking indicator, which accounts for 5% of the overall QS WUR score and measures an institution's environmental and social impact.

The correlation analysis stratifies universities into two groups: those in Europe or English-speaking countries versus those in non-European and non-English-speaking countries. This regional classification enables examination of potential geographic or linguistic disparities in how international research networks relate to other performance metrics. Previous research has shown that ranking methodologies may inherently favor certain regions due to historical, linguistic, or structural factors, making this comparative approach particularly relevant.

2) HEATMAP ANALYSIS OF IRN CORRELATION STRENGTH

Figure 4 presents a heatmap visualization of Pearson correlation coefficients between the International Research Network (IRN) score and eight core QS World University Rankings indicators, segmented by region (English-speaking or geographically European vs. non-English-speaking and non-European) and ranking year (2024 and 2025). This visualization enables regional and temporal comparisons of how IRN aligns with broader institutional performance metrics.

The analysis reveals stronger and more consistent associations between IRN and QS indicators for English-speaking or geographically European institutions across both ranking years. Among these institutions, Academic Reputation exhibits the highest correlation with IRN: 0.75 in the 2024 ranking year and 0.63 in the 2025 ranking year. In contrast, non-English-speaking and non-European institutions show notably lower correlations for the same indicator: 0.64 and 0.56, respectively. This suggests that international research connectivity is more tightly linked to institutional prestige in Western-centric academic environments.

The Sustainability metric also maintains a strong correlation with IRN, although this relationship slightly weakens over time. The correlation for English-speaking or geographically European institutions decreases from 0.74 in the 2024 ranking year to 0.66 in the 2025 ranking year, while for their counterparts, it drops from 0.71 to 0.60. This pattern suggests a temporal decoupling between sustainability initiatives and international collaboration, particularly among institutions outside the Western research core.

Citations per Faculty, a key proxy for research impact, presents a noteworthy shift. While English-speaking or geographically European universities experience a slight decline in correlation with IRN (from 0.57 to 0.52), non-Western universities show improvement—from 0.39 in the 2024 ranking year to 0.50 in 2025. This indicates a strengthening alignment between research visibility and international networks in emerging academic systems.

Indicators such as Employer Reputation and Employment Outcomes follow a similar regional pattern, with moderate correlations in both years and consistently higher values for English-speaking or geographically European institutions. For instance, Employment Outcomes correlates with IRN at 0.51 and 0.47 for the two ranking years, compared to 0.48 and 0.40 for their non-Western counterparts.

By contrast, International Faculty, International Students, and Faculty Student Ratio display the weakest correlations with IRN, particularly for non-English-speaking and non-European institutions. The International Faculty indicator, in particular, shows a marked disparity: 0.43 and 0.42 for English-speaking or geographically European institutions versus just 0.21 and 0.16 for others. This gap highlights institutional and structural barriers to faculty mobility and global engagement faced by many universities outside established academic hubs.

Importantly, all reported correlations were found to be statistically significant at the $p < 0.01$ level, with most values well below 0.001. Even the weakest observed relationships—such as the Faculty Student Ratio in non-Western universities—exhibited statistically reliable associations, confirming that these patterns are not due to random variation.

In sum, the heatmap underscores that IRN is more tightly integrated with reputation, research impact, and sustainability performance in English-speaking or geographically European institutions. For universities in non-Western contexts, these relationships are weaker and more variable, suggesting that the IRN metric—while globally framed—may inherently favor already well-connected institutions. Nevertheless, the increasing linkage between citation impact and IRN in non-Western regions points to emerging potential for research-driven international visibility beyond the traditional academic core [21].

3) REGIONAL AND TEMPORAL PATTERNS

Two notable trends emerge from the correlation analysis. First, universities located in Europe and other English-speaking countries consistently show stronger correlations between the International Research Network (IRN) indicator and other QS metrics, particularly Academic Reputation and Citations per Faculty. In the 2024 ranking cycle, the correlation differences exceed 0.1 points, indicating a significant gap compared to institutions in non-European and non-English-speaking regions. These disparities point to possible structural or methodological biases within the ranking system that may disadvantage universities outside the Western context in how their international collaborations are assessed.

Second, there is a consistent weakening of correlations between IRN and nearly all other indicators from the 2024 to

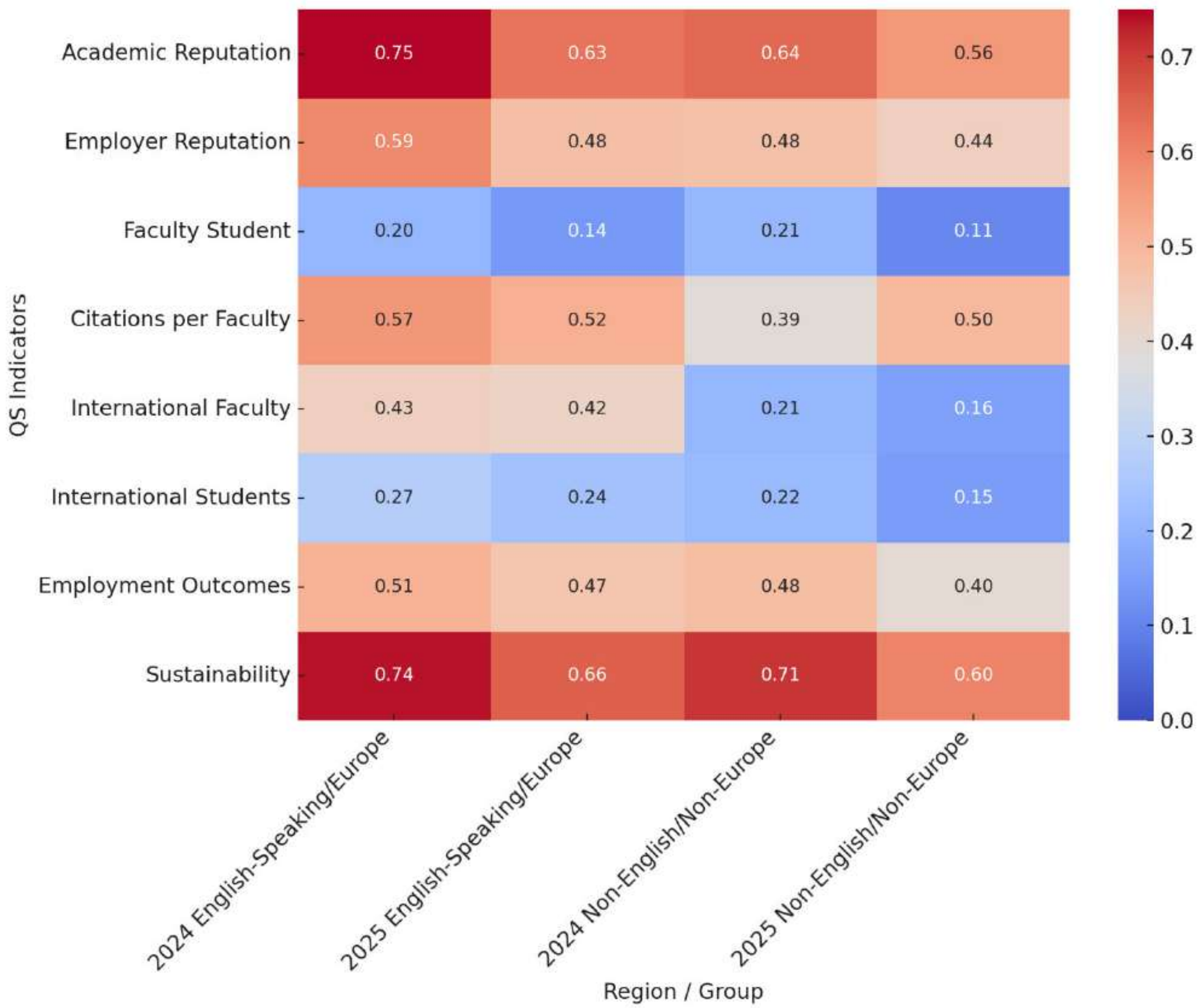

FIGURE 4. **Heatmap of IRN correlation strength (2024 vs 2025, English-speaking & European vs. Non-english & Non-european universities).**

2025 ranking year. This downward trend suggests a shift in how IRN was calculated, reducing its coherence with the rest of the QS framework. Such methodological variability undermines the credibility of IRN as a stable and reliable measure of international research activity, complicating long-term strategic planning for universities seeking to strengthen their global engagement.

These trends raise critical concerns about the underlying IRN methodology. The current formula prioritizes the geographic spread of collaborations over the intensity or number of partnerships, which tends to benefit institutions in regions with a higher density of countries, such as Europe. Furthermore, the use of a logarithmic denominator diminishes the impact of having a large number of partners, as each additional collaborator contributes progressively less to the overall IRN score. This structural design may unintentionally penalize institutions with extensive research networks.

4) ANALYSIS RESULTS

The correlation analysis between IRN and other QS indicators reveals notable regional disparities and methodological inconsistencies. While IRN shows relatively strong correlations with Academic Reputation and Sustainability (particularly for universities in Europe or English-speaking countries), its relationships with other indicators are weaker and less consistent, especially outside Western contexts. The overall decline in correlation coefficients from the 2024 to the 2025 ranking year further highlights methodological instability in the IRN calculation.

These findings suggest that the IRN indicator, as currently constructed, may not fully or equitably capture the depth and quality of international research collaboration across diverse institutional and regional contexts. For IRN to serve as a reliable and fair measure of global research engagement, methodologies must prioritize transparency, consistency, and sensitivity to regional differences. Such refinements would

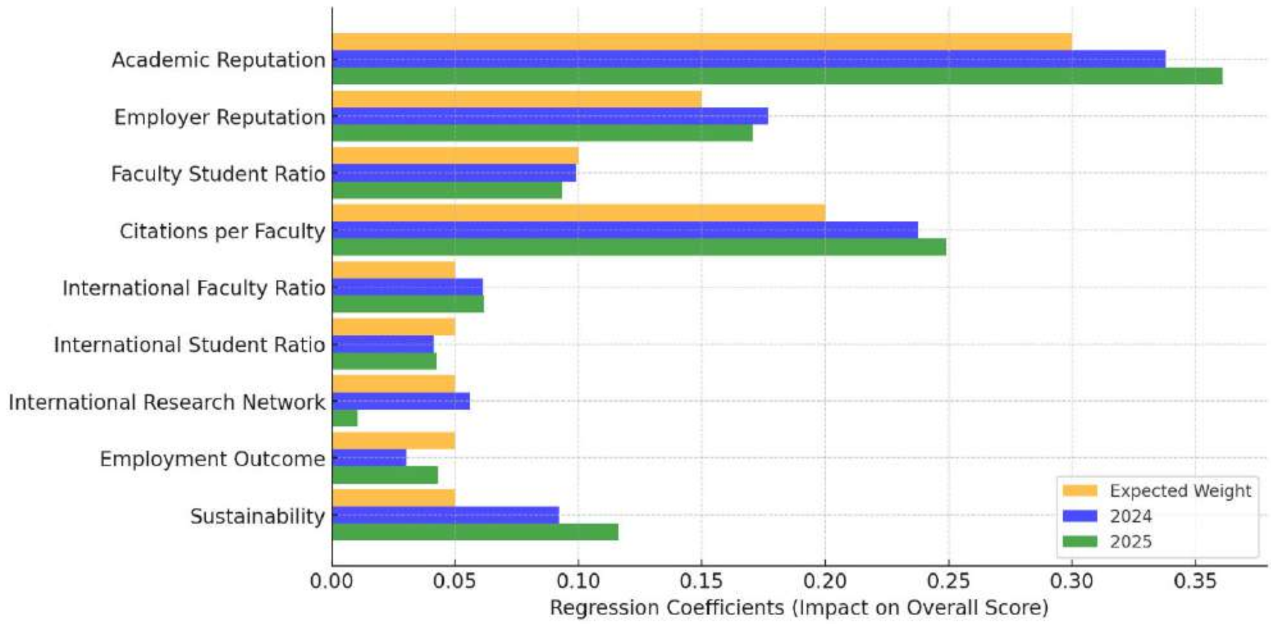

FIGURE 5. Comparison of indicator impact in QS WUR rankings (2024 vs 2025 ranking years).

better support the development of meaningful international collaborations that contribute to both institutional excellence and global sustainability goals.

F. REGRESSION ANALYSIS OF IRN'S PREDICTIVE INFLUENCE

Regression analysis extends beyond correlation by quantifying how independent variables predict changes in a dependent variable. While correlation identifies relationships between variables, regression specifically designates a dependent variable (in this case, the overall QS ranking score) and analyzes how each indicator contributes to predicting that outcome while controlling for other factors. This section employs multiple linear regression to assess the predictive influence of the International Research Network (IRN) indicator relative to other QS World University Rankings (WUR) metrics.

1) RESULTS OF REGRESSION ANALYSIS

The regression analysis evaluates how IRN and other QS indicators predict the overall QS ranking scores for the years 2024 and 2025. Table 6 compares the expected weights of each QS indicator against their actual regression coefficients, revealing insights into their real-world impact on university rankings.

2) INTERPRETATION OF REGRESSION FINDINGS

The regression analysis reveals significant disparities between the expected weights and actual influence of QS indicators. Academic Reputation and Citations per Faculty demonstrate outsized influence on the overall score, with coefficients exceeding their expected weights in both the 2024 and 2025 ranking years. This suggests that reputation and research impact remain the dominant factors in determining university rankings, despite QS's efforts to diversify its metrics.

TABLE 6. Regression coefficients of QS indicators (2024 & 2025).

Train	Expected Weight	2024 Ranking Year Regression Coefficient	2025 Ranking year Regression Coefficient
Academic Reputation	0.30	0.3379	0.3608
Employer Reputation	0.15	0.1767	0.1704
Faculty Student Ratio	0.10	0.0990	0.0935
Citations per Faculty	0.20	0.2376	0.2490
International Faculty	0.05	0.0614	0.0616
International Student	0.05	0.0413	0.0426
International Research Network	0.05	0.0560	0.0105
Employment Outcome	0.05	0.0301	0.0431
Sustainability	0.05	0.0922	0.1162
Sum of Coefficients	1.00	1.1322	1.1477

Employer Reputation maintains a relatively stable impact across both years, with coefficients (0.1767 in the 2024 ranking year, 0.1704 in the 2025 ranking year) closely aligning with its theoretical weight of 0.15. The Faculty-Student Ratio also shows consistent predictive power near its expected value of 0.10, with coefficients of 0.0990 and 0.0935 for the 2024 and 2025 ranking years, respectively.

Most notably, the International Research Network indicator experienced a dramatic reduction in predictive power, with its regression coefficient dropping from 0.0560 in the 2024 ranking year to 0.0105 in the 2025 ranking year—representing a decline of approximately 81%. This substantial decrease indicates that despite its assigned weight of 5%, IRN's actual influence on the overall ranking has become almost negligible in the 2025 ranking year.

This result brings into question how relevant the IRN indicator is as a measure for ranking. A useful ranking metric should not only represent institutional achievement but also help to meaningfully distinguish between universities within the ranking system. Yet, the IRN's low predictive power implies that its inclusion—at least as currently structured—offers little additional value to the overall ranking process. When a metric is assigned formal weighting but does not clarify differences in rankings, it creates ambiguity without providing analytical insight. Therefore, the IRN indicator seems to have limited usefulness as a QS ranking criterion, especially when contrasted with consistently impactful factors like Academic Reputation and Citations per Faculty.

Conversely, the Sustainability indicator shows increased influence, with its coefficient rising from 0.0922 in the 2024 ranking year to 0.1162 in the 2025 ranking year, well above its expected weight of 0.05. This trend reflects QS's growing emphasis on sustainability measures in university assessments, potentially responding to global priorities around environmental and social impact.

The sum of coefficients exceeding 1.0 in both ranking years (1.1322 in 2024 and 1.1477 in the 2025 ranking year) suggests potential multicollinearity or underlying dependencies among the ranking indicators. This over-adjustment indicates possible redundancy in the metrics and raises questions about the transparency and mathematical coherence of the QS methodology.

3) VISUAL ANALYSIS OF REGRESSION COEFFICIENTS

Figure 5 provides a visual comparison of expected weights versus actual regression coefficients for each QS indicator across the 2024 and 2025 ranking years. This visualization highlights the evolving influence of various metrics, with particular emphasis on the diminished predictive power of the IRN indicator.

The statistical significance analysis of the regression model indicates robust reliability, with consistent confidence levels across most coefficients. The model demonstrates strong explanatory power for both ranking years, confirming that the identified patterns represent genuine trends rather than statistical artifacts. The dramatic decline in IRN's coefficient is statistically significant ($p < 0.01$), confirming that this is not merely a random fluctuation but reflects a substantive methodological change.

The increased sum of coefficients from the 2024 to the 2025 ranking year (1.1322 to 1.1477) represents a concerning trend toward over-adjustment in the ranking system. This inflation suggests that the relative importance assigned to indicators may not accurately reflect their actual influence on overall scores, potentially compromising the ranking's interpretability and fairness.

4) ANALYSIS RESULTS

The regression analysis reveals critical inconsistencies in IRN's predictive power within the QS ranking system. Despite its assigned weight of 5%, the IRN indicator's actual regression coefficient decreased dramatically from 0.0560 in the 2024 ranking year to 0.0105 in the 2025 ranking year, rendering its impact on the overall ranking nearly inconsequential. This significant decline (approximately 81%) coincides with the methodological changes and score inflation observed in previous sections, where IRN scores clustered near the upper end of the scale in the 2025 ranking year, substantially reducing their differentiating power.

The negligible regression coefficient for IRN in the 2025 ranking year confirms that the indicator has lost its ability to meaningfully distinguish between universities. When most institutions receive similarly high IRN scores, the metric ceases to function as an effective differentiator and instead becomes redundant within the ranking system. This undermines the indicator's original purpose of measuring international research collaboration and diminishes its value for institutional benchmarking and improvement.

From a methodological perspective, the inflated IRN scores in the 2025 ranking year appear to have created an artificial leveling effect, where variations in international research networks are no longer accurately reflected in the ranking outcomes. This raises concerns about the validity and reliability of the IRN indicator as currently implemented, particularly for universities attempting to use these metrics to inform their internationalization strategies.

For the IRN indicator to regain relevance and credibility, QS should reconsider its current calculation methodology to ensure it meaningfully captures differences in international research collaboration. Potential improvements include refining the normalization procedures across the five faculty areas, reevaluating the emphasis on geographic diversity versus partnership density in the L/ln(P) formula, and ensuring greater methodological consistency between ranking cycles. More transparent documentation of computational methods and normalization techniques would also benefit institutions seeking to understand and improve their performance.

These findings contribute to broader discussions about the sustainability of university ranking methodologies and their impact on institutional behavior. Rankings that frequently change their methodologies or implement metrics with limited differentiating power may inadvertently create perverse incentives, leading universities to focus on artificial improvements rather than meaningful enhancements to international research collaboration. For rankings to support genuine progress in global research engagement, they must provide stable, transparent, and differentiating metrics that accurately reflect institutional performance.

IV. DISCUSSION AND RECOMMENDATIONS

This study reveals substantial methodological and structural concerns with the QS International Research Network (IRN) indicator, particularly regarding its limited differentiation, bias toward large and English-speaking/European universities, and pronounced score fluctuations across ranking cycles. The following discussion interprets these findings, examines their implications for higher education institutions, and offers recommendations for both universities and QS to improve the fairness, transparency, and effectiveness of the IRN metric.

A. INTERPRETATION OF KEY FINDINGS AND INSTITUTIONAL IMPLICATIONS

The analysis demonstrates that the IRN indicator structurally benefits larger universities, especially those located in Europe or English-speaking countries such as the UK, Canada, Australia, New Zealand, and South Africa. This advantage is evident in both the scatter plots and the heatmap of correlation strengths, where Academic Reputation and Sustainability scores show the highest alignment with IRN scores in these regions (Figure 4). The IRN calculation, which averages scores across five broad faculty areas, inherently disadvantages institutions lacking comprehensive faculty coverage, regardless of the quality or depth of their international research collaborations.

Moreover, the bibliometric foundation of the QS rankings relies on Scopus-indexed publications. While Scopus is a global database covering multiple languages, English remains overwhelmingly dominant, accounting for over 92% of indexed documents. Scopus's policy of requiring English-language titles, abstracts, and keywords further amplifies this effect, structurally favoring institutions whose research outputs are published in English. As a result, universities in English-speaking and European regions are more likely to have their research recognized and cited, reinforcing their advantage in global rankings and contributing to the observed regional disparities in IRN correlations and overall ranking performance [22], [23].

The observed inflation of IRN scores in the 2025 ranking year has further diminished the metric's ability to differentiate between institutions. With most universities receiving similarly high IRN scores, the indicator loses its value as a meaningful measure of international research engagement. This compression of scores complicates efforts by universities to benchmark their performance and develop targeted strategies for internationalization.

B. CONSTRAINTS AND LIMITATIONS OF THE IRN INDICATOR

Several critical limitations of the IRN indicator undermine its effectiveness as a measure of international research collaboration. First, the metric structurally favors institutions with broad faculty coverage and established international networks across multiple locations, making it difficult for smaller universities and those outside Europe or English-speaking regions to compete on equal footing [24]. Second, the 2025 ranking cycle saw widespread IRN score inflation, resulting in minimal variation and reduced differentiation among universities. This undermines the utility of the indicator for institutional benchmarking and strategic planning.

Third, the drastic drop in IRN scores in the 2024 ranking year, followed by a pronounced rebound in the 2025 ranking year, highlights significant inconsistencies in QS's calculation methods. Such volatility undermines the credibility of the ranking system and complicates long-term planning for universities seeking to enhance their global research engagement. Finally, limited transparency in IRN calculation methods—particularly regarding weighting mechanisms and normalization processes—raises concerns about the evidence base for methodological adjustments and the potential for arbitrary changes [25], [26].

This study not only highlights structural and regional differences in IRN scoring but also closely examines how practically useful the IRN indicator is as part of the QS World University Rankings. An essential purpose of any ranking measure is to meaningfully distinguish institutions by their quality, performance, and strategic priorities. Yet, the regression analysis from this research demonstrates that the IRN indicator adds very little to the variation in overall QS scores, especially in the 2025 rankings, where its regression coefficient fell to just 0.0105. This steep decrease indicates that, despite its official 5% weighting, the IRN metric has an almost negligible effect on where institutions are ranked. When a metric does not help differentiate ranks and instead introduces instability and structural bias, its presence can erode the credibility and interpretability of the entire ranking system. These results highlight significant issues regarding the IRN indicator's validity and practical value within the QS ranking approach.

Although the data show that the IRN indicator has little effect on final QS scores, it is worth recognizing its intended purpose. QS introduced IRN in response to increasing awareness of the value of globally distributed and inclusive research partnerships. By rewarding geographic diversity in co-authored publications, IRN aims to motivate universities to broaden their international collaborations beyond conventional, often regional, networks. This goal mirrors wider trends in global university ranking systems, such as the Times Higher Education (THE) World University Rankings, which uses an "international co-authorship" measure to encourage cross-border academic cooperation. In theory, such indicators play an important role by promoting research that is internationally recognized and interconnected. However, the present findings indicate that, despite its positive intentions, the current form of IRN does not effectively serve this function, due to structural biases, methodological inconsistency, and minimal statistical impact on rankings. Resolving these shortcomings is essential if IRN is to provide meaningful distinctions and guide institutional strategies on a global scale.

C. STRATEGIC RECOMMENDATIONS FOR UNIVERSITIES

Universities aiming to enhance their performance under the current QS IRN model should focus on broadening the scope of their international research collaborations by engaging with partners from a wide range of geographic regions, rather than limiting partnerships to a few countries. Expanding networks to include institutions in underrepresented or emerging areas such as Southeast Asia, Latin America, and Africa can significantly boost IRN scores without necessitating major institutional changes.

Ensuring that all five faculty areas are involved in international research is also essential. When internal resources are limited, fostering interdisciplinary and cross-faculty collaborations can help bridge gaps in global engagement among different academic disciplines.

Adopting cost-effective strategies, such as co-hosting international conferences, participating in virtual joint research projects, and producing collaborative publications with authors from diverse regions, can effectively demonstrate international connectedness and positively impact IRN performance.

It is also important for universities to stay informed about annual changes in QS methodology and to actively participate in QS feedback and consultation processes. By voicing concerns and contributing to advisory discussions, institutions can help shape future updates to the IRN metric, promoting greater transparency and fairness in global university rankings.

D. RECOMMENDATIONS FOR QS TO IMPROVE THE IRN INDICATOR

To improve the fairness and precision of the IRN metric, QS should revise its methodology to address inherent structural biases. A significant concern is the logarithmic penalty for repeated collaborations within the same country (L/ln(P)), which can unduly disadvantage institutions that work with many high-caliber partners in countries with dense academic networks, such as the United States or Mainland China. Introducing a cap on this penalty—for example, limiting diminishing returns after five or ten partners per country—could mitigate this issue.

QS might also adopt a density-weighted normalization that accounts for the number of QS-ranked universities in each country, acknowledging the varying scales of national academic ecosystems. Employing a hybrid scoring approach that integrates geographic diversity, institutional depth, and disciplinary coverage across the five faculty areas would more accurately capture the multifaceted nature of international collaboration.

Furthermore, QS could add a regional diversity modifier, granting extra points to universities that build partnerships across different global regions, including Sub-Saharan Africa, Southeast Asia, or Latin America. Incorporating longitudinal weighting to reward long-term partnerships—even within a single country—would shift the focus from the sheer number of locations to the quality and durability of collaborations.

Adjusting the IRN metric in these ways would prevent excessive score inflation, as seen in the 2025 cycle, restore meaningful distinctions among universities, and make the indicator more equitable for institutions in the Global South. Ensuring transparency in the weighting, normalization, and scoring processes is crucial for maintaining credibility, predictability, and enabling universities to plan strategically.

E. DIRECTIONS FOR FUTURE RESEARCH

Future research should explore alternative metrics for assessing international research networks that do not inherently favor large or English-speaking/European universities. Longitudinal analyses of IRN trends across multiple ranking cycles could provide deeper insights into the stability and reliability of the indicator, while qualitative case studies of institutions that have successfully improved their IRN scores despite structural disadvantages may offer practical strategies for others. Comparative studies with other global ranking systems could further inform the refinement of the IRN metric, promoting greater fairness and inclusivity in the assessment of international research engagement.

By implementing these recommendations, QS can enhance the credibility and utility of the IRN metric, ensuring that it more accurately reflects the diversity of international research collaboration. At the same time, universities can take a proactive approach to optimizing their international engagement, aligning their strategies with both ranking methodologies and broader goals of academic impact and global knowledge exchange.

V. CONCLUSION

This systemic analysis of the QS International Research Network (IRN) indicator, conducted using big data methodologies, reveals substantial methodological limitations that have direct implications for the fairness and effectiveness of global university rankings. The study demonstrates that the IRN framework-by prioritizing the geographic dispersion of international partnerships over the number or depth of collaborations-structurally favors large, English-speaking, or European universities. This design introduces regional inequalities, as institutions with robust but regionally concentrated research networks, particularly in Asia, the Middle East, and Latin America, are systematically disadvantaged. The pronounced volatility observed across ranking cycles, including the sharp decline in IRN scores in the 2024 ranking year and widespread inflation in the 2025 ranking year, further exposes inconsistencies in the QS scoring methodology and undermines the reliability of the IRN as a robust metric for international research collaboration.

These findings underscore the need for universities to adopt adaptive strategies that account for the unpredictability inherent in the current IRN scoring system, while also highlighting the urgency for ranking organizations to implement more transparent, equitable, and methodologically sound metrics. For the QS ranking system to maintain its credibility and utility, recalibrating the IRN indicator is essential to ensure balanced score distribution, meaningful differentiation among institutions, and the reduction of biases related to institutional size, language, or region. Enhanced transparency in the weighting, normalization, and calculation of IRN scores is critical for restoring stakeholder confidence and providing actionable insights for institutional improvement. To adapt to the current IRN methodology, universities must strategically diversify international collaborations and proactively engage with ranking bodies to help shape fairer and more inclusive evaluation frameworks.

Future research should build on this big data-driven, systemic approach by developing alternative and more inclusive metrics for assessing international research collaboration, conducting longitudinal analyses of IRN trends, and systematically comparing the QS methodology with other global ranking frameworks [27], [28]. By addressing these methodological challenges, both ranking organizations and universities can contribute to a more accurate and equitable evaluation of global research engagement, ultimately supporting the advancement of meaningful and sustainable international academic collaboration.

APPENDIX
COUNTRY CLASSIFICATION FOR REGIONAL GROUPING

This appendix provides the classification of countries used in the regional grouping of universities in this study. Countries are grouped into the following categories:

•**English-speaking countries**: Countries where English is a primary or official medium of instruction in higher education.

•**Countries in Europe**: Countries geographically located in Europe, including both EU and non-EU members.

•All other countries are classified as non-English-speaking and non-European.

This classification was applied consistently to institutions listed in the QS World University Rankings (WUR) for both 2024 and 2025.

A. QS WUR 2024 CLASSIFICATION

English-speaking or countries in Europe (42 countries, 790 universities)

English-speaking countries:

Australia (38), Canada (31), Ireland (8), New Zealand (8), South Africa (11), United Kingdom (90), United States (199)

Countries in Europe:

Austria (8), Belarus (3), Belgium (9), Bosnia and Herzegovina (1), Bulgaria (1), Croatia (4), Cyprus (1), Czech Republic (16), Denmark (5), Estonia (3), Finland (9), France (35), Georgia (2), Germany (49), Greece (8), Hungary (11), Iceland (1), Italy (42), Latvia (3), Lithuania (5), Luxembourg (1), Malta (1), Netherlands (13), Norway (6), Poland (22), Portugal (8), Romania (13), Russia (48), Serbia (5), Slovakia (5), Slovenia (3), Spain (35), Sweden (8), Switzerland (11), Ukraine (11)

Non-English-speaking and non-European countries (62 countries, 707 universities):

Argentina (25), Armenia (1), Azerbaijan (3), Bahrain (3), Bangladesh (15), Bolivia (3), Brazil (35), Brunei (2), Chile (25), China (Mainland) (71), Colombia (25), Costa Rica (3), Cuba (4), Dominican Republic (2), Ecuador (11), Egypt (15), Ethiopia (1), Ghana (2), Guatemala (1), Honduras (1), Hong Kong SAR (7), India (45), Indonesia (26), Iran, Islamic Republic of (7), Iraq (5), Israel (6), Japan (50), Jordan (9), Kazakhstan (21), Kenya (2), Kuwait (3), Kyrgyzstan (1), Lebanon (8), Macau SAR (2), Malaysia (28), Mexico (32), Morocco (1), Nigeria (2), Oman (1), Pakistan (14), Palestinian Territory, Occupied (3), Panama (2), Paraguay (1), Peru (10), Philippines (5), Puerto Rico (1), Qatar (2), Saudi Arabia (16), Singapore (4), South Korea (43), Sri Lanka (2), Sudan (2), Syrian Arab Republic (1), Taiwan (27), Thailand (13), Tunisia (4), Turkey (25), Uganda (1), United Arab Emirates (11), Uruguay (4), Venezuela (7), Vietnam (5)

B. QS WUR 2025 CLASSIFICATION

English-speaking or countries in Europe (43 countries, 785 universities)

English-speaking countries:

Australia (38), Canada (30), Ireland (8), New Zealand (8), South Africa (11), United Kingdom (90), United States (197)

Countries in Europe:

Austria (8), Belarus (3), Belgium (9), Bosnia and Herzegovina (1), Bulgaria (1), Croatia (4), Cyprus (1), Czech Republic (16), Denmark (5), Estonia (3), Finland (9), France (35), Georgia (2), Germany (48), Greece (7), Hungary (11), Iceland (1), Italy (42), Latvia (3), Lithuania (5), Luxembourg (1), Malta (1), Netherlands (13), Northern Cyprus (1), Norway (6), Poland (22), Portugal (8), Romania (13), Russia (47), Serbia (4), Slovakia (6), Slovenia (3), Spain (35), Sweden (8), Switzerland (10), Ukraine (11)

Non-English-speaking and non-European countries (63 countries, 718 universities):

Argentina (25), Armenia (1), Azerbaijan (3), Bahrain (3), Bangladesh (15), Bolivia (2), Brazil (35), Brunei (2), Chile (25), China (Mainland) (71), Colombia (24), Costa Rica (4), Cuba (4), Dominican Republic (2), Ecuador (11), Egypt (15), Ethiopia (1), Ghana (2), Guatemala (1), Honduras (1), Hong Kong SAR (7), India (46), Indonesia (26), Iran, Islamic Republic of (9), Iraq (5), Israel (6), Japan (49), Jordan (10), Kazakhstan (21), Kenya (2), Kuwait (3), Kyrgyzstan (3), Lebanon (6), Macau SAR (2), Malaysia (28), Mexico (32), Morocco (1), Nigeria (2), Oman (2), Pakistan (14), Palestinian Territory, Occupied (3), Panama (2), Paraguay (1), Peru (10), Philippines (5), Puerto Rico (1), Qatar (2), Saudi Arabia (20), Singapore (4), South Korea (43), Sri Lanka (3), Sudan (1), Syrian Arab Republic (1), Taiwan (27), Thailand (13), Tunisia (4), Turkey (25), Uganda (1), United Arab Emirates (12), Uruguay (4), Uzbekistan (2), Venezuela (7), Vietnam (6)

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BRIEF REPORT

Accessibility evaluation of top 25 QS-ranked world universities and top 25 QS-ranked Indian universities using WCAG 2.2: a comparative study

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Abstract
University websites offer a wide range of information presented in multiple formats, necessitating compatibility and accessibility for every user. This paper evaluates the accessibility of the top 25 world and the top 25 QS-ranked Indian universities using WCAG 2.2. This research uses SortSite, an automatic web accessibility and user-friendly web testing tool to efficiently checks websites for accessibility, usability, browser compatibility, and search engine optimization (SEO) issues was used to assess for accessibility. Among the Indian universities, '.ac.in' is the most used TLD, while among world universities, '.edu' is the most used TLD. Indian universities have the greatest number of violations at each conformance level (A, AA, and AAA) compared with world universities. The content on these websites is not very presentable, understandable, interactive and user-friendly, as the largest number of violations among all principles were found at conformance level A, followed by AAA and AA. Indian universities have the most common failures at conformance levels A and AAA while world universities have the most common failures at conformance level AA, caused by erroneous implementations of success criteria, more specifically related to CSS and HTML. Indian institutions have more compatibility issues than world universities. Compared to iOS, Safari, Android, Chrome, and Opera, the web browser Firefox was determined to be the most incompatible, while Edge was shown to be the most compatible.

Keywords Accessibility · Disability · Usability · W3C · WCAG 2.2 · World universities · Indian universities

1 Introduction

Since the Internet's launch, web developers have prioritized making web content accessible to all users, regardless of impairments or lack thereof. The World Wide Web is a rapidly expanding collection of websites providing access to knowledge and culture, catering to a diverse user population across all ages, educational levels, and computing experiences. A website is a collection of interlinked web pages with the same domain name, accessible over the Internet, and managed by individuals, groups, businesses, or organizations [1]. The developer designs a website's pages, which can range from one to hundreds, and incorporates a variety of information like text, photos, videos, audio, animation, graphics, and color. Websites provide diverse items in various formats, requiring compatibility and accessibility for all users through web browsers like Google Chrome, Firefox, Microsoft Edge, and Opera [2]. Therefore, developers aim to improve websites by adhering to the web content accessibility guidelines (WCAG), encompassing page accessibility, interoperability, compatibility, and other factors [3, 4], so that people can perceive, understand, navigate, and interact with the Web and contribute to the Web [5]. A good website aims to make websites accessible to all users, regardless of impairment, including auditory, cognitive, neurological, physical, speech and visual [5] and "making the web content available to all individuals, regardless of any disabilities or environmental constraints they experience" [6]. Assistive technologies, including screen reading software, alternative keyboards, and pointing devices, significantly enhance the accessibility of web content for disabled users [7]. Thus,

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web developers must consider language, impairments, and advanced age when developing software to ensure equal access to content and functionality through appropriate planning, development, and modification of websites.

The World Wide Web Consortium (W3C) prepared guidelines and principles to overcome the issue of inaccessibility of webpages among users with impairments or without impairments, which is known as web content accessibility guidelines (WCAG). The W3C, an international organization, aims to standardize websites and create a global standard for web content accessibility. In 1997, the web accessibility initiative (WAI) was established to enhance web accessibility, resulting in the development of WCAG. WCAG is a tool for web content creators, editors, and developers to ensure the accessibility of websites for all users, including those with or without impairments [8]. Subsequently, W3C first published WCAG 1.0 on May 5, 1999; it was a collection of 14 guidelines along with 65 checkpoints for web accessibility [9]. WCAG 2.0 was released on December 11, 2008, where all the guidelines of WCAG 1.0 were replaced with 4 principles, which were further divided into 12 guidelines and 61 success criteria [10]. Further, WCAG 2.1 was released on June 5, 2018, with 13 guidelines and 78 success criteria by adding 1 guideline and 17 success criteria [11]. The latest version, WCAG 2.2 was published on October 5, 2023, with the addition of 9 success criteria from WCAG 2.1 [12].

2 Related literature

Many websites remain inaccessible to persons with disabilities, despite the availability of tools and guidelines for accessibility [13]. Web users with sensory, motor, and cognitive disabilities use assistive technology like screen readers, voice recognition, and braille displays to navigate websites, enabling them to navigate effectively [14]. To overcome this, the World Wide Web Consortium (W3C) has published WCAG 2.0 to ensure web content accessibility for all, including persons with disabilities, by meeting success criteria [4]. The W3C web content accessibility guidelines (WCAGs) are a globally recognized set of accessibility standards, providing four principles for web accessibility [3]:

1. Perceivable: Information and user interface components must be presentable to users in ways they perceive;
2. Operable: User interface components and navigation must be operable;
3. Understandable: Information and the operation of the user interface must be understandable;
4. Robust: Content must be robust enough that it can be interpreted reliably by various user agents, including assistive technologies.

The principles of web accessibility include guidelines for content, controls, and interactions. For instance, guideline "1.1: Text Alternatives" outlines the need for alternative text for non-text elements like images. Alternative text can convert images into accessible content for users with disabilities, including speech, large print, and braille [11]. Thus, website accessibility is evaluated using success criteria for guidelines, which are used in regulations, design specifications, and agreements. Conformance levels are A, AA, and AAA, with AAA being the highest. W3C assigns each guideline to one of three conformance levels [11], indicating the impact failure of the criterion will have on people with disabilities:

- Level A - If the success criteria for this guideline are not met, one or more groups may find it difficult to access the presented information;
- Level AA - If the success criteria for this guideline are not met, one or more groups may struggle to access the presented information;
- Level AAA - If the success criteria for this guideline are not met, one or more groups may find it challenging to access the presented information.

Universities need websites to inform about their activities, courses, admissions, faculty profiles, achievements, and learning resources. To ensure accessibility and interoperability, developers must adhere to WCAG and develop holistic approaches for all users. A thorough WCAG evaluation of university websites ensures equal accessibility to learning resources for all users. Alayed's [15] study examined accessibility barriers for visibility-impaired Arabic speakers using banking applications from AlRajhi, Saudi National Bank, and Riyad Bank. The study reported that all applications did not meet WCAG 2.1 accessibility standards, with AlRajhi's application being the best and identified that the current accessibility situation in Saudi Arabia is not satisfactory, with the most violated principle being operable. Similarly, Akram et al. [16] assessed the accessibility features of 33 Saudi universities using the automated tools AChecker and TAW, identifying 11% known problems and 89% likely and potential issues. Khawaja [17] evaluated the accessibility of public library websites in the United States to disabled users using Deque's Axe evaluation tool to evaluate the website URLs of 120 public libraries on four different types of pages to test the websites for WCAG 2.1 compliance. The study websites failed to meet Sect. 508 of the Rehabilitation Act's accessibility standards, with common color contrast errors. Likewise, Kaundinya et al. [18] analyzed dermatology home page websites from 150 US hospitals using SortSite 6.42.924.0 and WAVE. They found an average of 6 failures to meet WCAG 2.1's baseline A criterion, with 5.7, 1.5, and 2.5 issues respectively. A study on web accessibility analysis of 54 official COVID-19 vaccination registration websites in the US found that AChecker, WAVE, and SortSite tools identified insufficient compliance with WCAG 2.0 and 2.1 criteria [19].

