BJM BRITISH JOURNAL of MANAGEMENT
BRITISH ACADEMY OF MANAGEMENT
Check for updates

British Journal of Management, Vol. 37, e70074 (2026)
DOI: 10.1111/1467-8551.70074

Too Much of a Good Thing? Striking a Balance Between Research Environment Inputs and Research Output Quality in UK Business Schools

Vasilis Theoharakis[1] and Georgios Batsakis[2,3]

[1]Cranfield School of Management, Cranfield University, Cranfield, UK, [2]Alba Graduate Business School, The American College of Greece, Athens, Greece, and [3]Brunel Business School, Brunel University of London, Uxbridge, UK
Corresponding author email: v.theoharakis@cranfield.ac.uk

The UK's Research Excellence Framework (REF) is one of the world's most established performance-based research funding systems, shaping universities' strategic choices. While the REF emphasizes investing in research inputs to enhance output quality, the investments in research environment inputs can, at some point, become counterproductive and lead to diminishing returns. Drawing on the research production function approach and the resource-based view (RBV), we examine how universities transform research environment inputs into research outputs and impact. We empirically investigate whether the production functions relating research environment inputs (external research income and doctoral programme size) to research outcomes (output and impact quality) follow an inverted U-shaped curve. Using REF2021 data on 108 UK business schools, we confirm that initial gains plateau and eventually decline as resources are stretched. We further find that Russell Group (RG) business schools operate under distinct production functions, enabling them to sustain research output quality with higher levels of external research input than non-RG peers. However, they do not exhibit superior production functions for research impact as defined by the REF, despite potential advantages in global reach, suggesting that different institutional types have developed equally effective but distinct approaches to generating societal value.

Introduction

Universities worldwide grapple with a fundamental strategic dilemma: how much research investment is optimal? As business schools compete intensely for research excellence, they face mounting pressure to expand external research income and doctoral programmes, that is, the inputs that research assessment systems such as the UK's Research Excellence Framework (REF) explicitly reward (Blackburn, Dibb and Tonks, 2024; Pidd and Broadbent, 2015). REF criteria intensify competition and guide university resource allocation decisions (Banal-Estañol *et al.*, 2023). But do universities benefit from increased research investment, or do optimal thresholds exist beyond which additional resources become counterproductive? While the resource-based view (RBV) suggests that more research resources improve performance, diminishing returns may emerge beyond an optimal threshold, suggesting production inefficiencies in university research.

This study adopts a research production function approach (Hanushek, 1979, 2020; Tassey, 2005), informed by the RBV. The RBV framework recognizes that institutions possess different resource endowments and capabilities (Barney, 2001) that may lead to fundamentally different production technologies for converting inputs into research outcomes. Production functions have extensive applications in education (Hanushek, 2020), allowing us to treat research inputs, that is, external research income, doctoral students and faculty, as factors combined to produce research outputs and impact. External research income both expands resources and constrains researcher autonomy through funder-specified objectives, timelines and reporting requirements. These constraints introduce coordination and compliance costs that absorb managerial attention and may limit productive efficiency beyond institutional capacity thresholds. This perspective allows us to empirically identify the shapes of the relationship between research environment investments and performance (Tassey, 2005). While institutional leaders can influence research direction through hiring, promotions, workload models and internal funding schemes (Joseph and Wilson, 2018), faculty autonomy limits central control. At the local level, business schools transform research environment inputs into research outputs and impact.

UK business schools face significant resource allocation trade-offs in achieving research excellence, requiring high-quality outputs and societal impact as measured by the REF (Audretsch *et al.*, 2022; Moore, Ulrichsen and Hughes, 2010). Given REF's emphasis on research environment measures, business schools may face pressure to expand external research income and doctoral programme size, making optimal investment particularly urgent. Unlike firms, external research income is competitively awarded and funder-constrained, limiting its redeployment towards REF-optimized outputs.

While business schools also receive internal funding through quality-related (QR) allocations and teaching cross-subsidization, we focus on external research income as the critical case. As an explicitly measured REF environment indicator, external income creates Key performance indicator (KPI)-driven strategic imperatives that internal funding does not face. Its competitive acquisition and funder constraints make it particularly likely to generate coordination costs and capacity overextension in the research production function. Deans and senior managers may partially offset these pressures through internal funding mechanisms, including the allocation of past REF-related QR funding, which in some institutions, particularly outside the Russell Group (RG), may exceed external income (Graddy-Reed, Lanahan and D'Agostino, 2021).

Strategic choice in university environments depends on institutional heterogeneity (Horner *et al.*, 2019), an important contingency when evaluating how research inputs transform into outcomes. We examine whether increasing research environment inputs enhances or undermines research quality and whether RG institutions, with superior resource endowments and capabilities, operate under different production functions than other UK universities. Specifically, we conceptualize research income as external research income, the REF-visible, competitively constrained input most likely to generate production inefficiencies. The REF provides a suitable setting to examine these production relationships between its three components: research environment (20%), research output quality (55%) and impact (25%)[1]; impact is defined by REF criteria emphasizing the 'reach and significance' of effects on the economy, society, culture, public policy, health and quality of life. Though weighted lowest, the research environment influences higher-weighted outcomes. Our research questions are: (i) What are the shapes of the research production functions relating research environment inputs (external research income and doctoral programme size) to research outputs and impact in UK business schools? (ii) Do RG and non-RG universities operate under different production functions, reflecting distinct institutional technologies for converting research inputs into outputs?

We focus on UK business schools (business and management departments) for three reasons. Firstly, business school academics must balance academic rigor with practical relevance, making them highly responsive to national research assessments (Salter, Salandra and Walker, 2017). Secondly, the discipline's 22 sub-disciplines make it well-suited for examining trade-offs between publication quality, income generation and impact. Thirdly, UK business schools face strong publication pressures from REF assessments, accreditations and rankings (Blackburn, Dibb and Tonks, 2024), yet external research income remains comparatively limited and often supplemented by teaching cross-subsidization. These characteristics make business schools a particularly stringent context for assessing how marginal increases in externally constrained funding translate into REF-quality outputs and impact.

Although empirically grounded in higher education, our framework speaks more broadly to strategic challenges faced by knowledge-intensive organizations operating under performance-based evaluation regimes. By empirically grounding our study in RBV, we identify capacity thresholds as a boundary condition to its accumulation logic, specifying when additional resources generate diminishing rather than increasing returns.

[1]The Research Outputs component assesses the quality of research publications (https://2021.ref.ac.uk/media/1848/ref2021_key_facts.pdf). The Research Impact component assesses the societal, economic and cultural impact of research. The Research Environment assesses 'vitality and sustainability' through strategy, resources and infrastructure that support research and enable impact based on statistical data, including research income and doctoral degrees awarded. The REF panel (Panel C) weights the four Environment sections equally; research income and doctoral degrees awarded (Section 3) contribute 25% of the Environment sub-profile, while the remaining 75% (Sections 1, 2, 4) comprises a qualitative narrative judged holistically by the panel. REF2029 replaces the 'Environment' with the 'Strategy, People and Research Environment' (SPRE) element, weighted at 20% of the overall quality profile. SPRE builds on the REF2021 Environment component and the PCE pilot (concluded late 2025), retaining emphasis on research culture while introducing an Institution-Level Statement that explicitly assesses institutional research and impact strategy moving beyond simple input-based metrics.

Hypotheses development

Research production functions in higher education

Following the production function logic outlined above, we develop specific hypotheses about the research input–output relationships in the REF context. As a performance-based evaluation system, the REF drives universities to improve research outcomes by optimizing resource allocation and applying isomorphic pressures to conform to normative expectations (DiMaggio and Powell, 1983). For business school leaders, this means optimizing resource allocation within institutional and externally imposed constraints.

Universities must strategically combine inputs to maximize research outcomes, yet input–output relationships may be nonlinear. Drawing on the RBV, we argue that while resources are essential for research production (Barney, 2001), returns to scale vary with institutional capacity and the effectiveness of their production technology (Ridge, Kern and White, 2014; Tassey, 2005). We argue that excessive focus on research environment inputs, particularly those constraining autonomy and imposing fixed overheads, may generate diminishing, or even declining, returns on research performance (Rhee and Leonardi, 2018).

While the RBV stresses accumulating valuable, rare, inimitable and non-substitutable resources, it places limited attention on the conditions under which additional resource accumulation may become counterproductive. Integrating RBV with research production functions, we argue that organizational capacity constraints, coordination costs and autonomy limits introduce diminishing returns to resource accumulation. Our framework thus complements RBV by specifying when and why additional resources cease to enhance performance.

External research income and supervising doctoral students

Initially, increased external research income enables business schools to support research activities through academic buyouts, dedicated research staff and project-specific resources (Lee, 1996). It also supports institutional capacity through overhead contributions and by demonstrating research capability that enables strategic hiring decisions. However, as external research income grows, the marginal productivity of additional funding may decline due to diminishing returns to scale in the research production process. Individual academics generate and manage external grants independently, while funder-imposed objectives, reporting requirements and non-discretionary overheads constrain resource redeployment towards REF-optimized outputs.

Pressure to meet performance metrics may shift institutional attention towards seemingly achievable, shorter term goals (Groen-Xu *et al.*, 2023), such as external research income generation or doctoral programme expansion. This shift can reduce attention devoted to high-quality research outputs, reflecting decreasing returns in the production function. As a result, research productivity per funding unit declines at higher funding levels, reflecting an inverted U-shaped relationship between external research income and research output quality (Yu, Dong and de Jong, 2022). This is compounded by heterogeneous grant deliverables, as research council funding typically mandates publishable outputs, while commercial grants often require confidential reports or proprietary solutions ineligible for REF submission.

Increased external research income initially boosts research output quality by enabling investment in high-impact research activities (Graddy-Reed, Lanahan and D'Agostino, 2021). Once individuals surpass their capacity to effectively manage their external research income, benefits plateau and begin to decline as resources become overextended and administrative burdens rise, creating inefficiencies in the production process. For example, German graduate schools demonstrated limited efficiency in translating external funding to regional innovation, suggesting that research funds aimed at boosting scientific knowledge do not necessarily improve innovation and societal impact (Krieger, 2024). This pattern appears in both research output quality (academic depth and rigor) and impact quality (broader societal value). We therefore hypothesize that:

H1a. *The relationship between external research income and research output quality in UK business schools follows an inverted U-shaped curve, such that research output quality increases with external research income but declines beyond a certain point.*

H1b. *: The relationship between external research income and research impact quality in UK business schools follows an inverted U-shaped curve, such that impact quality increases with external research income but declines beyond a certain point.*

Universities with extensive doctoral programmes tend to initially enjoy significant advantages as new doctoral candidates bring fresh ideas and produce high-quality research (Sarrico, 2022), though supervision demands may reduce faculty research time beyond optimal ratios. While Horta, Dautel and Veloso (2012) argue that doctoral programmes foster intellectual exchange, boosting research productivity, quality and impact, Campbell, Fuller and Patrick (2005) suggest this effect diminishes when supervision burdens intensify or when less prepared candidates are admitted. As doctoral programmes grow, these benefits can wane and supervisory capacity constraints emerge, compromising research excellence and impact (Golde, 2005). The production function for doctoral education may exhibit decreasing returns as faculty attention deteriorates.