Alajarmeh's [20] study reveals significant accessibility barriers in public health websites across 25 countries, particularly in information perception and interface operability, highlighting the ongoing COVID-19 epidemic and the need for improved accessibility to health information. Teixeira et al. [21] used access monitor and TWA, automatic evaluation tools to assess the accessibility of 182 travel agent websites in the Central Region of Portugal using WCAG 2.0. The study showed that the web accessibility of the travel agents was low and several problems and warnings were identified with WCAG principles of perceivable and robust emerging as the most critical. A study analyzed 39 government and private websites for elderly and interested users, focusing on accessibility barriers and reported that the most critical failure was non-text content and text alternatives [22], making it difficult for older users [23]. Dangol [24] assessed the accessibility of 25 Nepal's federal e-government websites using WCAG 2.1 and government website development directive 2021 and found that only 4% met satisfactory standards with levels of 'A' and 'AAA'.

A study evaluated the accessibility of 15 Delhi-National Capital Region libraries using WCAG 2.1 guidelines and the automated tool WAVE, revealing that 13 out of 15 websites had errors [25]. Paul [26] evaluated the accessibility of Indian e-government websites according to the WCAG 2.1 standard using the automated web accessibility testing tool, SortSite. The researcher takes a sample of 65 websites from various ministries. The study found that across all 65 websites, none of the websites had accessibility errors based on conformance Level AAA. In contrast, Conformance Level AA has a 1.74 accessibility checkpoint error and 8.34 for conformance Level A. Whereas, a study on status of web accessibility and WCAG conformance Level (A, AA, AAA) of Indian Institutes of Technology (IIT) library websites. The investigation was performed using the Siteimprove web tool. The study found that IIT Bombay has the maximum accessibility-related limitations, at conformance level A, while IIT Dhanbad, at conformance level AA, and IIT Gandhinagar and IIT Varanasi, at conformance Level AAA have the maximum accessibility-related limitations among the three conformance levels of WCAG 2.1 [27]. Likewise, a study analyzed 302 Indian university homepages using the University Grants Commission website. The university websites were analyzed under different conformance levels of the WCAG 2.0 recommendations. They used automated evaluation tools like AChecker, webpage Analyzer, and WAVE to find accessibility reports. The findings suggest measures for improving website accessibility [28]. Based on the reviewed literature this study intends to examine web accessibility evaluation of the top 25 Quacquarelli Symonds (QS) ranked (2023) world universities and the top 25 Quacquarelli Symonds (QS) ranked (2023) Indian universities. The study is guided by the following objectives:

1. To analyze the domain name of the university website;
2. To quantify and compare violations at three conformance levels of WCAG 2.2;
3. To find out the violation of WCAG 2.2 success criteria at 4 principles;
4. To quantify the common failure under WCAG 2.2 techniques;
5. To evaluate the website's compatibility with various internet browsers.

3 Research methodology

The study evaluated the website accessibility of the top 25 QS-ranked world universities (Appendix 1) and top 25 QS-ranked Indian universities (Appendix 2) using WCAG 2.2, verifying valid web addresses from Quacquarelli Symonds website (https://www.topuniversities.com/). QS Ranking, a globally recognized ranking system, has produced subject and course rankings since 2004 with over 650 global partners and 1500 institutions from 104 locations. The QS World University Ranking employs six indicators to evaluate four key areas, each with varying weights:

1. Academic reputation −40%;
2. Employer reputation −10%;
3. Faculty/student ratio −20%;
4. Citations per faculty −20%;
5. International student ratio −5%;
6. International staff ratio −5%.

The top 25 QS-ranked world universities were sourced from the list, while the top 25 QS-ranked Indian universities were obtained by filtering the list by country name. The list of ranked universities was gathered by individually searching their official websites from March 11th to March 25th, 2024.

3.1 Evaluation tool

SortSite, an automatic web accessibility and user-friendly web testing tool that efficiently checks websites for accessibility, usability, browser compatibility, and search engine optimization (SEO) issues was used to assess for accessibility of the top 25 QS-ranked world universities and top 25 QS ranked Indian universities websites. SortSite was chosen for its ability to assess and report accessibility violations in websites, aligning with WCAG 2.2 guidelines [29]. The data was collected between March 11th and March 25th, 2024.

4 Results

4.1 Domain analysis

Generic top-level domain (gTLD) is the most popular category among TLDs. The TLDs in this category are available for registration. There were seven gTLDs, including.com,.edu,.gov,.int,.mil,.net, and.org. The uses of 3 gTLDs i.e.,.gov,.net, or.org, have no restriction on who will use them, and anyone can register their domain name with these. The remaining 4 gTLDs i.e.,.com,.edu,.int, and.mil, are used strictly by the government. The Internet corporation authorized Some more gTLDs for assigned names and numbers (ICANN), such as. areo,.biz,.coop,.info,.museum,.name, and.pro. Country code top-level domains are the other most popular types of TLDs. It represents the countries, and each country code top-level domain is associated with a specific country. Generally, country code top-level domains (ccTLDs) are represented by two characters/letters, after the dot. with subdomains, country codes are also used, for example,.co.in which denotes a commercial entity in India.

Among the top 25 QS-ranked world universities' TLDs, 17 use '.edu' gTLDs, 8 do not use gTLDs, 5 use ccTLDs along with '.edu' gTLD., and 8 don't use ccTLDs (Appendix 3). It illustrates that 5 global universities use '.ac' TLD for academic institutions, along with '.uk' ccTLD, but '.ac' is not listed as a gTLD by ICANN. The finding recorded that 5 of the world universities are using the '.ac' TLD for academic institutions, along with the '.uk' ccTLD, but '.ac' is not listed as gTLD by the ICANN. Among the top 25 QS-ranked Indian universities, 22 use '.in' ccTLD, 4 use gTLDs where 3 use '.edu', and 1 use '.com'. JU is the only Indian university using gTLD and ccTLD, '.edu.in', while CU uses '.in' ccTLD. 20 Indian universities use '.ac' TLD for academic institutions (Appendix 4).

Table 1 Top level domains

	TLDs (Top Level Domains)	Number of Universities	Percentage
1	.ac.in	20	40
2	.edu	13	26
3	.ac.uk	5	10
4	.edu.au	3	6
5	.edu.cn	2	4
6	.ch	1	2
7	.edu.sg	1	2
8	.ca	1	2
9	.eu	1	2
10	.edu.in	1	2
11	.in	1	2
12	.com	1	2

Twelve different TLDs were used by 50 universities with 'ac.in' TLD used by 20 (40%) of both the top 25 world and Indian universities. The second most used TLD is '.edu' which is used by 13 (26%) universities followed by '.ac.uk' TLD used by 5 (10%) universities from the United Kingdom. The finding also recorded '.ch', '.edu.sg', '.ca', '.eu', '.edu.in', '.in', and '.com' TLDs which are used only by one university each (Table 1).

4.2 Violations in conformance level by top 25 QS-ranked world universities and top 25 QS-ranked Indian universities in 2023

4.2.1 Comparison of world and Indian universities at conformance level A

Table 2 shows the rank and comparison of world and Indian universities at conformance level A. The university that

Table 2 Comparison of conformance level A between world and Indian universities

Rank	World Universities	Conformance Level A		Indian Universities	Rank
1	UMELB	1	7	IITR	1
2	UCB	3	11	UC	2
3	HAVARD	4	14	IITD	3
4	SU	5	14	IITM	3
4	UCHI	5	14	IITH	3
4	UE	5	15	IISc	4
5	YALE	6	15	UH	4
6	MIT	7	16	JNU	5
6	COLUMBIA	7	17	JU	6
7	UPENN	8	18	IITI	7
8	PU	9	18	SPPU	7
9	UOX	11	19	UM	8
9	ICL	11	19	NITT	8
9	UNSW	11	21	IIT-KGP	9
9	TU	11	21	MADRAS	9
10	UCAM	12	21	SUBMS	9
10	ETH	12	22	DU	10
11	UT	13	22	IIT-BHU	10
12	PKU	14	23	CU	11
13	CALTECH	16	24	IITBH	12
14	UCL	17	27	IITB	13
14	PSL	17	27	VIT	13
15	CORNELL	18	30	AU	14
16	USYD	19	31	IITK	15
17	NUS	22	32	IITG	16
	Total	**264**	**498**		

Table 3 Comparison of conformance level AA between world and Indian universities

Rank	World Universities	Conformance Level AA		Indian Universities	Rank
1	SU	1	1	IITM	1
1	PU	1	1	IITR	1
1	UE	1	2	IISc	2
2	HAVARD	2	2	IITI	2
2	UCB	2	3	IIT-BHU	3
2	YALE	2	3	IITH	3
2	UNSW	2	3	NITT	3
3	MIT	3	3	UH	3
3	UCAM	3	4	IITD	4
3	UCL	3	4	IIT-KGP	4
3	UMELB	3	4	DU	4
3	CALTECH	3	4	MADRAS	4
3	USYD	3	4	JNU	4
3	UT	3	4	SPPU	4
3	COLUMBIA	3	4	UM	4
4	UOX	4	4	UC	4
4	UCHI	4	5	IITB	5
4	UPENN	4	5	IITBH	5
4	PSL	4	5	JU	5
5	ETH	5	5	SUBMS	5
5	CORNELL	5	5	VIT	5
5	TU	5	6	AU	6
6	ICL	6	6	CU	6
6	NUS	6	7	IITG	7
6	PKU	6	9	IITK	8
	Total	**84**	**103**		

Table 4 Comparison of conformance level AAA between world and Indian universities

Rank	World Universities	Conformance Level AAA		Indian Universities	Rank
1	UMELB	1	2	UC	1
2	CALTECH	2	3	IITR	2
2	UE	2	5	IIT-BHU	3
3	MIT	3	5	JNU	3
3	UCB	3	5	IITH	3
3	UCHI	3	6	IITD	4
3	COLUMBIA	3	6	IITM	4
4	UOX	4	6	IITG	4
4	ETH	4	6	SPPU	4
4	CORNELL	4	6	JU	4
4	UT	4	7	IITB	5
5	UCAM	5	7	IISc	5
5	HAVARD	5	7	IIT-KGP	5
5	SU	5	7	DU	5
5	UCL	5	7	AU	5
5	USYD	5	7	IITI	5
5	TU	5	7	MADRAS	5
6	ICL	6	7	IITBH	5
6	NUS	6	7	UM	5
6	UPENN	6	7	CU	5
6	YALE	6	7	SUBMS	5
6	PU	6	7	NITT	5
6	UNSW	6	7	UH	5
6	PSL	6	7	VIT	5
7	PKU	7	8	IITK	6
	Total	**112**	**156**		

violated the least guidelines in both world and Indian universities was listed at the top and ranked first. Indian universities violated 498 guidelines at conformance level A, whereas world universities violated 264, i.e., 46.98% less than Indian universities. UMELB violated only 1 of the guidelines and ranked as 1. Considering Indian universities, IITR violated only 7 guidelines and thus ranked first.

4.2.2 Comparison of world and Indian universities at conformance level AA

Table 3 shows the rank and comparison of world and Indian universities at conformance level AA. The university that violated the least guidelines in both world and Indian universities was listed at the top and ranked 1. Indian universities violated 103 guidelines, whereas world universities violated 84 at conformance level AA, i.e., 18.44% less than Indian universities. IITM and IITR ranked as the top-ranked Indian universities as they violated only 1 guideline. In contrast, SU, PU, and UE violated only 1 guideline and achieved rank 1.

4.2.3 Comparison of world and Indian universities at conformance level AAA

Table 4 shows the rank and comparison of world and Indian universities at conformance level AAA. The university violated the least guidelines in both world and Indian universities, which are listed at the top and ranked as 1. The total guideline violations made by Indian universities are 156 at conformance level AAA, whereas world universities violated 112, i.e., 28.20% less than Indian universities. Among Indian universities, UC ranked 1 as it violated only 2 guidelines, while UMELB, of the world universities achieved rank 1 as it violated only 1 guideline.

4.3 Violations of success criteria on 4 principles

4.3.1 Comparison of violations success criteria of 4 principles at conformance level A of world and Indian universities

Table 5 presents the number of violations of the success criteria by the websites of the top 25 world and Indian universities at conformance level A. The university that violated

Table 5 Violations and success criteria of 4 principles at conformance level A of world and Indian universities

Rank	World Universities	Principles (at Conformance Level A)								Indian Universities	Rank
		P	O	U	*R*	*P*	O	U	*R*		
1	SU	0	0	0	0	1	0	1	1	UH	1
1	ICL	0	0	0	0	0	1	0	3	IITM	2
1	UMELB	0	0	0	0	0	0	1	3	IITR	2
2	HAVARD	0	0	0	1	1	0	1	2	IITI	2
2	ETH	0	0	0	1	2	0	0	2	JNU	2
2	UCB	1	0	0	0	1	0	1	2	SPPU	2
2	PU	0	0	0	1	2	0	1	1	JU	2
3	YALE	1	0	0	1	2	0	1	2	IISc	3
3	UE	0	0	0	2	1	0	1	3	UC	3
4	MIT	0	1	0	2	1	0	1	4	IIT-KGP	4
4	UOX	0	0	0	3	1	1	1	3	MADRAS	4
4	UNSW	1	0	0	2	2	1	1	2	IITBH	4
5	UCHI	0	0	0	4	1	2	1	2	UM	4
5	UPENN	0	0	0	4	1	2	1	3	IITD	5
5	UT	0	0	0	4	0	1	0	6	SUBMS	5
5	TU	1	0	1	2	4	1	1	1	NITT	5
6	UCAM	0	0	3	2	4	1	1	2	IITH	6
6	PKU	1	1	1	2	2	0	0	6	CU	6
6	COLUMBIA	2	0	0	3	2	1	1	5	IIT-BHU	7
6	PSL	1	0	0	4	4	1	1	4	IITB	8
7	UCL	3	0	0	3	3	0	0	7	DU	8
8	NUS	2	1	1	3	3	1	1	6	IITK	9
8	CORNELL	3	0	0	4	2	0	1	10	IITG	10
9	CALTECH	2	1	0	5	3	1	1	8	AU	10
9	USYD	5	0	1	2	2	1	1	10	VIT	11
	Total	**23**	**4**	**7**	**55**	**45**	**15**	**20**	**98**		
	Total	**89**				**178**					

Where P = Perceptible, O = Operable, U = Understandable, and R = Robust

the least success criteria in both world and Indian universities was listed at the top and ranked as 1. Indian universities made 178 total violations of the success criteria of 4 principles at conformance level A, 50% more than the violations of world universities (89). Indian universities (98) and world universities (55) both had the highest number of success criteria violations at robust principle among 4 principles. Among Indian universities, UH achieved the rank 1 as the university only violated any of the 3 success criteria of the 4 principles, whereas among world universities SU, ICL and UMELB owned rank 1 as none of them violated any success criteria.

4.3.2 Comparison of violations success criteria of 4 principles at conformance level AA of world and Indian universities

Table 6 shows the rank and comparison of the top 25 world and Indian universities at conformance level AA. The university that violated the least success criteria in both world and Indian universities was listed at the top and ranked 1. Indian universities have made 57 violations of the success criteria of 4 principles at conformance level AA, which is 42.10% more than the violations of world universities (33). Indian universities (39) and world universities (26) had the highest number of success criteria violations on the principle of perceptible among 4 principles. While, on the principle of robustness both Indian and world universities do not violate any success criteria. Among Indian universities, IISc, IITM, IITR, DU, IITI, and IIT-BHU achieved rank 1 as all of these universities only violated 1 success criterion at the principle of perceptible among the 4 principles, while for world universities, MIT, HAVARD, SU, UCB, UNSW, and UT rank 1 as none of them violated any success criteria at any of the 4 principles.

4.3.3 Comparison of violations success criteria of 4 principles at conformance level Aaa of world and Indian universities

Table 7 shows the rank and comparison of the top 25 world and Indian universities at conformance level AAA. The university that violated the least success criteria in both world and Indian universities was listed at the top and ranked 1.

Table 6 Violations success criteria of 4 principles at conformance level AA of world and Indian universities

Rank	World Universities	Principles (at Conformance Level AA)								Indian Universities	Rank
		P	O	U	*R*	*P*	O	U	*R*		
1	MIT	0	0	0	0	1	0	0	0	IISc	1
1	HAVARD	0	0	0	0	1	0	0	0	IITM	1
1	SU	0	0	0	0	1	0	0	0	IITR	1
1	UCB	0	0	0	0	1	0	0	0	DU	1
1	UNSW	0	0	0	0	1	0	0	0	IITI	1
1	UT	0	0	0	0	1	0	0	0	IIT-BHU	1
2	UCL	1	0	0	0	1	1	0	0	IITB	2
2	UCHI	1	0	0	0	1	1	0	0	IIT-KGP	2
2	UPENN	1	0	0	0	1	1	0	0	AU	2
2	UMELB	0	1	0	0	1	1	0	0	MADRAS	2
2	CALTECH	1	0	0	0	1	0	1	0	IITH	2
2	YALE	1	0	0	0	1	1	0	0	SPPU	2
2	PU	1	0	0	0	1	1	0	0	IITBH	2
2	USYD	1	0	0	0	1	1	0	0	UM	2
2	UE	1	0	0	0	1	1	0	0	SUBMS	2
2	COLUMBIA	1	0	0	0	2	0	0	0	NITT	2
3	UCAM	2	0	0	0	0	2	0	0	UC	2
3	UOX	2	0	0	0	2	0	0	0	UH	2
3	ETH	1	0	1	0	1	1	0	0	VIT	2
3	CORNELL	1	1	0	0	2	1	0	0	IITD	3
3	PSL	1	0	1	0	3	0	0	0	JNU	3
4	ICL	2	1	0	0	2	1	0	0	JU	3
4	PKU	3	0	0	0	4	0	0	0	CU	4
4	TU	2	1	0	0	3	2	0	0	IITG	5
5	NUS	3	1	0	0	5	2	0	0	IITK	6
	Total	**26**	**5**	**2**	**0**	**39**	**17**	**1**	**0**		
	Total	**33**				**57**					

Where P = Perceptible, O = Operable, U = Understandable, and R = Robust

Indian universities have made 86 total violations of the success criteria of 4 principles at conformance level A, 17.44% more than the violations of world universities (71). Indian universities (62) and world universities (48) had the highest number of success criteria violations for the principle of operable among 4 principles. While, at the principle of understandable and robustness, both Indian and world universities do not violate any success criteria of the 4 principles. Among Indian universities, UC achieved rank 1 as the university only violated 1 success criterion at the principle of operable among the 4 principles. For world universities UMELB was ranked 1 as the university did not violate any success criteria at any principles.

4.4 Common failures under WCAG 2.2 techniques

4.4.1 Comparison of common failures at conformance level A of world and Indian universities

Table 8 shows the rank of world and Indian universities at conformance level A and their comparison. The university placed at the top and ranked 1 in both world and Indian universities, which recorded the least number of common failures. At conformance level A, the total number of common failures by Indian universities (301) is 48.50% higher than that of the world universities (155). IITR and IITH ranked first among Indian universities as they had only 5 common failures, whereas UMELB ranked first among world universities as it had only 1 common failure.

4.4.2 Comparison of common failures at conformance level AA of world and Indian universities

Table 9 shows the rank of world and Indian universities at conformance level AA and their comparison. The university placed at the top and ranked 1 in both world and Indian universities which recorded the least number of common failures. At conformance level AA the total number of common failures by Indian universities (27) is 22.85% less than that of world universities (35). UE and PU among the world universities are ranked first as they do not show any common failures. IITR, IITH, IITM, IISc, DU, and IITG ranked first among Indian universities as they had only 1 common failure.

Table 7 Violations success criteria of 4 principles at conformance level AAA of world and Indian universities

Rank	World Universities	Principles (at Conformance Level AA)								Indian Universities	Rank
		P	O	U	*R*	*P*	O	U	*R*		
1	UMELB	0	0	0	0	0	1	0	0	UC	1
2	CALTECH	1	0	0	0	1	1	0	0	IITR	2
2	UOX	1	0	0	0	1	1	0	0	IIT-BHU	2
3	ETH	1	1	0	0	1	1	0	0	JNU	2
3	MIT	0	2	0	0	1	1	0	0	IITH	2
3	UCAM	1	1	0	0	1	2	0	0	IITD	3
3	UCB	1	1	0	0	1	2	0	0	IITG	3
3	UCHI	1	1	0	0	1	2	0	0	SPPU	3
3	UE	1	1	0	0	1	2	0	0	JU	3
4	COLUMBIA	1	2	0	0	1	3	0	0	IITB	4
4	CORNELL	1	2	0	0	1	3	0	0	IISc	4
4	HAVARD	1	2	0	0	1	3	0	0	IIT-KGP	4
4	SU	1	2	0	0	1	3	0	0	IITM	4
4	TU	1	2	0	0	1	3	0	0	DU	4
4	UCL	1	2	0	0	1	3	0	0	AU	4
4	UT	1	2	0	0	1	3	0	0	IITI	4
5	ICL	1	3	0	0	1	3	0	0	MADRAS	4
5	NUS	1	3	0	0	1	3	0	0	IITBH	4
5	PKU	1	3	0	0	1	3	0	0	UM	4
5	PSL	1	3	0	0	1	3	0	0	CU	4
5	PU	1	3	0	0	1	3	0	0	SUBMS	4
5	UNSW	1	3	0	0	1	3	0	0	NITT	4
5	UPENN	1	3	0	0	1	3	0	0	UH	4
5	USYD	1	3	0	0	1	3	0	0	VIT	4
5	YALE	1	3	0	0	1	4	0	0	IITK	5
	Total	**23**	**48**	**0**	**0**	**24**	**62**	**0**	**0**		
	Total	**71**				**86**					

Where P = Perceptible, O = Operable, U = Understandable, and R = Robust

4.4.3 Comparison of common failures at conformance level AAA of world and Indian universities

Table 10 shows the rank of world and Indian universities at conformance level AAA and their comparison. The university placed at the top and ranked 1 in both world and Indian universities which recorded the least number of common failures. At conformance level AAA the total number of common failures by Indian universities (70) is 45.71% higher than that of world universities (38). IITR and UC ranked first among Indian universities as they had only 1 common failure. UE and COLUMBIA ranked first among world universities as they did not show any common failures.

4.5 Compatibility analysis of websites

4.5.1 Compatibility analysis of websites of world and Indian universities among different internet browsers

The total number of compatibility issues on the websites of the world universities is 222 (Table 11). The highest number of compatibility issues recorded are major (162), followed by minor (34) and missing (26). The highest number of compatibility issues are recorded in the browser Firefox (54), followed by iOS (45) and Safari (43). The least number of compatibility issues were recorded in the Edge browser. Also, the total number of compatibility issues on the websites of the Indian universities is 489 (Table 11). The highest number of compatibility issues recorded are major (282), followed by missing (121) and minor (86). The highest number of compatibility issues are recorded in the browser Firefox (118) followed by iOS (83) and Safari (82). The least number of compatibility issues were recorded in the browser Edge, i.e., 47.

4.5.2 Comparison of compatibility analysis of websites of world and Indian universities among different internet browsers

Tables 12 and 13, show that NUS (31) has the highest number of compatibility issues among the world universities, followed by USYD (27), UCB (16) and UNSW (16). While among the Indian universities, IITK (60) has the highest

Table 8 Comparison of common failures at conformance level A of world and Indian universities

Rank	World Universities	Frequency of Common Failures at A		Indian Universities	Rank
1	UMELB	1	5	IITR	1
2	COLUMBIA	2	5	IITH	1
2	HAVARD	2	6	UC	2
3	UE	3	6	IITD	2
3	MIT	3	8	IITM	3
3	UCB	3	10	IISc	4
4	UCHI	4	11	UH	5
4	SU	4	11	JNU	5
4	YALE	4	11	NITT	5
5	UT	6	11	DU	5
5	TU	6	12	IITI	6
5	UPENN	6	12	UM	6
5	UNSW	6	12	VIT	6
6	CALTECH	7	13	JU	7
6	UOX	7	13	SUBMS	7
6	PU	7	13	IIT-BHU	7
7	UCL	8	14	SPPU	8
7	USYD	8	14	IIT-KGP	8
8	ICL	9	14	CU	8
8	PKU	9	15	MADRAS	9
9	ETH	10	16	IITB	10
9	CORNELL	10	17	IITBH	11
9	UCAM	10	17	AU	11
9	NUS	10	17	IITK	11
9	PSL	10	18	IITG	12
	Total	**155**	**301**		

Table 9 Comparison of common failures at conformance level AA of world and Indian universities

Rank	World Universities	Frequency of Common Failures at AA		Indian Universities	Rank
1	UE	0	0	IITR	1
1	PU	0	0	IITH	1
2	UMELB	1	0	IITM	1
2	COLUMBIA	1	0	IISc	1
2	HAVARD	1	0	DU	1
2	UCB	1	0	IITG	1
2	SU	1	1	UC	2
2	YALE	1	1	IITD	2
2	UT	1	1	UH	2
2	CALTECH	1	1	JNU	2
2	UOX	1	1	NITT	2
2	USYD	1	1	IITI	2
2	UCAM	1	1	UM	2
3	MIT	2	1	IIT-BHU	2
3	UCHI	2	1	SPPU	2
3	TU	2	1	IIT-KGP	2
3	UPENN	2	1	CU	2
3	UNSW	2	2	VIT	3
3	UCL	2	2	JU	3
3	ICL	2	2	SUBMS	3
3	PKU	2	2	MADRAS	3
3	ETH	2	2	IITB	3
3	CORNELL	2	2	IITBH	3
3	NUS	2	2	AU	3
3	PSL	2	2	IITK	3
	Total	**35**	**27**		

number of compatibility issues, followed by AU (34) and IITB (31). Among the top 25 QS-ranked world universities MIT, UCL, UCHI, and UMELB do not show any compatibility issues, while among the top 25 QS-ranked Indian universities only IITR does not show any compatibility issues with the 7 listed browsers.

5 Discussion

Conducting a complete WCAG examination of university websites allows us to evaluate the website's accessibility to learning materials with and without disabilities. Failure to comply with the WCAG guidelines causes disruptions in access to learning resources, administrative tasks, and university activities for disabled students, faculty, and staff. Using the WCAG 2.2 promotes accessibility for people with impairments, which improves inclusion and usability. It assists institutions in meeting legal obligations, reduces the danger of fines, and displays a commitment to diversity and fairness. This compliance enhances the overall user experience by making the site more straightforward to use for all users and expanding the reach of the website's content to a broader audience, including potential students, professors, and staff members with disabilities.

One interesting finding from this study is that most of the universities primarily used 'ac.in' and '.edu' making it easier for anyone to recognize the domain as being associated with universities. Among the Indian universities, '.ac.in' is the most used TLD, while among world universities, '.edu' is the most gTLD in their TLD, and universities only with ccTLD '.uk' are using '.ac' as their second domain name. Alajarmeh's [20] finding indicates that when the conformance level increases, the number of known errors increases, indicating a worsening overall conformance with WCAG 2.0. This study shows that Indian universities have the greatest number of violations at each conformance level (A, AA, and AAA) compared with world universities. The result indicated that not even basic success criteria are being followed properly, as the most significant number of violations are found at conformance level A, followed by AAA and AA. UMELB and IITR have the least number of violations at the conformance level among the world and Indian universities, respectively. The total number of guideline violations made by the top 25 QS-ranked world universities is 460, of which the largest number of violations is at

Table 10 Comparison of common failures at conformance level AAA of world and Indian universities

Rank	World Universities	Frequency of Common Failures at AAA		Indian Universities	Rank
1	UE	0	1	IITR	1
1	COLUMBIA	0	1	UC	1
2	UMELB	1	2	IITM	2
2	UCB	1	3	IITH	3
2	UT	1	3	IISc	3
2	CALTECH	1	3	DU	3
2	UOX	1	3	IITG	3
2	USYD	1	3	IITD	3
2	MIT	1	3	UH	3
2	UCHI	1	3	JNU	3
2	CORNELL	1	3	NNITT	3
3	PU	2	3	IITI	3
3	HAVARD	2	3	UM	3
3	SU	2	3	IIT-BHU	3
3	YALE	2	3	SPPU	3
3	UCAM	2	3	IIT-KGP	3
3	TU	2	3	CU	3
3	UPENN	2	3	VIT	3
3	UNSW	2	3	JU	3
3	UCL	2	3	SUBMS	3
3	ICL	2	3	MADRAS	3
3	ETH	2	3	IITB	3
3	NUS	2	3	IIITBH	3
3	PSL	2	3	AU	3
4	PKU	3	3	IITK	3
	Total	**38**	**70**		

Table 11 Analysis of compatibility issues of websites of world and Indian universities

	World universities				
	Browser	**M1**	**M2**	**M3**	**Total**
1.	Firefox	3	6	45	54
2.	iOS	5	9	31	45
3.	Safari	4	9	30	43
4.	Opera	4	3	14	21
5.	Android	4	3	14	21
6.	Chrome	3	3	14	20
7.	Edge	3	1	14	18
	Total	**26**	**34**	**162**	**222**
	Indian universities				
	Browser	**M1**	**M2**	**M3**	**Total**
1.	Firefox	17	10	91	118
2.	iOS	18	18	47	83
3.	Safari	17	18	47	82
4.	Android	18	10	26	54
5.	Chrome	17	10	26	53
6.	Opera	17	10	25	52
7.	Edge	17	10	20	47
	Total	**121**	**86**	**282**	**489**

Note- M1 = Missing, M2 = Minor and M3 = Major

conformance level A (264), followed by conformance level AAA (112) and conformance level AA (84). The top 25 QS-ranked Indian universities have 757 violations of guidelines. The greatest number of violations is at conformance level A (498), followed by conformance level AAA (156) and the least violations are at conformance level AA (103). Findings from Dangol [24] indicate that the federal government of Nepal's websites are rated unsatisfactory, with only 4% conforming to "A" and "AAA" levels, and only 24% being contrast-oriented.

Moreover, understandable is the only principle out of 4 principles (perceptible, operable, understandable and robust) and Indian universities have violated the least number of 19 success criteria as compared with world universities. The findings display that the contents on these websites are not very presentable, understandable, interactive and user-friendly, as the largest number of violations among all principles were found at conformance level A, followed by AAA and AA. However, the study shows that these websites have fewer issues related to interoperability as the principle is robust at conformance level AA and AAA has no violations of success criteria. Another finding that stands out from the reported results is that Indian universities have the most common failures at conformance levels A and AAA. In contrast, world universities have the most common failures at conformance level AA, caused by erroneous implementations of success criteria, more specifically related to CSS and HTML. However, among Indian universities, IITR has the fewest common failures at all three conformance levels. Concerning browser compatibility, this study found that Indian institutions have more compatibility issues than world universities. Compared to iOS, Safari, Android, Chrome, and Opera, the Firefox web browser was determined to be the most incompatible, while Edge was shown to be the most compatible. Using AChecker and TAW, Akram et al. [16] categorize accessibility violations into 11% known problems and 89% likely/potential problems, with known issues requiring immediate action and likely/potential issues requiring human involvement. The study by Alajarmeh [20] indicates that public health websites across various countries still face accessibility barriers, particularly in terms of information perception and interface functionality.

6 Conclusion

The present study evaluated the top 25 QS-ranked world universities and the top 25 QS-ranked Indian universities following WCAG 2.2 using SortSite, an automated evaluation tool. Indian universities lag behind world universities in most cases, such as conformance level, violations of success

Table 12 Compatibility analysis of websites of world universities among different internet browsers

	World Universities	Browser																					Total
		Edge			Firefox			Safari			Opera			Chrome			iOS			Android			
		M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	
1	NUS	1	0	2	1	1	5	1	0	5	1	0	2	1	0	2	1	0	5	1	0	2	31
2	USYD	1	0	2	1	0	2	1	0	5	1	0	2	1	0	2	1	0	5	1	0	2	27
3	UCB	0	0	1	0	0	4	0	1	3	0	0	1	0	0	1	0	1	3	0	0	1	16
4	UNSW	0	0	1	0	1	1	0	1	4	0	0	1	0	0	1	0	1	4	0	0	1	16
5	CORNELL	0	1	1	0	1	2	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	15
6	SU	0	0	1	0	0	1	0	1	3	0	0	1	0	0	1	0	1	3	0	0	1	13
7	UCAM	0	0	1	0	0	4	0	1	1	0	0	1	0	0	1	0	1	1	0	0	1	12
8	YALE	0	0	1	0	0	4	0	0	0	1	0	1	0	0	1	0	0	1	0	0	1	10
9	UE	0	0	1	0	0	4	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	10
10	PKU	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	2	0	0	2	0	0	9
11	ETH	0	0	0	0	2	0	1	2	0	0	0	0	0	0	0	1	2	0	0	0	0	8
12	UT	0	0	0	0	0	3	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	8
13	UOX	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	7
14	HAVARD	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	7
15	ICL	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	7
16	TU	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	7
17	UPENN	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	5
18	PU	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
19	PSL	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	4
20	CALTECH	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
21	COLUMBIA	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
22	MIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	UCL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	UCHI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	UMELB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	3	1	14	3	6	45	4	9	30	4	3	14	3	3	14	5	9	31	4	3	14	222
	Total	18			54			43			21			20			45			21			

Note - M1 = Missing, M2 = Minor and M3 = Major

Table 13 Compatibility analysis of websites of Indian universities among different internet browsers

	Indian Universities	Browser																					Total
		Edge			Firefox			Safari			Opera			Chrome			iOS			Android			
		M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	
1	IITK	1	2	3	1	2	8	1	3	7	1	2	4	1	2	4	1	3	7	1	2	4	60
2	AU	1	1	2	1	1	8	1	2	4	1	1	3	1	1	3	1	2	4	1	1	3	43
3	IITB	1	1	3	1	1	7	1	1	3	1	1	3	1	1	4	1	1	3	1	1	4	41
4	IITBH	1	0	2	1	0	6	1	1	4	1	0	3	1	0	3	1	1	4	1	0	3	34
5	SUBMS	1	1	1	1	1	5	1	2	4	1	1	1	1	1	1	1	2	4	1	1	1	33
6	IITD	1	0	2	1	0	6	1	0	2	1	0	2	1	0	2	1	0	2	1	0	2	25
7	SPPU	0	1	1	0	1	5	0	2	2	0	1	2	0	1	2	0	2	2	0	1	2	25
8	MADRAS	1	1	1	1	1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
9	NITT	2	1	0	2	1	3	2	1	0	2	1	0	2	1	0	2	1	0	2	1	0	24
10.	IITG	2	0	1	2	0	1	2	0	2	2	0	1	2	0	1	2	0	2	2	0	1	23
11	IIT-KGP	1	1	0	1	1	3	1	1	1	1	1	0	1	1	0	1	1	1	1	1	0	19
12	JNU	1	0	1	1	0	4	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1	17
13	IISc	1	0	0	1	0	3	1	1	1	1	0	0	1	0	0	1	1	1	1	0	0	14
14	UM	0	0	1	0	0	4	0	0	3	0	0	1	0	0	1	0	0	3	0	0	1	14
15	UH	0	0	1	0	0	1	0	1	3	0	0	1	0	0	1	0	1	3	0	0	1	13
16	DU	1	0	0	1	0	3	1	1	0	1	0	0	1	0	0	1	1	0	1	0	0	12
17	VIT	0	0	0	0	0	4	0	0	1	0	0	1	0	0	1	1	0	1	1	0	1	11
18	IITI	1	0	0	1	0	3	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	10
19	UC	0	1	0	0	1	3	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	10
20	IITM	0	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	9
21	IITH	0	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	9
22	CU	1	0	0	1	0	0	1	0	1	1	0	0	1	0	0	1	0	1	1	0	0	9
23	JU	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	7
24	IIT-BHU	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
25	IITR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	17	10	20	17	10	91	17	18	47	17	10	25	17	10	26	18	18	47	18	10	26	489
	Total	47			118			82			52			53			83			54			

Note - M1 = Missing, M2 = Minor and M3 = Major criteria at 4 principles, common failure, and compatibility with browsers. Indian universities show better results with regards to the principle of understanding compared to the other 3 principles i.e., perceptible, operable and robust. The highest violations are at conformance level A, followed by AAA and AA. The websites of most of the universities have interoperability issues with the Firefox browser. The websites not in compliance with WCAG 2.2 make it hard for users to access and operate websites easily. Thus, to avoid these problems, universities should follow the WCAG 2.2 standard during the development of the websites and timely update with new standards and technologies that would be helpful to individuals with impairments.

Based on the study findings, universities should use academic (.ac) and educational (.edu) URL endings to make the websites identifiable by users as academic websites. Every university should apply WCAG 2.2 standards at least to the conformance level AA. To make academic or educational websites more accessible and interoperable, a guideline should be given to the web developers of the institutions to follow and implement the WCAG 2.2 standards. Moreover, universities should implement the 4 principles of WCAG 2.2, i.e. perceptible, operable, understandable, and robust. By implementing these principles, websites can be more presentable, operable/ interactive, understandable and compatible with assistive technologies. Universities should follow the instructions provided under the common failure techniques to avoid the existing issues after evaluating websites with WCAG 2.2 standards. Universities should develop websites with interoperability features to make them accessible and available for different types of users. The study indicates that web developers lack awareness of accessibility guidelines and legislation, necessitating urgent awareness, education, and training for diverse users, along with global law enforcement. Future research can use other tools such as AChecker, WAVE, W3C HTML Validator, W3C CSS Validator, etc. to evaluate institution websites, so that a larger sample can be covered, and government websites and non-governmental organization websites can be evaluated.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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Sustainability rankings in higher education: 'The right thing to do' or the pursuit of global recognition?

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Abstract

As universities strive to become more sustainable and support sustainable development broadly, sustainability assessments and rankings have proliferated and become influential in higher education worldwide. A growing number of universities in lower- and middle-income countries are participating, often with fewer economic and human resources than their counterparts in the Global North. We conceptualize these sustainability assessments and rankings as a new ranking product that both capitalizes off existing rankings infrastructures and logics, while also claiming to address limitations in existing rankings by focusing on societal impact and contributions to global challenges. Drawing on 28 interviews from universities located outside North America and Europe, we examine why universities participate in sustainability assessments or rankings to better understand their appeal. We find three major perceived benefits, namely, to improve institutional practices, to learn from other universities, and to enhance status and recognition. Our findings suggest that their growing power in higher education comes in part from their ability to imbue a marketized ranking product with moral legitimacy. Nonetheless, we also found important critiques: institutions highlighted the administrative and financial burdens of participating. Second, many found that the standardized metrics failed to reflect their context. We argue that that sustainability rankings and assessments do not well capture the realities and practices of universities outside of North America and Europe; this is concerning because the growing influence of sustainability rankings globally could both reinforce existing academic hierarchies while also limiting conceptions of universities' role in sustainability, all while benefitting from assumptions of their legitimacy.

Keywords Sustainability · Sustainable development · Higher education · Ranking · Sustainability ranking · Universities · Global North · Global South

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Introduction

Sustainable development is widely recognized as one of our most pressing global challenges and scholars argue that higher education can play a critical role in promoting sustainable development through research, teaching and community development (Chankseliani & McCowan, 2021; McCowan, 2019; Mula et al., 2017). Indeed, many universities are integrating sustainability and sustainable development into their mandates, operations, and curricula (Hong et al., 2023). Practices such as sustainability assessments and rankings (SARs) have emerged as institutions seek to become more sustainable organizations, communicate achievements to external audiences, and brand around commitments to sustainability (Kosta, 2019; Ragazzi & Ghidini, 2017; Urbanski & Filho, 2015; Calderon, 2023; Patara & Dhalla, 2022).