Unlike in science and engineering, where doctoral students often contribute to shared projects, heavier doctoral student loads in the social and behavioural sciences, fields lacking unifying frameworks, require highly individualized supervision, which reduces research productivity at higher student loads (Dundar and Lewis, 1998; Lodahl and Gordon, 1972).

Doctoral study typically spans 4 years. Even an average completion rate of 0.2 per full-time equivalent (FTE) per year, therefore, implies that individual academics supervise several doctoral candidates concurrently. Because supervision eligibility, topic fit and continuity requirements constrain the broad reallocation of supervisory loads, additional students disproportionately load the same supervisors.

As cohorts grow, supervision time and coordination costs escalate and crowd out research and mentoring quality, resulting in capacity-driven diminishing returns. We therefore argue that the relationship between doctoral programme size and research quality in UK business schools follows an inverted U-shaped curve: initial growth enhances research output and impact quality, but expansion beyond a certain point becomes counterproductive. We therefore hypothesize that:

H2a. *The relationship between doctoral programme size and research output quality in UK business schools follows an inverted U-shaped curve, such that research output quality initially improves with programme size but declines beyond a certain point.*

H2b. *The relationship between doctoral programme size and research impact quality in UK business schools follows an inverted U-shaped curve, such that research impact quality initially improves with programme size but declines beyond a certain point.*

Russell versus non-RG business schools

Research-intensive and teaching-oriented institutions differ significantly in resource endowment and institutional capabilities. Nearly half of doctoral students in US research-intensive universities are federally funded (Chang *et al.*, 2019), while elite universities enjoy labour advantages in accessing top-tier academic talent (Zhang *et al.*, 2022). In the UK, non-RG business schools typically have limited resources versus their RG counterparts (Baker, 2024), which are recognized as research powerhouses (The Russell Group, 2024). RG universities' advanced research infrastructure and strong financial backing enable consistent performance in research output quality, particularly in assessments, such as the REF (Banal-Estañol *et al.*, 2023; Taylor, 2011). Therefore, for non-RG institutions, initial research income increases can substantially address critical gaps, such as attracting talented researchers and upgrading facilities, leading to significant gains in research output quality and impact.

RG business schools also benefit from structural advantages in the research production process. Faculty at RG institutions have greater representation on high-level journal editorial boards and research council grant-awarding panels, providing insider knowledge about publication standards and funding priorities that enhance research output quality. RG business schools thus possess resources that are valuable, rare, inimitable and difficult to substitute, giving them significant advantages over non-RG counterparts.

These resource advantages suggest that RG universities may operate under different production functions, characterized by greater capacity to absorb and coordinate research inputs before diminishing returns set in. Their extensive resources enable more effective handling of larger external funding volumes, maintaining high-quality research output at higher input levels (Yu, Dong and de Jong, 2022). This implies flatter production functions for RG business schools with a later onset of diminishing returns. We therefore hypothesize:

H3a. *The inverted U-shaped relationship between external research income level and research output quality is less pronounced for the UK's RG business schools.*

Resource constraints limit universities' ability to sustain high doctoral student satisfaction and attention to activities that drive research output and impact quality (Harman, 2002). Non-RG business schools typically have fewer research-active faculty and limited research infrastructure may thus reach production capacity when expanding doctoral programmes much earlier and more intensely than RG counterparts.

In contrast, business schools with more resources (i.e. RG) are better positioned to handle the demands of larger doctoral programmes as they benefit from well-established research networks, advanced facilities and greater financial support, including scholarships and stipends (Zhang *et al.*, 2022). These resources attract high-calibre doctoral students who often need less supervising and are more likely to generate high-quality outputs (Bedeian *et al.*, 2010). We argue that RG business schools operate under production functions exhibiting higher supervisory and coordination capacity, resulting in lower diminishing returns in doctoral education. We therefore expect the inverted U-shaped relationship between doctoral programme size and research quality to be less pronounced for RG universities and hypothesize:

H3b. *The inverted U-shaped relationship between doctoral programme size and research output quality is less pronounced for the UK's RG business schools.*

While UK universities vary in strengths and resources, research-intensive universities focus on harder forms of engagement, such as collaborative research and intellectual property development, whereas newer/teaching-oriented universities tend to focus on softer forms of engagement, such as training and consultancy (Degl'Innocenti, Matousek and Tzeremes, 2019). Therefore, both RG and non-RG universities have the potential to excel in impactful research through distinct pathways.

RG business schools, with their extensive resources and global reach, can generate impact by utilizing their production technology to address high-profile, large-scale projects. Their global reputation and extensive networks enable them to partner with international organizations and tackle global challenges, producing findings that influence policy on a broader scale (Dutta, 2024). RG institutions may therefore appear to have an inherent structural advantage in REF impact assessments that emphasize 'reach and significance'. However, non-RG universities operate a production technology optimized for applied research tailored to local communities, minorities and regional industries (Croucher and Gooderham, 2022; Lockett, Wright and Wild, 2015). Their closer connections to local small businesses, local councils and communities enable them to create meaningful and immediate benefits, delivering high-value impact within their regions.

To interpret why RG membership does not moderate research impact, we advance a theoretically grounded explanation based on distinct production technologies optimized for different impact contexts. RG institutions may leverage a global engagement logic, addressing large-scale challenges through extensive international networks, while non-RG institutions leverage a local engagement logic, embedding in regional ecosystems to generate impact through immediate applicability and local partnerships. REF impact assessment criteria of 'reach and significance' recognize both logics: global reach is not inherently superior to local transformation. This explains why RG resource advantages in output production do not translate to impact advantages; the production technologies are different, optimized for distinct but equally valuable forms of societal contribution.

While these global and local engagement logics are theoretically grounded, but cannot be directly observed in available REF data, they provide an interpretive explanation for the absence of RG moderation effects on impact quality. In conclusion, RG business schools tend to generate impact by addressing global challenges through extensive international networks, while non-RG business schools deliver impact through applied research tailored to local or sector-specific contexts (Papatsiba and Cohen, 2020). Because these production pathways are distinct yet equally valued under REF impact criteria, RG resource advantages in research output do not translate into systematically superior impact production functions. We therefore hypothesize that:

H4a. *The relationship between external research income and research impact quality for business schools is not moderated by RG membership.*

H4b. *: The relationship between doctoral programme size and research impact quality for business schools is not moderated by RG membership.*

Data and methodology

Research context

This research draws on the REF2021 database.[2] REF is the UK's official independent system for assessing research quality in UK HEIs. This research focuses on the latest REF submission of 2021, which covers the 7-year period from 2014 to 2020. This study draws on Unit of Assessment 17 (UOA17), the business and management disciplinary field. In total, 108 HEIs participated in UOA17 of REF2021. The list of participating HEIs is in Table S9.

Data

The REF database reports data at the institutional and individual levels. This means that we can extract information on the performance of institutions in terms of output scores, that is, the average score each business school received for the submitted outputs to the REF (such as scholarly journal publications, book chapters or conference proceedings papers) based on the evaluation these outputs received from the respective REF panel of experts. Further, we can identify more objective information pertaining to each business school, such as research income generation, number of awarded doctoral degrees, number of faculty and percentage of faculty that submitted outputs to the REF. At the individual level, the database provides information about the outputs (i.e. title of research output, authors etc.) each research staff submitted to the REF. In addition to the quantitative REF scores used in our analysis, the dataset provides publicly available grade profiles (percentage distributions across quality categories), as well as access to submitted Impact Case Studies (ICS) and Environment templates, which enhance transparency regarding institutional research performance. Beyond the REF database, we draw complementary information

[2]https://results2021.ref.ac.uk.

from other publicly available sources such as RG affiliation, year of charter, Teaching Excellence Framework (TEF) scores and participation of business school academics on Sub-panel 17 for the REF2021.

Variables

Dependent variables. *REF output score* and *REF impact score.* The two dependent variables in our study are the institutional REF score for outputs and impact cases, which is publicly available through the REF2021 database. These variables represent the average percentage of an institution's (i) research outputs and (ii) research impact cases that expert judges in the respective panel categorized into five distinct categories. Specifically, in REF2021, research outputs and research impact were graded on the following 5-point (0–4) scale:

4* World-leading (i.e. quality that is world-leading in originality, significance and rigor);
3* Internationally excellent (i.e. quality that is internationally excellent in originality, significance and rigor but which falls short of the highest standards of excellence);
2* Recognized internationally (i.e. quality that is recognized internationally in originality, significance and rigor);
1* Recognized nationally (i.e. quality that is recognized nationally in originality, significance and rigor);

U Unclassified (i.e. quality that falls below the standard of nationally recognized work, or a submission that does not meet the published definition of research).

Here, it is important to note that funding allocation is closely tied to REF scoring. Mainstream QR funding that flows from REF results is allocated on the 3* and 4* portions of each unit's overall quality profile only, with quality weightings of 4 for 4*, 1 for 3* and 0 for 2*, 1* and unclassified (UK Research and Innovation, 2023). In other words, outputs/impact/environment assessed below 3* attract no mainstream QR, while 4*-rated quality carries four times the funding of 3*. This is the method used by Research England and adopted in similar form by SFC (Scotland; 4:1)[3] and Medr/HEFCW (Wales; 0/1/4 with a published sustainability threshold).[4]

Extant research has used the REF output and impact scores as dependent variables to capture research excellence and research performance in universities in general (Khoo *et al.*, 2024) and business schools in particular (Kellard and Śliwa, 2016; Morgan-Thomas *et al.*, 2024). The formula for the business school's GPA score, GPA_{REF}, can be expressed as a weighted average:

$$GPA_{REF} = \frac{4 \text{ x } p_4 + 3 \text{ x } p_3 + 2 \text{ x } p_2 + 1 \text{ x } p_1 + 0 \text{ x } p_0}{100}, \tag{1}$$

where, p_4 is the percentage of research outputs (impact cases) graded as 4*, p_3 is the percentage of research outputs (impact cases) graded as 3*, p_2 is the percentage of research outputs (impact cases) graded as 2*, p_1 is the percentage of research outputs (impact cases) graded as 1* and p_0 is the percentage of research outputs (impact cases) graded as U. Therefore, this formula estimates the institutional REF score for research outputs and impact by considering the distribution of research outputs and impact cases respectively across the different categories and applying appropriate weights to each category.