Although most prominent SARs were developed in Europe and North America, a growing number of universities in lower- and middle-income countries are participating (Ragazzi & Ghidini, 2017; Ulmer & Wydra, 2020) despite operating with fewer economic and human resources and different cultural norms than their Northern peers. One concern is that SARs may not well capture their sustainability practices. To date, most research on SARs focuses on institutions in the Global North (Caeiro et al., 2020; Yanez et al., 2019; Urbanski & Filho, 2015), even though lower- and middle-income countries in the Global South are disproportionately experiencing the effects of climate change and environmental degradation (Islam & Winkel, 2017) and many have innovative models for sustainability (Ragazzi & Ghidini, 2017). Brankovic et al. (2023) point to rankings' deep institutionalization and embeddedness in higher education and call on scholars to interrogate the nature of this institutionalization. Heeding their call, in this article, we seek to better theorize the spread of SARs globally by empirically investigating the rapid acceptance and use of SARs outside the Global North.

Conceptually, we argue that SARs are a new and specialized type of ranking; they simultaneously constitute a novel product for rankings companies to market, while also purporting to address critiques of existing global university rankings through their focus on societal impact. Like other global university rankings, SARs are undergirded by logics of standardization and comparability on the one hand, and a lack of attention to localization and contextualization on the other hand (Brankovic et al., 2018; Wilbers & Brankovic, 2023; Chun & Sauder, 2023; Shahjahan et al., 2017; Stack, 2020). Yet, unlike other global university rankings, which focus on research productivity and reputation, SARs claim to assess how universities' activities contribute to social good, particularly environmental sustainability, sustainable development, and the SDGs. This external focus imbues them with a degree of moral legitimacy that other rankings do not enjoy (Buckner & Zhang, 2024).

Empirically, we draw on 28 interviews spanning 16 countries to understand the appeal of participating in SARs for universities outside of North America and Europe. We identify three major perceived benefits, namely, to enhance institutional status and recognition, to improve operational and educational practices, and to learn from other universities. Importantly, we also find support for the idea that support for SARs participation is undergirded in part because becoming more sustainable is viewed as 'the right thing to do,' indicating a degree of moral legitimacy. That said, we also uncovered two important critiques: first, institutions were critical of the administrative and financial burdens of participating. Second, many found that the standardized metrics on sustainability rankings did not well reflect their distinctive contexts.

Notably, our findings on the perceived benefits and critiques of SARs closely mirror those made of other global university rankings. We argue the emergence and rapid acceptance of SARs is a clear extension of rankings logics to new domains that has been made possible by the institutionalization and legitimacy of university rankings generally, and the added moral legitimacy deriving from their claims to assess universities' impact and contribution beyond higher education. As such, we argue that SARs have become strategically useful to various actors: they represent a new arena for universities to pursue status and create new products for rankings' companies. Yet, as currently practiced, sustainability rankings do not capture well the realities and practices of universities outside of North America and Europe; this finding has far-reaching implications for practice because the growing participation and influence of SARs globally could both reinforce existing academic hierarchies while also limiting conceptions of what sustainability is and universities' role in supporting sustainability, all while benefitting from high degrees of moral legitimacy. In concluding, we offer suggestions for rethinking approaches to SARs.

Literature review

Universities around the world are integrating sustainability throughout their organizations. One practice, called sustainability reporting, involves producing public-facing reports on institutional actions related to sustainability (Ceulemans et al., 2015). A second practice, sustainability assessments, offer concrete ways for universities to assess how their curriculum, research, and operations align with externally defined standards. Sustainability assessments have grown in popularity and a variety of different benchmarking tools have emerged, the most prominent of which is STARS (Urbanski & Filho, 2015; Lambrechts & Ceulemans, 2013). Sustainability assessments are praised for aiding policy development and decision-making, institutionalizing sustainability throughout an institution and communicating progress to internal and external audiences (Calderon, 2023).

More recently, sustainability rankings have emerged and spread globally. Unlike assessments, rankings create hierarchies that deem some universities better at 'sustainability' than others (Calderon, 2023; Puertas & Marti, 2019). A growing number of universities worldwide participate in them (International Center for the Study of Research, 2023), and they are being used for international recognition (Calderon, 2023). Among the most prominent sustainability rankings and assessments are the Times Higher Education Impact Rankings (THEIR), QS Sustainability Rankings (QS-SR) and UI GreenMetrics. At the time of our data collection, QS-SR were not yet public; therefore, in this study, we focus on STARS, THEIR and UI GreenMetrics.

STARS was developed by the Association for the Advancement of Sustainability in Higher Education (AASHE), a not-for-profit organization based in the United States. STARS applies a broad definition of sustainability that includes the physical infrastructure, curriculum, research, operations, and finances. Universities report activities on predefined criteria, and allows institutions to document progress over time and compare themselves to others. Participation is voluntary, but institutions can elect to pursue a rating. In 2013, AASHE released STARS 2.0, which opened STARS up to institutions outside North America. In 2020, 1,017 institutions had registered for STARS and 671 had earned a rating. That said, use of STARS remains overwhelmingly concentrated in North America and high-income countries.

UI GreenMetric, established in 2010 by the University of Indonesia (Universitas Indonesia), is a global ranking of universities' environmental practices (Puertas & Marti, 2019). Participation is voluntary and rankings are based on responses to an annual online questionnaire, mapped onto six domains: energy and climate change (21%), waste (18%), education and research (18%), transportation (18%), setting and infrastructure (15%), and water (10%). In 2022, 1,050 institutions were ranked. Given the relatively low requirements for participation, GreenMetrics includes a larger number of institutions from low-income countries than other SARs.

The Times Higher Education Impact Rankings (THEIR) was developed by Times Higher Education, which also produces annual global university rankings. THEIR maps university activity onto the UN's SDGs in four broad areas: research, stewardship, outreach, and teaching and scores them on a scale of 0 to 100. The overall score is based on a combination of SDG seventeen (22%), and the three strongest SDGs that the institution provided evidence for (each worth 26%). Participation in THEIR is voluntary and subject to THE approval. In 2023, 1,705 universities from 115 countries and regions participated.

Conceptual framework

We conceptualize SARs as a new and specialized type of university ranking that adopts and has benefitted from the institutionalized logics and structures of other global university rankings. The extensive literature on university rankings has documented the logics that undergird their spread globally, as well as factors that incentivize institutional participation (Brankovic et al., 2023; Hazelkorn, 2015). Scholars point out that the spread of university rankings is related to "their ability to make heterogeneous characteristics of universities comparable through classification, normalization and standardization" (Hammarfelt et al., 2017, p. 393), while also recognizing the role they play in marketing and branding, as universities increasingly compete in global markets for reputation, students and funding (Brankovic et al., 2018; Hazelkorn, 2015; Lynch, 2014; Saisana et al., 2011; Sauder & Espeland, 2009). In response to the proliferation of rankings and their power, studies raise many critiques, including questioning the internal consistency of rankings (Saisana et al., 2011) and condemning the role rankings play in promoting competition between universities and in reifying existing hierarchies (Hazelkorn, 2015; Lynch, 2014; Stack, 2020, 2021).

In this article, we assume that SARs, like other university rankings, are premised on logics of standardization and comparability, which assume that sustainability is a singular concept that can be operationalized and measured quantitatively. However, we also view SARs as distinct from other university rankings. In particular, unlike other global university rankings, which focus on research productivity and reputation, SARs claim to assess how universities' activities contribute to social good, particularly in environmental sustainability, sustainable development, and the SDGs. This external focus imbues them with a degree of moral legitimacy that other rankings do not enjoy (Buckner & Zhang, 2024) by linking them to pro-social behaviors that serve the public good. Yet, because understanding of, approaches to, and priorities of sustainability vary greatly across different contexts, perhaps even more so than reputation and research that world-class university rankings focus on, the limitations of rankings' logics, particularly lack of localization and contextualization, are potentially exacerbated in SARs. Drawing on this conceptualization of SARs as the grafting of rankings' logics and moral legitimacy, we explore how these two ideas

Table 1 Number of universities by country

Country	Number of Universities
India	6
China	4
Mexico	4
Lebanon	2
Thailand	2
Colombia	1
Costa Rica	1
Ecuador	1
Malaysia	1
Pakistan	1
Palestine	1
Philippines	1
Qatar	1
Turkey	1
Venezuela	1
Total	28

emerge in discussions with universities in the Global South and shape their decisions to participate in SARs, as discussed below.

Data and analysis

Our data collection and analysis aim to understand why universities in countries outside North America and Europe participate in SARs. Because we sought a diverse range of participants, our primary inclusion criterion was that the university had to express commitment to sustainability or sustainable development, regardless of whether they chose to participate in SARs. We consulted public lists of participants in STARS, THEIR, and GreenMetrics and invited universities outside of North America and Europe who participate in any of those rankings. However, because we were also interested in why some institutions do not participate, we also sought out universities that had made public commitments in other ways. Therefore, we also examined institutional websites and invited universities that did not participate in rankings but did have public-facing web pages dedicated to sustainability to participate. We were able to recruit participants in India, Pakistan, and China this way.

Our data collection relied on a combination of emails, snowball sampling, and personal networks.[1] We targeted sustainability professionals and administrators, who we thought would be best positioned to speak about their universities' sustainability work. We conducted semi-structured interviews over Zoom with 28 universities in 16 countries: China (including Hong Kong), India, Lebanon, Malaysia, Pakistan, Palestine, Philippines, Qatar, Ecuador, Columbia, Costa Rica, Mexico, Venezuela, Thailand, Turkey, as shown

[1] The study was approved by the Research Ethics Board of the University of Toronto.

in Table 1. Interviews asked about how universities understand sustainable development, what their institutions are doing in the name of sustainable development, the challenges they face and their experience participating in SARs.

Interviews were recorded with participants' permission and transcribed. Roughly one quarter of interviews were translated from Chinese or Spanish. We used Atlas.ti to conduct thematic coding. Coding starting with an a priori codebook but was combined with iterative, inductive coding to add ideas that did not fall into the initially identified categories. For this article, we focused on excerpts coded at sustainability rankings or assessments, including sub-codes on benefits and challenges. We followed an iterative process of both descriptive and interpretive analysis that is common and appropriate for qualitative studies (Elliott and Timulak 2005). For our analysis, we focus on the recurring themes mentioned by many institutions; we recognize that our participants' universities are vastly different, and we do not intend to simplify their diversity; that said, many pointed to similar challenges and critiques, which we highlight below.

Findings

Findings indicated that universities highlighted three specific benefits of participating in SARs: (1) recognition or status ($N=16$, 57.14%), (2) self-tracking or self-improvement ($N=11$, 39.29%), and relatedly, (3) learning from other institutions ($N=8$, 28.57). While the most commonly cited benefit, recognition, reflects the extension of rankings logics to the domain of sustainability, the other two benefits, self-tracking and learning from others, both point to a high degree of faith in the ability of SARs to support institutions' commitments to sustainability. In fact, institutions stated that supporting sustainability was generally 'the right thing to do,' and that participation in SARs facilitated progress on that front. In this section, we interpret these findings to argue that the appeal SARs is undergirded by their ability to both confer recognition and status on institutions and their presumed legitimacy as tools for improving sustainability efforts and institutional impact more broadly.

Conferring both status and moral legitimacy

Status or external recognition was the most mentioned benefit, identified by 16 of 28 participants. Participants explained that participation in SARs allows universities to demonstrate their alignment with global best practices. Sometimes this commitment is made to please stakeholders, including students, and staff. However, it is also done to "seek international acknowledgment," as one participant from Qatar put it. Strong performance on rankings also allows universities to distinguish themselves from other universities. Interestingly, participants expressed both the desire for recognition but also a concern of being viewed as lagging behind best practices. One participant from Pakistan explained that on one hand, rankings: "are the only way of gauging where [an HEI] stands in the international cadre of universities. So this is something that is very important to us that our rankings keep improving every year…." (Pakistan). We make sense of the emphasis on external recognition in light of the broader literature on university rankings, which highlights how major shifts in the global environment mean that universities today are engaged in highly competitive landscapes for students and faculty, and within this globalized frame of reference, they are often engaging in strategic reputational management (Stack, 2020).

At the same time, however, many participants also stated that SARs provided frameworks to assess their institutional practices related to sustainability and that one of the main benefits of SARs was tracking institutional progress and supporting their institutional commitments to environmental sustainability, sustainable development, and the SDGs. The fact that institutions seemed to equate progress on SARs with progress towards sustainability is an important finding and points to the widespread moral legitimacy that SARs benefit from and that SARs are seemingly able to confer onto participating universities. The following statements reflect this idea:

> We started participating in the Times Higher Education Impact rankings. And from there, we got a very good overview of how to gauge the university's impact in terms of SDGs…We started participating in the UI GreenMetric. That also gave us a very good idea on how we can measure the campus operations part. (Pakistan)
>
> [Participating in SARs] gave us more inspiration to work toward these things [sustainability]…We are committed towards the SDG goals and we want to be [a] sustainable campus. (India)

As these quotes indicate, there was a shared sentiment that the rankings allow institutions to group and analyze data related to sustainability in a way that enabled them to develop more targeted approaches to sustainability. Among the most positive endorsements of SARs came from universities that suggested SARs facilitated self-reflection and learning. For example, one university stated that their participation in SARs streamlined the process of reporting on sustainability, explaining that SARs "provide a guide for how to structure self-assessment, reflection and reporting." They also suggested that SARs are not necessarily prescriptive but rather "a way to facilitate […] self-reflection." By facilitating data collection and organization, SARs provide a basis for institutional reflection and change.

Participants often spoke of progress over time. The statements below highlight the perception of the SARs as a guide and method of institutional assessment and advancement:

> If you look at the rankings, methodologies and what they are measuring, it is something that is commendable. And it's something that I think universities can easily adopt, not just for the sake of rankings, but just for the sake of, you know, propelling their sustainability initiatives and directions where they could set for themselves and to gauge their own performance. So I think this is a very good framework for the higher education sector. (Pakistan)
>
> [For] the rankings that we are participating in, mainly what we wanted was, and I think this is the case of many universities, to measure ourselves but against ourselves. It's great to see ourselves with the top universities in the world, but we wanted to see how much progress we made. (Mexico)

Others explained that SARs help to identify areas for improvement. A participant from Hong Kong captures this sentiment succinctly, stating: "if you are highly dependent on fossil fuels, or if you are not doing well with your diversity and inclusion, those are not just internal issues that should just be ignored." This comment highlights that participation in SARs and the public commitment to sustainability that it entails may push institutions to be transparent about areas for improvement. In some cases, participants explained they are also learning directly from other institutions, by comparing their practices to other institutions and learning from their peers.

In short, SARs seem to have dual benefits—on one hand, they represent a path to gaining international recognition while at the same time facilitating and measuring institutional change in regards to a domain of activities that confers a great deal of moral legitimacy. We argue that these dual benefits contribute to the rapid acceptance and institutionalization of SARs in higher education.

A lack of contextualization

Despite their benefits, participants raised many concerns about SARs, namely: 1) the administrative and financial burdens of participating in SARs and, 2) a lack of contextualization and localization. First, many participants outlined the logistical, financial, and administrative challenges, which participants named as a significant barrier or strain of participating. Four specific challenges emerged: difficulty compiling evidence ($N=16$, 57.14%), a lack of internal awareness ($N=12$, 42.86%), lack of financial resources ($N=9$, 32.14%), and lack of human resources ($N=6$, 21.43%).

Firstly, many participants expressed frustration over the logistical difficulties of measuring and quantifying aspects of operations and providing evidence. Some claim that the challenge of measurement has a serious, detrimental effect on their ranking position, as demonstrated by the following quotes:

> [C]ollecting data is not easy…we have around 3000 employees, we have 25,000 students, and a lot of activities everywhere in different schools. To collect all this data its a challenge actually. (Palestine)
> One thing I think that we can improve on is data collection. There are certain metrics that are very hard for us to capture. For example, food waste per person. It's something that takes time, because we are still struggling with recycling the waste, but we don't measure everything at the moment. (Hong Kong)

The logistical challenges related to compiling data and evidence are not specific to sustainability rankings and have been documented in world class university rankings as well, with research finding that extensive human and financial resources are needed (Chun & Sauder, 2022). Related to data and evidence, some participants also compared different rankings to one another. One university from Lebanon, for example, explained that participating in UI GreenMetrics was easier for them than THE Impact Rankings, which they described as "more complex." Another university simply stated that the THE Impact Rankings were "a very challenging process" (Malaysia).

Participants conveyed that it is difficult to succeed in SARs when an institution's staff and faculty are not aware of the criteria or the issue of sustainability more broadly. For example, a participant from Pakistan explained that "it's really hard to find trained people who understand this concept, and who can just directly work on this together with me." Similarly, an interviewee from Thailand explained: "One big issue that we face is behavioral change— how to change the habits of new generations and our staff." Meanwhile, a participant from Palestine explained that "engagement [is a big challenge] – not all staff members attend workshops." This highlights the difficulty of attempting to instill a new institutional value.

Similarly, universities connected the lack of human resources in sustainability promotion to their institution's lack of funding and staff. For example, when an interviewee from Mexico asked staff from a variety of departments to engage in sustainability initiatives, they explained that many responded by saying "of course I want to participate, but with what resources, with what personnel?". As with other global rankings, many universities state they do not have the resources to hire specialized personnel who are responsible for data collection and rankings participation.

Representatives of larger institutions also conveyed a challenge regarding human resources. This is reflected in the following statement from a participant from Malaysia stated:

> Resources for such a big university as ours – we need a lot more people to work on sustainability. Right now, it's only nine people, but we need much more engagement in terms of awareness. It's like a vicious cycle, awareness is low, and resources are low. (Malaysia).

This quote also highlights how a lack of human resources contributes to and exacerbates barriers to participating. In short, the process of data collection, verification, and reporting was deemed to be resource-intensive, requiring dedicated personnel and financial investments. Smaller institutions, especially those in economically disadvantaged regions, may find it challenging to allocate resources to meet the criteria set by sustainability rankings.

As discussed above, we conceptualize the emergence of SARs as creating new arenas for reputational management, which was in part, why participants felt they needed to invest significant resources into data collection and tracking. Although participants did not mention competitive pressures as a challenge explicitly, some discussed how participating in SARs raised concerns over performance and worried about the need to perform well on rankings. Interestingly, the risk of losing reputation was named as one reason for not participating, particularly for prestigious universities. For example, a participant from a prestigious Chinese university commented that:

> For top universities…they would have a lot to lose. They would think, 'if I'm involved in this ranking process and don't win, I may lose my reputation; or it will affect my enrollment this year if I do not get it. There are a lot of things that can be affected by such a ranking. (China)

Although few universities mentioned reputational management as a challenge explicitly, we interpret widely cited concerns over logistical and administrative burdens as implicitly undergirded by worries over reputation: if sustainability rankings were internal evaluation exercises for local audiences only, there would likely be less focus on collecting and producing particular forms of data and evidence, and also less concern over a lack of sufficient and high-quality data.

In addition to these logistical challenges and reputational risk, participants raised more fundamental issues with the relevance of SARs and the applicability of various indicators to their contexts. Roughly two-thirds of participants ($N=19$, 67.86%) mentioned that at least some aspects of SARs were not contextually relevant or did not apply to their contexts. For example, one participant from China explains clearly that in their opinion, "global rankings… have no way of considering many local conditions."

Critiques over relevance took different forms. We found that participants criticized indicators that seemed overly specific or idiosyncratic in ways that did not reflect their geographic or national realities. For example, some participants explained that specific practices, such as biking, was more compatible with some campuses than others and that universities' varied realities are not reflected in the rankings. In the quote below, a sustainability professional in Hong Kong explains how his institution is disadvantaged in the ranking scheme:

> The problem with great ratings and rankings is there's just always something that kind of irks you, like, you get points for being a bicycle-friendly campus, which is great if you're in the middle of the Midwest, in the United States, where everything's nice and flat, but, we're on a side of a mountain, from the coastline to where my office is, is 150 meters [...]. So with any kind of bike program on this campus all the bikes would end up at the bottom of the hill [...] so there's always something that kind of is like, 'Oh, gosh, you know, we can't get points for that, just because of who we are, where we are.' (Hong Kong)

A similar example comes from a participant in the Philippines, who explained:

> I think there were some questions or evidence they were looking for that maybe were not applicable to our context. For example, [a sustainability ranking may ask] Do you plant on your campus drought resistant plants? It's an oddly-specific question. It would make sense if our university is in Arizona. But in our country where it's wet half the year, and in some areas, it's wet the entire year, maybe that's not the best question to ask. (Philippines)

Although having drought-resistant plants or bicycles-friendly campuses may account for a tiny fraction of a point on a ranking, participants elaborated on the perceived unfairness of losing out on potential points due to aspects of geography or climate that are wholly outside of their control. This challenge highlights the distinction between SARs and other global university rankings in that universities' contributions to sustainability and sustainable development is even more dependent on local contexts such as climate and geography, in addition to socio-economic and cultural contexts. As such, approaches and priorities would look vastly different across contexts that contributions to sustainability are unlikely to be compared by a single set of criteria set by SARs.

In addition to technical critiques, participants also discussed how some aspects of sustainability rankings seem to systematically benefit resource-rich universities. For example, a participant from Lebanon explained that the financial crisis in the country has forced them to adapt their sustainability practices and frame the aid they provide for their communities in terms that are legible to SARs.

> The financial crisis affected a lot of our planning and spending. So, for example, most of the capital budgets, which were planned, were put on hold. So, the finances are left only for essential services. (Lebanon)

Similarly, a participant from Ecuador explained how the focus on endowments disadvantages universities without them:

> STARS is a tool that is not made for Southern countries like us, so, I think our experience has been more the fact that [...] certain categories and sections do not apply to us and will never apply to us, [and therefore] perhaps we are at a bit of a disadvantage because we could never reach one hundred percent because there are things that do not fit our reality. For example, for us the whole endowment issue and that entire investment section is something that does not fit. (Ecuador)

Meanwhile, a participant at a university in India explained that many of the criteria for sustainability seem to be resource-intensive, stating:

> A lot of these sustainability efforts also requires money…a lot of money is required to set up those solar panels or waste management and other stuff. […] So, lack of economic resources is at the core of lot of these things.

Another way that this privileging North American norms played out was in discussions of equity and diversity, and how they are measured by SARs. For example, some participants argued that in other regions of the world diversity—which is often conceptualized as racial and ethnic diversity—is not as relevant:

> In North America, in the United States in particular, diversity is really critically important right now. [...] And it should be getting [considered for] as many points as it possibly can [in the rankings]. But in Hong Kong that's not really one of our issues. Hong Kong is 96% Han Chinese so we're not very diverse, to begin with [...] we're not struggling with those kinds of issues. And maybe we should be focusing a little bit more on it. But it's not something that seems to be a problem, the way that it very clearly is in the United States. (Hong Kong)

Finally, a third and somewhat distinct critique of SARs was that they ignored some alternative approaches to sustainability. For example, participants explained that many SARs did not recognize the ways in which their universities were promoting sustainability. Participants suggested that the meanings and approaches of sustainability in their communities were simply not recognized or accounted for on many SARs. For example, a participant from Mexico raised the importance of community and social sustainability.

> I believe that in universities in Latin America, social leadership, or contact with the community is very different from universities in the United States, Canada, Europe, so on some occasions it led me to some debates around that topic because I said "I come to talk about social impact" - how I am working with society, how my students are immersed in the communities, how medical students have campaigns in vulnerable areas, and veterinary students generate projects that support the community and they fought a lot for these issues to also be considered, or talked about. Because if I went to a sustainable development conference, the only thing I heard about was the energy campus, mobility, [...] and I am talking about sustainable local regional development. (Mexico)

Meanwhile, a participant from India also emphasized social sustainability, stating:

> Let's not forget that some of these civilizations are so old, and they have their own ways of sustainability – economic, environmental, as well as social sustainability within their organizing principles, communities, families which needs to be studied, recognised and possibly also supported. (India)

Additionally, while some universities said that SARs permitted self-reflection and improvement over time, others suggested that they may undermine long-term and ongoing engagement with sustainability. For example, one critique of SARs is that they tend to focus more on outputs, rather than the institutional process for ongoing internal reflection. One participant from Thailand argued that current SARs "focus on outputs," in contrast to a nationally initiated process that focused more on the process of institutionalizing sustainability. Similarly, a participant from Pakistan suggested that there was a risk of homogenization that could come from external metrics, stating: "[There is a] risk of homogenization, or the risk of chasing something. So, I guess one should move with what one has and then try to see how far those things fit in with your own vision, rather than getting defined by definitions which are external."

In short, many of the universities we spoke with criticized both the logistical burdens and challenges associated with participation, while also raising more fundamental critiques on how they felt disadvantaged on SARs due to a lack of relevance to their context.

Conversely, they also raised the point that many indicators on SARs do not acknowledge their localized approaches and priorities. In these cases, participants were upset about the way that their realities disadvantage them on SARs, which in many ways reflects the growing power of these instruments to define what counts as sustainability and the recognition that institutional reputation and status are increasingly linked to performance on these metrics. Even more concerning to us were the critiques that highlight how the definitions and assumptions implicit in many indicators end up centering the realities of universities in the Global North.

While these critiques of SARs mirror those made of other university rankings, they also highlight how SARs are distinct from other global university rankings due to the new domain that they seek to measure and compare. While universities outside of North America and Europe share the sentiments that supporting sustainability and sustainable development are the right thing to do, they also stress that their understandings of, contributions to, and priorities for sustainability are distinctive to their contexts. Moreover, it is partly because SARs confer both status and moral legitimacy that universities' concerns over hierarchy and relevance are particularly salient. As the first section of our findings points out, SARs have benefited tremendously from assumptions of their legitimacy, which is related to their claims to assess societal impact and assumptions that they can support sustainability efforts. Yet, as the critiques made of SARs in this section indicate, in part due to the growing power of SARs and their ability to confer status, recognition and legitimacy that institutions are calling for better recognition of their distinct contexts and sustainability practices, rather than writing off SARs altogether.

Discussion and conclusion

In this article, we examine why universities outside of Europe and North America participate in sustainability assessments and rankings, and what challenges they face in doing so. Our study contributes to larger conversations about education and its linkages to sustainable development occurring within the field. Many have raised concerns about the impact of rankings to warp priorities in higher education worldwide, but so far, similar critiques have rarely been extended to sustainability rankings. On the one hand, our findings point to clear benefits that universities associate with participation, including seeing SARs as tools that could support self-improvement over time because universities are committed to sustainability as well as the promise of positive external recognition. This finding aligns to prior research, which reports international recognition and branding as one of the benefits and rationales for participation in sustainability rankings (Calderon, 2023). Nonetheless, they also face many challenges, both logistical and more fundamental, related to a lack of contextualization of indicators. Many participants thought that certain indicators measured on SARs were at times arbitrary and advantage universities in North America through their definition of criteria or their implicit assumptions.

Our findings build on long-standing critiques from scholars who question global development agendas and point to how technocratic approaches to education are deemed best practices for 'development,' with little attention given to systems of domination that continue to oppress institutions and individuals in the Global South that deem them underdeveloped (Sriprakash et al., 2020). Indeed, one concern with the rise and spread of SARs is that they may inadvertently contribute to the (re)production of hierarchy within the global higher education, along new lines. Other studies have found that performance on sustainability rankings often mirrors performance on rankings of world-class universities (Atici et al., 2021), while others have found that the best-performing institutions are in the United States and United Kingdom (Puertas & Marti, 2019). This finding echoes prior research on global rankings in higher education, which has found that these rankings consistently reify Western approaches to research and knowledge creation and are dominated by English-language universities (Shahjahan et al., 2017; Stockemer & Wigginton, 2019). While SARs permit universities' sustainability practices to be rendered legible to diverse audiences, the very practice of de-contextualized comparison inherent in ranking implicitly assumes a level playing field for all universities to be measured and compared. The authority conferred by quantification, and the conversion of diverse practices into numbers, ignores past or present circumstances that might affect performance on such indicators, including legacies of colonialism, under-development, conflict or resource extraction.

Another concern, found in our interviews and in the larger literature on university rankings, is that performance is often related to the amount and quality of evidence that is provided, which may be deeply decoupled from actual university practices (Chun & Sauder, 2022). Indeed, indicator-based approaches to sustainability rankings exemplify the way in which a complicated and context-specific concept such as sustainability can become parsed and quantified through specific indicators, with little attention to context. For example, sustainability rankings may award more points to universities that can prove LEED certification or other forms of energy efficiency in buildings; however, measuring this precisely may be quite costly, implicitly benefiting richer universities who can afford to perform well on metrics, even if total energy consumption or greenhouse gas emissions are higher. Even if rankers want to keep universities accountable for their claims, the infrastructure needed to produce evidence about specific initiatives is not directly related to the extent, quality, and relevance of sustainability work in local communities, and may detract attention from sustainability work. These findings suggest that sustainability rankings may inadvertently be contributing to rather narrow and technical approaches to advancing university sustainability that simultaneously position universities in North America and Europe as the most 'sustainable' in terms of current practices while ignoring the fact that the United States and European Union have historically been the largest climate polluters (Paddison & Choi, 2024).

Our findings support the idea that SARs constitute a new arena in which universities are engaged in reputational management, both by creating new global metrics through which they can pursue status and recognition as a "top" performer or global leader, while also raising new concerns, with new domains of activity being monitored and new comparisons where they could perform poorly, thereby undermining their reputations as responsive and forward-looking societal leaders. We note that many of these same critiques have been identified in prior literature regarding global university rankings. Yet, while SARs seem to benefit from the institutionalization and legitimacy of other global rankings, they nonetheless represent an important extension of rankings logics to new domains of university activity. In particular, in contrast to rankings that focus on reputation and research productivity, SARs claim to assess both internal operations and social impact beyond the university.

A key contribution of our study is to conceptualize SARs as a new and specialized ranking product that are appealing to institutions and other actors for varied reasons. For ranking companies, SARs represent new products and expertise to market and brand upon. For universities, SARs represent an avenue to demonstrate their social impact, through which they also gain global recognition. For some universities, status through SARs may also seem more attainable than rapid increases in research productivity.

These strategic uses of SARs by multiple actors likely creates new interdependencies between global organizations, governments, rankers, and universities (Brankovic et al., 2023). In particular, the specific alignment between the UN's SDGs and THE Impact Rankings represents a new interdependency, whereby the United Nations, its global development agenda, and Times Higher Education mutually reinforce one another's claims to moral legitimacy (Buckner & Zhang, 2024).

Additionally, a key conceptual contribution of our study is to recognize the appeal of SARs as related to its ability to capitalize on the deep institutionalization of rankings in higher education generally and pair it with the moral legitimacy that comes from being associated with sustainability and sustainable development generally and from SARs' claims to assess universities' social impact beyond higher education. We argue that this combination of moral legitimacy and ranking logics contribute to the rapid acceptance and institutionalization of SARs, while also accentuating the problematic claims of SARs. Because conceptualization, priorities and approaches to sustainability are vastly different, the "right" approach to sustainability is inherently context dependent. As such, the limitations of rankings logics in their lack of localization and contextualization are deemed particularly problematic by institutions that participate in SARs and seek recognition for their sustainability work.

One concern with this growing influence is that SARs may end up narrowing definitions and conceptions of sustainability and may devalue local practices and approaches over time. Prior research in higher education points to how rankings can powerfully shape institutional behavior by incentivizing particular practices (Lloyd & Ordorika, 2021; Sauder & Espeland, 2009). The logic of SARs is one of standardization—they imply sustainability is a singular concept that can be pursued through similar practices worldwide. Our participants reminded us that development priorities and sustainability practices worldwide are highly varied, and that participation in SARs may encourage universities to conform to a conception of sustainability that may not align with their cultural, environmental, or social context. These critiques echo those made of the SDGs, which many scholars have argued are infeasible, self-contradictory, and at odds with the future SDGs purport to achieve (Krauss, Jiménez Cisneros, and Requena-i-Mora 2022). In contrast to logics of standardization, we argue that there is a need for more localization: recognizing and valuing the distinct challenges and opportunities faced by institutions in diverse contexts is essential to understanding what it means to be a sustainable university.

The promise of SARs remains that they may promote more environmentally conscious practices in higher education and have longer-term impacts through their teaching and research. Yet, we maintain that contributions to sustainability are almost always locally contingent and thus, generalized and abstracted comparisons are largely meaningless. As such, our findings suggest that sustainability assessments likely hold more potential to support institutional practice than sustainability rankings, because assessments do not assume a zero-sum approach.

A more inclusive and equitable approach to defining and measuring universities' sustainability contributions may also create possibilities for new perspectives, definitions, and approaches that deepen commitments and actions that would be otherwise limited. As such, another practice for SARs to consider is the qualitative profiling of sustainability practices; this would give institutions the opportunity to define what sustainability is, articulate their priorities, challenges, and resources available, and document how they have made progress in addressing the sustainability challenges in their contexts and lessons learned in the process.

Finally, although we do not assume participation in SARs makes sense for all, or even most, universities, if universities in the Global South choose to participate, we believe that enhancing institutional and national capacity for performance measurement could equalize the playing field and contribute to the documentation of and progress on more diverse sustainability practices. Investing in sustainability education and the training of sustainability professionals could have similar benefits.

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Declarations

Ethics approval and consent to participate This study was approved by the University of Toronto Research Ethics Board and all participants consented to participate.

Competing interests The authors declare no competing interests.

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Implementation of a new research indicator to QS ranking system

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Abstract

The QS world university rankings employ six indicators with different weights; namely: academic reputation (40%), Employer reputation (10%), research performance (20% which is basically normalized citations per faculty, Faculty/Student Ratio (20%), International Faculty Ratio (5%) and International Student Ratio (5%). In this ranking system, the research performance is calculated by dividing total normalized citations by the number of full time equivalent faculty. Recently, Abdul-Majeed et al. (2021 proposed a new equation for predicting the research performance of universities, using four variables (number of published papers, number of researchers, total citations, number of non-citesd papers). In the present study, we investigate the influence of using Abdul-Majeed et al. equation on the rank of the top 100 universities of QS ranking. Results have shown that replacing the QS research indicator with that suggested by Abdul-Majeed et al. results in an apparent change in the rank of the 100 universities. The rank of 92 universities has been changed through this new proposal. Furthermore, we modify the Abdul-Majeed et al. equation by including reviewing activity based on information extracted from Publons site. Detailed calculations reveal that most of the top 100 universities have low level of reviewing activity. This modification causes a significant variation (the change reaches 98%) in the rank of the top 100 universities.

Keywords Research performance · QS ranking · Reviewing activity · Citations

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Introduction

Several parameters are adopted in the literature for measuring the research performance (or research indicators) of university faculty. Popular among them are the number of publications; the number of citations, the number of highly cited articles, citation per paper, number of internationally collaborative papers, and h-index. The h-index is a very widely used measure for predicting the performance of researchers, universities, journals, and even countries. Hirsch (2005) suggested that for any set of articles, the index is ***h*** if ***h*** articles have at least ***h*** citations. In the literature, some researchers (Glänzel, 2006, 2008; Prathap, 2010; Abdul-Majeed et al., 2021) highlight few limitations of using the h-index. For example, it does not account for the size of the universities. Besides, it ignores the extra citation of the articles, that is those number of citations which are greater than h-index. Due to these and other limitations, several revisions were proposed in the literature (Schubert and Glanzel, 2007; Garcia-Perez, 2009 Carbó-Dorca, 2010). Calculation of the above-mentioned parameters required access to a citation database. Three main citation databases exits: google scholar (GS), scopus and web of science (WoS). In comparison based on size, GS is the largest one, while WoS is the smallest. Recently, Digital Science offered a new online scholarly platform for publications, called Dimensions (Thelwall, 2018). GS and Dimensions are free online access, while WoS and Scopus are paid subscriptions.

There are a number of university ranking systems (URSs). The four widely used URSs are: the academic ranking of world universities (ARWU also popularly known as Shanghai Rankings), the times higher education rankings (THE Rankings), quacquarelli symonds (QS) World university rankings, and webometrics ranking of world universities (WR, which primarily ranks web domains of universities). All of these URSs include a research indicator (RI), with different weights. The QS and THE ranking systems suggested weight of 20% for estimating RI based on Scopus citation database. In these two ranking systems, RI is predicted by dividing the total citations (C_T) by the number of faculty (N_R). In ARWU system, RI weightage is 40%, calculated from the prizes, medals, highly cited researchers, papers published in Nature and Science, based on WoS citation database. For WR system, RI depends on the number of papers amongst the top 10% most cited in each one of the all 27 disciplines of the full database of WoS (SCIMAGO).

Recently, Abdul-Majeed et al. (2021), henceforth AM (2021), proposed a new equation for predicting RI of universities, based on four variables, namely: number of published papers (P_u), number of researchers (N_R), total citations (C_T) and number of non-cited papers (P_{unc}).

The aims of the present study are: (1) to investigate the influence of implementing AM (2021) equation on the rank of the top 100 universities of QS ranking and (2) to modify their equation by including the reviewing activity of universities.

Methodology

As mentioned above, QS ranking system calculates RI by dividing total citations by the number of researchers (in particular the number of full-time equivalent faculty) as shown in Eq. 1:

$$\mathrm{RI}_{\mathrm{QS}} = \frac{C_{\mathrm{T}}}{N_{\mathrm{R}}} \tag{1}$$

AM (2021) proposed the following equation for measuring RI:

$$\mathrm{RI}_{\mathrm{AM}} = \frac{C_{\mathrm{T}}}{P_{\mathrm{u}}} + \frac{P_{\mathrm{u}}}{N_{\mathrm{R}}} - \frac{P_{\mathrm{unc}}}{P_{\mathrm{u}}} \tag{2}$$

where RI_{QS} and RI_{AM} are research indicators of QS and AM (2021), respectively. C_T is the total number of citations in the previous 6 years (of papers in the previous 5 years), N_R is the number of researchers, P_u is the total number of published articles and P_{unc} is the number of non-cited published articles. Table 1 presents the top 20 universities based on the QS ranking of 2021 (https://www.topuniversities.com/university-rankings/world-university-rankings/2021). As can be seen, QS employs 6 indicators, namely: Academic Reputation (40%), Employer Reputation (10%), faculty per student (20%), citation per faculty (20%), International faculty (5%) and International students (5%).

Before implementing RI_{AM} instead of RI_{QS} and recalculating the rank of the 100 top universities, we would like to discuss the validation of Eq. 1. Table 2 presents the estimation of RI_{QS} using Eq. 1 for three universities. In case 1, the RI_{QS} values reveal that the three universities have the same level of research performance. However, a close look indicates the superiority of university X2, due to high citations coming from only 300 papers compared to 500 and 800 papers of universities X1 and X3, respectively. This reveals the high quality of the papers of university X2. In case 2, the RI_{QS} results highlight the advantage of university X1 over the other two universities due to the increase in researcher number. However, if we take the number of papers into consideration, we can conclude that university X3 yields the best performance depending on the high citations associated with less number of published articles. For case 3, the number of papers is equal for the three universities, and the RI_{QS} results show the progress of university X1 due to the higher number of citations compared to the others. In this case, Eq. 1 presents fair results, since the number of the published papers is equal for all universities. Based on this analysis, one can conclude that Eq. 1 is valid only if the number of published articles is similar for the compared universities. Of course, this assumption is unreasonable and impractical. Detailed analysis of the research data of the QS top 100 universities in the Scopus database indicates that no two universities have the same number of published papers. The range of the number of published papers covered by the top 100 universities is (8869-158134).

Gathering of the required data

Application of Eq. 2 requires access to the Scopus database to extract the values of P_u, C_T, and P_{unc} for the 100 universities from 2015 to 2019. The number of faculty (N_R) is obtained from QS site and validated from the sites of the included universities. The collection of all these data takes about three months.

Calculation of RI using AM (2021) Equation

Table 3 lists the gathered data and also the results of Eq. 2. The last column represents the normalized values of RI_{AM}. A comparison of RI_{QS} (column 6 in Table 1) and IR_{AM} (last column in Table 3) indicates a significant difference for most of the top 100 universities. It is expected that although the research criterion takes a low weight in QS (20%), the large change in RI will affect the overall rank of the included universities.

Figure 1 illustrates a comparison between IR_{QS} and IR_{AM} for some selected universities, which reveals a clear change in the RI values. It is worth noting that IR_{QS} is greater than IR_{AM} for the universities having high citations due to the direct relationship between

Table 1 QS ranking of the top 20 universities for 2021, based on Eq. 1

2021		Academic reputation	Employer reputation	Faculty student	Citations per faculty	International faculty	International Students	Overall
Rank	Institution name	Score	Score	Score	Score	Score	Score	Score
1	Massachusetts Institute of Technology (MIT)	100.0	100.0	100.0	99.1	100.0	91.9	100.0
2	Stanford University	100.0	100.0	100.0	98.1	99.7	63.6	98.4
3	Harvard University	100.0	100.0	98.6	99.1	85.2	69.9	97.9
4	California Institute of Technology (Caltech)	97.0	82.8	100.0	99.9	100.0	88.2	97.0
5	University of Oxford	100.0	100.0	100.0	81.3	99.4	98.3	96.7
6	ETH Zurich (Swiss Federal Institute of Technology)	98.7	96.6	80.8	96.4	100.0	97.9	95.0
7	University of Cambridge	100.0	100.0	100.0	69.2	100.0	97.4	94.3
8	Imperial College London	98.5	99.8	99.9	68.6	100.0	100.0	93.6
9	University of Chicago	99.4	91.3	94.4	86.3	67.1	82.6	93.1
10	UCL (University College London)	99.4	98.3	98.4	65.4	99.3	100.0	92.9
11	National University of Singapore (NUS)	99.7	98.4	90.7	72.9	100.0	71.4	91.5
12	Princeton University	99.9	99.0	68.6	100.0	71.6	65.6	91.0
13	Nanyang Technological University (NTU)	89.8	89.8	91.5	89.0	100.0	67.6	89.9
14	Ecole Polytechnique Fédérale de Lausanne (EPFL)	80.4	80.0	96.3	98.5	100.0	100.0	89.6
15	Tsinghua University	98.2	98.6	93.3	83.2	55.3	29.7	89.2
16	University of Pennsylvania	96.1	91.5	100.0	63.8	88.7	65.3	88.6
17	Yale University	99.9	100.0	100.0	52.8	85.3	54.5	88.0
18	Cornell University	98.5	90.9	63.7	88.6	93.7	70.0	87.6
19	Columbia University	99.7	97.3	100.0	48.5	37.2	96.3	86.5
20	University of Edinburgh	98.0	95.4	83.1	50.2	98.2	99.0	85.8

Table 2 Validation of Eq. 1

Case 1				
University	P_U	C_T	N_R	RI_{QS}
X1	500	30000	500	60
X2	300	30000	500	60
X3	800	30000	500	60
Case 2				
University	P_U	C_T	N_R	RI_{QS}
X1	500	30000	500	60
X2	600	30000	600	50
X3	250	30000	525	57
Case 3				
University	P_U	C_T	N_R	RI_{QS}
X1	500	30000	400	75
X2	500	28000	400	70
X3	500	26000	400	65

IR_{QS} and citations (Eq. 1). For the other universities (shown in Fig. 1), IR_{AM} is greater than IR_{QS}, owing to including the number of published papers and non-cited papers (Eq. 2). Another note that can be extracted from Fig. 1, is that Princeton University drops from 1st place with $IR_{QS} = 100$ to 6th place with $IR_{AM} = 78$. Based on Eq. 2, Ecole Polytechnique Fédérale de Lausanne arises from 10th position with $IR_{QS} = 98$ to the 1st position with $IR_{AM} = 100$.

Resorting the rank of the universities using AM (2021) Equation

To implement Eq. 2, we replace column 6 in Table 1 (citations per faculty) with column 10 of Table 3 (values of IR_{AM}) and resorting the rank of the top 100 universities (listed in Table 1) using the same weights of QS ranking. The results are listed in Table 4. A comparison of the overall rank of the top 100 universities in Table1 with that in Table 4 shows that only eight universities have maintained their ranks and 92 universities have new positions due to the significant change in the values of RI. It is worth noting that some universities jump only one level, like MIT and the University of Oxford. In contrast, many universities move up/down more than four levels like Tsinghua, Columbia, Kyoto, Toronto, and others. We think that the revised QS ranking is fair and more reasonable than the currently used one, due to considering the effect of P_u and P_{unc} variables.

Enhancements to Previous work

Following the recommendation of the previous authors to include more variables in measuring the RI (Garcia-Perez, 2009; Carbó-Dorca, 2010; Bornmann & Marx, 2011; Bornmann et al., 2011; Chi & Glänzel, 2022), we decide to consider the reviewing activity of

Table 3 Calculation of IR_{AM} for the top 20 universities

Institution name	Researchers	Papers	Citations	Non-Cited	Pu/NR	CT/Pu	Punc/Pu	Eq. 2	Normalized IRAM
Massachusetts Institute of Technology (MIT)	3065	54745	1912079	5629	17.861	34.927	0.1028	52.891	82
Stanford University	4725	70813	2332971	7920	14.987	32.946	0.1118	48.044	75
Harvard University	4646	158134	4678803	17268	34.037	29.588	0.1092	63.733	99
California Institute of Technology (Caltech)	968	23390	707919	2295	24.163	30.266	0.0981	54.527	85
University of Oxford	6708	77092	2034133	9732	11.493	26.386	0.1262	38.005	59
ETH Zurich (Swiss Federal Institute of Technology)	2719	63796	1611013	6004	23.463	25.253	0.0941	48.810	76
University of Cambridge	5800	62306	1685517	7453	10.742	27.052	0.1196	37.914	59
Imperial College London	3970	64452	1687407	7007	16.235	26.181	0.1087	42.524	66
University of Chicago	2703	33281	941408	4467	12.313	28.287	0.1342	40.733	63
UCL (University College London)	7195	82472	2049536	9905	11.462	24.851	0.1201	36.434	57
National University of Singapore (NUS)	4288	49353	1142112	5540	11.510	23.142	0.1123	34.764	54
Princeton University	1050	22883	649730	2997	21.793	28.394	0.1310	50.318	78
Nanyang Technological University (NTU)	3812	39945	944972	5215	10.479	23.657	0.1306	34.266	53
Ecole Polytechnique Fédérale de Lausanne (EPFL)	633	24844	618843	2991	39.248	24.909	0.1204	64.278	100
Tsinghua University	6174	81006	1627501	11631	13.121	20.091	0.1436	33.355	52
University of Pennsylvania	5154	61636	1547726	7670	11.959	25.111	0.1244	37.194	58
Yale University	5391	48164	1275757	5971	8.934	26.488	0.1240	35.546	55
Cornell University	2843	52078	1368634	6216	18.318	26.280	0.1194	44.718	70
Columbia University	7087	57830	1509373	7747	8.160	26.100	0.1340	34.394	54
University of Edinburgh	4734	40366	1009297	4778	8.527	25.004	0.1184	33.649	52

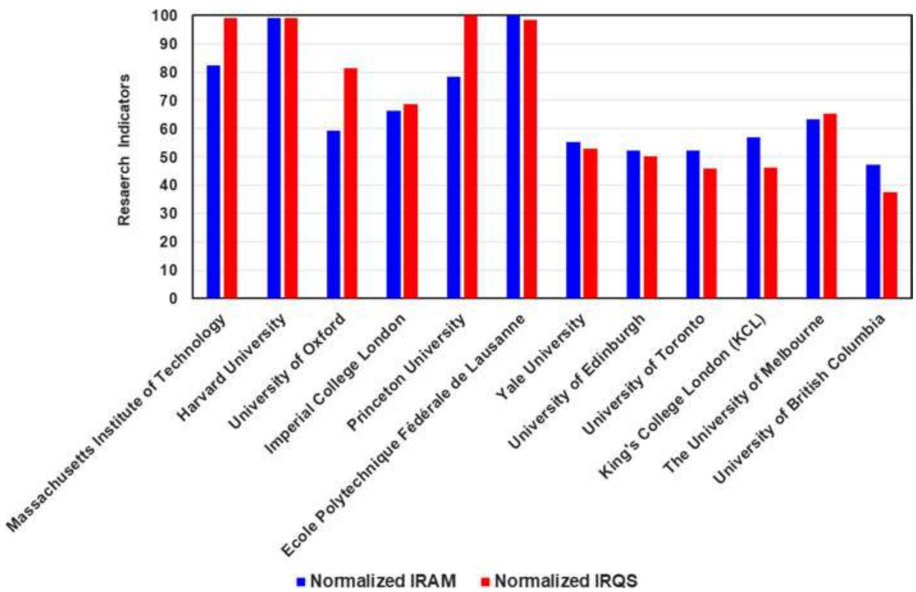

Fig.1 Comparison between IR_{QS} and IR_{AM} for some selected universities

the universities in predicting RI. The reviewing contribution has received no attention by all the existing RI models. To achieve this goal, we select the Publons site, which provides a free service for academics to track and verify their peer review. This site was launched in 2012 and was bought by Clarivate Analytics in 2017 (which also owns WoS). It claims that over 200,000 researchers have joined the site, adding more than one million reviews across 25,000 journals. Access to this site is free, and from the Institutions link, we extract the total verified reviews (T_{VRS}) of 1500 universities, including the QS top 100 universities. A first look at the extracted data reveals that most of the top 100 universities have low level of contribution to reviewing activity. For example, the T_{VRS} of the QS top three universities (MIT, Stanford, and Harvard) are 1591, 3261, and 1365 respectively, whereas for São Paulo University, T_{VRS} equals 44294. For consistency with the QS ranking of 2021, we obtain the T_{VRS} values from Publons site at the end of 2021 (https://publons.com/institution/?order_by=num_researchers).

To account for the reviewing activity, we add a new term to Eq. 2, calculated by dividing T_{VRS} by the number of faculty (N_R). The modified form of Eq. 2, becomes as shown below:

$$RI_{MAM} = \frac{C_T}{P_u} + \frac{P_u}{N_R} - \frac{P_{unc}}{P_u} + \frac{T_{VRS}}{N_R} \tag{3}$$

where RI_{MAM} is the modified AM (2021) research indicator. Figure 2 presents a histogram plot of RI_{QS}, $RI_{AM,}$ and RI_{MAM} for some universities listed in the QS ranking. As noted, QS_{MAM} is greater than QS_{AM} due to adding the new term of reviewing contribution. On the other hand, IR_{MAM} is almost larger than IR_{QS} due to using five variables in predicting IR instead of only two variables, with the exception of those universities with relatively high citation and low faculty numbers.

Table 4 QS ranking of the top 20 universities for 2021, based on Eq. 2

Institution name	Academic reputation Score	Employer reputation Score	Faculty student Score	IRAM Score	International faculty Score	International students Score	Overall Score
Massachusetts Institute of Technology (MIT)	100.0	100.0	100.0	82.3	100.0	91.9	98.4
Stanford University	100.0	100.0	100.0	74.7	99.7	63.6	95.2
Harvard University	100.0	100.0	98.6	99.2	85.2	69.9	100.0
California Institute of Technology (Caltech)	97.0	82.8	100.0	84.8	100.0	88.2	95.9
University of Oxford	100.0	100.0	100.0	59.1	99.4	98.3	90.3
ETH Zurich (Swiss Federal Institute of Technology)	98.7	96.6	80.8	75.9	100.0	97.9	96.0
University of Cambridge	100.0	100.0	100.0	59.0	100.0	97.4	87.8
Imperial College London	98.5	99.8	99.9	66.2	100.0	100.0	88.6
University of Chicago	99.4	91.3	94.4	63.4	67.1	82.6	88.6
UCL (University College London)	99.4	98.3	98.4	56.7	99.3	100.0	86.2
National University of Singapore (NUS)	99.7	98.4	90.7	54.1	100.0	71.4	85.9
Princeton University	99.9	99.0	68.6	78.3	71.6	65.6	94.8
Nanyang Technological University (NTU)	89.8	89.8	91.5	53.3	100.0	67.6	83.9
Ecole Polytechnique Fédérale de Lausanne (EPFL)	80.4	80.0	96.3	100.0	100.0	100.0	92.2
Tsinghua University	98.2	98.6	93.3	51.9	55.3	29.7	82.5
University of Pennsylvania	96.1	91.5	100.0	57.9	88.7	65.3	81.7
Yale University	99.9	100.0	100.0	55.3	85.3	54.5	80.7
Cornell University	98.5	90.9	63.7	69.6	93.7	70.0	90.7
Columbia University	99.7	97.3	100.0	53.5	37.2	96.3	78.7
University of Edinburgh	98.0	95.4	83.1	52.3	98.2	99.0	81.2

Determining the rank of universities using Eq. 3

The same procedure described above has been used to determine the rank of the universities using the modified AM equation (Eq. 3), where IR_{QS} is replaced by IR_{MAM} and resorted the data of Table1. Table 5 presents the ranks of the top 20 universities. The results of the top 100 universities reveal that 98% of the universities move to new places. In contrast, only two universities stay in their previous positions, as given by the original QS ranking.

Discussion of results

The rank of the universities using the three equations (Eqs. 1, 2 and 3) is summarized in Table 6. Several observations can be made from this Table. First, as mentioned earlier, 92 universities have new places using Eq. 2, whereas 98 universities move to different ranks based on Eq. 3. This observation reveals that although the weight of RI is only 20%, including new research sub-indicators results in a clear change in the rank of the Universities. Second, based on Eq. 2, the universities having high C_T with a moderate number of P_u move up in the ranking sequence, whereas the universities with high C_T and high P_u move down in the rank Table. This behavior is not reflected in Eq. 1 due to the absence the parameter P_u. An example of universities that improved in their ranks, using Eq. 2, is Yale University, which jumped from 17 to 10th place ($P_u = 48162$). On the other hand, Peking University dropped from 23rd to 27th place ($P_u = 71829$). Third, using Eq. 3, the universities that are active in reviewing process got better ranks, like McGill University moved to 23rd position with overall score = 85.3, in comparison to its score of 80 (using Eq. 1) and 82 (using Eq. 2). Fourth, a detailed analysis of reviewing

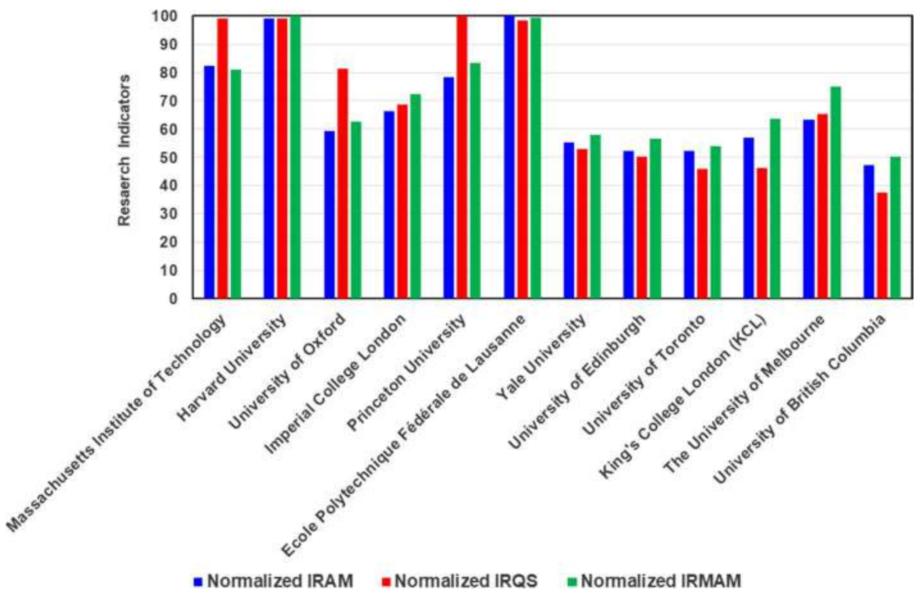

Fig.2 Comparison between IR_{QS}, IR_{AM}, and IR_{MAM} for some QS ranking universities

Table 5 QS ranking of the top 20 universities for 2021, based on Eq. 3

Institution name	Academic reputation Score	Employer reputation Score	Faculty student Score	IRAMA Score	International faculty Score	International students Score	Overall Score
Massachusetts Institute of Technology (MIT)	100.0	100.0	100.0	81.0	100.0	91.9	98.3
Stanford University	100.0	100.0	100.0	73.7	99.7	63.6	95.3
Harvard University	100.0	100.0	98.6	100.1	85.2	69.9	100.0
California Institute of Technology (Caltech)	97.0	82.8	100.0	87.2	100.0	88.2	96.3
University of Oxford	100.0	100.0	100.0	62.8	99.4	98.3	94.8
ETH Zurich (Swiss Federal Institute of Technology)	98.7	96.6	80.8	82.1	100.0	97.9	94.0
University of Cambridge	100.0	100.0	100.0	63.6	100.0	97.4	95.0
Imperial College London	98.5	99.8	99.9	72.5	100.0	100.0	96.3
University of Chicago	99.4	91.3	94.4	66.9	67.1	82.6	90.9
UCL (University College London)	99.4	98.3	98.4	63.0	99.3	100.0	94.2
National University of Singapore (NUS)	99.7	98.4	90.7	61.0	100.0	71.4	90.9
Princeton University	99.9	99.0	68.6	83.3	71.6	65.6	89.3
Nanyang Technological University (NTU)	89.8	89.8	91.5	59.2	100.0	67.6	85.6
Ecole Polytechnique Fédérale de Lausanne (EPFL)	80.4	80.0	96.3	99.5	100.0	100.0	91.6
Tsinghua University	98.2	98.6	93.3	54.6	55.3	29.7	85.1
University of Pennsylvania	96.1	91.5	100.0	60.1	88.7	65.3	89.5
Yale University	99.9	100.0	100.0	57.9	85.3	54.5	90.8
Cornell University	98.5	90.9	63.7	74.1	93.7	70.0	86.4
Columbia University	99.7	97.3	100.0	55.6	37.2	96.3	89.6
University of Edinburgh	98.0	95.4	83.1	56.7	98.2	99.0	88.8

Table 6 Summary of QS ranking for 2021 using Eqs. 1, 2 and 3

QS 2021 using Eq. 1			QS 2021 using Eq. 2			QS 2021 using Eq. 3		
Rank	Institution name	Score	Rank	Institution name	Score	Rank	Institution name	Score
1	Massachusetts Institute of Technology (MIT)	100.0	1	Harvard University	100.0	1	Harvard University	100.0
2	Stanford University	98.4	2	Massachusetts Institute of Technology (MIT)	98.7	2	Massachusetts Institute of Technology (MIT)	98.3
3	Harvard University	97.9	3	California Institute of Technology (Caltech)	96.0	3	California Institute of Technology (Caltech)	96.3
4	California Institute of Technology (Caltech)	97.0	4	Stanford University	95.7	4	Imperial College London	96.3
5	University of Oxford	96.7	5	Imperial College London	95.2	5	Stanford University	95.3
6	ETH Zurich (Swiss Federal Institute of Technology)	95.0	6	University of Oxford	94.2	6	University of Cambridge	95.0
7	University of Cambridge	94.3	6 =	University of Cambridge	94.2	7	University of Oxford	94.8
8	Imperial College London	93.6	8	UCL (University College London)	93.1	8	UCL (University College London)	94.2
9	University of Chicago	93.1	9	ETH Zurich (Swiss Federal Institute of Technology)	92.9	9	ETH Zurich (Swiss Federal Institute of Technology)	94.0
10	UCL (University College London)	92.9	10	Ecole Polytechnique Fédérale de Lausanne (EPFL)	91.9	10	Ecole Polytechnique Fédérale de Lausanne (EPFL)	91.6
11	National University of Singapore (NUS)	91.5	11	Yale University	90.4	11	University of Chicago	90.9
12	Princeton University	91.0	12	University of Chicago	90.4	12	National University of Singapore (NUS)	90.9
13	Nanyang Technological University (NTU)	89.9	13	National University of Singapore (NUS)	89.7	13	Yale University	90.8
14	Ecole Polytechnique Fédérale de Lausanne (EPFL)	89.6	14	Columbia University	89.4	14	Columbia University	89.6
15	Tsinghua University	89.2	15	University of Pennsylvania	89.3	15	University of Pennsylvania	89.5
16	University of Pennsylvania	88.6	16	Princeton University	88.5	16	Princeton University	89.3
17	Yale University	88.0	17	University of Edinburgh	88.1	17	University of Edinburgh	88.8
18	Cornell University	87.6	18	University of Hong Kong (HKU)	86.0	18	University of Hong Kong (HKU)	87.3

Table 6 (continued)

QS 2021 using Eq. 1			QS 2021 using Eq. 2			QS 2021 using Eq. 3		
Rank	Institution name	Score	Rank	Institution name	Score	Rank	Institution name	Score
19	Columbia University	86.5	19	University of Toronto	85.8	19	Cornell University	86.4
20	University of Edinburgh	85.8	20	Cornell University	85.6	20	University of Michigan-Ann Arbor	86.0
21	University of Michigan-Ann Arbor	84.6	21	University of Michigan-Ann Arbor	85.4	21	University of Toronto	86.0
22	University of Hong Kong (HKU)	83.7	22	New York University (NYU)	85.2	22	Nanyang Technological University (NTU)	85.6
23	Peking University	83.5	23	Tsinghua University	84.7	23	McGill University	85.3
24	The University of Tokyo	83.2	24	Nanyang Technological University (NTU)	84.5	24	New York University (NYU)	85.1
25 =	Johns Hopkins University	82.7	24 =	Technische Universität München	84.5	24 =	Tsinghua University	85.1
25 =	University of Toronto	82.7	26	The University of Manchester	84.2	24 =	King's College London (KCL)	85.1
27 =	The Hong Kong University of Science and Technology (HKUST)	82.1	27	King's College London (KCL)	83.8	27	The University of Manchester	84.9
27 =	The University of Manchester	82.1	28	Peking University	82.9	28	Technische Universität München	84.4
29	Northwestern University	81.5	29	Johns Hopkins University	82.3	29	Peking University	83.0
30	University of California, Berkeley (UCB)	80.8	30	The University of Tokyo	82.0	30	The University of Tokyo	82.8
31 =	Australian National University (ANU)	80.0	30 =	McGill University	82.0	30 =	Johns Hopkins University	82.8
31 =	King's College London (KCL)	80.0	32	Kyoto University	80.8	32 =	Kyoto University	81.6
31 =	McGill University	80.0	32 =	Northwestern University	80.8	33	Northwestern University	81.1
34	Fudan University	79.9	34	Duke University	80.0	34	Australian National University (ANU)	80.4
35	New York University (NYU)	79.4	35	Seoul National University (SNU)	79.9	35	Duke University	80.2
36	University of California, Los Angeles (UCLA)	79.2	36	Fudan University	79.8	36	Seoul National University (SNU)	80.1
37	Seoul National University (SNU)	79.0	37	Université PSL (Paris Sciences & Lettres)	79.4	37	The University of Melbourne	80.0
38	Kyoto University	78.9	38	Australian National University (ANU)	79.0	38	Fudan University	79.9

Table 6 (continued)

QS 2021 using Eq. 1			QS 2021 using Eq. 2			QS 2021 using Eq. 3		
Rank	Institution name	Score	Rank	Institution name	Score	Rank	Institution name	Score
39	KAIST—Korea Advanced Institute of Science and Technology	78.6	39	University of British Columbia	78.4	39	The University of Sydney	79.4
40	The University of Sydney	77.1	40	The University of Melbourne	77.8	40	Université PSL (Paris Sciences & Lettres)	79.1

the performance of the top 100 institutions (listed in Publons.com site) using our suggested indicator (T_{VRS}/N_R) shows that only 21 universities are listed in the QS top 100 university list. This observation concludes that although the QS top 100 universities are active in publishing high-quality articles, they are less active in reviewing of manuscripts for publications.

We do believe that the journal articles reviewing activity process is a good indicator of the research potential and research contribution of a university. It can be alluded that the reluctance of researchers to review scientific articles is one of the reasons that may lead to the publication of poor quality papers.

For more focus on the contribution of the universities in reviewing efforts, the values of the reviewing term (T_{VRS}/N_R) for the 1500 institutions (listed in Publons.com site) are calculated and normalized. Figure 3 presents the normalized (T_{VRS}/N_R) for the University of Porto (which takes the highest score of 100%, based on data of Publons.com) in addition to 18 universities, listed in QS ranking.

It is clear that the QS top 5 universities (MIT, Stanford, Harvard, California Institute of Technology and Oxford) have limited scores in the reviewing sub-indicator, as compared to Porto University (which is not listed in QS top 100 universities). From the QS top 100 Universities, Queensland University shows the highest score, followed by McGill University, whereas the lowest score is shown by Paris Sciences and Lettres University, with score of 1% (not included in Fig. 3).

It is worth mentioning that Publons reviewing data covers reviews in journals indexing in WoS, Scopus and also journals not indexed by these two citation data bases. Therefore, if QS ranking makers are satisfied with our approach, they may filter the reviewing data to only the reviews of Scopus journals.

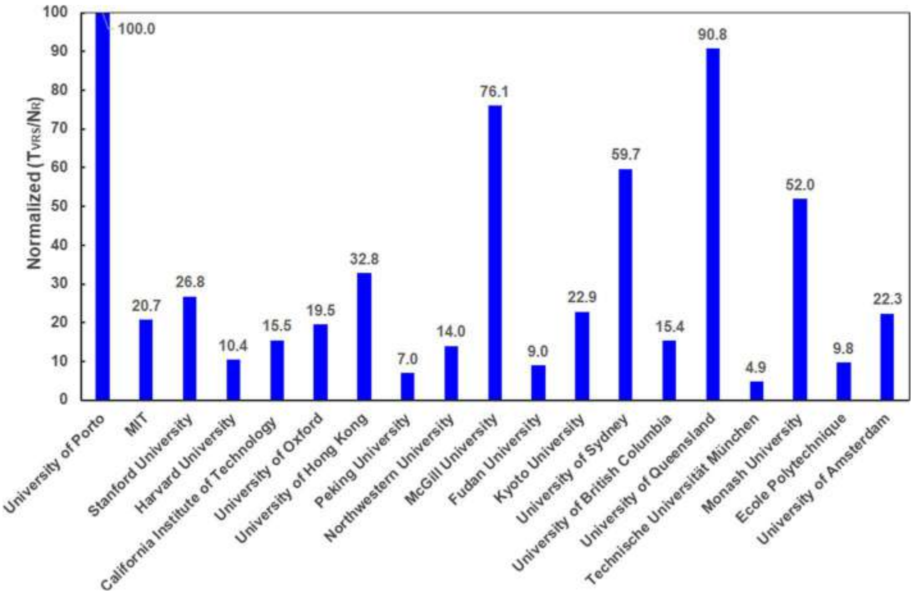

Fig. 3 Normalized reviewing indicator for Porto University and 17 Universities listed in QS top 100 ranking Universities

Conclusion

In this article, we study the effect of implementing the research indicator equation of AM (2021) on the rank of the top 100 universities of QS ranking. This equation accounts for four variables, whereas the QS research indicator considers only two. Results of this implementation reveal an apparent change in the rank of the 100 universities. The rank of 92 universities change. In this work also, we modify the previously proposed equation by adding a new variable that represents the reviewing activity based on information extracted from Publons site. Detailed analysis reveals that most of the top 100 universities have low level of reviewing contribution. This modification causes a significant variation (the change reaches 98%) in the rank of the top 100 universities. We believe that the proposed additions will add fairness and are reasonable, as these may result in the publication of high quality articles.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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On the credibility of QS and THE ranking by subject area: misalignment of subject mapping to academic disciplines

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Abstract

In this study, we point the attention to some inaccuracies in the mapping between the journal subject classification by Elsevier and the narrow subject field used by QS (Quacquarelli Symonds) and THE (Times Higher Education) in their World University Rankings by subject. We noticed that inaccuracies in this mapping will result in classifying some publications under far disciplines, rendering the announced subject ranking inaccurate. To give an example of these inaccuracies, publications on fuel technology, nuclear engineering, and all energy-related studies are classified under Civil Engineering in THE ranking and under Electrical and Electronics Engineering under the QS ranking. This is completely unfair as many of these studies are conducted by researchers in Mechanical or Chemical engineering disciplines. To demonstrate the effect of this erroneous mapping on the final ranking, we obtained the publications data for 13 institutions from the top 20 institutions in the Arab World from 2017 to 021 and their citations until mid-2022 as indexed in Scopus. Following QS and THE subject ranking methodology, we then re-ranked these institutions based on citations per paper and h-index indicators based on a modified subject mapping suggested by a sample of 12 faculty members from 6 different engineering departments at the authors' institution. We found that the new ranking differed considerably from the one calculated by QS and THE based on their controversial subject mapping. Many institutions (sometimes 10 out of 13) had their rank change in some subject areas with the rank of some institutions dropping 6 ranks out of 13 in some cases! We believe this study sheds light on the inaccuracies in subject rankings and the importance of coming up with a unified subject mapping to be used by the different ranking bodies.

Keywords QS subject ranking · THE subject ranking · University ranking · Arab world · Subject mapping

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Introduction

University rankings affect many aspects of higher education from students' choice of which university to join to employment opportunities after graduation. The first global university ranking was published in 2003 by Shanghai Jiao Tong University (SJTU) in China under the name Academic Ranking of World Universities (ARWU) (Carnegie, 2023). This ranking system was originally intended to help compare Chinese universities with international counterparts and was later adopted by many countries for the same purpose. Currently, there are about 18 global university ranking systems published by many institutions and organizations worldwide with many additional specialized rankings based on field, subject, region, and university age (Osareh et al., 2023). The most famous of these rankings are the ARWU which is currently published by Shanghai Ranking Consultancy instead of SJTU, QS World University Ranking published by Quacquarelli Symonds, and Times Higher Education World University Ranking compiled by UK Times Higher Education (THE). QS and THE rankings were the same ranking until 2010 when THE created its own new ranking criteria in partnership with Thomson Reuters (Mroz, 2009).

Now, after 20 years of its inception, university rankings have become an integral part of the realm of higher education with impacts on all its components. The most obvious impact is on students' choice of which university to join. Many studies have shown that students rely on university rankings to refine and narrow down their choices (Hazelkorn, 2008; Obermeit, 2012; Wut et al., 2022). Another impact of the university rank is on employment opportunities. A highly ranked university means better employment opportunities for its graduates. A study in 2007 reported that some US law firms use the US News World Ranking to determine the threshold for the graduates they want to interview (Espeland & Sauder, 2007).

Another implication of the rank of a university is its ability to attract top faculty and to secure funding from governments, the industry, or philanthropists (Hazelkorn, 2008). For example, the Japanese government announced, in March 2023, a national endowment fund for research worth US$ 75 billion which will be accessible to a group of universities in Japan to be able to compete with their US competitors ('Elite university' strategies might boost profile & rankings—but at what cost, 2023). Also, in the UK, two-thirds of the quality-related (QR) public funding is directed to the Russell Group which comprises 24 research-intensive universities ('Elite university' strategies might boost profile & rankings — but at what cost, 2023). Another example is the recent International Faculty Program announced by the Ministry of Education in the United Arab Emirates in 2023. This program aims to attract faculty from the top 10 Universities worldwide according to QS ranking to co-teach online courses in UAE universities (International Faculty Program, 2023). Besides government funding, industries prefer to collaborate with and fund research projects in top-ranking institutions. A report released by THE indicated that universities in the top 200 institutions attract an average of $36,000 per staff member compared to $5,000 per staff member for universities ranking 801 and above (Consultancy, 2020).

There is also evidence that government officials and policymakers use university rankings to guide their decisions. For example, the Malaysian government established a special Inquiry Commission to investigate why the rank of its two top universities fell by 100 positions in one year (Hazelkorn, 2008). Another example is the decision by the Brazilian government to direct their national scholarship program, Science Without Borders, to send students to top universities according to the QS and THE university rankings (Hazelkorn, 2008).

Knowing that the strengths of different programs within the same university may differ greatly, ranking bodies started releasing new rankings according to each discipline. This was driven by the need to help prospective students identify the top institutions in their chosen fields. These rankings include Global Ranking of Academic Subjects by Shanghai Ranking Consultancy, QS World University Rankings by Subject by Quacquarelli Symonds, and World University Rankings by Subject which is published by Times Higher Education. These rankings divide academic disciplines into a few broad categories with multiple degree programs under each category, this classification is shown in Table 1. However, they all use the number of publications generated by the institution and the number of citations these publications receive as part of the criteria to assess the institution's research capacity (Osareh et al., 2023). For example, QS ranking assigns 15% weight to the number of research citations per paper and 15% weight to the h-index of an institution (https://support.qs.com/hc/en-gb/articles/4410488025106-QS-Subject-Rankings), Table 2. On the other hand, THE assigns 29% weight to the research environment and 27.5% to research quality. These two broad categories are partially based on the quantity and quality of both the publications produced by the institution and the citations these publications receive. The portion of the weight based on publications and citations is divided among the following sub-categories:

- Research productivity, which is based on the number of publications in academic journals per scholar, scaled for institutional size and normalized for subjects,
- Citation impact, which is the average number of times a university's published work is cited by scholars globally
- Research strength, which is based on the 75th percentile of field-weighted citation impact,
- Research excellence, which looks into the number of research publications in the top 10 percent for field-weighted citation impact worldwide,
- Research influence, which takes into account the quality of citing papers (i.e. a citation from an "important" paper is more significant than a citation from an "unimportant" one, as THE states on their website).

The weight of each of these subcategories differs from one subject ranking to another (i.e. the weights in the ranking of Engineering and Technology are different from the weights in the ranking of Education) and is not clearly published by THE on their website. It is listed only for the World University ranking (https://www.timeshighereducation.com/world-university-rankings/world-university-rankings-2024-methodology), not the university ranking by Subject. For each indicator in ARWU subject ranking, institutions are calculated as a percentage of the top-scored institution, then the square root of the percentage is multiplied by the allocated weight. The final score is obtained by adding the score of each indicator, and universities are ranked in descending order. For QS and THE subject rankings, the weight of each indicator was obtained from the following two webpages: https://support.qs.com/hc/en-gb/articles/4410488025106-QS-Subject-Rankings, and https://www.timeshighereducation.com/world-university-rankings-2024-subject-engineering-methodology, respectively.

A main challenge that arises during the assessment of the research outcome based on the number of publications and citations for subject ranking is the mapping of institution publications to the different subject fields. For example, for a publication reporting a new design of the intake duct in an internal combustion engine to achieve better air/fuel mixing and, therefore, better combustion efficiency, should this publication be counted under mechanical engineering, chemical engineering, or both? Each one of the three most famous rankings, QS, THE, and ARWU, has its own subject mapping between the discipline assigned to

Table 1 Comparison between the most famous subject rankings published by Shanghai Ranking Consultancy, Quacquarelli Symonds, and Times Higher Education

Global Ranking of Academic Subjects (ARWU)		QS World University Rankings by Subject (QS)		World University Rankings by Subject (THE)	
Broad subject area	Narrow subject area	Broad subject area	Narrow subject area	Broad subject area	Narrow subject area
Engineering	1. Mechanical Engineering 2. Electrical & Electronic Engineering 3. Automation & Control 4. Telecommunication Engineering 5. Instruments Science & Technology 6. Biomedical Engineering 7. Computer Science & Engineering 8. Civil Engineering 9. Chemical Engineering 10. Materials Science & Engineering 11. Nanoscience & Nanotechnology 12. Energy Science & Engineering 13. Environmental Science & Engineering 14. Water Resources 15. Food Science & Technology 16. Biotechnology 17. Aerospace Engineering 18. Marine/Ocean Engineering 19. Transportation Science & Technology 20. Remote Sensing 21. Mining & Mineral Engineering 22. Metallurgical Engineering	Engineering and Technology	1. Computer Science & Information Systems 2. Engineering - Chemical 3. Engineering - Civil & Structural 4. Engineering - Electrical & Electronic 5. Engineering - General 6. Engineering - Mechanical, Aeronautical & Manufacturing 7. Engineering - Mineral & Mining 8. Engineering - Petroleum	Engineering	1. Chemical Engineering 2. Civil Engineering 3. Electrical & Electronic Engineering 4. Mechanical and Aerospace Engineering 5. General Engineering

Table 1 (continued)

Global Ranking of Academic Subjects (ARWU)		QS World University Rankings by Subject (QS)		World University Rankings by Subject (THE)	
Broad subject area	Narrow subject area	Broad subject area	Narrow subject area	Broad subject area	Narrow subject area
Natural sciences	1. Mathematics 2. Physics 3. Chemistry 4. Earth Sciences 5. Geography 6. Ecology 7. Oceanography 8. Atmospheric Science	Natural Sciences	1. Chemistry 2. Earth & Marine Sciences 3. Environmental Sciences 4. Geography 5. Mathematics 6. Materials Science 7. Physics & Astronomy 8. Geology 9. Geophysics	Physical Sciences	1. Mathematics and statistics 2. Physics and astronomy 3. Chemistry 4. Geology, environmental, earth, and marine sciences
Social Sciences	1. Economics 2. Statistics 3. Law 4. Political Sciences 5. Sociology 6. Education 7. Communication 8. Psychology 9. Business Administration 10. Finance 11. Management 12. Public Administration 13. Hospitality & Tourism Management 14. Library & Information Science	Social Sciences and Management	1. Accounting & Finance 2. Anthropology 3. Business & Management Studies 4. Communication & Media Studies 5. Development Studies 6. Economics & Econometrics 7. Education 8. Hospitality & Leisure Management	Social Sciences	1. Communication and media studies 2. Politics and international studies 3. Sociology 4. Geography

Table 1 (continued)

Global Ranking of Academic Subjects (ARWU)		QS World University Rankings by Subject (QS)		World University Rankings by Subject (THE)	
Broad subject area	Narrow subject area	Broad subject area	Narrow subject area	Broad subject area	Narrow subject area
Life Sciences	1. Biological Sciences 2. Human Biological Sciences 3. Agricultural Sciences 4. Veterinary Sciences	Life Science and Medicine	1. Agriculture & Forestry 2. Anatomy & Physiology 3. Biological Sciences 4. Dentistry 5. Medicine 6. Nursing 7. Other Studies & Professions Allied to Medicine 8. Pharmacy & Pharmacology 9. Psychology 10. Veterinary Science	Life Sciences	1. Agriculture and forestry 2. Biological sciences 3. Veterinary science 4. Sport science
Medical Sciences	1. Clinical Medicine 2. Public Health 3. Dentistry & Oral Sciences 4. Nursing 5. Medical Technology 6. Pharmacy & Pharmaceutical Sciences	Arts and Humanities	1. Archaeology 2. Architecture 3. Classics & Ancient History 4. English Language & Literature 5. History 6. Linguistics 7. Performing Arts 8. Philosophy 9. Theology, Divinity & Religious Studies	Arts and Humanities	1. Archaeology 2. Architecture 3. Art, performing arts and design 4. History, Philosophy and Theology 5. Languages, literature, and linguistics

Table 1 (continued)

Global Ranking of Academic Subjects (ARWU)		QS World University Rankings by Subject (QS)		World University Rankings by Subject (THE)	
Broad subject area	Narrow subject area	Broad subject area	Narrow subject area	Broad subject area	Narrow subject area
				Business and economics	1. Business and management 2. Accounting and finance 3. Economics and econometrics
				Education	1. Education 2. Teacher training 3. Academic studies in education
				Law	None
				Computer Science	None
				Clinical and Health	1. Medicine and dentistry 2. Other health
				Psychology	1. Psychology 2. Educational/sport/business/animal psychology 3. Clinical psychology

Table 2 Criteria used for subject ranking by different ranking bodies. If different weights exist for different areas, those for Engineering are shown

Global Ranking of Academic Subjects (ARWU)[a] Data collected from Web of Science and Incites databases		QS World University Rankings by Subject (QS)[a] Data collected from Scopus database		World University Rankings by Subject (THE)[a] Data collected from Scopus database	
Indicator	Weight	Indicator	Weight	Indicator	Weight
Research output (Q1) The research output of the university in the corresponding subject in Q1 journals based on the impact factor	100	Academic reputation	40%	Teaching: • Teaching reputation • Staff-to-student ratio • Doctorate-to-bachelor's ratio • Doctorates-awarded-to-academic-staff ratio • Institutional income	28%
Research influence (CNCI) Category Normalized Citation Impact (CNCI) is the ratio of citations of papers published to the average citations of papers in the same category	100	Employer reputation	30%	Research environment: • Research Reputation • Research income • Research Productivity	29%
International collaboration (IC) The ratio of the number of publications that have been found in at least two different countries in addresses of the authors to the total number of publications in the respective subject for an institution during a 5-year period	20	Research citations per paper	15%	Research quality: • Citation impact • Research strength • Research Excellence • Research influence	27.5%
Research quality (Top) The number of papers published in Top Journals in an Academic Subject for an institution during a 5-year period. Top Journals are nominated by distinguished scholars through an Academic Excellence Survey	100	h-index	15%	International outlook • Proportion of international students • Proportion of international staff • International collaboration	7.5%
International academic awards (Award). The total number of the staff of an institution winning a significant award in an Academic Subject since 1981	100	International research network (by broad faculty area)	5% (applied to specific subjects)	Industry • Income • Patents	8%

any publication by the indexing database (e.g. Scopus) and the subject fields of the ranking system. Needless to say, changes in this mapping scheme can significantly affect the ranking results.