Independent variables. Our two independent variables capture the research activities of the examined business schools, that is, (i) research income generation per FTE and (ii) doctoral degrees awarded per FTE. Both research activities complement the research outputs and impact of the business school's faculty. Firstly, *Research income per FTE* is measured as the external research income generated by the business school, as reported by the REF, over the 7-year period examined, divided by the number of faculty members (FTE). Following REF conventions, external research income is reported in disaggregated streams (e.g. UK Research Councils, charities, industry and other public and international sources), which allows us to examine how different types of competitively acquired funding contribute to research production at the business school level. Our second variable is the number of *Doctoral degrees awarded per FTE* (Groen-Xu *et al.*, 2023). This is measured as the number of completed doctoral degrees awarded per FTE by the business school over the 7-year period of examination. It is important to note that we divide both research income and doctoral degrees awarded by *all* academic FTE on the school's payroll (not *submitted* FTE only), to reflect total research and supervisory capacity.[5]

Moderating variables. The RG comprises 24 prestigious and old universities in the UK that are dedicated to conducting research of the highest quality, providing excellent teaching and offering unparalleled networking with businesses and the public sector. When compared to other universities, these research-intensive higher education institutions often exhibit a strong focus on generating income through knowledge exchange (Benneworth, Pinheiro and Sánchez-

[3]https://www.sfc.ac.uk/research-innovation/research-funding/.
[4]https://www.medr.cymru/wp-content/uploads/2024/07/W22-24HE-HEFCWs-research-funding-method-from-AY-2022_23-English.pdf.

[5]The REF standard analysis uses *submitted* FTE instead of *all* FTE, hence, for example, the higher ratio in their report as compared to our calculations in terms of doctoral degrees awarded per submitted FTE as compared to per all FTE (1.39 in their report vs 1.15 here).

Table 1. Description of variables

Variable name	Description	Source
REF output score	The average score attributed to research outputs submitted to the REF2021.	www.results2021.ref.ac.uk
REF impact score	The average score attributed to research impact cases submitted to the REF2021.	www.results2021.ref.ac.uk
Research income per FTE	The annual research income generated per FTE of the business school for the 7-year period 2014–2020.	www.results2021.ref.ac.uk
Doctoral degrees awarded per FTE	The number PhDs awarded (per FTE) from the business school for the 7-year period 2014–2020.	www.results2021.ref.ac.uk
RG	Dummy variable taking the value 1 if the university is part of the group of 24 Russell universities and the value 0 otherwise.	www.russellgroup.ac.uk
Year of charter	The year the university was recognized as a chartered university.	Universities'websites
FTE	The average number of FTE faculty.	www.results2021.ref.ac.uk
TEF	Ordinal variable that assigns universities 3, 2, 1, or 0 points according to their 2017–2019 Teaching Excellence Framework rating—gold, silver, bronze, or no award, respectively.	Times_Higher_Education
REF panel	For each business school, the variable records the total number of unique individuals who held one of the following REF-panel roles on Sub-panel 17 for the REF2021: Panel chair, Deputy chair, Panel member, Assessor and Panel secretariat.	www.2021.ref.ac.uk

Barrioluengo, 2016). We consider that RG universities will, by nature, be more research-intensive, aspiring to maintain their legacy by devoting more resources and effort to research, thus outperforming their peers. RG affiliation has been previously used as an independent or moderating variable (Banal-Estañol *et al.*, 2023).

Control variables. We include several control variables that may influence research output and impact quality. Firstly, we control for institutional age (Geuna, 1998) using the year each university gained its Royal Charter. Historic universities are likely more experienced, research-led institutions, orchestrating resources more efficiently and achieving better research results. Secondly, we control for faculty size, as larger faculties reflect greater overall research capacity and may be associated with differences in research activity levels and resource deployment across institutions. We measure this variable as the FTE of *all* academic staff in the respective institution's business school (Degl'Innocenti, Matousek and Tzeremes, 2019). Thirdly, we control whether the respective institution has participated in the first phase of the TEF that was published in the period 2017–2019. TEF is a government assessment of the quality of undergraduate teaching in universities and other higher education providers nationally, which has been applied to determine the quality of education provided and whether public universities are permitted to raise tuition fees. TEF is an ordinal variable that assigns universities 3, 2, 1 or 0 points according to their 2017–2019 TEF rating, that is, gold, silver, bronze or no award, respectively. This information was retrieved from the Times Higher Education publication. Finally, we control for the participation of business school academics in the REF assessment process, measured as the total number of unique individuals from each business school who served in one of the following REF-panel capacities on Sub-panel 17 for the REF2021: Panel chair, Deputy chair, Panel member, Assessor and Panel secretariat. Table 1 provides a short description of the variables and their sources.

Analytical approach

Model specification 1. Our model aims to assess the role of research income and the number of doctoral degrees awarded per FTE in explaining the REF output and REF impact score, and how RG and non-RG academic institutions affect these relationships.

Our baseline models are as follows:

$$\begin{aligned} GPA_{REF_{OUTPUT\,i}} = {} & \beta_0 + \beta_1 Res_{income\,i} + \beta_2 Res_{income\,i}^{\;2} \\ & + \beta_3 PhDs_{awarded\,i} + \beta_4 PhDs_{awarded\,i}^{\;2} \\ & + \beta_5 Russell_{group_i} + \sum_{n=1}^{N} \varphi_n Controls_n + \varepsilon_i \end{aligned} \quad (2)$$

$$\begin{aligned} GPA_{REF_{IMPACT\,i}} = {} & \beta_0 + \beta_1 Res_{income\,i} + \beta_2 Res_{income\,i}^{\;2} \\ & + \beta_3 PhDs_{awarded\,i} + \beta_4 PhDs_{awarded\,i}^{\;2} \\ & + \beta_5 Russell_{group_i} + \sum_{n=1}^{N} \varphi_n Controls_n + \varepsilon_i \end{aligned} \quad (3)$$

where $GPA_{REF_{OUTPUT\,i}}$ is the REF output score and $GPA_{REF_{IMPACT\,i}}$ is the REF impact score (see (1) above), $Res_{income\,i}$ is the research income per FTE generated, $Res_{income\,i}^{\;2}$ is its squared term, $PhDs_{awarded\,i}$ denotes the number of students who have been awarded a PhD per FTE, the $PhDs_{awarded\,i}^{\;2}$ denotes its squared term and $Russell_{group_i}$ is a dummy variable indicating whether the university is a RG member. $Controls_n$ is a vector of control variables that we described previously. Further, β_0 is the intercept and ε_i is the error term for each observation. Our conjectures are that an inverted U-shaped relationship exists between research income per FTE and REF output and research income per FTE and REF impact score. We also project an inverted U-shaped relationship for doctoral degrees awarded per FTE and REF output score, as well as for doctoral degrees awarded per FTE and REF impact score. Therefore, we expect positive and significant coefficients for β_1 and β_3 and negative and significant coefficients for β_2 and β_4.

Model specification 2. After estimating the direct relationships mentioned earlier, our next step is to estimate how RG affiliation moderates the relationship between (i) research income per FTE and REF output (REF impact) score and (ii) doctoral degrees awarded per FTE and REF output (REF impact) score.

The model below is an extension of Eqs. (2) and (3), respectively, including the aforementioned interaction effects, and is expressed as follows:

$$\begin{aligned} GPA_{REF_{OUTPUT}\,i} = {} & \beta_0 + \beta_1 Res_{income\,i} + \beta_2 Res_{income}{}_i^2 \\ & + \beta_3 PhDs_{awarded\,i} + \beta_4 PhDs_{awarded}{}_i^2 \\ & + \beta_5 Russell_{group_i} + \beta_6 Res_{income\,i} x Russell_{group_i} \\ & + \beta_7 Res_{income}{}_i^2 x Russell_{group_i} \\ & + \beta_8 PhDs_{awarded\,i} x Russell_{group_i} \\ & + \beta_9 PhDs_{awarded}{}_i^2 x Russell_{group_i} \\ & + \sum_{n=1}^{N} \varphi_n Controls_n + \varepsilon_i \end{aligned} \tag{4}$$

$$\begin{aligned} GPA_{REF_{IMPACT}\,i} = {} & \beta_0 + \beta_1 Res_{income\,i} + \beta_2 Res_{income}{}_i^2 \\ & + \beta_3 PhDs_{awarded\,i} + \beta_4 PhDs_{awarded}{}_i^2 \\ & + \beta_5 Russell_{group_i} + \beta_6 Res_{income\,i} x Russell_{group_i} \\ & + \beta_7 Res_{income}{}_i^2 x Russell_{group_i} \\ & + \beta_8 PhDs_{awarded\,i} x Russell_{group_i} \\ & + \beta_9 PhDs_{awarded}{}_i^2 x Russell_{group_i} \\ & + \sum_{n=1}^{N} \varphi_n Controls_n + \varepsilon_i \end{aligned} \tag{5}$$

where the coefficients of interest are β_7 and β_9. These coefficients of the respective interaction terms aim to test whether RG affiliation is an important moderating factor for the relationship between (i) research income per FTE and REF output (REF impact) score and (ii) doctoral degrees awarded per FTE and REF output (REF impact) score. Specifically, we expect β_7 and β_9 to be positive and statistically significant, indicating that the inverted U-shaped relationships of the previous model will be less steep for RG universities. Based on our analysis, we expect that RG universities with moderate to high levels of (i) research income per FTE and (ii) doctoral degrees awarded per FTE will achieve a relatively higher REF output score, on average. Additionally, we anticipate that any decrease in the REF output score will occur at a lower intensity, indicating that business schools being part of RG universities will display stronger resistance to the trade-offs posed by research activities at moderate-to-high levels of research income per FTE and doctoral degrees awarded per FTE. However, we do not anticipate the effect of RG affiliation to significantly moderate the relationship between (i) research income per FTE and REF impact score and (ii) the number of doctoral degrees awarded per FTE and REF impact score.

Analysis

Table 2 presents descriptive statistics and pairwise correlations. Among the variables of interest, the average REF output score is 2.86, with a minimum score of 1.45 and a maximum of 3.73. The average REF impact score is 3.06, with a minimum score of 1.5 and a maximum of 3.79. The average research income per FTE is £56,017 (minimum is £1428 and maximum is £386,862), the average number of completed doctoral degrees per FTE is 1.15 (minimum is 0.03 and the maximum is 7.38), and 22.2% (i.e. 24 out of 108) of our sample's business schools are departments of RG-affiliated universities. Further, the average year universities received the Royal Charter was 1933. As per the size of the business schools, the average size of our sample's faculty is 91.38 faculty members (minimum is 7.79 and the maximum is 513.33). Moreover, of the 108 universities, 92 appear in the TEF rankings, and of them, 39.1% received the gold, 51.1% received the silver and 9.8% received the bronze rank. Finally, academics from 34 out of 108 universities were members of Sub-panel 17 for the REF2021, with 7 universities having two or more panel members.