Both QS and THE subject rankings use Scopus database by Elsevier to assess the quality and quantity of an institution's research outcome. Scopus uses the aims and scope of the publication source (e.g. a journal) to assign it a subject field from its list of subject fields termed All Science Journal Classification (ASJC). Then QS and THE use their own mapping between the subject fields assigned to a certain publication under ASJC and the different subject fields in the ranking system. The currently used subject mapping used by QS and THE is shown in Table 3. We noticed a considerable mismatch between some subject fields in Scopus and their mapped QS subjects. For example, publications on fuel technology, nuclear engineering, and all energy-related studies are classified under Civil Engineering in THE ranking and under Electrical and Electronics Engineering under the QS ranking. This contradicts standard academic practices where energy-related studies are heavily studied by researchers in chemical and mechanical engineering departments. Obviously, such a mismatch will result in classifying publications under inaccurate subject fields. Given that the institution's H-index and amount of citations account for 15–40% of the ranking score, according to the discipline,[1] any misclassification of subjects will affect the ranking results considerably.

In this current study, we examined the mapping used by QS and THE ranking to map the publications' ASJC subject field to the closest subject field in the QS and THE systems and pointed out controversial mappings. We also suggest a better classification of these controversially mapped topics. We then went ahead and downloaded the publications and citation data of 13 reputable universities in the Arab world from the SciVAL database, an online tool provided by Elsevier to enable institutions and researchers to assess their performance based on publications indexed in Scopus, and re-ranked them based on our new proposed mapping using QS methodology. We focused on QS and THE university ranking by subject because they are two of the most famous university rankings used by students, policymakers, and funding agencies to decide on the caliber of educational institutions worldwide. Also, the indicator weights of the faculty-area rankings used by QS and THE are published on their website, which allowed us to recalculate the ranking based on the new subject mapping we suggested in our study.[2]

We found that considerable rank changes resulted for many of the 13 examined universities. For some disciplines, the ranks of some universities changed by 6 ranks (out of 13) in some subject fields. We believe our study will shed light on the importance of examining the methods used by different ranking bodies and the need to get involved in designing these methods to transparently reflect the true strengths of each institution.

Methodology

In their published 2024 QS ranking for Engineering and Technology subject area results (the latest available at the time of writing this manuscript), QS assigns 30% of the total weight to the institution's research output through two main ranking criteria items, citations

[1] For each indicator, institutions are calculated as a percentage of the top-scored institution, then the square root of the percentage is multiplied by the allocated weight. The final score is obtained by adding the score of each indicator, and universities are ranked in descending order.

[2] https://support.qs.com/hc/en-gb/articles/4410488025106-QS-Subject-Rankings

Table 3 The mapping of Subjects in bold is controversial and could be assigned to acompletely different field or more than one field

ASJC Code	Publication subject according to Scopus (ASJC—All Science Journal Classification)	QS Subject	THE Subject
1700	Computer Science (all)	Computer Science & Information Systems	Computer Science
1701	Computer Science (miscellaneous)	Computer Science & Information Systems	Computer Science
1702	Artificial Intelligence	Computer Science & Information Systems	Computer Science
1703	**Computational Theory and Mathematics**	**Computer Science & Information Systems**	**Computer Science**
1704	**Computer Graphics and Computer-Aided Design**	**Computer Science & Information Systems**	**Computer Science**
1705	Computer Networks and Communications	Computer Science & Information Systems	Computer Science
1706	Computer Science Applications	Computer Science & Information Systems	Computer Science
1707	**Computer Vision and Pattern Recognition**	**Computer Science & Information Systems**	**Computer Science**
1708	**Hardware and Architecture**	**Computer Science & Information Systems**	**Computer Science**
1709	Human–Computer Interaction	Computer Science & Information Systems	Computer Science
1710	Information Systems	Computer Science & Information Systems	Computer Science
1711	**Signal Processing**	**Computer Science & Information Systems**	**Computer Science**
1712	Software	Computer Science & Information Systems	Computer Science
1802	Information Systems and Management	Computer Science & Information Systems	Mathematics and Statistics
2207	**Control and Systems Engineering**	**Computer Science & Information Systems**	**Electrical and Electronic Engineering**
2614	Theoretical Computer Science	Computer Science & Information Systems	Mathematics and Statistics
1500	Chemical Engineering (all)	Engineering—Chemical	Chemical Engineering
1501	Chemical Engineering (miscellaneous)	Engineering—Chemical	Chemical Engineering
1502	Bioengineering	Engineering—Chemical	Chemical Engineering
1503	Catalysis	Engineering—Chemical	Chemical Engineering
1504	Chemical Health and Safety	Engineering—Chemical	Chemical Engineering
1505	Colloid and Surface Chemistry	Engineering—Chemical	Chemical Engineering
1506	Filtration and Separation	Engineering—Chemical	Chemical Engineering
1507	**Fluid Flow and Transfer Processes**	**Engineering—Chemical**	**Chemical Engineering**
1508	Process Chemistry and Technology	Engineering—Chemical	Chemical Engineering

Table 3 (continued)

ASJC Code	Publication subject according to Scopus (ASJC—All Science Journal Classification)	QS Subject	THE Subject
2205	Civil and Structural Engineering	Engineering—Civil & Structural	Civil engineering
2100	**Energy (all)**	**Engineering—Electrical & Electronic**	**Civil engineering**
2101	**Energy (miscellaneous)**	**Engineering—Electrical & Electronic**	**Civil engineering**
2102	**Energy Engineering and Power Technology**	**Engineering—Electrical & Electronic**	**Civil engineering**
2103	**Fuel Technology**	**Engineering—Electrical & Electronic**	**Civil engineering**
2104	**Nuclear Energy and Engineering**	**Engineering—Electrical & Electronic**	**Civil engineering**
2105	**Renewable Energy, Sustainability and the Environment**	**Engineering—Electrical & Electronic**	**Civil engineering**
2208	Electrical and Electronic Engineering	Engineering—Electrical & Electronic	Electrical and Electronic Engineering
2200	Engineering (all)	Engineering—General	General Engineering
2201	Engineering (miscellaneous)	Engineering—General	General Engineering
2213	Safety, Risk, Reliability and Quality	Engineering—General	Civil Engineering
2202	Aerospace Engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Mechanical and Aerospace Engineering
2203	Automotive Engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Mechanical and Aerospace Engineering
2206	Computational Mechanics	Engineering—Mechanical, Aeronautical & Manufacturing	Mechanical and Aerospace Engineering
2209	Industrial and Manufacturing Engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Mechanical and Aerospace Engineering
2210	Mechanical Engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Mechanical and Aerospace Engineering
2211	Mechanics of Materials	Engineering—Mechanical, Aeronautical & Manufacturing	Mechanical and Aerospace Engineering
1906	Geochemistry and Petrology	Engineering – Mineral & Mining	Geology, Environmental, Earth and Marine Sciences
1907	Geology	Engineering – Mineral & Mining	Geology, Environmental, Earth and Marine Sciences

Table 3 (continued)

ASJC Code	Publication subject according to Scopus (ASJC—All Science Journal Classification)	QS Subject	THE Subject
1908	Geophysics	Engineering – Mineral & Mining	Geology, Environmental, Earth and Marine Sciences
1909	Geotechnical Engineering and Engineering Geology	Engineering – Mineral & Mining	Geology, Environmental, Earth and Marine Sciences
2212	Ocean Engineering	Engineering – Mineral & Mining	General Engineering
2215	**Building and Construction**	**Architecture / Built Environment**	**Civil Engineering**

per paper with a 15% weight and the H-index with a 15% weight as well [https://www.topuniversities.com/subject-rankings]. On the other hand, THE subject ranking assigns 27.5% weight to research quality of which 15% is assigned to citation impact (citations per paper). To assess the credibility and robustness of the QS and THE ranking by subject and ensure the correct mapping of research areas to academic subjects, the work presented here was conducted through the following three steps.

1- **Propose an updated subject mapping:** A group of 12 faculty members from the authors' institution were asked to review the mapping of ASJC subject areas to the QS and THE narrow subject areas provided in Table 3. Faculty members were randomly selected to cover all five subject areas covered in the subject rankings. We sought the opinion of 2 faculty members from each of the following departments: Chemical Engineering, Civil Engineering, Computer Science and Computer Engineering, Electrical Engineering, Industrial Engineering, and Mechanical Engineering. We believe involving a wide range of academic backgrounds and research expertise is essential for coming up with an inclusive and unbiased subject mapping. All faculty members had PhD degrees in their respective fields. Faculty members were asked individually to identify any disagreements with the currently used mapping between ASJC subjects and QS/THE narrow subject fields and to provide a more appropriate subject mapping to the Engineering and Technology narrow subject areas used in the QS and THE subject ranking. All selected faculty had prior knowledge of QS subject ranking, but they did not have prior knowledge of the details of mapping ASJC subjects to QS or THE subject fields. An Excel file with all ASJC subject fields was shared with the selected faculty members and they were individually asked to map these fields to the narrow subject fields used in QS and THE based on their view. No prior knowledge of the QS and THE ranking methodology was required. Reviews of subject mapping were done individually, responses were collected and aggregated by the authors as needed. The new narrow Engineering and Technology subject fields proposed by the surveyed faculty were used in addition to the narrow subject fields currently used by THE and QS. With the given multidisciplinary nature of research nowadays, research areas with no full agreement of the mapping among the respondents were assigned to the top two voted narrow Engineering and Technology subject areas in addition to the existing ones used by QS and THE. Identified subject mapping disagreements with the currently used QS subject mapping are shown in Table 4.
2- **Research data collection:** Research output data for 13 universities in the Middle East region was downloaded through the Elsevier SciVal analytics portal [https://www.scival.com]. Selected universities were: The American University in Cairo (AUC), The American University of Beirut (AUB), the American University of Sharjah (AUS), Jordan University of Science and Technology (JUST), Khalifa University of Science and Technology (KU), King Abdulaziz University (KAZU), King Fahd University of Petroleum and Minerals (KFUPM), King Saud University (KSU), Qatar University (QU), Sultan Qaboos University (SQU), United Arab Emirates University (UAEU), University of Jordan (UoJ), and University of Sharjah (UoS). We focused our analysis on universities in the Arab World as a region that has seen a lot of its universities recently emphasizing the importance of improving their ranking. These selected universities were among the top 20 universities in the Arab region according to QS Arab Region University Rankings 2024 [https://www.topuniversities.com/arab-region-university-rankings]. The downloaded data included research articles, reviews, conference papers, books, book

Table 4 The new Engineering and Technology subject mapping proposed in this study to replace the current QS and THE mapping to Scopus ASJC subjects. For some ASJC subjects, two proposed subject areas were suggested. The second proposed subject for such ASJC ones is listed in the last column

ASJC Code	ASJC Description	QS Subject	THE subject	Additional Proposed Subject Area 1	Additional Proposed Subject Area 2
1111	Soil Science	Agriculture & Forestry	Agriculture and Forestry	Engineering—Civil & Structural	
2215	Building and Construction	Architecture / Built Environment	Civil Engineering	Engineering—Civil & Structural	
3313	Transportation	Architecture / Built Environment	Sociology	Engineering—Civil & Structural	
3322	Urban Studies	Architecture / Built Environment	Sociology	Engineering—Civil & Structural	
2204	Biomedical Engineering	Biological Sciences	General Engineering	Engineering—Electrical & Electronic	Engineering—Chemical
1702	Artificial Intelligence	Computer Science & Information Systems	Computer science	Engineering—Electrical & Electronic	
1703	Computational Theory and Mathematics	Computer Science & Information Systems	Computer science		
1704	Computer Graphics and Computer-Aided Design	Computer Science & Information Systems	Computer science	Engineering—Mechanical, Aeronautical & Manufacturing	
1705	Computer Networks and Communications	Computer Science & Information Systems	Computer science	Engineering—Electrical & Electronic	
1707	Computer Vision and Pattern Recognition	Computer Science & Information Systems	Computer science	Engineering—Electrical & Electronic	
1708	Hardware and Architecture	Computer Science & Information Systems	Computer science	Engineering—Electrical & Electronic	
1709	Human–Computer Interaction	Computer Science & Information Systems	Computer science	Engineering—Electrical & Electronic	
1711	Signal Processing	Computer Science & Information Systems	Computer science	Engineering—Electrical & Electronic	

Table 4 (continued)

ASJC Code	ASJC Description	QS Subject	THE subject	Additional Proposed Subject Area 1	Additional Proposed Subject Area 2
2207	Control and Systems Engineering	Computer Science & Information Systems	Electrical and Electronic engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Engineering—Electrical & Electronic
1909	Geotechnical Engineering and Engineering Geology	Earth & Marine Sciences	Geology, Environmental, Earth and Marine Sciences	Engineering—Civil & Structural	
1507	Fluid Flow and Transfer Processes	Engineering—Chemical	Chemical Engineering	Engineering—Mechanical, Aeronautical & Manufacturing	
2100	Energy (all)	Engineering—Electrical & Electronic	Civil engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Engineering—Chemical
2101	Energy (miscellaneous)	Engineering—Electrical & Electronic	Civil engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Engineering—Chemical
2102	Energy Engineering and Power Technology	Engineering—Electrical & Electronic	Civil engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Engineering—Chemical
2103	Fuel Technology	Engineering—Electrical & Electronic	Civil engineering	Engineering—Chemical	Engineering—Mechanical, Aeronautical & Manufacturing
2104	Nuclear Energy and Engineering	Engineering—Electrical & Electronic	Civil engineering	Engineering—Chemical	Engineering—Mechanical, Aeronautical & Manufacturing
2105	Renewable Energy, Sustainability and the Environment	Engineering—Electrical & Electronic	Civil engineering	Engineering—Mechanical, Aeronautical & Manufacturing	Engineering—Chemical
2305	Environmental Engineering	Environmental Sciences	Geology, Environmental, Earth and Marine Sciences	Engineering—Civil & Structural	Engineering—Chemical

Table 4 (continued)

ASJC Code	ASJC Description	QS Subject	THE subject	Additional Proposed Subject Area 1	Additional Proposed Subject Area 2
2312	Water Science and Technology	Environmental Sciences	Geology, Environmental, Earth and Marine Sciences	Engineering—Civil & Structural	Engineering—Chemical
2611	Modeling and Simulation	Mathematics	Mathematics and Statistics	Engineering—General	
2502	Biomaterials	Materials Science	General Engineering	Engineering—Chemical	
2504	Electronic, Optical and Magnetic Materials	Materials Science	General Engineering	Engineering—Electrical & Electronic	
3607	Medical Laboratory Technology	Other Studies & Professions Allied to Medicine	Other Health	Engineering—Electrical & Electronic	
3105	Instrumentation	Physics & Astronomy	Physics and Astronomy	Engineering—Mechanical, Aeronautical & Manufacturing	Engineering—Electrical & Electronic

chapters, articles in-press, business articles, data papers, and reports indexed in Scopus from 2017–2021 and citations to these publications to mid-2022 as indicated by the QS and THE ranking methodology for the 2024 ranking cycle [https://www.elsevier.com/academic-and-government/qs-university-rankings-data].

3- **Ranking comparison**: Citations per paper and H-index metrics were evaluated for the 13 universities under the currently used QS and THE subject mapping and also according to our new proposed subject mapping which assigns the institution publications and citations to the new proposed narrow subject fields in addition to the existing subject fields used by QS and THE. For QS ranking, an overall research score with weights of 15% to citations per paper and 15% to H-index was calculated and then scaled to 0—100 scale. For THE ranking an overall 0 – 100 score was calculated based on citations per paper reflecting the research contribution of the universities which has a weight of 15% in the THE ranking. Although the new proposed subject mapping will also affect the THE ranking indicators of research productivity, Research strength, Research excellence, and Research influence, we were not able to include these indicators in our ranking because of the complexity of the calculation which requires additional information not available to us (e.g. number of scholars per institution and number of publications in the top 10 percent for field-weighted citation impact worldwide per institution). Universities were then ranked based on the obtained overall research score of 0 – 100 for the QS and THE methodologies.

Results and discussion

Results of our modified mapping scheme

We used our modified subject mapping to rank 13 of the top 20 universities[3] in the Arab world according to the H-index and Citations per paper indicators for QS subject ranking and the citation impact (citations per paper) for THE ranking. The H-index and Citations per paper indicators account for 30% of the total ranking score in the broad subject area Table 5 "Engineering and Technology" for QS ranking methodology whereas the citation impact (citation per paper) account for 15% of the total ranking score for THE ranking methodology. We limited our analysis to the five most common narrow engineering subject areas that exist in most universities and are covered by the ranking agencies, namely: Chemical Engineering, Civil & Structural Engineering, Electrical & Electronic Engineering, Mechanical, Aeronautical & Manufacturing Engineering, and Computer Science & Information Systems. We found substantial differences between the ranks obtained according to our modified subject mapping and those obtained according to QS and THE subject mapping in all subject areas except Computer Science & Information Systems, which had two institutions only swapping their places in the THE ranking, Figs. 1, 2, 3, 4, 5. Detailed results are shown in Tables 5–9 for the five Engineering subject areas. For better readability, results in Figs. 1, 2, 3, 4, 5 and Tables 5–9 are ordered following the institution's current research rank according to QS.

[3] https://www.timeshighereducation.com/world-university-rankings-2024-subject-engineering-methodology

Table 5 Research ranking results for QS, THE, and proposed subject mapping for **Engineering—Mechanical, Aeronautical & Manufacturing** narrow subject area. The ranks that changed are highlighted in orange

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
King Abdulaziz University (KAZU)	1608	70,070	43.58	121	100	1	1608	70,070	43.58	100	1	4063	161,259	39.69	164	100	1	100	1
King Saud University (KSU)	1367	42,425	31.04	93	92.3	2	1367	42,425	31.04	84.6	3	3346	98,435	29.42	128	92.3	2	84.6	3
Qatar University (QU)	882	30,288	34.34	82	84.6	3	882	30,288	34.34	92.3	2	2245	67,088	29.88	106	84.6	3	92.3	2
King Fahd University of Petroleum and Minerals (KFUMP)	1215	35,168	28.94	92	76.9	4	1215	35,168	28.94	69.2	5	3436	87,932	25.59	121	76.9	4	69.2	5
University of Sharjah (UoS)	649	18,999	29.27	69	69.2	5	649	18,999	29.27	76.9	4	1521	43,691	28.73	102	69.2	5	76.9	4
Khalifa University (KU)	1304	30,140	23.11	75	61.5	6	1304	30,140	23.11	53.8	7	2838	65,325	23.02	99	61.5	6	61.5	6
Sultan Qaboos Univ. (SQ)	350	8538	24.39	44	53.8	7	350	8538	24.39	61.5	6	862	19,424	22.53	66	53.8	7	53.8	7

Table 5 (continued)

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
United Arab Emirates University (UAEU)	382	7553	19.77	46	46.2	8	382	7553	19.77	38.5	9	1078	20,242	18.78	65	46.2	8	38.5	9
American University of Sharjah (AUS)	413	8172	19.79	42	38.5	9	413	8172	19.79	46.2	8	691	13,097	18.95	54	46.2	8	46.2	8
Jordan Univ. of Science and Technology (JUST)	330	5397	16.35	39	30.8	10	330	5397	16.35	23.1	11	772	12,906	16.72	52	23.1	11	23.1	11
American University in Cairo (AUC)	212	3572	16.85	29	23.1	11	212	3572	16.85	30.8	10	501	7074	14.12	44	15.4	12	15.4	12
University of Jordan (UoJ)	244	3900	15.98	31	23.1	11	244	3900	15.98	15.4	12	716	12,570	17.56	52	30.8	10	30.8	10
American University of Beirut (AUB)	304	4031	13.26	31	7.7	13	304	4031	13.26	7.7	13	600	8232	13.72	39	7.7	13	7.7	13

Between 2 to 10 institutions (out of a total of 13 institutions) had their rank change in each narrow engineering subject area. In some cases, the institution rank shifted up or down by more than 6 ranks (out of 13) when our modified subject mapping was used. An example is the increase in the rank of the University of Jordan from the 11th position to the 5th position in Electrical and Electronic Engineering according to QS methodology, Fig. 4.

This large relative shift in ranking indicates the sensitivity of the subject ranking to the mapping between the discipline assigned to any publication by the indexing database (e.g. Scopus in this case) and the subject fields of the QS and THE ranking systems. Although the institution's overall ranking may not change as significantly when the weight of other criteria, such as Academic reputation and Employer reputation, are included, proper subject mapping is required to provide an accurate ranking that truly reflects the strength of the institution in each subject. After all, this is the main purpose of the subject ranking.

We believe the reason for this considerable change in the university rank based on our modified mapping is that the current subject mapping used by QS and THE rankings is flawed. Out of the 48 subjects labeled under the Engineering and Technology broad subject area by QS and THE, 28 ASJC subjects are either assigned to an inappropriate subject or should be assigned to more than one subject, Table 4. That's more than 50% of the Engineering subjects. Some obvious errors include assigning "Fuel Technology" to Electrical and Electronic Engineering in the QS ranking and Civil Engineering in the THE ranking, "Nuclear Energy" to Electrical and Electronic Engineering in the QS ranking and Civil Engineering in the THE ranking, and "all energy" research areas to Civil engineering in the THE ranking. Other examples of flawed subject mapping in the QS ranking include assigning "Signal Processing" to Computer Science only without Electrical Engineering, "Building and Construction" to Architecture only without Civil Engineering, and "Renewable Energy" to Electrical Engineering only without Mechanical or Chemical Engineering.

Subject mapping methods

Generally speaking, mapping different subjects to engineering disciplines is a challenging task given the interdisciplinary nature of modern science. Many current scientific disciplines rely heavily on advances in other disciplines. For example, Dentistry is dependent on advances in material sciences, biomedical engineering depends on advances in imaging, signal-processing, and chemical analyses, and renewable energy is dependent on advances in chemistry, and chemical, electrical, and mechanical engineering (Waltman et al., 2014). A recent study showed that 40–70% of the research in biomedical sciences at John Hopkins University in 2017–2018 was interdisciplinary in nature (Weston et al., 2020). Similarly, a study conducted on researchers from Slovenia found that Biotechnology was the most interdisciplinary field of science in terms of collaborations on projects or co-authorships on publications (Karlovčec & Mladenić, 2015). Furthermore, most of the new and emerging research areas such as nanotechnology, renewable energy, environmental sciences, and AI, are interdisciplinary in nature.

That being said, finding a proper mapping to classify publications into narrow subject fields is of utmost importance for any University Subject-Ranking system. Currently, deciding the appropriate academic discipline for a certain publication by ranking bodies is done at the journal level. This means that the subject field of the journal in which an article is published determines the academic discipline this article will be classified under by scientific databases and, consequently, by the ranking body. As you may expect, this is not the

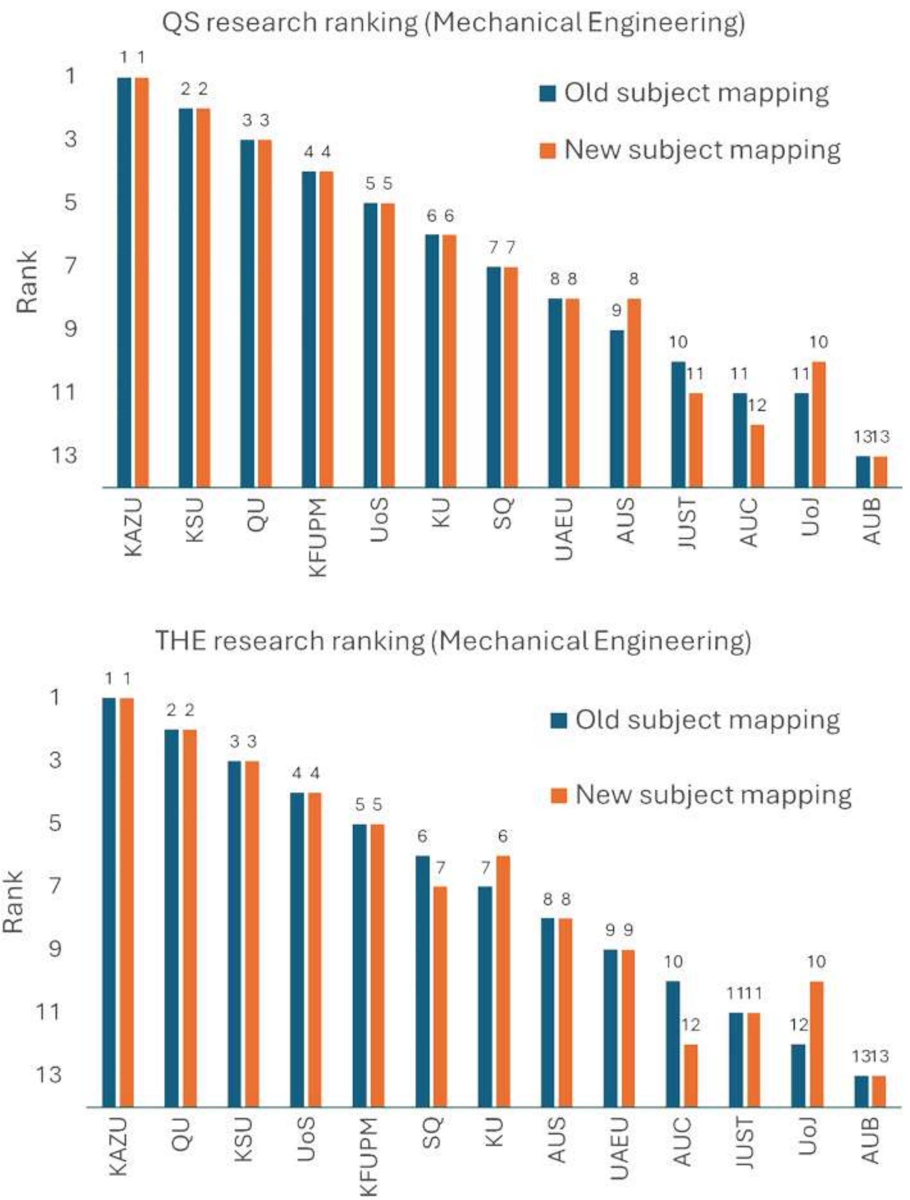

Fig. 1 Comparison between the research ranking of the 13 chosen universities according to QS and THE methodologies in Mechanical Engineering using the old subject mapping and the new subject mapping. Table 5 shows the full calculations behind this ranking

optimum classification system since it is not uncommon for journals to publish broad-topic articles outside their narrow subject fields. We will address this point in more detail in the next section.

Scientific databases use their own classification to map publications to distinct subject areas. For example, Scopus uses All Science Journal Classification (ASJC) which divides

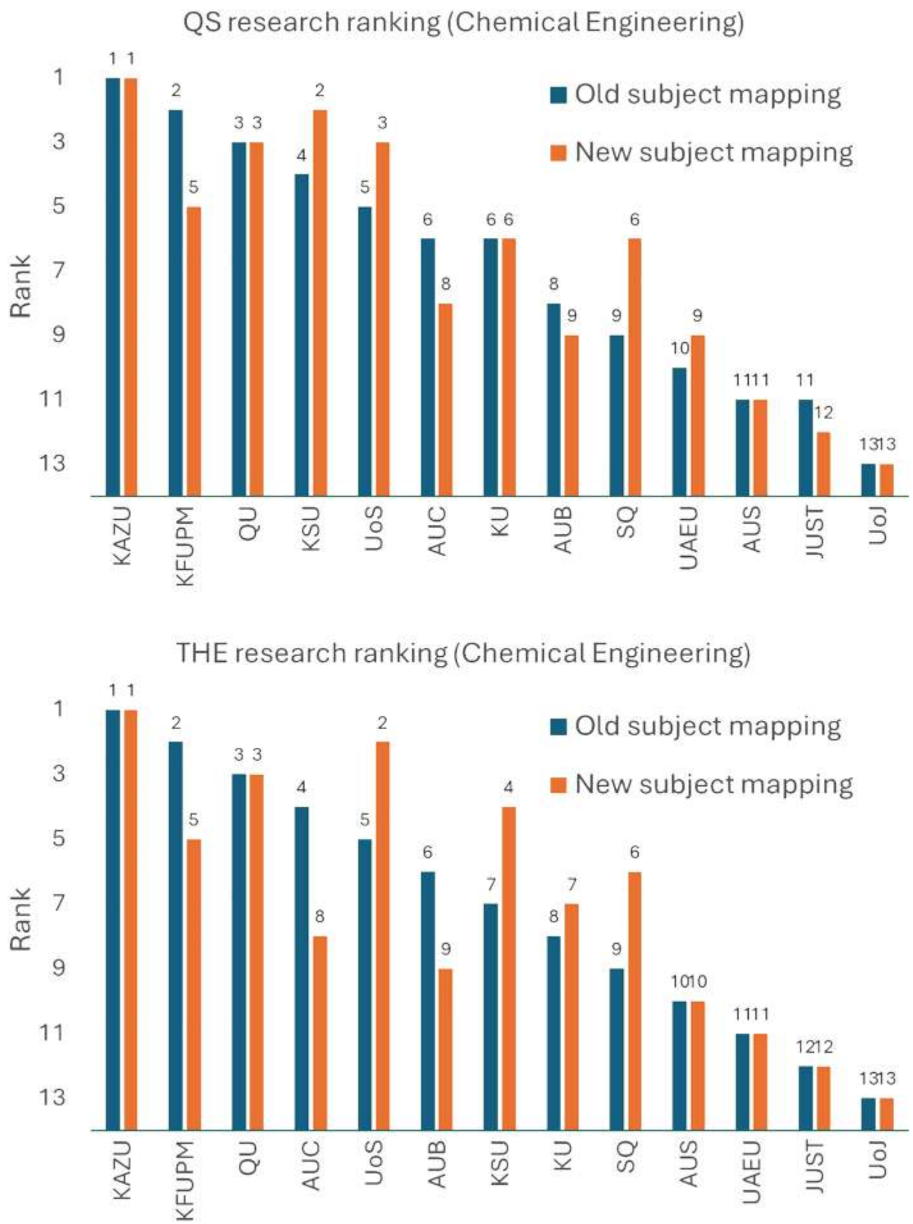

Fig. 2 Comparison between the research ranking of the 13 chosen universities according to QS and THE methodologies in Chemical Engineering using the old subject mapping and the new subject mapping. Table 6 shows the full calculations behind this ranking

the entire spectrum of science into 300 subject fields, whereas Web of Science (WoS) offers two different classification schemes: by category and by research area (Pranckutė, 2021). The first comprises 252 categories, based on tASCA (traditional ASCA—American School Counselor Association) whereas the second comprises 150 categories only.

Table 6 Research ranking results for QS, THE, and proposed subject mapping for **Engineering—Chemical** narrow subject area. The ranks that changed are highlighted in orange

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
King Abdulaziz University (KAZU)	2461	111,087	45.14	145	100	1	2461	111,087	45.14	100	1	4504	198,946	44.17	180	100	1	100	1
King Fahd University of Petroleum and Minerals (KFUMP)	1379	50,888	36.9	99	92.3	2	1379	50,888	36.9	92.3	2	3309	104,758	31.66	128	69.2	5	69.2	5
Qatar University (QU)	924	33,791	36.57	86	84.6	3	924	33,791	36.57	84.6	3	2190	73,129	33.39	109	84.6	3	84.6	3
King Saud University (KSU)	2677	83,089	31.04	111	76.9	4	2677	83,089	31.04	53.8	7	4753	151,429	31.86	144	92.3	2	76.9	4
University of Sharjah (UoS)	365	12,209	33.45	58	69.2	5	365	12,209	33.45	69.2	5	1158	45,531	39.32	106	84.6	3	92.3	2
American University in Cairo (AUC)	190	6641	34.95	49	61.5	6	190	6641	34.95	76.9	4	458	10,763	23.5	56	46.2	8	46.2	8
Khalifa University (KU)	984	29,776	30.26	77	61.5	6	984	29,776	30.26	46.2	8	2447	66,094	27.01	100	61.5	6	53.8	7

Table 6 (continued)

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
American University of Beirut (AUB)	171	5392	31.53	37	46.2	8	171	5392	31.53	61.5	6	547	12,547	22.94	53	38.5	9	38.5	9
Sultan Qaboos Univ. (SQ)	344	10,042	29.19	53	38.5	9	344	10,042	29.19	38.5	9	930	26,450	28.44	77	61.5	6	61.5	6
United Arab Emirates University (UAEU)	423	11,539	27.28	55	30.8	10	423	11,539	27.28	23.1	11	1103	24,219	21.96	67	38.5	9	23.1	11
American University of Sharjah (AUS)	137	3757	27.42	29	23.1	11	137	3757	27.42	30.8	10	461	10,284	22.31	53	23.1	11	30.8	10
Jordan Univ. of Science and Technology (JUST)	173	4008	23.17	32	23.1	11	173	4008	23.17	15.4	12	524	10,370	19.79	50	15.4	12	15.4	12
University of Jordan (UoJ)	261	4685	17.95	32	7.7	13	261	4685	17.95	7.7	13	653	10,785	16.52	46	7.7	13	7.7	13

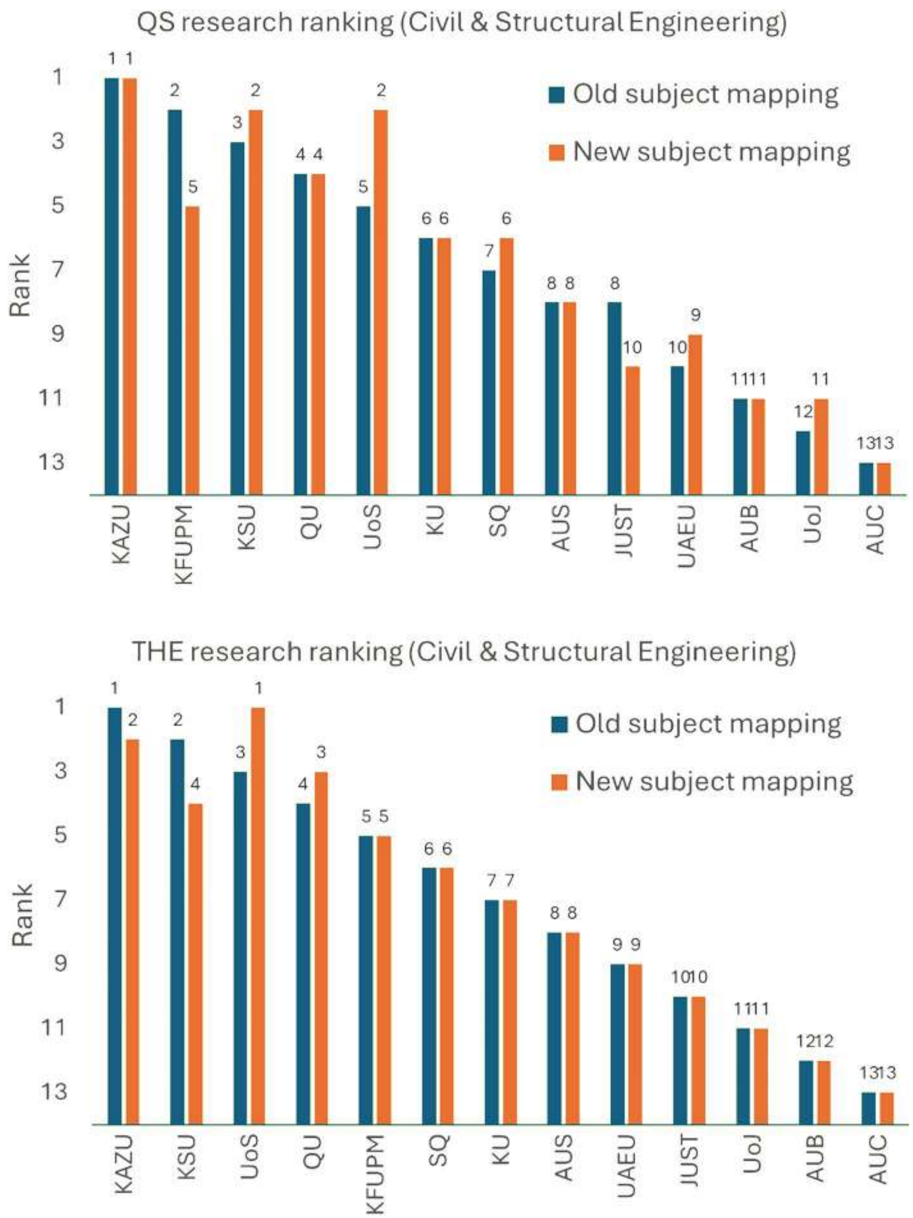

Fig. 3 Comparison between the research ranking of the 13 chosen universities according to QS and THE methodologies in Civil and Structural Engineering using the old subject mapping and the new subject mapping. Table 7 shows the full calculations behind this ranking

Although these classifications themselves are not perfect and had many concerns raised about them (Thelwall & Pinfield, 2024; Wang & Waltman, 2016), we focus our attention here on the mapping used by ranking bodies to assign each of the subjects in the ASJC to different subjects in the ranking system.

Table 7 Research ranking results for QS, THE, and proposed subject mapping for **Engineering—Civil & Structural** narrow subject area. The ranks that changed are highlighted in orange

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
King Abdulaziz University (KAZU)	361	14,459	40.05	69	100	1	1897	77,618	40.92	100	1	1102	39,392	35.75	98	100	1	92.3	2
King Fahd University of Petroleum and Minerals (KFUMP)	398	13,352	33.55	63	92.3	2	2493	69,553	27.9	69.2	5	1170	33,100	28.29	83	69.2	5	69.2	5
King Saud University (KSU)	291	9791	33.65	50	84.6	3	1684	53,662	31.87	92.3	2	1168	37,376	32	91	92.3	2	76.9	4
Qatar University (QU)	352	11,690	33.21	52	76.9	4	1598	45,890	28.72	76.9	4	880	30,775	34.97	76	76.9	4	84.6	3
University of Sharjah (UoS)	245	6131	25.02	40	69.2	5	1022	31,715	31.03	84.6	3	477	18,947	39.72	74	92.3	2	100	1
Khalifa University (KU)	260	5589	21.5	41	61.5	6	1697	39,541	23.3	53.8	7	826	21,196	25.66	68	61.5	6	53.8	7
Sultan Qaboos Univ. (SQ)	93	2367	25.45	28	53.8	7	532	12,946	24.33	61.5	6	482	13,494	28	57	61.5	6	61.5	6

Table 7 (continued)

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
American University of Sharjah (AUS)	187	3989	21.33	34	46.2	8	456	8774	19.24	46.2	8	339	8105	23.91	49	46.2	8	46.2	8
Jordan Univ. of Science and Technology (JUST)	250	4354	17.42	35	46.2	8	634	10,581	16.69	30.8	10	382	6540	17.12	39	30.8	10	30.8	10
United Arab Emirates University (UAEU)	240	3869	16.12	34	30.8	10	778	13,952	17.93	38.5	9	513	9704	18.92	48	38.5	9	38.5	9
American University of Beirut (AUB)	275	2811	10.22	28	23.1	11	595	7285	12.24	15.4	12	504	6356	12.61	36	23.1	11	15.4	12
University of Jordan (UoJ)	154	2149	13.95	22	15.4	12	509	6897	13.55	23.1	11	387	5431	14.03	35	23.1	11	23.1	11
American University in Cairo (AUC)	130	958	7.37	18	7.7	13	391	4303	11.01	7.7	13	239	2297	9.61	26	7.7	13	7.7	13

The mapping used by QS to assign publications in a certain ASJC description to a QS narrow subject area is available for download on the website of SciVAL (https://supportcontent.elsevier.com/RightNow%20Next%20Gen/SciVal/ASJC%20to%20QS%20Sept2023.xlsx). Similarly, the mapping used by THE is also available on SciVAL albeit not with full details (https://service.elsevier.com/app/answers/detail/a_id/21717/supporthub/scival/kw/subject+classification/). We had to contact the customer support of Times Higher Education to get the detailed mapping list of ASJC subjects to the 31 subject fields used by THE. However, we did not find any explanation of the rationale behind the methodology used to map ASJC to QS or THE subject areas. Also, QS and THE customer support were not able to provide meaningful answers to our questions regarding the rationale behind some of the controversial mapping reported in this study. We believe any ranking body such as QS and THE should share with the public the rationale behind their subject mapping classifications, especially for the controversial fields listed in Table 3.