As far as the sample's pairwise correlations are concerned (Table 2), as expected, some variables are highly correlated, yet there is no correlation above 0.7. Given the employment of quadratic and interaction effects in our models, we decide to standardize all scale variables to decrease the likelihood of inflated variance inflation factors (VIFs). Indeed, the mean VIF of our full model is below the commonly accepted critical value of 10 (Baum, 2006). Hence, correlations and VIFs suggest that multicollinearity levels are within acceptable range.

Table 3 presents the results of the two-sample *t*-test between business schools of RG and non-RG universities. Specifically, we proceed to the mean comparison and their differences of the REF output score, REF

Table 2. Pairwise correlations and descriptive statistics

		1	2	3	4	5	6	7	8	9
1	REF output score	1								
2	REF impact score	0.655	1							
3	Research income per FTE	0.515	0.368	1						
4	Doctoral degrees awarded per FTE	0.135	−0.010	0.282	1					
5	RG	0.535	0.418	0.314	0.005	1				
6	Year of charter	−0.402	−0.305	−0.398	−0.019	−0.394	1			
7	FTE	0.120	0.271	−0.074	−0.273	0.126	0.063	1		
8	TEF	0.138	0.107	0.060	0.014	0.091	0.007	0.133	1	
9	Panel member	0.316	0.297	0.182	0.087	0.304	−0.163	0.339	0.086	1
	Mean	2.864	3.065	56.018	1.152	0.222	1932.750	91.384	1.954	0.389
	Std. dev.	0.403	0.478	62.838	1.079	0.418	148.547	68.875	1.008	0.639
	Min	1.450	1.500	1.428	0.029	0.000	1096	7.789	0.000	0.000
	Max	3.729	3.786	386.862	7.382	1.000	2013	513.333	3.000	3.000

Note: Pairwise correlations above |0.27| are significant at the 5% level.

Table 3. Two-sample t-test with unequal variances (non-RG vs. RG)

	Mean non-RG	Mean RG	Difference	*p*-value
1. REF output score	2.749	3.265	−0.516	*0.000*
2. REF impact score	2.958	3.437	−0.478	*0.000*
3. Research income per FTE	45.522	92.752	−47.229	*0.001*
3a. Industry research income per FTE (post hoc variable)	6.035	17.102	−11.067	*0.033*
3b. Non-industry research income per FTE (post hoc variable)	39.486	75.649	−36.162	*0.001*
4. Doctoral degrees awarded per FTE	1.149	1.162	−0.013	*0.958*
5. PhD programme quality (post hoc variable)	2.916	4.958	−2.041	*0.001*

Note: Russell = 24, non-Russell = 84.

impact score, research income per FTE (with a further breakdown into industry and non-industry research income per FTE) and doctoral degrees awarded per FTE. We find significant and strong differences between all variables apart from the doctoral degrees awarded per FTE. The differences between the two groups are represented more clearly in the boxplots (see Figures 1–4).

Table 4 (Models 1–6) reports the OLS estimates for our two dependent variables, REF output score (Models 1–3) and REF impact score (Models 4–6). Standardized β-coefficients are shown, with robust standard errors in parentheses and p-values in italics.

Research income, doctoral degrees awarded and REF output score

Model 2 of Table 4 presents the regression analysis results for Eq. (2). This model introduces, on top of the control variables that have already been regressed in Model 1, the independent and moderating variables, that is, the linear and quadratic terms of research income per FTE and doctoral degrees awarded per FTE, as well as the RG dummy variable. For readers less familiar with quadratic models, an inverted U-shaped relationship implies that increasing a resource initially improves performance, but only up to an optimal point. Beyond this point, additional resources reduce performance rather than enhance it. In our context, this means that moderate levels of external research income or doctoral programme size support high-quality outputs and impact, but excessive expansion stretches supervisory, administrative and coordination capacity. As a result, the marginal contribution of additional income or doctoral students becomes negative once institutional capacity thresholds are surpassed.

The coefficient of the RG variable is positive and statistically significant ($\beta = 0.270$, $p = 0.001$), indicating that RG membership is positively linked to a higher REF output score. To assess the existence of an inverted U-shaped curve, we follow the three-step procedure proposed by Haans, Pieters and He (2016). Firstly, we test whether the effect of the quadratic coefficient is significant and of the expected sign. The coefficient of the linear term of research income per FTE is positive and statistically significant ($\beta = 0.941$, $p = 0.000$). In contrast, its quadratic term is negative and statistically significant ($\beta = -0.714$, $p = 0.000$). Similarly, the coefficient of the linear term of doctoral degrees awarded per FTE is positive and statistically significant ($\beta = 0.329$, $p = 0.052$), and its quadratic term is negative and statistically significant ($\beta = -0.392$, $p = 0.003$). Therefore, we meet the first condition for confirming the existence of an inverted U-shaped curve since the quadratic terms of both independent variables are negative and statisti-

Table 4. The effect of research income and doctoral degrees awarded per FTE on REF output and REF impact score

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*
	REF output score								REF impact score			
Year of charter	−0.369 (0.000)	*0.000*	−0.237 (0.000)	*0.000*	−0.201 (0.000)	*0.000*	−0.293 (0.000)	*0.000*	−0.176 (0.000)	*0.007*	−0.163 (0.000)	*0.003*
FTE	0.050 (0.001)	*0.567*	0.119 (0.000)	*0.092*	0.172 (0.000)	*0.018*	0.224 (0.001)	*0.071*	0.264 (0.001)	*0.015*	0.280 (0.001)	*0.017*
TEF	0.115 (0.033)	*0.169*	0.083 (0.024)	*0.162*	0.050 (0.022)	*0.375*	0.065 (0.037)	*0.404*	0.039 (0.032)	*0.563*	0.031 (0.031)	*0.639*
REF panel membership	0.229 (0.044)	*0.001*	0.058 (0.043)	*0.398*	0.061 (0.038)	*0.318*	0.168 (0.049)	*0.012*	0.047 (0.047)	*0.453*	0.041 (0.047)	*0.511*
RG			0.270 (0.072)	*0.001*	1.297 (0.209)	*0.000*			0.186 (0.075)	*0.005*	0.451 (0.183)	*0.006*
Research income per FTE			0.941 (0.001)	*0.000*	1.515 (0.002)	*0.000*			0.598 (0.001)	*0.000*	0.828 (0.003)	*0.017*
Research income per FTE squared			−0.714 (0.000)	*0.000*	−1.538 (0.000)	*0.001*			−0.420 (0.000)	*0.003*	−0.627 (0.000)	*0.162*
Doctoral degrees awarded per FTE			0.329 (0.063)	*0.052*	0.416 (0.065)	*0.019*			0.374 (0.100)	*0.100*	0.330 (0.112)	*0.196*
Doctoral degrees awarded per FTE squared			−0.392 (0.008)	*0.003*	−0.487 (0.008)	*0.000*			−0.485 (0.013)	*0.009*	−0.466 (0.014)	*0.022*
Research income per FTE × RG					−0.619 (0.003)	*0.122*					−0.648 (0.003)	*0.071*
Research income per FTE squared × RG					0.863 (0.000)	*0.068*					0.510 (0.000)	*0.245*
Doctoral degrees awarded per FTE × RG					−1.660 (0.373)	*0.001*					−0.197 (0.278)	*0.523*
Doctoral degrees awarded per FTE squared × RG					0.798 (0.136)	*0.006*					0.188 (0.090)	*0.234*
R-squared	0.242		0.581		0.642		0.207		0.396		0.413	

Note: Number of observations (business schools) = 108; robust standard errors and standardized coefficients are reported.

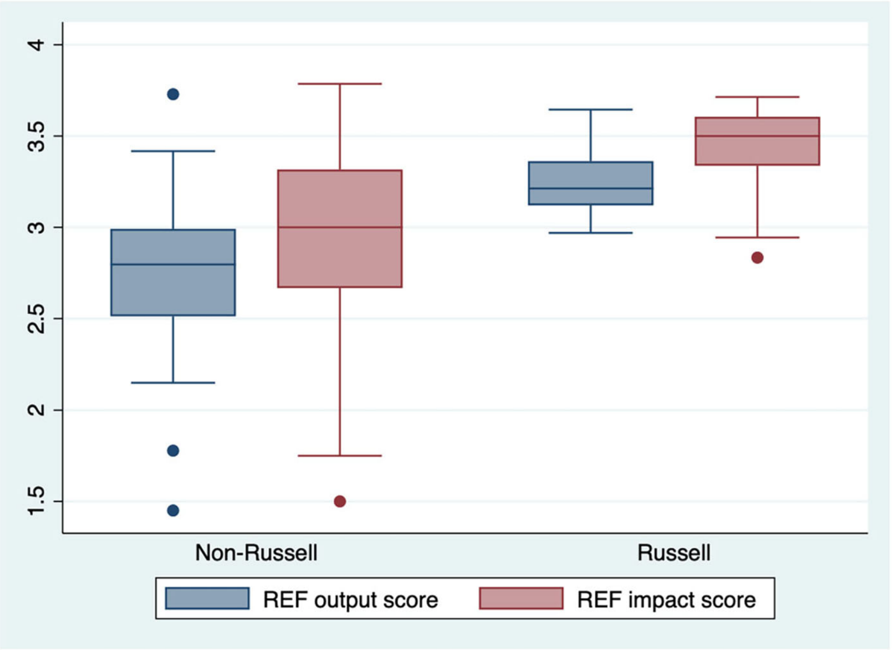


Figure 1. Boxplot of REF output score and REF impact score per group

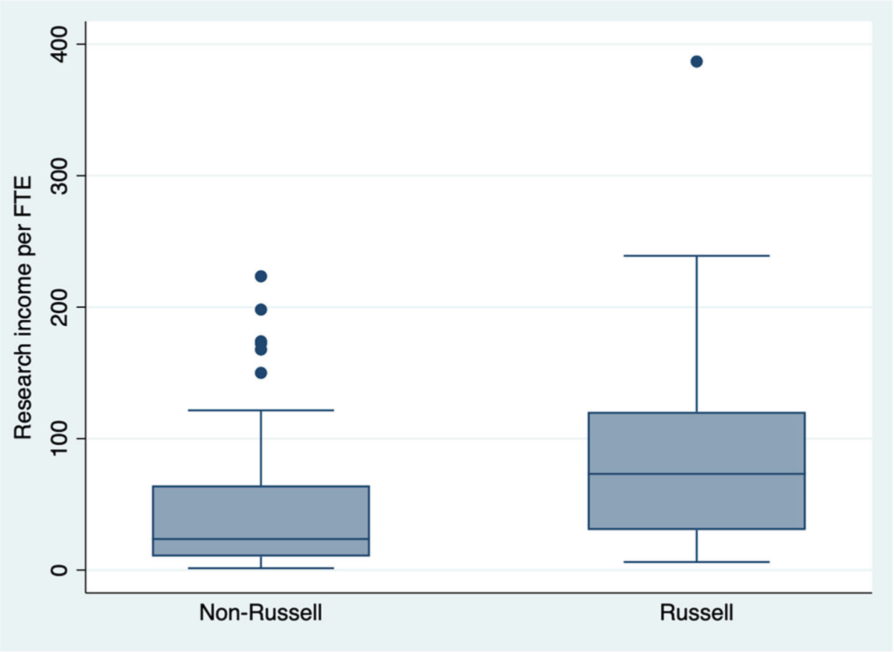


Figure 2. Boxplot of research income per FTE per group

cally significant. Secondly, the slope must be sufficiently steep at both ends of the data range. As far as the research income per FTE is concerned, we find that the slope at the low end of the variable's range is positive and statistically significant ($\beta = 0.006, p = 0.000$),[6] while the slope at the high end of the variable's range is negative and statistically significant ($\beta = -0.007, p = 0.000$). Similarly, the slope at the low end of the doctoral degrees awarded per FTE range is positive and statistically significant ($\beta = 0.122$, $p = 0.053$), and the slope at the high end of the variable's range is negative and statistically significant ($\beta = -0.229$, $p = 0.000$). Therefore, we meet the second condition of the three-step procedure. The third condition states that the curve's turning

[6]The reported coefficient *b* is the unstandardized regression coefficient, as estimated after testing the significance of the slope using the lincom command on STATA.