Two good subject mapping classifications that can be useful here are the Field of Research (FoR) classification used by The Australian and New Zealand Standard Research Classification (ANZSRC) and the Fields of Research and Development (FORD) classification prepared by the OECD (Organization for Economic Co-operation and Development). FoR follows a hierarchical methodology where all science fields are classified under Divisions (the broadest level), Groups, and Fields (the finest level) and gives a detailed description of the topics to go under each category. Both classifications map their subject fields to ASJC fields and also directly to all the sources available in Scopus (i.e. journals and conference proceedings). We believe these two classifications can be a good basis for helping ranking bodies map the different ASJC fields into the different engineering disciplines.

Alternative methods to classify publications

There are potentially many alternative methods that can be used to assign publications to narrow subject fields for ranking purposes. However, before we consider these methods, we need to remember that subject rankings aim to assess the performance of academic departments not general research areas. After all, the purpose of the rankings is to help students know the best academic program to join. For example, it is more useful for a prospective undergraduate student to know that a certain university has a strong industrial engineering program, rather than knowing that its researchers produce a lot of publications in Supply Chain Management. The latter could be due to a strong business school rather than a strong industrial engineering program. Putting this in mind, one alternative method is to map publications to the different academic disciplines based on the affiliation of the authors. The advantage of this method is that academic departments with active researchers will stand out and rank high irrespective of the field in which they publish. This will help students see which university has the most active department in a certain discipline (e.g. Civil engineering). On the other hand, mapping publications in interdisciplinary fields, with authors from many departments, can be misleading in this case as not all author contributions are equal.

A second alternative is to use more accurate mapping between ASJC fields by Scopus and the different engineering disciplines. This can be achieved with the aid of existing subject classifications, such as FoR and FORD as described above, or by consulting with existing accreditation organizations like ABET (the American Board of Engineering and Technology) or professional societies like the IEEE (Institute of Electrical and Electronic Engineers), ASME (The American Society of Mechanical Engineers), and the AIChE (The American Institute of Chemical Engineers). For example, the ABET 2025–2026 Criteria

Fig. 4 Comparison between the research ranking of the 13 chosen universities according to QS and THE methodologies in Electrical and Electronic Engineering using the old subject mapping and the new subject mapping. Table 8 shows the full calculations behind this ranking

for Accrediting Engineering Technology Programs include a detailed description of the curricular topics that fall under every engineering discipline in a very comprehensive manner that can rectify many of the deficiencies in the existing QS and THE subject mapping.

Table 8 Research ranking results for QS, THE, and proposed subject mapping for **Engineering—Electrical & Electronic** narrow subject area. The ranks that changed are highlighted in orange

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
King Abdulaziz University (KAZU)	3289	113,563	34.53	138	100	1	2653	70,737	26.66	100	1	6128	212,993	34.76	174	100	1	100	1
King Saud University (KSU)	2828	82,334	29.11	118	92.3	2	2131	52,388	24.58	84.6	3	5568	156,163	28.05	146	92.3	2	92.3	2
Qatar University (QU)	1826	54,795	30.01	96	84.6	3	1280	33,130	25.88	92.3	2	3125	85,450	27.34	111	84.6	3	84.6	3
King Fahd University of Petroleum and Minerals (KFUMP)	2745	71,340	25.99	111	76.9	4	1373	27,377	19.94	76.9	4	3793	94,105	24.81	119	76.9	4	69.2	5
University of Sharjah (UoS)	1210	34,756	28.72	95	69.2	5	989	17,692	17.89	53.8	7	2017	48,681	24.14	101	69.2	5	61.5	6
Sultan Qaboos Univ. (SQ)	566	13,066	23.08	57	61.5	6	346	4594	13.28	15.4	12	1010	19,108	18.92	66	46.2	8	46.2	8
Khalifa University (KU)	2234	51,081	22.87	91	61.5	6	1447	28,332	19.58	69.2	5	3226	70,058	21.72	97	53.8	7	53.8	7

Table 8 (continued)

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
United Arab Emirates University (UAEU)	874	15,564	17.81	57	46.2	8	546	9659	17.69	46.2	8	1436	21,660	15.08	62	30.8	10	15.4	12
American University of Sharjah (AUS)	448	8177	18.25	46	38.5	9	359	5077	14.14	23.1	11	764	11,847	15.51	52	30.8	10	23.1	11
American University of Beirut (AUB)	447	8369	18.72	41	30.8	10	359	6110	17.02	38.5	9	846	13,739	16.24	50	30.8	10	30.8	10
University of Jordan (UoJ)	560	9619	17.18	46	23.1	11	476	9297	19.53	61.5	6	1248	32,691	26.19	78	69.2	5	76.9	4
Jordan Univ. of Science and Technology (JUST)	627	10,401	16.59	50	23.1	11	558	9083	16.28	30.8	10	1339	22,478	16.79	69	46.2	8	38.5	9
American University in Cairo (AUC)	490	5219	10.65	36	7.7	13	345	3103	8.99	7.7	13	773	10,165	13.15	49	7.7	13	7.7	13

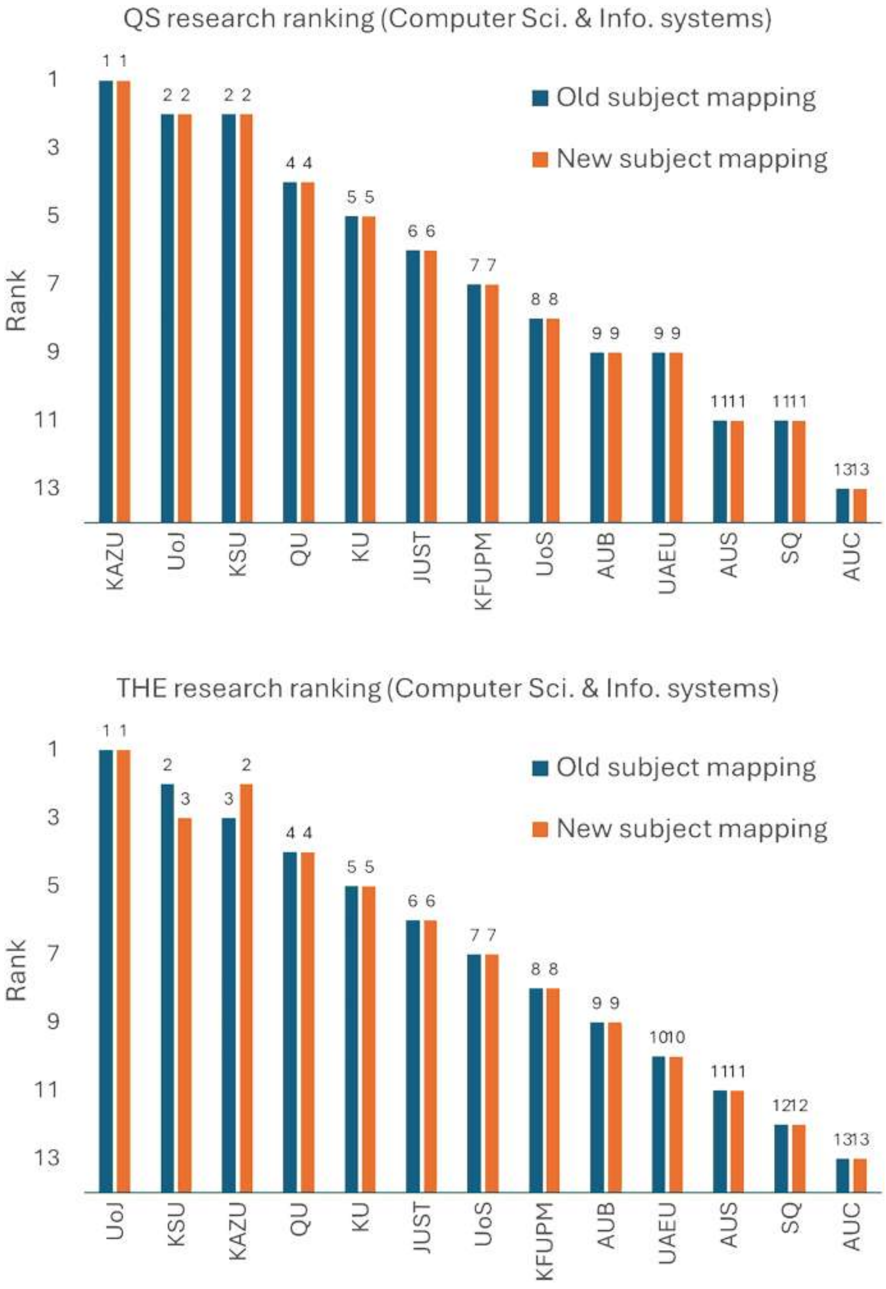

Fig. 5 Comparison between the research ranking of the 13 chosen universities according to QS and THE methodologies in Computer Science and Information systems using the old subject mapping and the new subject mapping. Table 9 shows the full calculations behind this ranking

Table 9 Research ranking results for QS, THE, and proposed subject mapping for **Engineering—Computer Science & Information Systems** narrow subject area. The ranks that changed are highlighted in orange

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
King Abdulaziz University (KAZU)	4777	130,179	27.25	140	100	1	4517	123,321	27.3	84.6	3	4777	130,179	27.25	140	100	1	92.3	2
University of Jordan (UoJ)	1314	39,028	29.7	84	92.3	2	1256	38,678	30.79	100	1	1314	39,028	29.7	84	92.3	2	100	1
King Saud University (KSU)	4209	113,150	26.88	133	92.3	2	4077	111,541	27.36	92.3	2	4209	113,150	26.88	133	92.3	2	84.6	3
Qatar University (QU)	2489	60,774	24.42	100	76.9	4	2311	57,385	24.83	76.9	4	2489	60,774	24.42	100	76.9	4	76.9	4
Khalifa University (KU)	1999	38,205	19.11	81	69.2	5	1803	35,451	19.66	69.2	5	1999	38,205	19.11	81	69.2	5	69.2	5
Jordan Univ. of Science and Technology (JUST)	1187	20,682	17.42	66	61.5	6	1132	19,787	17.48	61.5	6	1187	20,682	17.42	66	61.5	6	61.5	6
King Fahd University of Petroleum and Minerals (KFUMP)	1850	28,799	15.57	71	53.8	7	1724	27,115	15.73	46.2	8	1850	28,799	15.57	71	53.8	7	46.2	8

Table 9 (continued)

University	QS Subject Mapping						THE Subject Mapping					Proposed Subject Mapping							
	Publications	Citations	Citations per Paper	H-index	Score	Rank	Publications	Citations	Citations per Paper	Score	Rank	Publications	Citations	Citations per Paper	H-index	QS Score	QS Rank	THE Score	THE Rank
University of Sharjah (UoS)	1469	23,962	16.31	65	46.2	8	1359	22,933	16.87	53.8	7	1469	23,962	16.31	65	46.2	8	53.8	7
American University of Beirut (AUB)	781	12,048	15.43	51	38.5	9	757	11,778	15.56	38.5	9	781	12,048	15.43	51	38.5	9	38.5	9
United Arab Emirates University (UAEU)	1279	18,896	14.77	58	38.5	9	1193	17,788	14.91	30.8	10	1279	18,896	14.77	58	38.5	9	30.8	10
American University of Sharjah (AUS)	606	7880	13	40	23.1	11	565	7272	12.87	23.1	11	606	7880	13	40	23.1	11	23.1	11
Sultan Qaboos Univ. (SQ)	723	8940	12.37	46	23.1	11	653	8247	12.63	15.4	12	723	8940	12.37	46	23.1	11	15.4	12
American University in Cairo (AUC)	482	4216	8.75	27	7.7	13	463	4081	8.81	7.7	13	482	4216	8.75	27	7.7	13	7.7	13

A last and more comprehensive alternative is to encourage scientific databases to start using the advancement in Machine Learning, Data mining, and Natural Language Processing algorithms to classify publications at the article level instead of the journal level. Natural language understanding algorithms can be trained on existing classified articles and then used to classify any publication under a set of academic disciplines based on its content regardless of the journal it is published in. An effort that is worth mentioning here is the Omniscience research taxonomy created by Elsevier which comprises around 50,000 topics organized across 17 levels to cover all the scientific domains of articles indexed in Scopus. Any other subject classification (e.g. QS, THE…etc.) can be mapped to Omniscience and the same trained models developed by Elsevier data analytics team can be used to classify the output of a certain institution according to this new subject classification. We believe this artificial intelligence-based subject mapping will be more reflective of the actual research productivity of academic institutions in different disciplines.

Conclusion

University ranking by subject is a very useful tool for helping students choose the strongest program to join, helping the industry find the best pool of researchers to collaborate with, and helping policymakers assess the outcome of the country's research and education policies. However, a meaningful university ranking by subject needs an accurate mapping between the subjects of the research output and the different academic disciplines. The current mapping system used by ranking bodies such as QS and THE is defective and contains many controversial mapping between QS and THE narrow subject fields and the AJSC subjects in Scopus. Based on the opinion of 12 faculty members from 6 engineering departments we found improper mapping in the systems used by QS and THE. When we modified the mapping to match the opinions of the 12 consulted faculty members and ranked 13 top universities in the Arab world, we found considerable changes in the rank of many of these universities (up to 10 changes in some disciplines like Electrical and Electronic Engineering). Some universities have their rank increased by 5 ranks out of 13. This is a clear indication of the ranking sensitivity to the used subject mapping.

To present a ranking system that reflects the true capabilities of engineering academic departments in different institutions, we suggest two possible solutions. The first one is to have ranking bodies work closely with existing accreditation organizations like ABET and professional societies like IEEE, ASME, and AIChE to set a unified mapping between the subject fields of different publications and the narrow subject fields of the ranking bodies. Existing science classifications such as FORD by the OECD (Organization for Economic Co-operation and Development) can help guide this new mapping. This unified mapping should be made publicly available and referred to whenever the concerned ranking is mentioned. Ranking bodies that refuse to follow this unified mapping should describe the reasons behind their decision and mention the alternative mapping they used and its rationale. This way, we guarantee that the public is well informed of the basis of each subject ranking, and, more importantly, is aware that university rankings by subject are not absolute and are heavily affected by debatable subject classifications.

The second solution is to use the current advancement in machine learning and natural language processing algorithms to map the institution's research output to the different narrow subject fields on the article level, not the journal level. We believe these two solutions can render university ranking by subject more reflective of the actual strength of different departments in different institutions.

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Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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ORIGINAL ARTICLE

Assessing Institutional Reputation Beyond Quality Rankings

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Abstract
The recent massification and globalization of higher education coupled with the changing trends in global economy have seen a surge in benchmarking and ranking practices at the international level. Quality rankings rely on public information gathered mainly from reputational surveys, some input measures, and indicators of research performance. While all these rankings and related indicators have questionable validity as predictors of effective student learning, they have become highly influential on academic behavior, often encouraging institutions to invest time, resources, and effort in improving their rated reputation and image rather than actually improving their academic standards. At the same time, the quality ranking score significantly impacts reputational surveys; reputation is, therefore, both the outcome and the medium of rankings. Consequently, basing the reputation of a higher education institution on rankings and surveys bears several pitfalls as reputation holds many facets, and it would be simplistic to reduce it to one aspect. Nevertheless, universities have a lot to gain from a good reputation (and a good ranking as a matter of fact) and should, therefore, be able to assess it, monitor it, and even control it. The first purpose of this paper is to demonstrate that reputation is not limited to international rankings and surveys. The second one is to propose a list of indicators that higher education institutions can use to assess their own institutional reputation thoroughly, based on objective metrics. Measuring those "reputational indicators" would help identify areas of improvement and serve as a roadmap for institutions wishing to work on building their reputation, monitoring it, and enhancing it.

Keywords Reputation · Higher Education Institutions · Universities · Auto-Evaluation · Quality rankings · Indicators · Performance · Media visibility · Social engagement · University Social Responsibility

Introduction

Worldwide, higher education systems and institutions have undergone massive reform over the past two decades. With the growing competition for students, international students, researchers, and public funds, higher education institutions are forced to demonstrate more quality and greater performance. Moreover, higher education institutions are now under increased pressure by stakeholders for more transparency, accountability, efficiency in the use of resources, and better graduates' employability (Hemsley-Brown et al. 2016; Lafuente-Ruiz-de-Sabando et al. 2018; Sun & Lim 2023). A significant outcome of this trend has been the implementation of more systematic and formalized quality assurance processes at most institutions with a drive to produce systematic evidence of effectiveness and efficiency (Chalmers 2008).

At the same time, the recent massification and globalization of higher education coupled with the changing trends in global economy have seen a surge in benchmarking and ranking practices at the international level (Harvey Editor 2008; Hazelkorn 2007; Ngoc & Tien 2023). While all these rankings and related indicators have questionable validity as predictors of effective student learning, they have become highly influential on academic behavior, often encouraging institutions to invest time, resources, and effort in improving

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their rated reputation and image rather than actually improving their academic standards (Dill 2007; Lafuente-Ruiz-de-Sabando et al. 2018; Hazelkorn 2007).

In fact, the reputation of any higher education institution is a very subjective and versatile topic. It is influenced by the value of its interaction and connectedness with the external environment and by the stakeholders' perception. At the same time, it is a crucial topic as it is directly linked to international rankings (a quick browse on any search engine is enough to prove that point). Quality rankings mostly base their calculations on the results of reputational surveys of academic peers, students, or industry experts to assess how major stakeholders view the institutions (Marope et al. 2013). *On the one hand, reputational hierarchies are measured by rankings; on the other, rankings influence reputational hierarchies by that very measurement* (Federkeil 2009). Therefore, basing the reputation of an institution on rankings and surveys bears several pitfalls, as reputation holds many facets and it would be simplistic to reduce it to one aspect.

We will start by defining the concept of reputation while emphasizing on its volatility particularly in higher education. We will then demonstrate the role of institutional reputation as a critical competitive advantage. In the second section, quality rankings and the ranking methodology of three of the most prominent ranking media outlets will be presented. The third section will tackle the reliability of reputational surveys in defining an institution's reputation before proposing a list of performance indicators aimed at assisting higher education institutions in evaluating and monitoring their reputation in order to identify areas of improvement based on their priorities and context. The proposed model will be applied on a private university based in Lebanon in the last section.

Literature Review

Institutional Reputation

Defining institutional reputation is difficult, as the concept of reputation is not easily quantified (Amado Mateus & Juarez Acosta, 2022), very subjective and dependent upon individual perspectives. We will, however, retain the following definition of corporate reputation presented by Fombrun in 1996: "*The perceptual representation of past actions and future expectations of a company that describes the firm's overall appeal to all its key constituents when compared with other rivals"* (Miotto et al. 2020). In higher education, an institution that enjoys a good reputation can be one that adequately prepares graduates for the job market, carries out impactful research, fosters critical thinking among its students, and emphasizes civic engagement. It can also be the institution that prepares good top civil servants, who find work easily upon graduation in reputable organizations, educates the future elites of the country, produces many Nobel Prize winners, or that increases the social networking of its students (Pérez-Díaz & Rodríguez 2015). Both descriptions are true and at the same time not enough.

In order to define reputation, one has to consider objective (reflecting the reality) and subjective (reflecting expectations and perceptions) measures. Objective factors are measured with a set of input and output indicators of real performance that are linked to estimations of reputation, such as size, age, financial resources, students/faculty members ratio, academic record of students, distribution of students, publications, graduates' employability, etc. While some of those indicators are taken into consideration in the rankings, they are not enough to build a satisfying notion of an institution's reputation. Subjective factors on the other hand, greatly depend on the type of stakeholder (faculty member, higher education expert, student, employer, etc.) who is giving an opinion, his personal experience, and the extent of his influence on the individuals (Pérez-Díaz & Rodríguez 2015). In all cases, the analysis of corporate reputation measurement methods applied for higher education institutions indicate that there is a lack of a thorough understanding of corporate reputation indicators and factors (Šontaite & Bakanauskas 2011; Manzoor et al. 2021). Moreover, studies on reputation in the higher education sector are relatively recent (Lafuente-Ruiz-de-Sabando et al. 2018) and limited, especially those related to conditions that determine a higher education institution's reputation as perceived by local students or by international ones (Plewa et al. 2016).

The reputation of a higher education institution is a valuable intangible asset. Along with legitimacy, it constitutes a key factor for gaining a sustained competitive advantage (Miotto et al. 2020). Institutions who enjoy a good reputation have easier access to resources since they inspire trust among stakeholders more than their competitors. A positive reputation is, therefore, a strategic resource for building credibility and support among different stakeholders (Miotto et al. 2020). Moreover, reputation is considered as a critical proxy for quality, affecting students' evaluation and selection of the institution they want to attend (Plewa et al. 2016). Data collected from 395 business students studied the role of institutional image and reputation in building customer loyalty and increasing retention. The results indicate that the degree of loyalty has a tendency to be higher when perceptions of both institutional reputation and institutional image are favorable (Nguyen & LeBlanc 2001; Manzoor et al. 2021). Another German study showed that 52% of prospective students select a university because of its high reputation, and it is one of the most common factors in the decision-making process (Federkeil 2009). In a US survey of thousands of high school students each year, four reasons for college choice emerge: image or reputation, location, cost, and availability of a specific major (Larsen 2003). In view of the influence that reputation has on stakeholders, many higher education institutions saw the need to work on building a solid positive image and reputation by assigning more resources to boost their image. However, institutions' intentions and stakeholders' perception do not always converge and there is still little knowledge of key aspects for an effective and efficient management of institutional image and reputation (Lafuente-Ruiz-de-Sabando et al. 2018).

Some researchers have identified the main factors that might contribute to the reputation of higher education institutions; admissions selectivity, intellectual productivity, accomplishments of alumni, quality of faculty members, size of endowment, operating budget, media presence, number of library holdings, peer rankings, leadership quality, etc. (Larsen 2003). However, there is no unanimity and such data is most likely unavailable to most stakeholders involved in reputational surveys. Moreover, other researchers have argued that no conclusive approach for assessing and monitoring the reputation of higher education institutions has found consensus among higher education experts or researchers. Redler & Morschheuser presented three main possible reasons for that: the complexity of defining the concept of reputation as presented above, divergent points of view regarding the most suitable methods of measuring reputation and lack of adaptation of the concept of reputation to the characteristics of the higher education sector (Redler & Morschheuser, Three root causes for the impasse in reputation measurement for higher education institutions, 2024).

Another important factor that influences an institution's reputation is its brand identity and image. Today, in the increasingly competitive and global environment of higher education, institutions are more than even keen on strengthening their brand, developing distinctive identities, understanding stakeholders' perceptions, improving their image, and enhancing their reputation. While studies on branding, image, and reputation and their link to performance are widely used in the business sector, much still needs to be learned about their influence on higher education institutions (Hemsley-Brown et al. 2016).

Quality Rankings

The creation of national and global markets for higher education have created a public demand for information on the performance of higher education institutions and resulted in the establishment of national and global quality rankings and league tables, mostly by media outlets such as THE World University Rankings, QS World University Rankings, Academic Ranking of World Universities by Shanghai Jiao Tong University, US News Education Rankings, etc. (OECD 2017), as well as some Web rankings sites (such as G-factor International University Ranking or Webometrics Ranking of World Universities; Thakur 2007). Although present since the 1990s, quality rankings have recently gained notoriety due to the increasingly competitive landscape in the international higher education marketplace. Moreover, they are believed to provide significant information to a broad list of stakeholders (García-Rodríguez & Gutierrez-Tano, 2024). They inform (1) potential students about their employment opportunities upon graduation, (2) employers about the expected skills of their graduates, (3) the government and policymakers about the contribution of the institution to national strategies and comfort them in their funding decisions (Hazelkorn 2007).

Quality rankings attempt to "grade" higher education institutions according to several indicators deriving from publicly available data published by the institution itself, national performance indicators scores, questionnaires and surveys filled by various stakeholders. While the exact calculation algorithm remains unknown for both the institutions and the stakeholders, the main indicators used to rank institutions focus on teaching and most importantly on research performance, as they are perceived to be the most appropriate proxies to indicate quality (Hazelkorn 2007). We will present the ranking methodology of three of the most prominent ranking media outlets: Quacquarelli Symonds (QS), Times Higher Education (THE) and Shanghai Ranking (the Academic Ranking of World Universities—ARWU; Terry 2021; Olatokun & Ani 2023).

THE World University Rankings assesses around 1,400 institutions worldwide and bases its ranking on performance indicators grouped into five areas: *Teaching* (the learning environment) accounts for 30%; *Research* (volume, income and reputation) accounts for another 30%; *Citations* (research influence) for 30%; *International outlook* (staff, students and research) for 7.5%; and *Industry Income* (knowledge transfer) for 2.5% detailed as following:

- Teaching: Reputation survey 15%, staff-to-student ratio 4.5%, doctorate-to-bachelor's ratio 2.25%, doctorates-awarded-to-academic-staff ratio 6%, and institutional income 2.25%;
- Research: Reputation survey 18%, research income 6%, and research productivity 6%;
- International outlook: Proportion of international students 2.5%, proportion of international staff 2.5%, and international collaboration 2.5% (Times Higher Education, 2019).

QS World University Rankings ranks around 1500 universities yearly according to six metrics: Academic Reputation that accounts for 40%; Employer Reputation 10%; Faculty/Student Ratio 20%; Citations per faculty 20%; International

Faculty Ratio 5%; International Student Ratio 5% (QS Staff 2020).

The Academic Ranking of World Universities (ARWU) has been published and copyrighted by Shanghai Ranking Consultancy since 2009. Although the initial purpose of ARWU was to find the global standing of top Chinese universities, today it ranks more than 1800 universities yearly and publishes the best 1000. It uses six indicators to rank world universities, including the number of alumni and staff winning Nobel Prizes and Fields Medals weighing respectively 10% and 20%, the number of highly cited researchers for 20%, the number of articles published in journals of Nature and Science 20%, the number of articles indexed in Science Citation Index—Expanded and Social Sciences Citation Index 20%, and per capita academic performance of a university for 10% (Terry 2021).

While many in higher education, question the validity of universities rankings, the reality is that rankings do, indeed, have significant impact on institutional behavior (Larsen 2003) and impact the institutions at various levels; they influence students' decisions when selecting an institution, affect political and funding decisions, and in some cases, even impact accreditation decisions. Nevertheless, one of the most important effects of rankings is their impact on the reputation of institutions, both nationally and internationally (Federkeil 2009; Terry 2021).

Many authors argue that global rankings are an opaque, subjective approach of hierarchizing competing higher education institutions that do not take into consideration the local contexts of the institutions. According to the IREG Observatory on Academic Ranking and Excellence, ranking outlets need to "*Recognize the diversity of institutions and take the different missions and goals of institutions into account. Quality measures for research-oriented institutions, for example, are quite different from those that are appropriate for institutions that provide broad access to underserved communities*" (Terry 2021). Many believe it lacks clear and transparent measurement metrics and fails to prompt institutional implication in quality improvement (Hazelkorn 2007; Proulx 2009; Thakur 2007; van Vught & Westerheijden, 2010). Despite the fact that methodology and indicators adopted by existing ranking systems lack transparency, rigor, and remain controversial, they are nonetheless reshaping institutions' strategic planning and national higher education policies and reforms. The US, the UK, Europe, and Japan are competing for an increasingly competitive market for international students and rankings affect the decisions of students. The international league tables attract most of international students even though the basis of the ranking lacks teaching indicators or indicators that truly reflect the quality of teaching (Chalmers et al., 2008). Those reasons are only the tip of the iceberg. Beyond the methodological concerns, the risk of overall homogenizing effects on the academic system may represent the most important problem because world university rankings are deeply influencing institutional practices (Proulx 2009; Collins & Park 2016; Thakur 2007), decision making, and strategy (Hazelkorn 2007). Moreover, many authors argue that those quality rankings always favor the well-established research-intensive higher education institutions who get caught in a virtuous cycle; good rankings engender better reputation which attracts the best researchers, better reviews, and more funds which in turn improves ranking.

Limitation of Reputational Surveys

The largest and most common element of the ranking is a reputation score determined by reputational surveys. Those surveys are questionnaires filled by higher education stakeholders (higher education experts essentially but also faculty members, students, parents, graduates, staff, employers, etc.) to assess an institution's overall impression of excellence or quality. It gathers experts and non-experts' opinions on various topics such as teaching and research quality, perceived standing and image, size, quality of faculty members, infrastructure, governance, visibility, offered services, emotional engagement, etc. (Miotto et al. 2020; Lafuente-Ruiz-de-Sabando et al. 2018). However, those stakeholders are often people who are external to the institution and whose decisions might be influenced by several personal factors. They might also lack a proper global outlook to be able to summarize the strength and weaknesses of a whole institution in a survey, no matter how sharp and pertinent that survey is. Various stakeholders view higher education institutions differently depending on their context and perspective, causing institutions to have multiple images and reputations. Moreover, those stakeholders focus on different qualities when determining higher education institutions' reputation because they have different priorities (Larsen 2003; Thakur 2007; van Vught & Westerheijden, 2010). Therefore, assessing quality and reputation heavily depends on the point of view and different interests of its stakeholders; from the faculty members' perspective, it can be the focus on research to gain a better ranking position, students and their parents look at the graduates' preparation for the labor market, employers base their opinion on how well they find graduates' skills adequate for the job, while governments look at a set of standard performance metrics that relate to the topics of accountability and effective use of public finances.

Objectifying Reputation

For institutions seeking to monitor or improve their reputation (and consequently their ranking), it is crucial to first recognize the impact of their data, second, understand the inner mechanisms of ranking outlets and last but not least, monitor the inputs and outputs that influence reputation. In other words, institutions need to adjust (and control) their practices in a way that will positively influence their reputation. While some criteria can be straightforward, the overall reputation factor can be a lot trickier to impact. Moreover, measuring quality in higher education is multidimensional and rankings should not be the sole reference to assess it (Olcay & Bulu 2017), even less having as main criterion the results of reputational surveys. We believe that several metrics and criteria, including reputational surveys, should be combined to be able to reach a realistic and holistic picture of an institution's reputation.

According to a study done on 70 articles published in 40 journals up until 2015, there are four main knowledge gaps associated with university image, reputation and perception. First of all, there is no agreement as to which dimensions encompass higher education image and reputation. Second, it remains unclear how diverse stakeholders perceive differently an institution's image and reputation. Third, there is no unified measurement instrument of reputation that can be applied to all stakeholders, and last, there is still little knowledge about how geographical areas might influence the dimensions of a higher education institution's image and reputation (Lafuente-Ruiz-de-Sabando et al. 2018). What particularly holds our attention is the third point. The mere fact that reputation should be measured differently based on who is measuring, suggests that using a couple of reputational surveys filled by higher education experts or some employers will not actually give it justice. Different stakeholders have different and sometimes conflicting priorities and perceptions of academic reputation, consequently, the valuation of institutional reputation should not be only based on the results of those reputational surveys. The diversity of dimensions related to an institution's reputation have not always been reflected in the measurement methods that are commonly used and there is obviously no unanimity on that subject. Some researchers have considered several dimensions to evaluate the reputation of a given higher education institution—meaning that there is not just one global reputation but diverse reputations based on different dimensions—, while others argue that reputation should be measured using a simpler scale (Miotto et al. 2020).

Methodology

This research paper is part of a larger study aimed at measuring the overall performance of a higher education institution as part of quality efforts, based on performance indicators and covering all aspects of higher education. In this paper, we identify six areas that mostly influence reputation and we propose a list of direct and indirect indicators suggested along with their calculation method(s), that aim to measure and monitor an institution's reputation in an objective approach. While the suggested indicators might be mostly indirect, they are also mutually beneficial and can create a snowball effect; when students or employers are satisfied, it is safe to say that the institution produces a valuable workforce and that its educational level is satisfactory which reflects positively on reputation. When the institution is active within its community, it probably builds a positive public perception and creates good reputation. In other terms, we propose meaningful (direct and indirect) performance indicators that should *provide mutually reinforcing measures that only together provide an accurate picture* (Ewell & Jones 1996).

The six dimensions selected for this study; employability of graduates, social engagement, external partnerships, alumni impact, social/economic impact, and media visibility were chosen for their comprehensive representation of institutional reputation in higher education. These dimensions were identified through an extensive literature review and aligned with the mission, strategic priorities, and operational realities of higher education institutions. They represent both direct measures (such as employment rates, alumni engagement) and indirect measures (public perception, social impact) to provide a holistic evaluation framework, away from traditional reputation surveys.

This qualitative study proposes 43 indicators, defined and explained, each tailored to capture unique facets of the six reputational dimensions. These indicators, derived from a synthesis of academic literature, benchmarking studies, and best practices within the sector, are to be used by higher education institutions to monitor their reputation whether for self-assessment/internal improvement or to prepare for quality rankings and reputational surveys. They were designed to balance measurability and relevance, ensuring their applicability across diverse institutional contexts.

A case study on a higher education institution, based in Lebanon, will follow the presentation of the indicators as an application to the method.

The first step of the method is to select a panoply of performance indicators that best define the institution's motivation out of the proposed list in this paper. The choice and number of indicators would be based on the institution's priorities, objectives, mission, profile, size or needs. The purpose is to answer the following backward and forward-focused questions:

(1) What actions can we take to enhance our reputation/How did we perform on these actions during a given period?
(2) What actions should we undertake to obtain the desired results during the following period?

Those questions imply that one not only needs to know today's reputation, strengths and weaknesses, but also be able to "evaluate" tomorrow's reputation by predicting the impact of specific actions taken today. ***The second step*** is to calculate the selected indicators over a predefined period of time. ***The third step*** is to compare the results with a predefined objective or target. The target can be a historical value, a benchmark (if available) or an average of previous results. The ultimate purpose would be to identify the gaps between intended values and attained ones in order to take the necessary corrective actions and create a continuous improvement cycle.

As reputation is the result of a complex combination of interdependent and complementary factors, meaning that one resource can positively or negatively influence other ones, higher education institutions should, therefore, aim at building mutually reinforcing resources that contribute to their reputation. Consequently, the value of a higher education institution's reputation would rationally need to be demonstrated through various interrelated and complementary dimensions. As an example, excellent faculty members complement an institution's physical resources and they both create an improved student experience and contribute to the overall institutional reputation (Plewa et al. 2016; Baig & Yadegaridehkordi 2024).

This study proposes a multidimensional method to value and monitor an institution's reputation using multiple interconnected performance indicators. Efforts done to improve those indicators would result in an improved overall reputation. Institutions aiming at improving their international ranking would also be able to identify which indicators should be closely monitored and adjusted to positively influence their reputation and consequently improve their ranking.

Novelty of the Study

While numerous researchers have developed methods to assess institutional performance using various indicators, each approach carries certain limitations (Asif & Searcy 2014; Grygoryev & Karapetrovic 2005; Redler & Morschheuser, Somehow bogged down: why current discussions on measuring HEI reputation go round in circles, and possible ways out., 1–25). Many focused on only one aspect of higher education (such as research or finance) or were designed to address specific issues or generate decision alternatives among options under evaluation. Additionally, none have specifically tackled the challenge of assessing institutional reputation through an approach other than a reputation survey. This paper introduces 43 indicators across six reputational dimensions unique to higher education. Moreover, it is the first to incorporate media visibility as a dimension within the higher education sector. A previous work by Asif and Searcy (Asif & Searcy 2014) on creating a composite index for measuring performance in higher education institutions outlined the requirements for developing performance indicators that effectively evaluate overall institutional performance. However, their study lacked indicators explicitly tailored to assess reputation, focusing instead on general sectorial indicators related to teaching, research, and finance. Similarly, other studies, such as the one conducted by Chen et al. (2015) included "School reputation" and customer satisfaction as their only dimensions related to reputation, without providing the breadth and objectivity our study seeks.

Consequently, this proposed study addresses all dimensions of higher education reputation, with the dual purpose of assessing institutional reputation and offering a structured approach for institutions to achieve, enhance and monitor their reputation.

Another study that further confirmed the need and value of the proposed approach in this article is the literature review done by Lafuente-Ruiz-de-Sabando et al. (2018). Their research provided a comprehensive review of literature on higher education institutions' image and reputation, aiming to identify knowledge gaps and future research directions. Key findings suggested that there is little consensus on the specific dimensions that define university image and reputation. The review highlighted four main gaps: lack of agreement on image dimensions, limited understanding of varying stakeholder perspectives, absence of a universal measurement tool, and limited research on cultural or geographic influences on image perception. The authors recommended that further research should focus on creating standardized measurement tools and exploring cross-cultural differences to aid higher education institutions in better managing their public perception and reputation. Another analysis examined the stagnation in measuring the reputation of higher education institutions, arguing that existing frameworks adapted from business contexts fail to account for the unique characteristics of higher education, thereby limiting their applicability. The authors, therefore, recommend shifting toward higher education institutions-specific and multidimensional metrics, the integration of innovative methodologies such as data-driven marketing and social listening, and enhanced collaboration with practitioners. They also propose exploring alternative constructs emphasizing the need for a conceptual restart to make research more relevant and actionable for higher education management (Redler & Morschheuser, Somehow bogged down: why current discussions on measuring HEI reputation go round in circles, and possible ways out., 1–25), further confirming the relevance and significance of the proposed study.

List of Reputation Indicators

In the list, each indicator is explained along with its calculation and possible variation. The variation column specifies a different grouping method. It can be by institution, subject area, degree level, faculty, department, etc. depending on the need of the institution, its size, as well as the meaning and scope given to the indicator.

We have identified six areas that mostly influence the reputation of a higher education institution:

- *The employability of graduates*. Employment or rather unemployment rates are a measure (and a result) of the reputation of a higher education institution because of the underpinning idea that graduates from reputable institutions are more or less "employable". Though the chance of being unemployed would be affected by a number of other factors (such as the state of the local labor markets, the attractiveness of the subject discipline, age, gender, ethnicity, student's personality, etc.), there is evidence that the reputation of an institution is a major consideration for many employers in their graduate recruitment although it may be based on the learning and teaching ten or more years earlier (Pollard, et al., 2015). While it is an indicator already used in some universities' rankings, it was important to keep it as an important quantitative dimension in assessing an institution's reputation. Higher education institutions with a high students' employability rate inevitably evoke high standards of teaching that meet the market needs and instigate a good reputation.
- *The institution's social engagement*. Considering that higher education institutions are an important pillar of society their social dimension plays an important role in defining their reputation. Higher education institutions are now expected to help their respective local communities through funding activities and facilities to achieve sustainability. Nowadays higher education institutions' mission is more about training for various vocations in order to have social relevance than about simply issuing diplomas; more about helping students find their sense of direction and think beyond individual interest (Vasilescu et al., 2010); more about influencing students' character and morals and building their social foundations. Institutions that demonstrate social engagement are able to positively influence the public opinion. Many institutions have increasingly allocated resources and attention towards student development in areas such as personal and social responsibility, moral formation, service leading and responsible judgment.
- *External partnerships*. External partnerships are agreements with other academic/research institutions or with the industry. The interdependent relationship between higher education institutions and companies enables both entities to sustain growth in their areas and benefit the society as well. While companies rely on university researchers for product innovations and employees' recruitment, institutions gain prestige and enhanced reputational image through increased external research funds, access to cutting-edge equipment, curriculum updating and increased graduates' employment possibilities. The number of effective and active partnerships that a higher education institution sustains with the industry implies research quality and relevance as well as the likelihood of having programs' content and learning outcomes that meet the job market needs. As for the term academic partnership, it describes a variable set of experiences among a number of different higher education institutions. It can be between two geographically distanced and culturally diversified institutions, the opposite, or between high-income and low-income countries. Such partnerships contribute endlessly to academic and scientific progress. A higher education institution highly open to international partnerships confers a number of advantages. It demonstrates an ability to attract faculty and students from across the world, which in turn suggests that it possesses a strong international brand. It implies a highly global outlook and provides both students and faculty with a multinational environment, facilitating exchange of best practices and beliefs. Consequently, it provides students with international understandings and global awareness, skills that are increasingly valuable to employers. For domestic students, it offers the opportunity to travel internationally and vice versa for students at partnered Institutions. It also enables institutions to better understand the culture of other nations, thereby facilitating their international marketing success there. International collaboration programs help by providing students with the ability to study, work, and travel in an international capacity. For faculty members, it provides the opportunity to conduct joint research, gain international exposure and gain valuable experience, all of which greatly contributes to an institution's reputation.
- *The alumni*. Creating an engaged, supportive alumni network is crucial to an institution's success and reputation. Good alumni relationships bring many benefits to both the institution and the alumni. As graduates of the institution, alumni have a special connection with their alma mater and as a result are likely to be some of its most loyal supporters and best ambassadors, spreading a positive and constructive image. An engaged alumni network allows the institution to benefit from their skills and experience by offering support to current students, to the institution and to each other while offering invaluable marketing and promotion across their personal and professional networks. Talented alumni probably have a wealth of experience

and skills to share with current students through talks, newsletters and in certain cases, by offering to practically support students in work placements, work shadowing, professional networking opportunities and help them launch their careers. In some cases, alumni are in a position to become international ambassadors to the institution by helping to provide prospective foreign students with real insight into the country and the institution. Moreover, alumni are often generous with fundraising efforts used by the institution to offer scholarships or establish advanced facilities and equipment for teaching and research. Therefore, the extent and value of the alumni's engagement typically reflect on the institution's reputation.

- *The institutions' social and economic impact*. The role of higher education institutions goes far beyond teaching and research. They hold an important social and economic impact by knowledge transfer and the provision of an adequate workforce. Only institutions that provide positive economic, social, and environmental impacts for all stakeholders may be considered well reputed (Miotto et al. 2020). Assessing the social impact of a higher education institution is the process of understanding and evaluating its effect or influence on its human (community), economic, cultural and ecological environments as a result of its activities. It is a very vast concept that encompasses several processes and aspects of an institution's activities. We will, however, limit the scope to assessing the impact of sustainable and economic developments and engagement as they are of great influence on community perception and reputation.
- *Media visibility*. Media visibility is one of the factors that stakeholders use to determine reputation (Plewa et al. 2016), it has a significant influence on public opinion and contributes strongly to building companies' corporate reputation (Capriotti 2007). The perception of an institution's brand image or identity by stakeholders is closely linked to its reputation. Higher education institutions have lately become more and more comfortable with including social media as part of their integrated marketing communication although accusations of a technological lag between higher education and the rest of society can be traced back to the last century (Selwyn 2012). A study on 56 UK universities showed a positive effect following the use of social media on brand performance and student recruitment in higher education especially when an institution attracts a large number of "Likes" on Facebook and a high number of "Followers" on Twitter (Hemsley-Brown et al. 2016). Therefore, a strong (online) presence nowadays is likely to positively influence an institution's reputation. According to another UK study, the main driver for higher education institutions to use social media is the marketisation or promotion of their "brand" as well as the protection of their institutional reputation (McNeill, 2012). Therefore, improving media visibility is yet another way of influencing reputation (Table 1).

Case Study

The above method was applied on a small-size private university based in Lebanon, in order to assess the state of its reputation and be able to come-up with corrective actions accordingly. Since international quality rankings do not apply on that specific university (knowing that Lebanese institutions' place in those rankings is already quite feeble), the focus of the university—according to the university council—was to measure its performance related to two important dimensions: the social engagement of the university and its media visibility. The other dimensions were either inapplicable or not a priority.

For each reputational dimension, the most relevant indicators were selected, calculated, and compared for the following pre-pandemic periods: academic year 2017–2018 and academic year 2018–2019. The results are shown in Table 2.

Table 2 allows the university's management to identify the areas that need improvement, understand the trend of some indicators (output indicators) based on the impact of other indicators (input indicators) and propose corrective actions founded on objective metrics.

In this case study, the university has more than doubled its media budget ratio (input) between academic years 2017–2018 and 2018–2019 which resulted in the increase of two (output) indictors, web traffic and conversion rates. However, there was a clear decrease in two main (output) indicators that mostly affect media visibility; engagement and reach. While sound judgement in business practice would suggest that an increase in the media budget would inevitably generate a growth in all related indicators, the observation of those metrics proves otherwise. Closely examining this situation would help the university understand that its media budget hasn't been used wisely and didn't bring the envisioned benefits. Monitoring those indicators would help the university identify its weakness and take appropriate actions to improve performance in the areas with a negative trend and maintain those that are growing.

On another hand, it seems the university has shifted its budget from social actions to media, as the community service budget ratio has clearly decreased between those two years, nearly cut in half. While most of the selected indicators still show a slight improvement (that is probably due to previous years' efforts paying off), the decline in future social and community actions should be closely monitored

Table 1 List of performance indicators

Performance indicator	Calculation	Variation	Description
Employment			
Students' employability or first destination of graduates	Number of students who find an "adequate" and gainful job within six months from graduation in a related field/Total number of graduating students	Can be calculated by faculty, department or program and for postgraduates too	Students' employability is a common indicator used in various higher education dialogs. It can be a gage of quality teaching and learning, or an indicator of the role of higher education institutions in societal change or the contribution they make to society. It is used in various public reports in line with transparency requirements. Working on improving employability rates will positively influence reputation and vice versa
Corrected employability rate	Effective number of students who are looking for a full-time job and who have found one within six months from graduation/Total number of students who graduated	Same as above	Any consideration of post-higher education destinations must take account of the fact that there are at least three major sets of outcomes: employment, unemployment and further study. Different approaches of these multiple outcomes have given rise to different claims to be at the "top" of the graduate employment league table
Employment resulting from an internship	Number of students who were employed following an internship/Total number of students who attended an internship	Same as above	Another measure that reflects students' employability and adequacy of their acquired skills is when the training field offers an employment following an internship. Employers who are able to test and supervise students and accordingly offer them a job constitute the best proof of students' knowledge and skills' adequacy
Average starting salary	Sum of salaries of first time employed graduates/Total number of first time employed graduates	Same as above	The average starting salary informs about the appropriateness of the obtained jobs with regards to the degree and field of study. It also indicates how much graduates/or degrees from a specific higher education institution are actually valued
Employers' satisfaction rate	Sum of employers' satisfaction points/Total number of points	Can be calculated by faculty, department	Those surveys give an idea about the employers' level of satisfaction as to the graduates' knowledge, skills, qualifications and attitudes and whether they match the job market needs or not. Employers' satisfaction is important for the institution's reputation and graduates' employability and helps identify areas of improvement to increase the satisfaction rate. Higher satisfaction rates will yield better results in the reputational surveys
Internship fields satisfaction rate	Sum of internship fields' satisfaction points/Total number of points	By major or overall	Same as above
Social engagement			
Community service budget	Total community service budget/Total institutional budget	It can be calculated with the actual amount spent on community service as opposed to the budgeted amount or by type of activity	This ratio tracks the amount of money allocated in the budget (or spent) for providing services to the local community with the aim of linking the institution with the external stakeholders. These services can include training courses, awareness campaigns, development and voluntary activities, etc. A high ratio indicates a higher amount allocated to or spent on community services, which translates the extent of the civic commitment of the institution and consequently, the likely impact on reputation

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Athletic success rate	Number of meaningful athletic successes/Total number of attempts	Can be calculated by athletic events or by students	In some countries, sports have a big impact on the culture and influence far beyond the playing field. A sport provides its athletes with many benefits. Not only can sports provide athletes with popularity, authority and money, sports can also provide them with a sense of internal achievement and success. Athletic success serves as a powerful marketing tool for higher education institutions with regards to its reputation and appeal to attract new students. (Forster 2012)
University social responsibility	Number of activities that promote and sustain culture during a specific period Number of social involvements that provide access for all social categories, irrespective of their financial resources Number of activities that promote health and health education Number of activities that promote knowledge transfer to less fortunate communities Number of activities related to human rights Number of free development and continuing education programs addressed to the public (involvement in regional skills strategies)		Social responsibility is increasingly considered an intrinsic aspect of higher education. Today, it goes far beyond the "philanthropy" of the past. It is about the business contribution to sustainable development and about proactive solutions to societal and environmental challenges. University Social Responsibility (USR) can be defined as a philosophy of a university as an ethical approach to develop and engage with the local and global community in order to sustain the social, ecological, environmental, technical, and economic development (Chen et al. 2015) An institution's social responsibility is not a quantifiable concept. However, implementing activities that contribute to and develop this civic commitment can help in increasing the institution's social responsibility and consequently enhancing its reputation
Community perception	Sum of points of the community perception survey/Total number of points		Monitoring community perception through frequent surveys allows institutions to get feedback on the quality of their efforts with regards to social programs and reputation as perceived by the community. It also provides insights into the public's expectations helping institutions to set strategies accordingly and identify areas of improvement. They are different from reputational surveys as they target more specific and direct questions
Community services	Number of outreach programs with the community	Can be separated by type of programs	Beyond education, the social and economic implications of upholding a relationship between institutions and local communities is gaining importance now more than ever. It presents a great opportunity for those institutions to influence societal progress and gain positive public perception Outreach programs are actions dedicated to underprivileged groups, it can take many forms such as donating goods or services, providing expertise, accomplishing projects
Continuing Education Programs (CEPs)	Number of CEPs held during an academic year	By field or overall or by client (for corporate trainings)	Continuing Education Programs (CEPs) are paid courses, workshops or certificate programs that impart relevant and up-to-date knowledge and skills in an array of fields, serving a wide variety of adult learners who seek professional advancement. The presence and involvement of higher education institutions with the industry on one hand, with its community on another, is partly exemplified by the scope of its CEPs

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
CEPs participation rate	Total number of participants to CEPs/Total number of CEPs held	Same as above	Measuring the number of participants to the CEPs held by the Institution is an indirect means to evaluate the success of those programs, their potential sustainability as well as help adapt the offerings
ROI of the degree	Total financial benefits of the degree over 20* years/Cost of earning a degree *Some references calculate the ROI over 15 or 30 years and some others until retirement. We used a middle value	Can be calculated by field of studies	Calculating the Return on Investment of a private Institution's degree is a proxy way of assessing the value of the degrees it delivers. Although it is very difficult to calculate and results are often uncertain, we consider that it is important to mention that this indicator exists for the sake of exhaustivity. It basically compares the amount invested in higher education (cost of a degree) with the return from attending a private higher education institution (main financial benefit or sum of expected future income usually calculated over 20 years)
External partnerships			
Partnerships with the industry	Number of active partnerships with the industry	Can be calculated by fields or sectors	Various academic programs already require an internship period at a company. The breakthrough is having institutions incorporating real-world business experience and professional training into courses that have traditionally been exclusively academic. Both students and industry view this as a competitive advantage that impacts reputation
Involvement of employers in curriculum development	Number of changes brought to a curriculum following an employer's suggestion	Can be separated by faculty or department	Actively involving employers in the development of the curricula is an effective approach towards closing the gap between education and job market. Measuring this involvement is a way to prove and document their participation. Increasing it is a way of prompting reputation especially employers' perception
Academic partnerships	Number of active academic partnerships Number of international exchange students—incoming Number of international exchange students—outgoing Number of international faculty exchange—incoming Number of international faculty exchange—outgoing	Can be separated by continent, by the countries' income level or by discipline	Measuring the number of academic partnerships that are active (and not only a signed document) allows to better understand and assess the institution's academic exposure and involvement which without a doubt, brings an added-value, improves quality and consequently boosts reputation

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Partnerships with professional bodies	Number of active partnerships with professional bodies	Can be calculated by discipline	With students seeking out degrees that set them apart from their competitors in a crowded graduate job market, higher education institutions came to recognize the value of curricula and courses oriented towards the industry's needs. Embracing a tighter integration between the job market and higher education is one way to meet this demand. Another approach is the creation of links with professional bodies and not only individual companies such as professional syndicates, foundations, organizations, federations, alliances, and institutes that award professional certifications. A growing number of higher education institutions are implementing partnerships with professional bodies, integrating professional certification into traditional degrees, launching courses that incorporate qualifications from a trusted professional body and setting-up joint councils of experts to develop new courses and enhance current programs
Partnership with councils for scientific research	Number of active partnerships with councils for scientific research Number of joint research activities Total funding received from councils for scientific research/Total research budget	Same as above	Academic researchers depend on their extensive collaborations with colleagues. Sharing techniques and expertise speeds up their projects, and gives life to new ideas and scientific breakthroughs. The presence of established channels that allow effective communication, stable partnerships and large networks between academics enables the flow of critical information and resources among them and the acquisition of specialized and new expertise. Those networks take place through national or international scientific research councils that enhance links between researchers and implement regional projects. They are a reliable partner to institutions committed to local, regional and international progress and evolution in science and research. Moreover, with the increased shrinking in government funding, institutions of higher education would call for every potential source for financial support. Their most valuable assets, the faculty members and their research work, can be very beneficial and influential in receiving grants from other sources such as national or international councils for scientific research The extent of research and funding are a major factor in influencing reputation
Alumni			
Alumni participation rate	Number of alumni members/Total number of (living) graduates	Can be calculated by cohort and discipline	One of the first indicators of the institution's success in engaging and connecting with the alumni is the rate of graduates who officially join the association. The higher the rate, the higher the benefits that can be provided by the alumni community. Institutions could also analyze alumni diversity (gender, nationality, culture, social status, employment location, etc.), as a diverse alumni community gives access to a greater range of talents, enriches current students' experience, promotes growth and strengthens inclusion and community ties; all of which increasing chances of enhancing reputation

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Alumni engagement	Number of interactions done by the alumni		A strong relationship between an institution and its alumni is crucial for both parties. An inactive or disengaged alumnus doesn't bring any value to the institution and doesn't influence reputation. This indicator measures the effective engagement of the alumni. Alumni interaction includes attendance at meetings or events, mentoring students, providing internship fields, donating, lecturing as visiting instructor, being member of boards or councils, recruiting students, networking, etc.
Alumni donations	Amount of alumni donations per academic year Amount of alumni donations per academic year/Total income of the year Amount of alumni donations per academic year/Total budget of the year		As already mentioned, many higher education institutions deeply count on alumni donations to even out their budget. The amount of those donations reflects alumni engagement and sincere involvement
Alumni satisfaction	Sum of satisfaction questionnaire points/Total number of points		Alumni satisfaction can be surveyed through questionnaires. A satisfied alumnus is more likely to participate actively, assist the institution in several ways and give constructive feedback
Alumni average salaries	Sum of alumni salaries/Total number of alumni	Can be calculated for each degree level separately (bachelor, master and PhD) or/and by discipline	Knowing the median earning of graduates is important for several reasons. First and foremost, it is used for benchmarking purposes when compared to other higher education institutions. The higher the average salaries are, the more attractive is the institution towards prospective students as the "return on investment" in their education is higher. It is an important selling point. It means students who graduate from this institution will secure better employment opportunities and are valued in the job market. It most importantly means that the institution has a good reputation
Alumni employers' profile	Distribution of alumni between categories of employers* Alumni employed by industries' leaders/Total number of employed alumni *Employers can be categorized by size, total budget, income, profits, market share, history, etc.	Same as above	The profile of the companies who employ graduates is as important as the salaries' level. Although both indicators are closely linked and consequential, understanding the profile of employers gives insights about the desirability of those graduates and the quality of the jobs they secured, which is a reflection of the institution's reputation. By closely working with reputable employers (through partnerships, PR, etc.), higher education institutions can improve this indicator and influence reputation While analyzing the distribution of the alumni between different categories of employers is pertinent, it isn't an indicator that can be measured. Therefore, we added the ratio of alumni employed by leaders in their respective industries, knowing that a clear description of leader should be first defined

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Alumni entrepreneurship	Number of alumni who founded or co-founded an enterprise/Total number of alumni	Same as above	Measuring the number of alumni who started their own venture is an indication of graduates' entrepreneurial skills and level of inspiration, self-confidence, and talent. Those same graduates are more likely to found and lead dynamic new ventures and transform any organization they join or manage. To add value, graduates need to have the entrepreneurial skills that enable them to seize and exploit opportunities, solve issues and problems, generate and communicate ideas, and make a difference in their communities regardless of their discipline. It is consequently an indication of an Institution's quality of education and contribution to the development of society (Herrmann et al. 2008)
Alumni positions by level	Number of alumni for each job level/Total number of alumni	Same as above	Each job level is typically associated with a salary range, incentives and job titles. Job levels can be grouped in five areas: executive management, middle management, management, advisory and employees or staff with senior and junior positions for each. Sorting alumni by job level is another way to appreciate the employability and prospects of professional development of graduates. Working on having alumni holding higher positions is a proxy way of positively affecting reputation
Alumni employment rate	Number of employed alumni at a certain point in time/Total number of alumni actively looking for a job		Monitoring alumni's employment rate is another manner to assess graduates' desirability and consequently, the institution's attractiveness and reputation. Staying in contact with the alumni and proposing job opportunities even after years of graduation will ensure a high long term employment rate
Social and economic impact			
Litigations and lawsuits	Number of ongoing litigations and lawsuits during an academic year		Litigations affecting higher education institutions can result from a wide range of intended or unintended actions, from admissions' tampering, discrimination, sexual assault/misconduct, racism, suppressing freedom of speech, to faculty dismissal and intellectual property rights. While the mission of higher education institutions and core of quality assurance standards revolve around integrity, honesty and transparency, one would think that higher education institutions would by no means be in a position to face accusations and lawsuits. Moreover, scandals that hit higher education institutions are very publicized, can quickly damage reputation and are hard to overcome. Monitoring the number of lawsuits conducted against the institution is one indicator of its compliance with legal accountability and integrity principles that both directly affect reputation

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Sustainable Development (SD)	Institution's environmental impact (waste and energy consumption, recycling activities) OR Number of actions that limit ecological damage and green campus building Number of times where the campus facilities were made available for local communities Number of SD actions and awareness campaigns Institutional budget dedicated to SD efforts OR Institutional budget dedicated to SD efforts/Total budget Number of outreach programs engaging the community OR surrounding school OR underprivileged groups, and promoting sustainability Number of trainings and workshops Number of faculty members OR staff OR students trained on environmental issues Number of programs OR courses in curriculum, covering the topic of SD Number of research dealing with SD issues		Since the Stockholm Declaration of 1972, there has been a steady development of national and international sustainability declarations relevant to higher education. Institutions attempt to become more sustainable by signing these declarations and are already (or in the process of) incorporating and implementing them in their activities (Wright 2002). There are several reasons why a higher education institution would integrate sustainable development within its mission and objectives, from quality assurance purposes to image polish and reputation. Sustainability in higher education is complex and ambiguous as the concept applies to diverse institutional settings. David Orr proposes five criteria to rank campus sustainability that sums-up institutional commitment to sustainable development: 1) What quantity of material goods does the institution consume on a per capita basis? 2) What are the institution's management policies for materials, waste, recycling, purchasing, landscaping, energy use, and building? 3) Does the curriculum engender ecological literacy? 4) Do higher education institutions finances help build sustainable regional economies? 5) What do the graduates do in the world? (Shriberg 2002) As higher education is a catalyst for sustainable development for the next generation, communicating the impact on sustainable development of its institutions is becoming an essential part of satisfying accountability expectations from public and private funders, policymakers, accreditation agencies, students and faculty. At the same time, there is a lack of clarity and a divergent understanding of the concept of impact of higher education on sustainable development (Findler et al., 2019). The proposed indicators highlight direct and indirect impacts on sustainable development arising from the activities of higher education institutions. Those indicators are important as they demonstrate the institution's serious commitment to sustainable development which will help boost its reputation among community members and policymakers

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Economic development and engagement	Number of strategic rewards and incentives delivered to faculty members and staff that encourage innovative teaching (community-engaged research and scholarship; patenting and commercialization of discoveries; other forms of innovation in solving economic, policy, or social problems; and creative works) Number of adapted courses OR programs based on community needs Number of health-related endeavors Number of lifelong-learning programs Scholarships' budget		Within advanced economies, there is a general concern that teaching and research within higher education institutions are not directed enough towards specific economic and social objectives. Regionally engaged higher education institutions can become a key asset for economic development. The requirements for regional engagement embrace many facets and is supposed to meet the various needs of a more diverse client population such as flexible structures for lifelong learning created by changing skill demands; more locally based education as public support for students has declined; greater links between research and teaching; more engagement with the end users of research (Chatterton & Goddard 2000). Higher education institutions enhance the competitiveness of their communities and regions while serving the global society through many diverse programs, services, and activities in the areas of human development, research and innovation and stewardship of place (as explained by the Association of American State Colleges and Universities (AASCU), stewardship of place is the idea that higher education institutions have a responsibility to collaborate with community stakeholders in the places they are located to maximize shared opportunities and jointly address critical issues.) Accordingly, the economically engaged institution seeks to adapt and enact, in ways consistent with its mission, the following general Strategic Program Principles: - Embed economic engagement, innovation, and entrepreneurship across institutional missions; - Engage in regional innovation ecosystem; - Engage with communities—in social, physical, and virtual forms—and actively pursue working and collaborating for the common good with other community stakeholders; - Serve regional human capital and workforce needs; - Contribute to the health and wellbeing of the community it serves; - Enhance opportunities for faculty, students, and staff to engage with the public, industry, and government beyond their disciplines and institutions; - Innovate continuously in teaching and learning practice (traditional and flipped classroom, online/virtual, discovery-based, experiential, service, and international modes of education) The challenge is to link within the institution the teaching, research and community service roles by internal mechanisms (funding, staff development, incentives and rewards, communications) and to engage the institution with all facets of the regional development process (skills enhancement, technological development and innovation, cultural awareness) Playing the card of regionally engaged institution is a smart way to enhance reputation

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Media visibility			
Media Favorability Index (MFI)	Number of positive messages/Number of negative messages	Can be calculated by media type (print, social media, digital, audiovisual, etc.) or overall	This indicator shows favorable publications about the institution based on the tone of the messages. If MFI > 1, then during the period there were more positive publications than negative ones. This indicator is to be compared with the mentions related to the competitors as well as with the average market value during a certain period. It also allows to understand what types of media concentrate more on positive or negative messages, on what levels and when. It also shows where media visibility isn't contributing to building a positive and solid reputation and helps identify corrective actions
Media budget	Media budget/Total institutional budget	Can be divided by type of media	This indicator measures the weight or amount of money allocated by the institution to support media activities that should strengthen the institution's image and reputation. The higher the budget, the more visible the institution, the higher the media impact and the more likely to have a positive influence on its reputation
Media mentions	Number of media mentions during a period of time	Can be separated between intended (owned) content and earned content	The media can more or less mention the institution with positive or negative content. The more positive (or even neutral) media mentions, the higher the impact on reputation and image. This indicator also allows institutions to keep negative mentions in check and to monitor the frequency of media mentions with unintended and unpaid content
Share of Voice (SoV)	Institution's number of publications/Total number of publications in the same market Number of mentions of the brand/total number of brand mentions Institution's advertising/Total market advertising Institution's impressions/Total eligible impressions	Mentions can be compared in key and non-key media, in national and regional outlets	SoV is a measure of the market that a "brand" owns compared to its competitors. It acts as a gauge for the brand's visibility and awareness and how much it dominates the conversation in the industry or relevant market. The higher the market share, the greater popularity and authority the "brand" likely has among users and prospective customers (Bredava 2020). There are many ways to calculate SoV depending on the marketing area or on the institution's goals. In general, it is the institution's measure (in the area that is calculated) compared to the total market measure in the same area. Increasing the SoV will make the institution stand-out and eventually improve its reputation
Web traffic	Web analytics report		Analyzing the traffic on the institution's website is a valuable way of assessing visibility and media effectiveness. If a website is a hub for engaging the audience, then web analytics are a good proxy for measuring and monitoring reputation. Website visitors can be divided into three groups, depending on their source: • through owned content on the pages of the institution's website; • through earned content from third-party websites where posts were published or the institution was mentioned in the media articles; • through social content from social networks Website visits indicate if the social media strategy is going the extra mile and attracting users to actively seek more information about the institution and its services which will increase the "brand" awareness and consequently impact reputation

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Search Engine Optimization (SEO) ROI	(Value of Conversions—Cost of Investment)/ Cost of Investment		SEO strategy uses keywords and other specific criteria to help push a website toward the top of search engine rankings. SEO drives awareness of a brand (product or service) in the early stages of the buying process. Search engine rankings have a critical impact on the number and quality of the received leads and growth of users' trust. In order to assess the impact of an SEO strategy on an institution's reputation, it is useful to calculate the ROI of the SEO strategy
Backlinks	Number of backlinks during a period of time	Can be calculated by types of backlinks	Backlinks are links from other sites that direct traffic to the website. This is a good source of traffic that helps to strengthen reputation among target audiences and search engines. However, not all references are equally useful. They vary in size and impact. There are three types of backlinks ranked by level of value: 1) Good backlinks that mention the institution in a positive way without an active link. 2) Very good backlink remembers the brand/name and contains an active link. 3) The best backlink refers to the website and mentions the positive aspects of the brand/institution. Their quantity and quality should be tracked to identify appropriate resources and adjust the content plan accordingly
Conversion	Number of targeted events that have been successfully completed/Total number of such events	Can be calculated by event type	Conversion is defined as a meaningful action done by prospective clients following an interaction with an ad (for example, clicking on a text ad or viewing a video) and then completing a desired goal intended through the ad (such as a purchase, a call or filling a form). It is the holy grail of marketing, an underestimated indicator in public relations and media visibility. It is the clearest indicator in terms of the number of leads received. The higher the conversion rate, the better the visibility and eventually the reputation

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Net Promoter Score (NPS)	Percentage of promoters—percentage of detractors		NPS is the most popular indicator for customer loyalty measurement on a scale from 1 to 10. Depending on the answer to the question "What is the probability that you would recommend our product/service (in this case the institution and its degrees) to your friends, family, colleagues, partners)?" customers are divided into three groups: • 1–6—detractors or brand critics. This is the growth zone: a dissatisfied critic (student, faculty member or employer) can be turned into a promoter; • 7–8—neutrals. Neither negative nor positive. This is a risk zone—the client does not understand the value of the product/service, can use/purchase out of habit, more sensitive to price changes, may go to a competitor, such as students who choose a higher education institution without a firm belief, and have a high risk of transferring to another institution for futile reasons; • 9–10—promoters are brand advocates who actively use the product/service (students effectively enrolled or alumni), generate recommendations and positive feedback The higher the NPS score, the better the reputation of the institution. This indicator allows institutions to identify the detractors and neutrals and work on minimizing their numbers in order to enhance reputation
Engagement	Number of fans "talking about" retrieved from the social media account	Can be done by media type or overall or by engagement type (number of likes, number of reposts, number of comments, etc.) Can be divided between positive references or negative ones	Engagement is probably the most tracked metric for social media marketing, it includes tracking likes, comments, views, shares, downloads, reposts, etc. An active and engaged community guarantees additional visibility and better reputation (Podobnik 2013). However, one must assess whether engagement is driving actual value. While it helps to extend the reach, it is not to be used as an indicator of overall success. A balance of engagement and other metrics is needed to really grasp the adequacy of content strategy to the social community and the likelihood of generating business and reputation benefits to the name/brand
Community growth	Number of followers or fans (Number of followers or fans at end of period)—(Number of followers or fans at beginning of period)/(Number of followers or fans at beginning of period)	Can be done by media type or overall	Month-over-month followers' growth is a good metric to track. While many argue that it's not the most pertinent metric, some studies showed that it is one of the most important social media marketing indicators (Podobnik 2013). In theory, the more social followers/fans an institution has, the more reach its content will get, the better the impact on reputation and image. Growing social communities can help get more visibility, makes social advertising more cost effective and projects the idea that the name/brand is likeable

Table 1 (continued)

Performance indicator	Calculation	Variation	Description
Impressions/Reach	Impressions/frequency (knowing that it can be retrieved from the reports of online marketing)		The amount of people being served the content (reach) and the number of times the content is being served (impressions) can say a lot about how the content is performing. The algorithms used in the social news feeds dictate who sees what content, so a rapid drop in these visibility metrics can indicate that a content doesn't engage well with the algorithms, and thus, what people are responding to. It is important to reference these metrics to ensure the delivery of the ads, and to determine how engaging they are by looking at the click-through-rate. A low rate on these metrics might indicate that the ad doesn't attract viewers or that the brand/name isn't appealing

to depict any early sign of social "disengagement". Regardless of the allocated budget, now the university management knows where to focus (on the number of USR activities and CEPs in this case), if its objective is to become more socially engaged and hopefully increase its score on the community perception questionnaire, as a first step to influencing its overall reputational survey score.

Following this study, the university took several corrective actions in the purpose of improving all important indicators. Though the pandemic years made it difficult to implement most of those decisions, we are citing them for the sake of completeness:

- Maintaining the media budget level but splitting efforts between increasing engagement/reach and conversion rates;
- Comparing the conversion rate to actual new enrolments from social media advertisements;
- Widening the geographical scope of the community perception questionnaire to include further areas. When ratings become similar from year to year, it means it is time to either change the questions or change the audience. Till now, the questionnaire was only distributed in the geographical area around the university to assess the social impact of the university in its immediate milieu. Involving additional regions would better assess the social impact on a wider scope;
- Start gathering data on Alumni in order to introduce alumni-related indicators in the future.

As previously mentioned, it is important to know that any action taken today probably won't create an immediate impact. It takes time and continuous efforts to make a difference and to maintain it. Also, it is essential to be able to compare those indicators with several previous years in order to depict a meaningful trend, understand the connection between the indictors and act accordingly. Therefore, the scope of this example is limited and doesn't allow a deep analysis of the indicators, their mutual influence and the impact of any corrective action. The pandemic years forced universities (and the world) to halt any social activity, avoid gatherings and cancel all kinds of events. While social media might have gained ground during lockdown, digital advertising for higher education might have not reached its objective. The pandemic environment was not quite favorable to education.

Conclusion and Future Works

It was established that the reputation of higher education institutions is a valuable asset considering the important role it plays in students' decisions, government funding and

Table 2 Case study of a Lebanese university

Dimension	Indicator	2017–2018	2018–2019	Difference
Social engagement	Community service budget	4.2%	2.3%	−45.2%
	University social responsibility	38	39	+2.6%
	Community perception (a questionnaire of 10 points with a maximum result of 50)	0.76	0.8	+5.2%
	Continuing education programs	8	5	−37.5%
Media visibility	Media budget	2.1%	4.6%	+119%
	Web traffic	28 270	32 389	+14.5%
	Conversion rate (Instagram)	4.1	4.4	+7.3%
	Engagement	15 373	10 259	−33.2%
	Community growth (Fb and Insta)	3.3% and 16%	3.4% and 2%	+3% and −87.5%
	Impressions/reach	783 085	551 197	−29.6%

employers' choices. At the same time, reputation is a complex and versatile concept that tends to be overly subjective and contingent on the stakeholders' point of view and personal experience. International quality rankings on the other hand, initially created to rank higher education institutions based largely on the reputational surveys and some other factors, are today actually making or breaking those institutions' reputation.

There is no magic formula that can calculate a higher education institution's reputation or one single action that can build a reputation. There are several interrelated factors that influence reputation and could help assess it at a certain point in time. The present article proposed a list of direct and indirect indicators to be used for measuring and monitoring an institution's reputation through several dimensions crucial to higher education. Whether the purpose is internal improvement or climbing the quality ranking ladder, those indicators will help identify areas of improvement and decide on corrective actions to be implemented accordingly.

The case of the university studied in this paper clearly shows the weaknesses of the university and the impact of a decision to reduce the media budget, as evidenced in the decrease of key indicators related to media visibility. The analysis also put into perspective where efforts should be made in the future to reach better results.

Since the pandemic changed the face of teaching, learning, and on-campus life, it was impossible to follow-up on the results obtained in the case study by proposing corrective actions and reassessing the results after their implementation. As a future work, it would be interesting to repeat this exercise with a larger array of indicators to be compared over three to four years while monitoring the impact of specific corrective actions on the related indicators.

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Declarations

Conflicts of interest Marianne Haddad-Adaimi, Roy Abi Zeid Daou and Yves Ducq declare that they have no conflict of interest with any research or reviewer other than their colleagues in their proper institutions.

Ethical Approval This article does not contain any studies with human participants performed by any of the authors.

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Relationship between bibliometric indicators and university ranking positions

Péter Szluka[1], Edit Csajbók[1,2] & Balázs Győrffy[3,4]✉

A growing interest for demonstrating prestige and status of higher education institutions has spurred the establishment of several international ranking systems. A major percentage of these rankings include parameters related to scientific productivity. Here, we examined the differences between diverse rankings as well as correlation with bibliometric parameters and disciplines for the top universities. We investigated the top 300 universities from four international rankings, the Times Higher Education World University Ranking (THE), the QS World University Rankings (QS) the ShanghaiRanking-Academic Ranking of World Universities (ARWU) and the U.S.News Best Global Universities Ranking (USNews). The assessed parameters include ranking positions, size related and bibliometrics-related indicators of each selected ranking. The weight of scientometric parameters ranges between 20% (QS) and 75% (USNews). The most important parameters defining ranking positions include citations, international reputation, and the number of researchers, but the correlation strength varies among ranking systems. The absolute number of publications and citations are particularly important in ARWU and USNews rankings, and scientific category normalized (field weighted) citation impact is central in THE and USNews rankings. Our results confirm that universities having outstanding results in rankings using size-independent indicators (QS and THE) compared to others have significantly lower number of students. High impact research can improve position in ARWU and USNews ranking lists. Regarding to different disciplines, the main results show that outstanding universities in THE ranking have higher publication activity in social sciences and universities which perform better in USNews and QS ranking have more publications in science, technology, and medicine fields and lower score in social sciences. In brief, here we present a comprehensive analysis of the correlation between scientometric parameters and university ranking positions, as well as the performance of outstanding universities and their correlation with different disciplines, to help decision makers select parameters for strengthening and to attract the interest of prospective students and their parents via a better understanding of the functions of different ranks.

Abbreviations

THE	Times Higher Education World University Ranking
QS	QS World University Rankings
ARWU	ShanghaiRanking-Academic Ranking of World Universities
USNews	USNews Best Global Universities Ranking
WUR	World University Ranking
FTE	Full Time Equivalent

Success of a higher education establishment can be measured by different metrics, like by the academic results of the admitted students, by the employment characteristics of graduates, by the participation of industry, or by the research output. In the case of universities, there are several metrics enabling qualitative assessment, including the oversubscribed proportion of the admissions, the admission score, the proportion of international students, the ratio of students to lecturers, the number of lecturers with PhDs, etc. In this field, before the publication of university rankings, the reputation of the university was the decisive argument for the choice. Expanding globalization created a widespread demand for higher university reputation[1]. Reputation, however, did not

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always prove to be appropriate, because it takes many, many years to gain and establish it. On the other hand, it is not so easy for a university with a history of hundreds of years to lose it either. According to several authors, a university's reputation is a decisive factor that increases the number of international students[2].

As early as 1863, a research was published with the purpose to compare and analyze the German polytechnic schools—Hanover, Karlsruhe, and Zurich—for the upcoming reorganization of the Technical College in Prague[3]. Hundred years later, in 1986, the US News and Report US Colleges Ranking was published, which was the first national level comparison of universities. The first truly global international university ranking, the Shanghai Jiao Tong University's Academic Ranking of World Universities, was published in 2003. Since then, more and more university rankings have appeared, some of which have a long history and became recognized, while some others have lost attention over time.

The purpose of university rankings is to compare universities based on their merit and performance. There are as many methodologies as there are rankings, and their data collection can be based on data submitted by universities and data extracted from other sources and databases. Using these data, ranking systems aim to provide a common definition of value[4]. The range of indicators used is wide, there are metrics that depend on or are independent of the size of the university, and there are rankings where the reputation of the university is part of the method, which is assessed with the help of questionnaires. Despite their different methodologies, there are reasonable similarities between the rankings[5], and a common feature of rankings is the use of bibliometric indicators.

Studies have been conducted to assess the effect of university rankings on the selection preferences of prospective students. A study mapped Chinese students' knowledge of university rankings using a survey of more than 900 students and found that thirty percent of the students was aware of ranking positions[6]. On the other hand, progress achieved in ranking lists had little or no effect on the students' choice of university[2]. According to others, the university rankings had an impact on the choice of university and among the indicators of the rankings, students consider those universities that refer to mentoring, faculty infrastructure, and general satisfaction of students as the most important aspects, while the characteristics that are aimed at research are less relevant to them[7]. Other studies have also shown that prospective students and their parents rely on university rankings when making decisions about higher education[8]. Based on data from a medium-sized German university, the university's place in the rankings had high importance for both international and national students, similarly to other determinants of reputation and quality[9]. A study using Google trends and QS World University Rankings found positive and significant relationship between QS ranking results and Google Search volumes for universities in the top 500[10]. Nevertheless, international students are mostly concentrated at large universities[11].

For the determination of scientific output, a new branch of science, scientometrics, has emerged, the purpose of which is to provide an objective, qualitative picture of research output with the help of mostly quantitative indicators. The analysis of scientometric performance, an easily quantifiable output, is a key feature in each ranking. The aim of our study was to investigate the possible correlations between different scientometric variables and the results achieved by a university in each ranking and to find the common scientometric and discipline characteristics of universities that have achieved outstanding results in one ranking compared to other rankings. We also aimed to compare the importance of different parameters when determining ranking outcome. It's important to emphasize that universities should avoid prioritizing rankings as their only objective. Instead, their focus should include enhancing teaching quality, advancing scientific research, and elevating the standard of their services. In this aspect, ranking is one of the tools at hand for monitoring relative output.

Results

Setting up a matched ranking for top universities. The ranking presented by the Times Higher Education (THE) magazine performs its own data collection for the included universities. It had common roots with QS ranking between 2004–2009, but in 2010 it switched to a different methodology. THE is based on 13 performance indicators grouped into five areas: teaching (30%), research (30%), citations (30%), knowledge transfer (2.5%), and international outlook (7.5%). All together 13 indicators are used, and out of these the total weight of bibliometric indicators is 38.5%. All indicators are normalized to university size or scientific area. Elsevier's SciVal (based on Scopus data) is used as publication and citations source.

The QS—World University Ranking is published by the Quacquarelli Symonds (QS) company. Universities are ranked based on six key metrics in the ranking: academic reputation (40%), employer reputation (10%), faculty/student ratio (20%), citations per faculty (20%), international faculty ratio (5%), and international student ratio (5%). There is only one bibliometric indicator (citations per faculty—20%) which is normalized to the scientific area, and self-citations are excluded. Elsevier's SciVal (based on Scopus data) is used as publication and citations source.