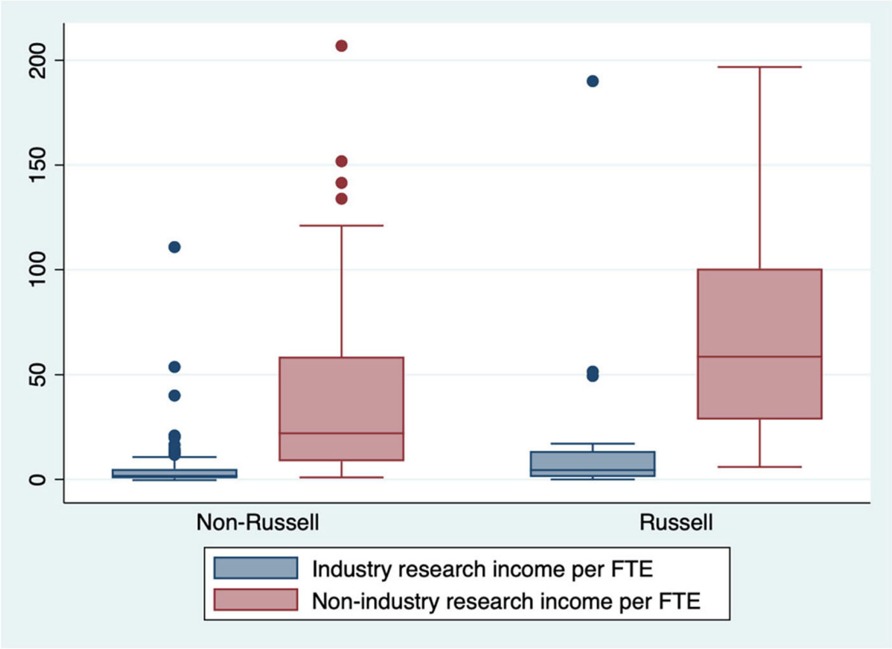


Figure 3. Boxplot of industry versus non-industry research income per FTE per group

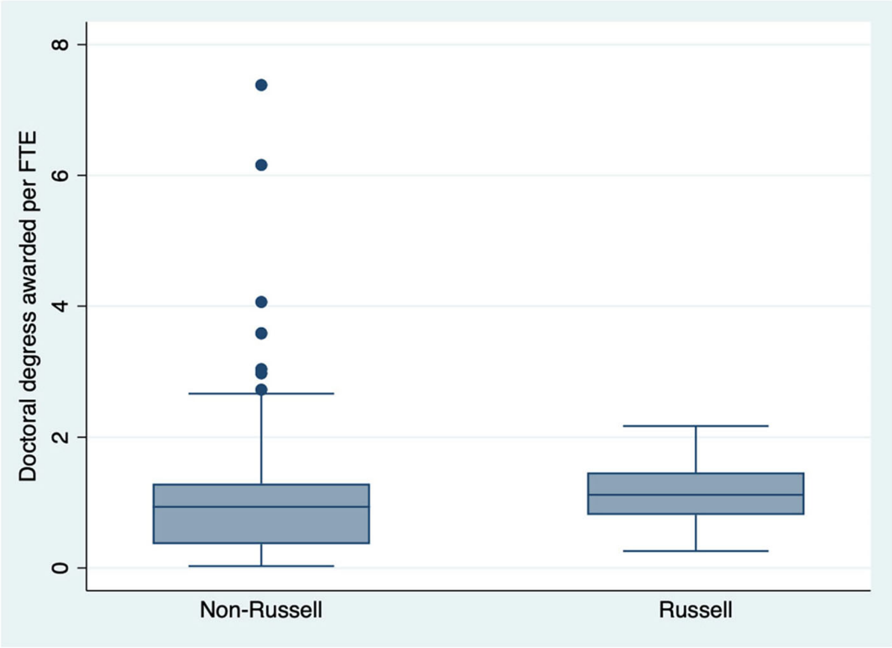


Figure 4. Boxplot of doctoral degrees awarded per FTE per group

point must lie within the data range. Figures 5 and 6 graphically illustrate the quadratic effects in the examined relationships. Figure 5 shows that the turning point of the inverted U-shaped curve for research income per FTE is £183K on average. Figure 6 shows that the turning point of the inverted U-shaped curve for doctoral degrees awarded per FTE is 2.6 doctoral degrees on average. Both turning points are positioned well within the data range, indicating that the third condition of the aforementioned three-step procedure is also met. This pattern indicates that while additional resources initially improve research output quality, beyond a threshold, they generate coordination and capacity inefficiencies that reduce performance. We, therefore, conclude that the conjectured inverted U-shaped relationship with the REF output score holds for both independent variables.

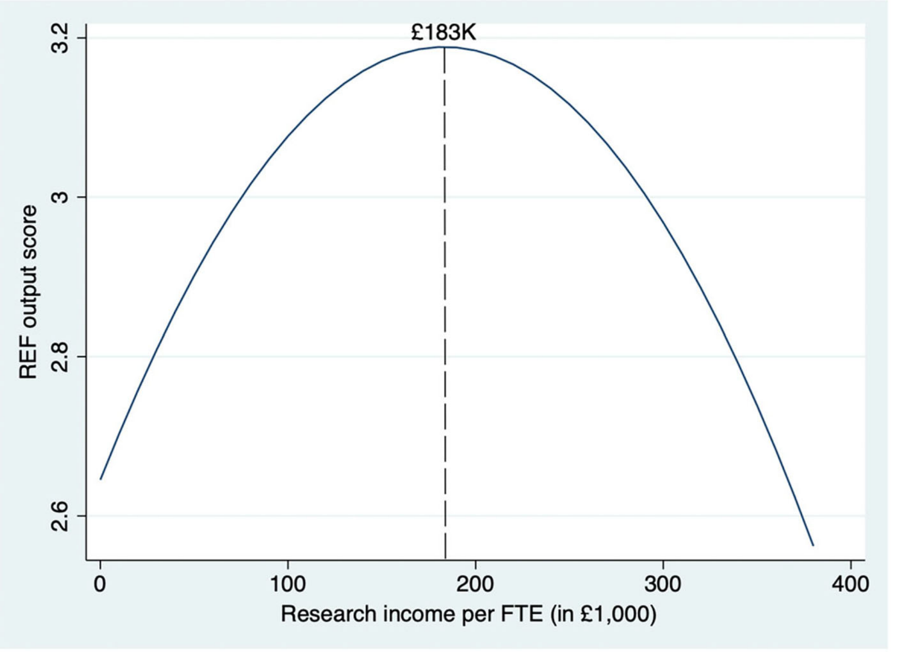


Figure 5. The inverted U-shaped relationship between research income per FTE and REF output score.

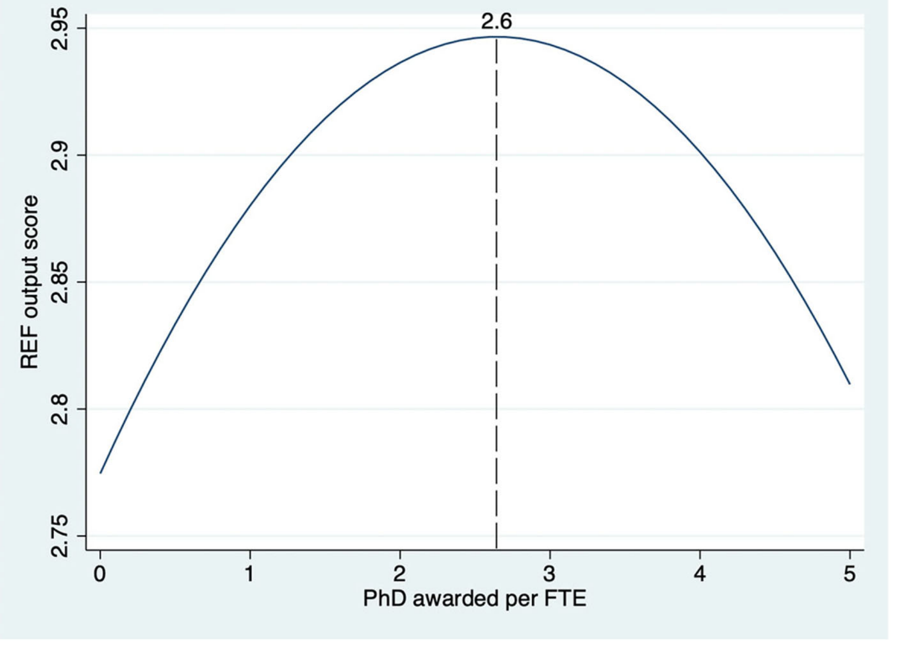


Figure 6. The inverted U-shaped relationship between doctoral degrees awarded per FTE and REF output score.