The Academic Ranking of World Universities (ARWU, also called ShanghaiRanking) was first published in 2003. Since 2009 the ARWU has been published by ShanghaiRanking Consultancy, which is a fully independent organization. It ranks the first 1000 universities, using six indicators, including quality of education (10%), quality of faculty (40%), research output (40%), and per capita performance (10%). The two normalized bibliometric indicators have a total weight of 40%, and one bibliometric related (number of highly cited researchers) indicator weights 20%. Clarivate's InCites database (based on Web of Science Core Collection data) is used as publication and citations source.

The U.S.News Best Global Universities Ranking was launched by U.S.News & World Report in 2014. It ranks universities based on thirteen indicators, including global research reputation (12.5%), regional research reputation (12.5%), and eleven bibliometric indicators (75%). It contains size-dependent indicators, but some indicators are normalized. Clarivate's InCites database (based on Web of Science Core Collection data) is used as publication and citations source.

After analyzing all four rankings, we got a common list with 470 universities included in at least one ranking among the top 300 universities. Of these, nine universities were found in one ranking only, 25 universities were found in two rankings, 48 universities were missing from one ranking, and 388 institutions were found in all four rankings.

Ranking positions vs. determined parameters. First, we compared the ranking positions to the selected scientometric parameters, the number of students, and enrollment. All together 105 correlations were computed, and in 98 cases there were correlations ($p < 0.05$) between ranking positions and the determined parameter. The high proportion of significant correlations between ranking indicators and rank positions of the universities in most cases proves that bibliometrics related indicators play an important role in each of the examined rankings. The correlations were stronger with a particular ranking's own indicators. We observed lower correlation in four cases: USNews international collaboration (relative) (corr.coeff = 0.24, p = 1.25e−07), USNews conferences (corr.coeff = 0.31, p = 5.86e−12), THE international outlook (corr.coeff = −0.41, p = 1.61e−19), and QS citations per faculty (corr.coeff = −0.44, p = 1.78e−22), Of these, the first three represent indicators with low weight, but the last one gives 20% weight of the entire ranking. University sizes shows medium correlation with ARWU and USNews ranking results, but there is no correlation with THE and QS rankings. The highest positive correlation coefficients were present for citations and percentage of papers in the top 1%, while the strongest negative correlations were present for two non-ranked parameters, the number of highly cited researchers and publications in Nature and Science. The complete results are presented in Fig. 1.

Differences in ranking positions vs. determined parameters. Next, we investigated the correlation between the ranking position differences and the determined scientometric parameters. In this analysis, high correlation values mean high importance for this parameter and low correlations mean small importance in determining ranking differences between the four investigated rankings. All together 126 correlations were evaluated, and in 99 cases we found significant correlations ($p < 0.05$).

The most significant correlations were observed in case of the THE citations and the USNews normalized citation impact indicators. Although both of these indicators represent the citation impact of publications relative to their scientific discipline, but they use two different data sources, Web of Science and Scopus. The two indicators show higher correlation in THE–QS and in THE–ARWU pairs proving that universities with higher discipline-specific citation reach better ranking in THE compared to QS or ARWU. Albeit with lower correlation values, these universities also have better ranks in USNews. When comparing THE and USNews, THE has a positive value also linked to the higher weight of citation in THE (30%).

In case of THE–QS and of the ARWU–USNews pairs, the differences do not show correlation with university size while in case of the QS/ARWU vs THE/USNews pairs the differences show high correlation values. These results support the notion that QS and THE rankings are better for small universities with high impact while larger universities can reach better scores in ARWU and USNews rankings.

The detailed analysis results are shown in Fig. 2.

Comparing all determined parameters to each other. We also correlated all the investigated parameters to each other across all included universities. In this, 441 associations were checked, 399 of which had a significant correlation ($p < 0.05$).

Particularly high correlations can be observed for USNews scientometric parameters including the number of publications in the top 10% and top 1%, and citations in the top 10% and top 1%. These results provide evidence that the overall impact of these parameters is amplified by their influence on the other parameters. Of note, the percentage of top 10% and top 1% are also positively correlated.

Similarly, significant correlations can be observed between the size-dependent parameters of ARWU and USNews. The complete results for all parameters are depicted in Fig. 3.

Outstanding universities. A particularly interesting analysis involves the "outstanding universities", which have excellent position in one ranking but mediocre position in another. All together twelve outstanding university groups were compared with the control groups (which include all non-outstanding universities) for the 22 determined parameters. The analysis includes universities outstanding in THE vs. the three other rankings (Fig. 4A), universities outstanding in QS vs. the three other rankings (Fig. 4B), universities outstanding in ARWU compared to the other universities (Fig. 4C), and universities outstanding in USNews compared to other rankings (Fig. 4D). Note that because outstanding universities have better positions (lower number), the ranking difference is negative for almost each parameter.

We also studied the typical disciplines of the universities selected with this method. We examined the differences of OpenAlex root level concepts scores (19 concepts and three concept groups) between outstanding university groups and control groups. In this analysis, we found significant differences (Mann–Whitney $p < 0.01$, two-tailed) in case of 98 outstanding groups (see result in Fig. 5A–D). The main results show that outstanding universities in THE ranking have higher score in social sciences and universities which perform better in USNews and QS ranking have higher score in science, technology, and medicine fields and lower score in social sciences.

The university size parameter was also examined when comparing outstanding and control university groups. Results show that universities outstanding in QS and THE compared to ARWU and USNews have significantly differed with lower number of students (Mann–Whitney $p < 0.01$ two-tailed) and conversely, universities outstanding in ARWU and USNews compared to THE and QS had higher median of number of students (Fig. 6).

	THE calculated rank	QS calculated rank	ARWU calculated rank	USNews rank	Best Rank
Continuous indicators (scores)					
THE FTE of Students	-0.02 n=440	0.04 n=421	**-0.39** n=406	**-0.36** n=423	**-0.18** n=440
USNews Enroll (# of Students)	0.03 n=290	0.07 n=285	**-0.34** n=282	**-0.27** n=293	**-0.16** n=293
QS citations per faculty	**-0.52** n=421	**-0.44** n=433	**-0.40** n=403	**-0.46** n=421	**-0.49** n=433
THE citation	**-0.70** n=440	**-0.29** n=421	**-0.41** n=406	**-0.59** n=423	**-0.43** n=440
THE research	**-0.85** n=440	**-0.76** n=421	**-0.66** n=406	**-0.69** n=423	**-0.78** n=440
THE international outlook	**-0.41** n=440	**-0.42** n=421	-0.08 n=406	**-0.25** n=423	**-0.25** n=440
ARWU # highly cited researchers	**-0.60** n=406	**-0.45** n=403	**-0.82** n=431	**-0.75** n=423	**-0.67** n=431
ARWU Nature and Science	**-0.67** n=406	**-0.55** n=403	**-0.83** n=431	**-0.78** n=423	**-0.71** n=431
ARWU publications	**-0.48** n=406	**-0.48** n=403	**-0.79** n=431	**-0.70** n=423	**-0.64** n=431
ARWU per capita performance	**-0.64** n=406	**-0.58** n=403	**-0.62** n=431	**-0.62** n=423	**-0.63** n=431
Ranked indicators					
USNews publications	**0.56** n=423	**0.53** n=421	**0.82** n=423	**0.78** n=451	**0.70** n=451
USNews books	**0.65** n=423	**0.52** n=421	**0.56** n=423	**0.67** n=451	**0.57** n=451
USNews conferences	**0.19** n=423	**0.39** n=421	**0.40** n=423	**0.31** n=451	**0.39** n=451
USNews normalized citation impact	**0.63** n=423	**0.26** n=421	**0.39** n=423	**0.61** n=451	**0.40** n=451
USNews total citations	**0.67** n=423	**0.55** n=421	**0.86** n=423	**0.88** n=451	**0.75** n=451
USNews # top 10% cited	**0.66** n=423	**0.53** n=421	**0.87** n=423	**0.89** n=451	**0.74** n=451
USNews % top 10% cited	**0.64** n=423	**0.32** n=421	**0.48** n=423	**0.66** n=451	**0.46** n=451
USNews international collaboration (relative)	**0.12** n=423	**0.18** n=421	**0.22** n=423	**0.24** n=451	**0.21** n=451
USNews # top 1% cited	**0.70** n=423	**0.54** n=421	**0.86** n=423	**0.92** n=451	**0.75** n=451
USNews % top 1% cited	**0.60** n=423	**0.30** n=421	**0.46** n=423	**0.64** n=451	**0.43** n=451

Figure 1. Spearman rank correlation of ranking positions and selected indicator values/ranks. High correlations show that the given indicator/rank affects the rank position in different rankings. Continuous indicators are scores, where higher values mean better positions, while USNews indicators are ranks, where the lower value means a better position. Best rank was computed by using the best positions across all four ranking for each university and reflects the power of each feature in predicting the best position of a university. Significant differences ($p < 0.05$) are marked with bold correlation coefficients. (The colors show the distance from the zero. Green to Yellow < 0; Yellow to Red 0 <).

Discussion

Here, we have determined the effects of scientometric parameters in four international ranking systems. Our results confirm previous observations that there are reasonable similarities between the rankings[5]. Of course, this does not mean that all universities perform equally in each ranking—we can also confirm the size dependence, which lead to better result for larger universities[14]. Our results clearly show that smaller universities have better results in size independent rankings including the THE and QS, while bigger universities can perform better in USNews and ARWU rankings which both have size-dependent indicators. Overall, large universities can

	RankDiff THE-QS	RankDiff THE-ARWU	RankDiff THE-USNews	RankDiff QS-ARWU	RankDiff QS-USNews	RankDiff ARWU-USNews
Continuous indicators						
THE FTE of Students	-0.07 n=421	**0.49** n=406	**0.50** n=423	**0.49** n=393	**0.47** n=409	**-0.16** n=400
USNews Enroll (# of Students)	-0.06 n=284	**0.48** n=280	**0.48** n=290	**0.45** n=275	**0.44** n=285	**-0.17** n=282
QS citations per faculty	-0.03 n=421	**-0.12** n=393	**-0.14** n=409	-0.07 n=403	-0.04 n=421	0.05 n=398
THE citation	**-0.52** n=421	**-0.34** n=406	**-0.28** n=423	**0.11** n=393	**0.27** n=409	**0.29** n=400
THE research	-0.07 n=421	**-0.21** n=406	**-0.30** n=423	**-0.14** n=393	**-0.14** n=409	-0.04 n=400
THE international outlook	0.07 n=421	**-0.45** n=406	**-0.35** n=423	**-0.38** n=393	**-0.29** n=409	**0.30** n=400
ARWU # highly cited researchers	**-0.13** n=393	**0.23** n=406	**0.13** n=400	**0.36** n=403	**0.26** n=398	**-0.22** n=423
ARWU Nature and Science	**-0.13** n=393	**0.20** n=406	0.06 n=400	**0.26** n=403	**0.17** n=398	**-0.21** n=423
ARWU publications	0.07 n=393	**0.39** n=406	**0.30** n=400	**0.32** n=403	**0.23** n=398	**-0.24** n=423
ARWU per capita performance	-0.07 n=393	-0.01 n=406	**-0.13** n=400	0.05 n=403	0.00 n=398	**-0.10** n=423
Ranked indicators						
USNews publications	-0.03 n=409	**-0.34** n=400	**-0.30** n=423	**-0.30** n=398	**-0.26** n=421	**0.20** n=423
USNews books	**0.15** n=409	0.05 n=400	-0.01 n=423	-0.05 n=398	**-0.14** n=421	**-0.09** n=423
USNews conferences	**-0.32** n=409	**-0.25** n=400	**-0.26** n=423	-0.01 n=398	0.08 n=421	**0.15** n=423
USNews normalized citation impact	**0.45** n=409	**0.28** n=400	**0.16** n=423	**-0.13** n=398	**-0.32** n=421	**-0.33** n=423
USNews total citations	**0.09** n=409	**-0.25** n=400	**-0.25** n=423	**-0.32** n=398	**-0.33** n=421	**0.09** n=423
USNews # top 10% cited	**0.09** n=409	**-0.25** n=400	**-0.25** n=423	**-0.34** n=398	**-0.35** n=421	**0.10** n=423
USNews % top 10% cited	**0.38** n=409	**0.19** n=400	0.08 n=423	**-0.18** n=398	**-0.32** n=421	**-0.23** n=423
USNews international collaboration (relative)	-0.06 n=409	**-0.11** n=400	**-0.16** n=423	-0.05 n=398	-0.05 n=421	0.00 n=423
USNews # top 1% cited	**0.14** n=409	**-0.21** n=400	**-0.23** n=423	**-0.33** n=398	**-0.36** n=421	0.03 n=423
USNews % top 1% cited	**0.37** n=409	**0.18** n=400	0.06 n=423	**-0.18** n=398	**-0.32** n=421	**-0.25** n=423

Figure 2. Spearman rank correlation between ranking position differences and the investigated scientometric parameters. High correlation values mean high importance of this parameter in determining the ranking-specific positions. Low correlation values mean small importance in determining ranking differences between the four investigated rankings. RankDiffs are the ranking position differences of a university between two rankings (ranked place of first ranking minus ranked place in the second ranking). RankDiff value is low (negative) if the university is ranked higher in the first ranking than in the second, and high (positive) if it is ranked higher in the second ranking. Significant differences ($p < 0.05$) are marked with bold correlation coefficients. (The colors show the distance from the zero. Green to Yellow < 0; Yellow to Red 0 <).

emphasize size and/or quality parameters, while smaller universities can reach better positions in staff normalized rankings.

We have determined the effect of scientometric indicators on ranking positions. Previously, it has been shown that ranking scores correlate with the publication output and citations of a university[15]. It was also established and extended that broader field coverage is also an advantage in rankings[16]. Our results confirmed that scientometric indicators play a major role in rankings. We have found significant correlations between almost all bibliometric-related indicators and positions in each examined ranking. Our results also show that the absolute number of publications and citations are particularly important in ARWU and USNews rankings, and scientific category normalized (field weighted) citation impact is important in THE and USNews rankings.

Each ranking uses different indicators to measure the performance of universities, which vary from one ranking to another. Remarkably, many of these different parameters used for the rankings are not truly independent and we found strong correlations between examined parameters in some cases. These similarities can be divided to two groups: first, the correlation is actually high because of the natural phenomenon that the indicators can be similar in different rankings, e.g., ARWU publications and USNews publications or THE citation and USNews normalized citation impact show similar data from different sources which have significant

	USNews Enroll (# of Students)	QS citations per faculty	THE citation	THE research	THE internationa outlook	ARWU # highly cited researchers	ARWU Nature and Science	ARWU publications	ARWU per capita performance	USNews publications	USNews books	USNews conferences	USNews normalized citation impact	USNews total citations	USNews # top 10% cited	USNews % top 10% cited	USNews international collaboration	USNews # top 1% cited	USNews % top 1% cited
Continuous indicators																			
THE FTE of Students	**0.97** n=290	-0.03 n=421	**-0.11** n=440	**0.11** n=440	**-0.27** n=440	**0.31** n=406	**0.23** n=406	**0.60** n=406	-0.07 n=406	**-0.59** n=423	**-0.33** n=423	**-0.45** n=423	**0.14** n=423	**-0.53** n=423	**-0.53** n=423	**0.08** n=423	-0.04 n=423	**-0.48** n=423	0.08 n=423
USNews Enroll (# of Students)		-0.08 n=285	**-0.12** n=290	0.03 n=290	**-0.33** n=290	**0.25** n=282	**0.18** n=282	**0.56** n=282	-0.09 n=282	**-0.52** n=293	**-0.24** n=293	**-0.40** n=293	**0.16** n=293	**-0.45** n=293	**-0.45** n=293	**0.11** n=293	-0.07 n=293	**-0.40** n=293	0.09 n=293
QS citations per faculty			**0.33** n=421	**0.54** n=421	**0.23** n=421	**0.41** n=403	**0.36** n=403	**0.32** n=403	**0.50** n=403	**-0.35** n=421	**-0.26** n=421	**-0.36** n=421	**-0.25** n=421	**-0.39** n=421	**-0.43** n=421	**-0.41** n=421	**-0.22** n=421	**-0.41** n=421	**-0.29** n=421
THE citation				**0.31** n=440	**0.37** n=440	**0.48** n=406	**0.43** n=406	**0.20** n=406	**0.52** n=406	**-0.22** n=423	**-0.45** n=423	**0.18** n=423	**-0.88** n=423	**-0.40** n=423	**-0.40** n=423	**-0.78** n=423	-0.04 n=423	**-0.49** n=423	**-0.81** n=423
THE research					**0.24** n=440	**0.51** n=406	**0.62** n=406	**0.57** n=406	**0.55** n=406	**-0.64** n=423	**-0.58** n=423	**-0.42** n=423	**-0.28** n=423	**-0.65** n=423	**-0.65** n=423	**-0.36** n=423	**-0.18** n=423	**-0.63** n=423	**-0.27** n=423
THE international outlook						**0.14** n=406	**0.12** n=406	**-0.11** n=406	**0.36** n=406	0.05 n=423	**-0.37** n=423	**0.13** n=423	**-0.40** n=423	-0.06 n=423	-0.05 n=423	**-0.35** n=423	**0.11** n=423	**-0.11** n=423	**-0.35** n=423
ARWU # highly cited researchers							**0.64** n=431	**0.64** n=431	**0.50** n=431	**-0.64** n=423	**-0.44** n=423	**-0.30** n=423	**-0.45** n=423	**-0.71** n=423	**-0.74** n=423	**-0.57** n=423	**-0.18** n=423	**-0.77** n=423	**-0.56** n=423
ARWU Nature and Science								**0.57** n=431	**0.56** n=431	**-0.63** n=423	**-0.56** n=423	**-0.25** n=423	**-0.45** n=423	**-0.71** n=423	**-0.71** n=423	**-0.52** n=423	**-0.23** n=423	**-0.72** n=423	**-0.50** n=423
ARWU publications									**0.35** n=431	**-0.96** n=423	**-0.47** n=423	**-0.57** n=423	**-0.09** n=423	**-0.91** n=423	**-0.90** n=423	**-0.19** n=423	**-0.15** n=423	**-0.84** n=423	**-0.15** n=423
ARWU per capita performance										**-0.38** n=423	**-0.43** n=423	-0.05 n=423	**-0.53** n=423	**-0.47** n=423	**-0.46** n=423	**-0.55** n=423	**-0.19** n=423	**-0.50** n=423	**-0.52** n=423
Ranked indicators																			
USNews publications											**0.53** n=451	**0.56** n=451	**0.14** n=451	**0.97** n=451	**0.96** n=451	**0.23** n=451	**0.13** n=451	**0.91** n=451	**0.22** n=451
USNews books												**0.23** n=451	**0.40** n=451	**0.60** n=451	**0.59** n=451	**0.38** n=451	-0.04 n=451	**0.58** n=451	**0.33** n=451
USNews conferences													**-0.31** n=451	**0.45** n=451	**0.47** n=451	**-0.16** n=451	**0.26** n=451	**0.38** n=451	**-0.22** n=451
USNews normalized citation impact														**0.36** n=451	**0.36** n=451	**0.88** n=451	0.06 n=451	**0.46** n=451	**0.90** n=451
USNews total citations															**0.99** n=451	**0.43** n=451	**0.13** n=451	**0.98** n=451	**0.42** n=451
USNews # top 10% cited																**0.46** n=451	**0.15** n=451	**0.98** n=451	**0.43** n=451
USNews % top 10% cited																	**0.17** n=451	**0.54** n=451	**0.89** n=451
USNews international collaboration (relative)																		**0.16** n=451	**0.16** n=451
USNews # top 1% cited																			**0.56** n=451

Figure 3. Spearman rank correlations between all the investigated parameters across all included universities. High correlations show that the given indicator/rank affects the other indicator/rank. Significant differences ($p < 0.05$) are marked with bold correlation coefficients. "n" means the number of universities where both indicator/rank data were available. (The colors show the distance from the zero. Green to Yellow < 0; Yellow to Red 0 <).

overlap (e.g., data from Web of Science or Scopus). The second group involves indicators correlated to each other within one ranking. We found that indicators measuring absolute values in USNews ranking are highly correlated with each other. For example, universities performing well in the publications indicator also rank well in the citation's indicator, similar to the #top 1% cited and #top 10% cited indicators.

We have to mention several criticisms of university rankings formulated by different research groups. Vernon et al. summarized several doubts about the rankings, suggesting that the significance of the reputation questionnaire should be kept below 10%[12]. QS has the highest weight of reputation indicator (50%) of all the rankings we examined, followed by THE (33%) and USNews (25%). Daraio et al. abridged the main criticisms of the rankings into following four issues: monodimensionality, i.e. the rankings focus mainly on research among the education, research, and third missions of universities; statistical robustness, i.e. statistical problems of the individual indicators; dependence on university size and subject mix; and lack of consideration of the input–output structure[13]. As our results show, that ARWU and USNews rankings have high correlation with university size, while THE and QS rankings use normalized parameters.

We have to note a limitation of our study: the university ranking websites usually do not provide detailed information on the indicators, so approximations had to be used in some cases. In the THE ranking, the "Research" and "International Outlook" pillars, whose values are publicly available, were calculated by combining bibliometric and other indicators, so the effect of bibliometric parameters can be distorted in the correlation calculations. In the USNews ranking, the order of each indicator was available instead of the score values, and this contains less information. The exact ranking position in the ARWU list can only be calculated as an approximation, which also causes some bias. A second limitation is the use of different university names. In some ranking sites the English name only while in other sites the local language versions are used. We tried to identify each university in each list precisely, but we cannot completely exclude the possibility of a mismatch. Notably, as we found strong correlation between number-related parameters, it seems that at least for the THE, USNews, and QS rankings this potential bias is negligible. Finally, although we aimed to make all data openly available, the copyright of the original data sources prohibited this goal.

Unfortunately, in our study it was not possible to give a perfect guide, as one of the limitations of our project is that we only looked at bibliometric indicators (and the university's size). However, each ranking attempts to find the best universities by weighting different indicators. In our study, we found that, even when using the most objective bibliometric indicators, significant differences in the performance of several universities in each ranking can be detected when using certain types of indicators, and that publication differences in the disciplines

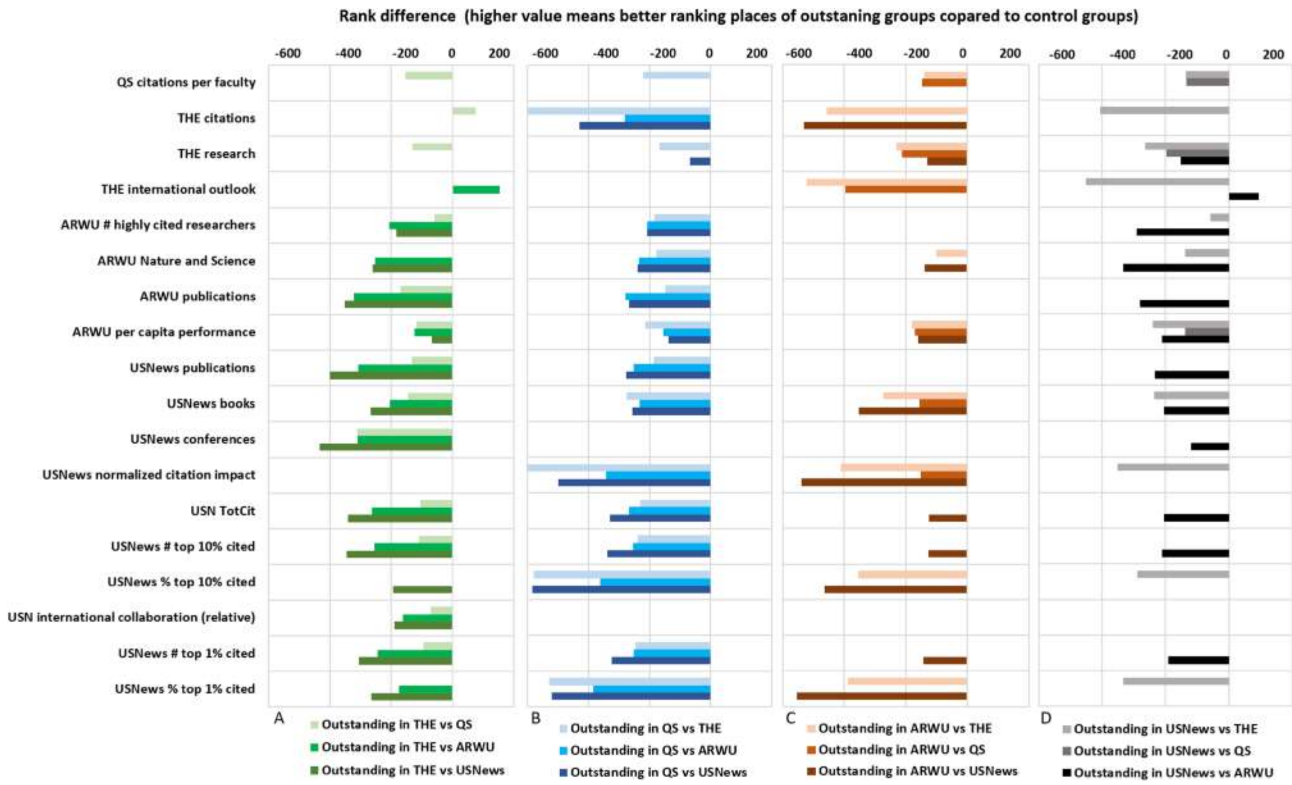

Figure 4. Differences of medians of indicator ranks between outstanding university groups compared to control groups comprising all non-outstanding universities in the given pair. Outstanding universities were those which had a ranking advantage of at least 100 positions compared to position in the other ranking. Outstanding universities and control groups were compared using the Mann–Whitney two-sample rank-sum test. Only those median differences are shown where the two group significantly differed ($p < 0.01$).

also affect the performance in each ranking. Based on these considerations, it is likely that the use of discipline-specific rankings would be more effective than overall rankings for the study of education, research and services.

University ranking systems are on the rise and influence the perceived prestige of a university. Here, we have determined the effects of scientometric parameters on university ranking positions. Notably, there are also other reasons why one group of universities have significantly different results in rankings, e.g., diversified territorial and educational contexts can cause structural biases[17]. In this study we have identified factors significantly related to the outstanding status. Overall, strong publication activity is an important factor in each ranking, but significant differences in ranking places depend on both the selected indicators used by the ranking and the publication and citation characteristics of the universities.

Methods

Setting up a matched ranking for top universities. We selected four internationally recognized rankings from three continents, Europe, North-America and Asia. A common characteristic of these rankings was the availability of detailed ranking data. We used the most recent version of the four chosen rankings including the Times Higher Education World University Ranking 2022 edition (THE), the QS World University Rankings 2022 edition (QS) the ShanghaiRanking—Academic Ranking of World Universities 2021 edition (ARWU), and the U.S.News Best Global Universities Ranking 2022 edition (USNews).

Recomputing ranking scores for scientometric indicators. Because most ranking websites do not publish exact ranking results, only bins, we had to calculate the ranking positions of the universities according to the ranking's published methodology. For example, in ARWU, the total scores were available only for the first 100 universities, for the other universities the total scores could not be derived from the public data, so we used estimation of the total score based on the values of each indicator using their methodology.

We selected bibliometrics-related indicator values from the four rankings, which were available on the webpage of the rankings. This includes altogether twenty indicators (one indicator from QS, three indicators from THE, four indicators from ARWU, and 12 indicators from USNews) which are described in detail in Table 1. Notably, the total weight of scientometric parameters is 60% in THE, 60% in ARWU, 20% in QS, and 75% in USNews.

We also collected available data on university sizes, which was the "Number of Students" parameter from THE and "Enrollment" value from USNews. These two parameters were the same for most universities, but they originate from different data collection processes.

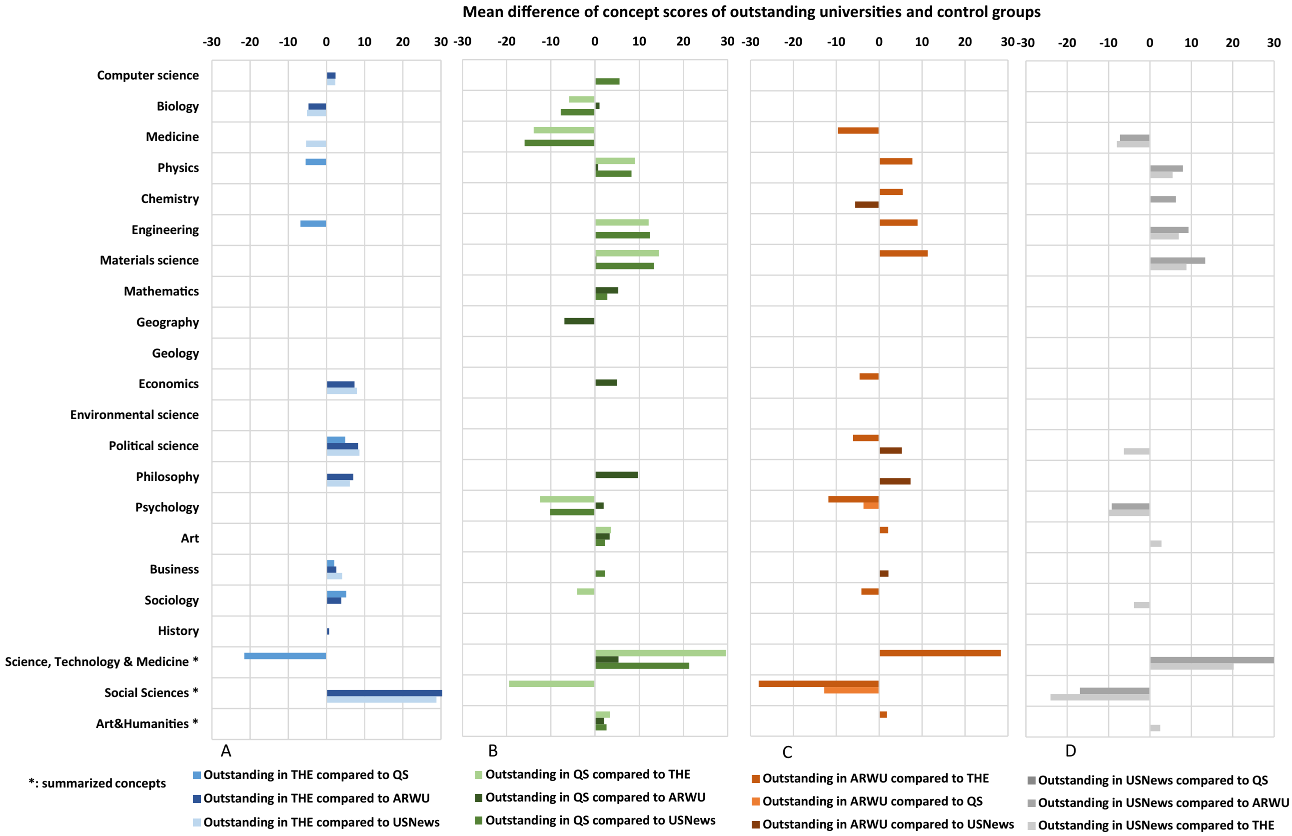

Figure 5. Differences of means of score values of root level concepts between outstanding university group compared to control groups comprising all non-outstanding universities in the given pair. Outstanding universities were those which had a ranking advantage of at least 100 positions compared to position in the other ranking. Outstanding universities and control groups were compared using the Mann–Whitney two-sample rank-sum test. Only those mean differences are shown where the two group significantly differed ($p < 0.01$).

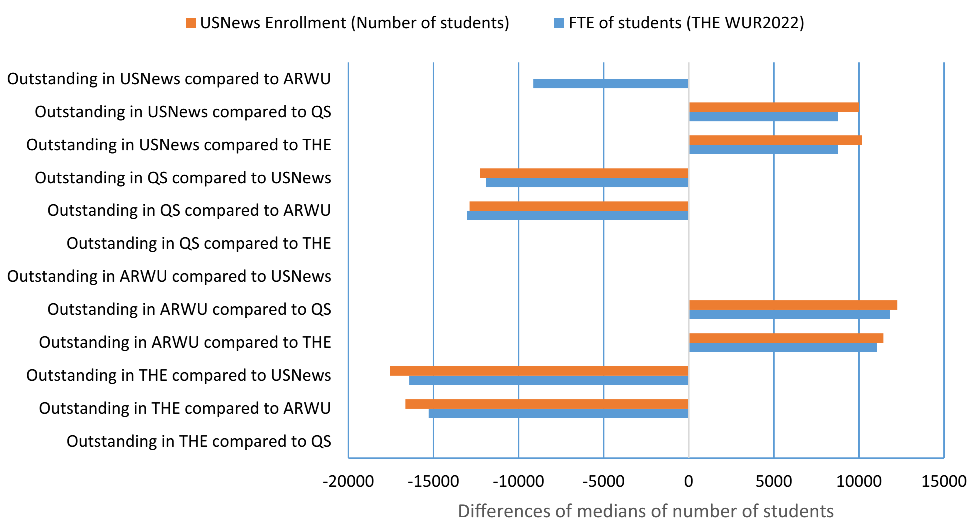

Figure 6. Differences of medians of university size parameters between outstanding university groups compared to control groups comprising all non-outstanding universities in the given pair. Outstanding universities were those which had a ranking advantage of at least 100 positions compared to the other ranking. Outstanding universities and control groups were compared using the Mann–Whitney two-sample rank-sum test. Only those median differences are shown where the two group significantly differed ($p < 0.01$).

Indicator abbreviation	Ranking	Indicator original name	% of overall	size dependent	Definition	Indicator origin (database)	Indicator type
THE citation	THE	Citations	30%	no	Citation ratio compared to average in same field, area, type and year	Scopus	Citation
THE research	THE	Research (Includes research productivity)	30% (6%)	no	Number of publications (article, review)/number of staff FTE	Scopus	Publication
THE international outlook	THE	International Outlook (Includes collaboration)	7.5% (2.50%)	no	% of articles	Scopus	Publication
QS citations per faculty	QS	Citations per faculty	20%	yes	The total number of citations received by all papers produced by an institution across a five-year period by the number of faculty members at that institution	Scopus	Citation
USNews publications	USNews	Publications	10%	yes	The total number of scholarly papers—reviews, articles and notes	Web of Science	Publication
USNews books	USNews	Books	2.50%	yes	The total number of books	Web of Science	Publication
USNews conferences	USNews	Conferences	2.50%	yes	The total number of conference abstracts, proceeding papers	Web of Science	Publication
USNews normalized citation impact	USNews	Normalized citation impact	10%	yes	The total number of citations per paper	Web of Science	Citation
USNews total citations	USNews	Total citations	7.50%	yes	The total number of citations	Web of Science	Citation
USNews # top 10% cited	USNews	Number of publications that are among the 10% most cited	12.50%	yes	The number of papers that have been assigned as being in the top 10% of the most highly cited papers in the world for their respective fields	Web of Science	Publication
USNews % top 10% cited	USNews	Percentage of total publications that are among the 10% most cited	10%	no	The percentage of a university's total papers that are among the top 10% of the most highly cited papers in the world—per field and publication year	Web of Science	Publication
USNews # top 1% cited	USNews	Number of highly cited papers that are among the top 1% most cited in their respective field	5%	yes	Number of highly cited papers that are among the top 1% most cited in their respective field based on the Clarivate's Essential Science Indicators™	Web of Science	Publication
USNews % top 1% cited	USNews	Percentage of total publications that are among the top 1% most highly cited papers	5%	no	The number of highly cited papers for a university divided by the total number of documents it produces	Web of Science	Publication
USNews international collaboration (relative)	USNews	International collaboration—relative to country	5%	no	The proportion of the institution's total papers that contain international co-authors divided by the proportion of internationally co-authored papers for the country that the university is in	Web of Science	Publication
ARWU Nature and Science	ARWU	N&S—Papers published in Nature and Science	20%	yes	The number of papers published in Nature and Science between 2016 and 2020. To distinguish the order of author affiliation, a weight of 100% is assigned for corresponding author affiliation, 50% for first author affiliation (second author affiliation if the first author affiliation is the same as corresponding author affiliation), 25% for the next author affiliation, and 10% for other author affiliations	Web of Science	Publication

Continued

Indicator abbreviation	Ranking	Indicator original name	% of overall	size dependent	Definition	Indicator origin (database)	Indicator type
ARWU publications	ARWU	PUB—Papers indexed in Science Citation Index-Expanded and Social Science Citation Index	20%	yes	Total number of papers indexed in Science Citation Index-Expanded and Social Science Citation Index in 2020. Only publications of 'Article' type are considered	Web of Science	Publication
ARWU per capita performance	ARWU	PCP—Per Capita Performance	10%	no	The weighted scores of the five indicators divided by the number of full-time equivalent academic staff give PCP scores. If the number of academic staff for institutions of a country cannot be obtained, the weighted scores of the above five indicators are used	Web of Science	Publication
ARWU # highly cited researchers	ARWU	HiCi—Highly Cited Researchers	20%	yes	Number of researchers in "highly cited researchers" list by Clarivate	Web of Science	Special

Table 1. Summary of examined scientometric indicators.

Notably, in the THE ranking, the value of the Research productivity and International collaboration indicators are not published, only the aggregated value of these combined with other indicators (Research and International Outlook). As USNews ranking did not publish the scores of different indicators, only by the rank by the indicator values, we calculated the ranking positions for each used indicator in order to make these indicators easily comparable where this was reasonable.

Creating merged ranking of universities listed among the top 300 in at least one ranking. A unified ranking of universities was created by merging universities which were among the top 300 in any of selected four rankings. Different university names in different rankings have been manually identified and merged (e.g., in some cases a local name was used in one ranking and English name in another). For each university in the merged list, we collected the ranking positions and indicator scores and/or ranking position values from all four selected rankings even in case the university was not listed in the other rankings. If the university was not listed at all in a ranking, the ranking place and the determined parameter indicators were left empty. In each case, we tried to identify the reason for being excluded from a particular ranking. In some cases, we found that QS did not list some universities because they are specialized in one specific field. Some institutions were listed as a part of a larger institution in one ranking, and separately in other rankings (e.g., Indian Institute of Technology).

Determining typical disciplines of universities. To identify the most typical scientific fields of each university we used OpenAlex database concepts which classifies scientific works using an automated algorithm[18]. OpenAlex has 19 root level concepts, and concepts score values are aggregated at the university level. We have collected the score values of root level concepts of all universities, and we summarized score values of concepts to three categories, including (1) Science, Technology, and Medicine which contains the following concepts: Computer science, Biology, Medicine, Physics, Chemistry, Engineering, Materials science, Mathematics, Geography, Geology, and Environmental science; (2) Social Sciences, which contain Economics, Political science, Philosophy, Psychology, Business, and Sociology; and (3) Arts & Humanities, including Art and History.

Statistical analysis. We used Spearman's rank correlation coefficient to evaluate the correlation between ranking positions and determined parameters in order to assess the overall weight of the investigated parameters. Also, Spearman's rank correlation was computed to correlate the positions in different rankings vs. the parameters, and between the determined parameters.

In a separate analysis, for each ranking pair (THE-QS, THE-USNews, THE-ARWU, QS-USNews, QS-ARWU, USNews-ARWU, and their reverse complementary pairs) universities for which the difference in ranking positions exceeded 100 were classified as "outstanding universities" in the given pair of rankings. Parameters and score values of OpenAlex concepts of outstanding groups and control groups were compared using the Mann–Whitney two-sample rank-sum test. Statistical significance was set at $p < 0.01$ in the study.

Data availability

THE World University Ranking (WUR) Ranking 2022: https://www.timeshighereducation.com/world-university-rankings/2022/world-ranking; QS WUR Ranking 2022: https://www.topuniversities.com/university-rankings/world-university-rankings/2022; Shanghai_ARWU Ranking 2021: https://www.shanghairanking.com/rankings/arwu/2021. The other datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Author contributions

P.S. and B.G. conception of the work; P.S. and B.G. design of the work; P.S. and E.C. design of data; E.C. acquisition of data; P.S. and E.C. clean of data; P.S. and B.G. interpretation of data; P.S., E.C. and B.G. wrote the manuscript; All the authors contributed to revision of the manuscript.

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Competing interests

The authors declare no competing interests.

Additional information

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