Research income, doctoral degrees awarded and REF impact score

Model 5 of Table 4 presents the regression analysis results as shown in Eq. (3). The coefficient of the RG variable in this model is positive and statistically significant ($\beta = 0.186$, $p = 0.005$), proving that RG membership is positively associated with a higher REF impact score. Similar to the previous analysis, we once again test the existence of an inverted U-shaped curve following the three-step procedure proposed by Haans, Pieters and He (2016). Regarding the coefficients of interest, the coefficient of the linear term for research income per FTE is positive and statistically significant ($\beta = 0.598$, $p = 0.000$). However, its quadratic term is negative and statistically significant ($\beta = -0.420$, $p = 0.003$). In terms of the second independent variable, doctoral degrees

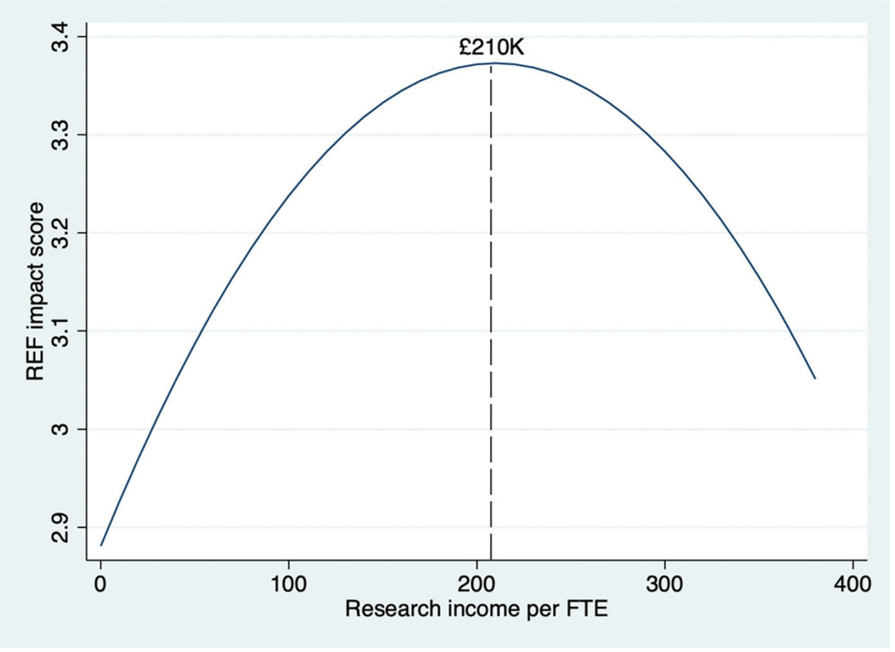


Figure 7. The inverted U-shaped relationship between research income per FTE and REF impact score.

awarded per FTE, the coefficient of the linear term is positive and statistically significant but only weakly ($\beta = 0.374$, $p = 0.100$), and its quadratic term is negative and statistically significant ($\beta = -0.485$, $p = 0.009$). Therefore, the first condition is being met. Secondly, the slope at the low end of the range of research income per FTE is positive and statistically significant ($\beta = 0.005$, $p = 0.000$), while the slope at the high end of the variable's range is negative and statistically significant ($\beta = -0.004$, $p = 0.015$). As regards, the doctoral degrees awarded per FTE variable, the slope at the low end of it is positive and statistically significant ($\beta = 0.164$, $p = 0.100$), and the slope at the high end of the variable's range is negative and statistically significant ($\beta = -0.349$, $p = 0.001$). The second condition of the procedure is thus met. The third and final condition states that the curve's turning point lies within the data range. Figures 7 and 8 graphically depict the quadratic relationship that characterizes the examined relationships. Figure 7 shows that the turning point of the inverted U-shaped curve for research income per FTE is £210K on average, while Figure 8 indicates that the turning point of the inverted U-shaped curve for doctoral degrees awarded per FTE is 2.4 doctoral degrees on average. Both points are within the data range and indicate that more is not always better: although moderate investment supports impact generation, excessive expansion can stretch institutional capacity and reduce effectiveness. We, therefore, find support for an inverted U-shaped relationship between the REF impact score and the two independent variables.

The moderating role of RG affiliation

Model 3 in Table 4 shows the regression analysis results as shown in Eq. (4). In this model, we test the interaction of the linear and quadratic terms of research income per FTE and doctoral degrees awarded per FTE with the RG variable. We conjecture that RG business schools, with moderate-to-high levels of research income and doctoral degrees awarded per FTE, will achieve a relatively higher REF output score and experience a less steep decline after the turning point of the curve. Our results show that the interaction coefficient between the quadratic term of research income per FTE and RG affiliation is positive and statistically significant ($\beta = 0.863$, $p = 0.068$). Further, the estimates show that the interaction coefficient between the quadratic term of doctoral degrees awarded per FTE and RG affiliation is also positive and statistically significant ($\beta = 0.798$, $p = 0.006$).

The graphic illustration (i.e. predictive margins) of the interaction coefficient between the quadratic term of research income per FTE and RG affiliation, as depicted in Figure 9, shows that the turning point of research income for non-RG business schools is £135K on average, which is achieved at a level where the REF output score is 3.17. For RG business schools, this is £187K of research income per FTE on average, and this is met at a level where the REF output score is 3.68. Also, the steepness of the curve for RG business schools is less intense. This means that the slight change in the number of students with doctoral degrees has a minimal effect on the REF output score. Further, the graphic illus-

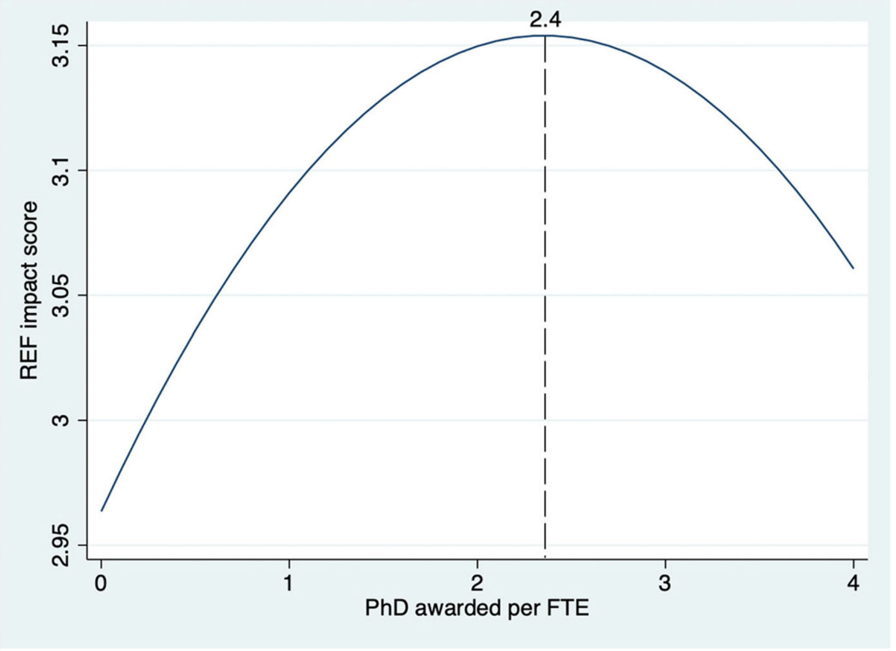
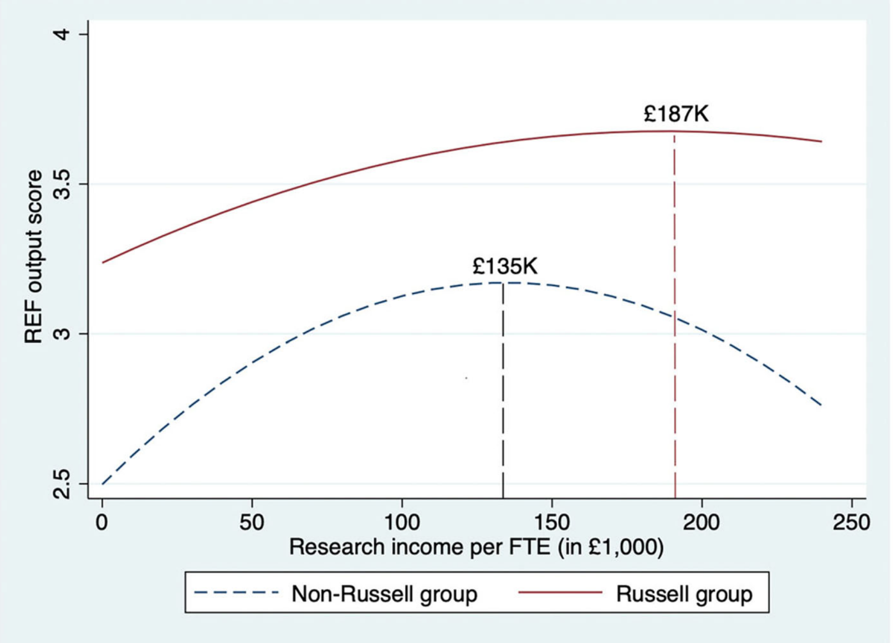


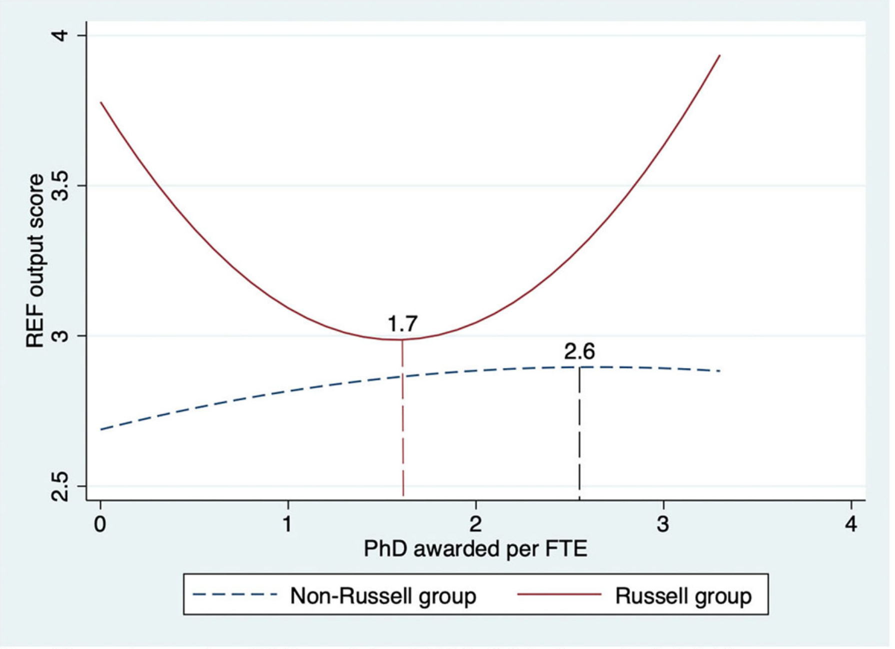
Figure 8. The inverted U-shaped relationship between doctoral degrees awarded per FTE and REF impact score.



Note: The maximum value of Research income per FTE for non-RG business schools is £223K.

Figure 9. The moderating effect of RG affiliation on the relationship between research income per FTE and REF output score. The maximum value of research income per FTE for non-RG business schools is £223K

tration (i.e. predictive margins) of the interaction coefficient between the quadratic term of doctoral degrees awarded and RG affiliation (Figure 10) shows that the turning point of doctoral degrees awarded per FTE for non-RG business schools is 2.6 doctoral degrees on average, achieved where the REF output score is 2.9. At the same time, for RG business schools, we observe a shape-flip, where a U-shaped curve has replaced the inverted U-shaped curve, with RG business schools encountering a decline in the REF output score for low to moderate levels of doctoral degrees awarded per FTE and an increase for moderate to high levels of doctoral degrees awarded per FTE, with a turning point set at 1.7 doctoral degrees on average, met at the point where the REF output score is 2.98. After this turning point, RG business schools increase their REF output score to 2.17



Note: The maximum value of PhD awarded per FTE for RG business schools is 2.17

Figure 10. The moderating effect of RG affiliation on the relationship between doctoral degrees awarded per FTE and REF output score. The maximum value of PhD awarded per FTE for RG business schools is 2.17

doctoral degrees, the maximum level for the RG business school sample. This pattern suggests that RG institutions possess greater supervisory and organizational capacity, allowing them to sustain and ultimately benefit from higher doctoral training intensity.

Model 6 of Table 4 presents the regression analysis results as shown in Eq. (5). In this model, we also test the interaction of the linear and quadratic terms of research income per FTE and doctoral degrees awarded per FTE with the RG variable, this time predicting their effect on REF impact score. We predict that RG business schools will not moderate the relationship between (i) research income per FTE and (ii) doctoral degrees awarded per FTE with REF impact score. Our results support these projections since the interaction coefficient between the quadratic term of research income per FTE and RG affiliation is statistically nonsignificant ($\beta = 0.510$, $p = 0.245$). Similarly, the interaction coefficient between the quadratic term of doctoral degrees awarded per FTE and RG affiliation is also statistically non-significant ($\beta = 0.188$, $p = 0.234$).

Post hoc analyses

Decomposing research income into industry- versus non-industry sources. We re-estimated the core models after decomposing total external research income per FTE into industry- and non-industry-funded streams. Each stream was entered linearly and quadratically alongside doctoral degrees per FTE, and RG moderation was tested via interaction terms. Separate specifications were estimated for REF outputs and impact. This analysis examines whether funding source differentially relates to performance and whether these relationships vary by institutional status (Table 5).

Research quality as an additional independent variable. To assess whether doctoral programme quality matters beyond programme size, we constructed a PhD-programme quality index based on textual analysis of each business school's REF narrative. The index was entered linearly and quadratically alongside research income per FTE and doctoral degrees awarded per FTE, with RG interactions, and estimated separately for REF outputs and impact. This specification tests whether doctoral training helps explain performance and whether this relationship depends on RG status (Table 6).

Details about the aforementioned post hoc tests can be found in the Supporting Information.

Sensitivity tests

We conducted a series of robustness tests to assess the sensitivity of our estimates, including alternative performance measures, sample restrictions, model specifications and funding definitions. Across all tests, the substantive results remained unchanged. Full details and results are reported in the online appendix (Tables S1–S8).

Table 5. Post hoc analysis: The effect of industry research income and non-industry research income, and doctoral degrees awarded per FTE on REF output and REF impact score

	Model P1.1		Model P1.2		Model P1.3		Model P1.4	
	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*
	REF output score				REF impact score			
Year of charter	−0.230 (0.000)	*0.001*	−0.278 (0.000)	*0.001*	−0.126 (0.000)	*0.092*	−0.176 (0.000)	*0.024*
FTE	0.119 (0.000)	*0.098*	0.173 (0.000)	*0.020*	0.264 (0.001)	*0.016*	0.278 (0.001)	*0.021*
TEF	0.078 (0.026)	*0.228*	0.065 (0.025)	*0.308*	0.040 (0.031)	*0.549*	0.053 (0.032)	*0.434*
REF panel membership	0.063 (0.044)	*0.369*	0.045 (0.040)	*0.476*	0.046 (0.048)	*0.468*	0.029 (0.049)	*0.652*
RG	0.268 (0.074)	*0.001*	1.281 (0.172)	*0.000*	0.200 (0.077)	*0.004*	0.442 (0.198)	*0.012*
Industry funding per FTE	0.335 (0.003)	*0.078*	0.672 (0.008)	*0.138*	0.342 (0.004)	*0.064*	0.348 (0.008)	*0.369*
Industry funding per FTE squared	−0.424 (0.000)	*0.008*	−1.012 (0.000)	*0.092*	−0.270 (0.000)	*0.089*	−0.140 (0.000)	*0.791*
Non-Industry funding per FTE	0.746 (0.002)	*0.004*	1.047 (0.003)	*0.002*	0.596 (0.002)	*0.012*	0.682 (0.003)	*0.025*
Non-Industry funding per FTE squared	−0.434 (0.000)	*0.025*	−0.780 (0.000)	*0.008*	−0.449 (0.000)	*0.033*	−0.473 (0.000)	*0.088*
Doctoral degrees awarded per FTE	0.330 (0.063)	*0.054*	0.403 (0.066)	*0.025*	0.326 (0.102)	*0.158*	0.258 (0.118)	*0.337*
Doctoral degrees awarded per FTE squared	−0.391 (0.008)	*0.004*	−0.461 (0.008)	*0.001*	−0.455 (0.013)	*0.017*	−0.412 (0.015)	*0.057*
Industry funding per FTE × RG			−0.507 (0.009)	*0.251*			−0.234 (0.010)	*0.578*
Industry funding per FTE squared × RG			0.635 (0.000)	*0.277*			0.036 (0.000)	*0.947*
Non-Industry funding per FTE × RG			−0.953 (0.004)	*0.013*			−0.606 (0.005)	*0.147*
Non-Industry funding per FTE squared × RG			0.921 (0.000)	*0.003*			0.419 (0.000)	*0.205*
Doctoral degrees awarded per FTE × RG			−1.353 (0.295)	*0.001*			−0.142 (0.313)	*0.683*
Doctoral degrees awarded per FTE squared × RG			0.652 (0.103)	*0.003*			0.175 (0.104)	*0.338*
R-squared	0.583		0.657		0.402		0.421	

Note: Number of observations (business schools) = 108; robust standard errors and standardized coefficients are reported.

Discussion

Research contribution

This study examines how research environment investments, external research income and doctoral programme size are transformed into research quality across 108 UK business schools. Our findings confirm inverted U-shaped production functions: scaling research inputs initially boosts research outputs and impact, but diminishing returns emerge once institutional capacity thresholds are surpassed. These results redefine research excellence from an input-maximization logic to an optimization challenge in which institutional capabilities determine optimal resource thresholds. This logic extends beyond universities to knowledge-intensive organizations operating under performance-based evaluation regimes, where externally imposed KPIs can similarly generate coordination costs and diminishing returns when exceeding organizational capacity.

Our contribution lies not in identifying diminishing returns, which is well established in strategy and organizational theory, but in empirically grounding RBV boundary conditions within a high-stake institutional setting. In particular, we demonstrate how performance-based evaluation systems and KPI pressures actively shape the conditions under which capacity thresholds emerge. RG institutions employ more efficient production technologies that delay the onset of diminishing returns and sustain higher research output quality at higher external funding levels. However, even these in-

Table 6. Post hoc analysis: The effect of research income per FTE, doctoral degrees awarded per FTE and doctoral programme quality on REF output and REF impact score

	Model P2.1		Model P2.2		Model P2.3		Model P2.4	
	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*	Coef. (std. err.)	*p-val.*
	REF output score				REF impact score			
Year of charter	−0.255 (0.000)	*0.000*	−0.213 (0.000)	*0.000*	−0.194 (0.000)	*0.002*	−0.178 (0.000)	*0.001*
FTE	0.137 (0.000)	*0.062*	0.182 (0.000)	*0.022*	0.283 (0.001)	*0.011*	0.306 (0.001)	*0.011*
TEF	0.096 (0.022)	*0.085*	0.052 (0.020)	*0.294*	0.050 (0.034)	*0.488*	0.034 (0.033)	*0.625*
REF panel membership	0.084 (0.043)	*0.218*	0.099 (0.041)	*0.130*	0.069 (0.047)	*0.280*	0.059 (0.050)	*0.375*
RG	0.292 (0.075)	*0.000*	1.195 (0.212)	*0.000*	0.207 (0.081)	*0.004*	0.354 (0.211)	*0.057*
Research income per FTE	0.904 (0.001)	*0.000*	1.544 (0.002)	*0.000*	0.576 (0.001)	*0.001*	0.890 (0.003)	*0.016*
Research income per FTE squared	−0.687 (0.000)	*0.000*	−1.651 (0.000)	*0.000*	−0.406 (0.000)	*0.006*	−0.730 (0.000)	*0.153*
Doctoral degrees awarded per FTE	0.339 (0.060)	*0.037*	0.391 (0.063)	*0.023*	0.383 (0.097)	*0.083*	0.313 (0.113)	*0.222*
Doctoral degrees awarded per FTE squared	−0.394 (0.008)	*0.003*	−0.460 (0.008)	*0.001*	−0.488 (0.012)	*0.005*	−0.454 (0.014)	*0.022*
PhD programme quality	−0.615 (0.038)	*0.023*	−0.685 (0.040)	*0.015*	−0.518 (0.047)	*0.067*	−0.581 (0.059)	*0.096*
PhD programme quality squared	0.573 (0.004)	*0.024*	0.674 (0.003)	*0.006*	0.466 (0.004)	*0.056*	0.489 (0.005)	*0.130*
Research income per FTE × RG			−0.662 (0.003)	*0.066*			−0.737 (0.003)	*0.046*
Research income per FTE squared × RG			0.969 (0.000)	*0.025*			0.632 (0.000)	*0.195*
Doctoral degrees awarded per FTE × RG			−1.651 (0.336)	*0.000*			−0.140 (0.288)	*0.661*
Doctoral degrees awarded per FTE squared × RG			0.806 (0.122)	*0.002*			0.177 (0.084)	*0.232*
PhD programme quality × RG			0.532 (0.082)	*0.298*			0.269 (0.095)	*0.587*
PhD programme quality squared × RG			−0.484 (0.007)	*0.174*			−0.169 (0.009)	*0.640*
R-squared	0.614		0.677		0.420		0.440	

Note: Number of observations (business schools) = 108; robust standard errors and standardized coefficients are reported.

stitutions ultimately face capacity limits, indicating fundamental constraints in the research production process (Jang, 2024).

Non-RG institutions operate with more constrained production technologies and reach capacity limits earlier, particularly in scaling doctoral supervision. Their production functions exhibit steeper diminishing returns, reflecting limited supervisory and coordination capacity; expanding doctoral cohorts without adequate support can reduce research quality (Ehrenberg *et al.*, 2007). RG business schools, by contrast, initially experience diminishing returns at lower supervision levels but subsequently reverse this pattern at higher doctoral intensity, indicating greater capacity to sustain excellence through selectivity and focused resource deployment (Figure 10 shows that this reversal occurs at approximately 1.7–2.17 doctoral degrees awarded per FTE).

While inverted U-shaped relationships also characterize research impact, RG membership does not moderate these effects, suggesting that both institutional types employ effective but distinct production technologies to generate impact (Sengupta and Ray, 2017). Whether RG institutions leverage global engagement logics addressing large-scale challenges through international networks, while non-RG institutions focus on locally embedded, applied solutions, as we conjecture, remains an open empirical question. Future research could examine the geographic scope and beneficiary contexts documented in REF impact case studies to test this directly.

By integrating the production function approach with the RBV perspective in a knowledge-intensive context, we demonstrate that resource allocation involves not only selecting which research resources to invest in but also understanding the shape and constraints of the institutional production function. Operating beyond the efficiency threshold can reduce productivity, a strategic challenge applicable across industries. Institutions with superior resource endowments and capabilities are better equipped to achieve higher efficiency levels and mitigate diminishing returns. We thus highlight the importance of balancing input-related KPIs (external income and doctoral students) against output-related KPIs (outputs and impact).

Policy implications

Our findings have implications for both research evaluation policy and business school leaders' strategic decisions. By demonstrating institutional production heterogeneity, our results reinforce the need to move beyond a 'one size fits all' approach to research assessment and management (Benneworth, Pinheiro and Sánchez-Barrioluengo, 2016). The inverted U-shaped production functions suggest that evaluation systems should reward not only input levels but also the effectiveness with which institutions deploy resources, consistent with REF 2029's new Strategy, People and Research Environment (SPRE) element, which explicitly assesses institutional research and impact strategy alongside research culture.

For deans and senior leaders, our findings call for a shift from research input maximization to active capacity management. Rather than reducing research activity, institutions operating beyond optimal thresholds should prioritize research portfolio management and capacity-aligned administrative support to improve their effective production frontier. Specific strategies include limiting supervisory and project loads per faculty member, prioritizing externally funded projects that align with institutional research strengths and REF objectives, investing in grant-development and post-award administrative support to reduce academic coordination burdens. Non-RG schools, which reach their turning points earlier, should prioritize reallocation over expansion, while RG schools, with greater absorptive capacity, should focus on channelling resources towards REF-eligible outputs. Such managerial responses align with REF2029's SPRE element, which explicitly assesses institutional research and impact strategy alongside research culture,[7] consistent with our finding that the returns to resource accumulation are non-linear and institution-specific.

Secondly, our evidence shows that RG and non-RG institutions employ distinct yet equally effective production technologies to generate impact. This supports REF2021's separation of outputs and impact, recognizing that different institutional types can achieve excellence through distinct pathways (Sealy *et al.*, 2017). Academic rigor and practice relevance are therefore complementary rather than hierarchical, with both contributing to valuable societal impact through differently oriented global and local engagement pathways (Bennis and O'Toole, 2005; Stremersch *et al.*, 2021).

These dynamics extend beyond universities to professional service firms, R&D laboratories and other knowledge-intensive organizations, where managerial attention, coordination capacity and performance metrics similarly shape the returns to resource accumulation.

Limitations and future research agenda

This study has important limitations to acknowledge. Firstly, we focus on external research income, while business schools may also support research through internal QR allocations and teaching cross-subsidies that are not systematically observable at the unit level. External research income nonetheless represents the dimension where production function inefficiencies are most likely to arise, as it is an explicit REF performance metric generating KPI pressures that can drive capacity overextension. Unlike internal funding, external income is competitively won, project-bound and accompanied by funder-specified deliverables and compliance requirements, making it a uniquely salient source of coordination costs and capacity strain. Secondly, our use of institutional-level REF data aggregated at the business school level potentially obscures heterogeneity across sub-disciplines, staff contract types and internal resource allocation practices. Our estimates thus capture average institutional production relationships rather than micro-level research processes, and may also reflect variation in business school autonomy within parent universities. Thirdly, our analysis focuses on research impact as defined within the REF framework. While REF impact captures reach and significance across economic, societal, cultural and policy domains, alternative definitions may prioritize different outcomes or time horizons. Our findings regarding the absence of RG moderation effects should therefore be interpreted as specific to REF-defined impact.

Future research could examine production functions across different UOAs to test whether curvilinear relationships hold in other disciplines. As our analysis focuses on aggregate institutional research income rather than individual-level grant distribution, future research could examine how the concentration versus dispersion of research income among faculty members affects

[7]https://www.publicengagement.ac.uk/resources/briefings/ref-2029-whats-story-public-engagement.

these production function relationships. Studies could also examine how changes in REF weighting structures affect institutional production optimization strategies. The transition to SPRE in REF2029 introduced explicit assessment of institutional research strategy, which may reshape resource allocation beyond traditional input metrics, consistent with 'The Metric Tide' (Gadd, Wilsdon and Curry, 2022) and evolving principles from the 'UK Forum for Responsible Research Metrics' (Johnson, 2017). Finally, to open the 'black box' of teaching cross-subsidization, future research should build harmonized business school-level panels linking costing ledgers, workload models and student FTE/tuition flows to measure how teaching-generated surpluses translate into research quality. While the *Transparent Approach to Costing* accounts for the full economic costs of research activity, it focuses on cost attribution and financial accountability, rather than the effectiveness or performance consequences of different resource configurations, a gap that future research should address.

Acknowledgements

We are grateful for the thoughtful guidance and rigorous comments provided by the Editor and the three anonymous reviewers, which significantly improved the quality and clarity of the manuscript. We also thank Nick Lee, Nicky Yates, Emel Aktas, Olga Epitropaki, Robert Wapshott, Nick Papageorgiadis, Afshin Mansouri and Elina Meliou for their valuable comments on earlier versions of this research. Finally, we express our sincere gratitude to the participants of the *Journal of Management Studies* workshop held on 6 March 2025, at Alba Graduate Business School, for their constructive feedback and insightful discussions that helped shape this paper.

References

Audretsch, D. B., M. Belitski, M. Guerrero and D. S. Siegel (2022). 'Assessing the impact of the UK's Research Excellence Framework on the relationship between university scholarly output and education and regional economic growth', *Academy of Management Learning & Education*, **21**, pp. 394–421.

Baker, I. (2024). 'Federations of academic departments: performance-based funding and academic field-level expenditures at Russell group universities', *Journal of Education Policy*, **40**, pp. 1–22.

Banal-Estañol, A., M. Jofre-Bonet, G. Iori, L. Maynou, M. Tumminello and P. Vassallo (2023). 'Performance-based research funding: evidence from the largest natural experiment worldwide', *Research Policy*, **52**, art. 104780.

Barney, J. B. (2001). 'Resource-based theories of competitive advantage: a ten-year retrospective on the resource-based view', *Journal of Management*, **27**, pp. 643–650. https://doi.org/10.1177/014920630102700602.

Baum, C. F. (2006). *An Introduction to Modern Econometrics Using Stata*. Texas: Stata Press.

Bedeian, A. G., D. E. Cavazos, J. G. Hunt and L. R. Jauch (2010). 'Doctoral degree prestige and the academic marketplace: a study of career mobility within the management discipline', *Academy of Management Learning & Education*, **9**, pp. 11–25. https://doi.org/10.5465/amle.9.1.zqr11.

Benneworth, P., R. Pinheiro and M. Sánchez-Barrioluengo (2016). *One Size Does Not Fit All! New Perspectives on the University in the Social Knowledge Economy, Science and Public Policy*. Oxford: Oxford University Press.

Bennis, W. G. and J. O'Toole (2005). 'How business schools have lost their way', *Harvard Business Review*, **83**, pp. 96–104.

Blackburn, R., S. Dibb and I. Tonks (2024). 'Business and management studies in the United Kingdom's 2021 research excellence framework: implications for research quality assessment', *British Journal of Management*, **35**, pp. 434–448.

Campbell, S. P., A. K. Fuller and D. A. G. Patrick (2005). 'Looking beyond research in doctoral education', *Frontiers in Ecology and the Environment*, **3**, pp. 153–160. https://doi.org/10.2307/3868543.

Chang, W.-Y., W. Cheng, J. Lane and B. Weinberg (2019). 'Federal funding of doctoral recipients: what can be learned from linked data', *Research Policy*, **48**, pp. 1487–1492. DOI: https://doi.org/10.1016/j.respol.2019.03.001.

Croucher, R. and P. Gooderham (2022). *Research Impact and the Role of Social Justice in REF 2022 Results*. The Chartered Association of Business Schools.

Degl'Innocenti, M., R. Matousek and N. G. Tzeremes (2019). 'The interconnections of academic research and universities' "third mission": evidence from the UK', *Research Policy*, **48**, art. 103793.

DiMaggio, P. and W. Powell (1983). 'The iron cage revisited: institutional isomorphism and collective rationality in organizational fields', *American Sociological Review*, **48**, pp. 147–160.

Dundar, H. and D. R. Lewis (1998). 'Determinants of research productivity in higher education', *Research in Higher Education*, **39**, pp. 607–631. https://doi.org/10.1023/A:1018705823763.

Dutta, S. (2024). 'Developing a responsible research strategy at Saïd Business School'. In E Cornuel, H. Thomas, and M. Wood (Eds.), (1st ed.). *Business School Research Excellence, Academic Quality and Positive Impact*, pp. 47–52. London: Routledge.

Ehrenberg, R. G., G. H. Jakubson, J. A. Groen, E. So and J. Price (2007). 'Inside the black box of doctoral education: what program characteristics influence doctoral students' attrition and graduation probabilities?', *Educational Evaluation and Policy Analysis*, **29**, pp. 134–150.

Gadd, E., J. Wilsdon and S. Curry (2022). *The Metric Tide*, revisited. WONKHE.

Geuna, A. (1998). 'Determinants of university participation in EU-funded R&D cooperative projects', *Research Policy*, **26**, pp. 677–687.

Golde, C. M. (2005). 'The role of the department and discipline in doctoral student attrition: lessons from four departments', *The Journal of Higher Education*, **76**, pp. 669–700.

Graddy-Reed, A., L. Lanahan and J. D'Agostino (2021). 'Training across the academy: the impact of R&D funding on graduate students', *Research Policy*, **50**, art. 104224. DOI: https://doi.org/10.1016/j.respol.2021.104224.

Groen-Xu, M., G. Bös, P. A. Teixeira, T. Voigt and B. Knapp (2023). 'Short-term incentives of research evaluations: evidence from the UK Research Excellence Framework', *Research Policy*, **52**, art. 104729.

Haans, R. F. J., C. Pieters and Z.-L. He (2016). 'Thinking about U: theorizing and testing U- and inverted U-shaped relationships in strategy research', *Strategic Management Journal*, **37**, pp. 1177–1195. https://doi.org/10.1002/smj.2399.

Hanushek, E. A. (1979). 'Conceptual and empirical issues in the estimation of educational production functions', *Journal of Human Resources*, **14**, pp. 351–388.

Hanushek, E. A. (2020). 'Education production functions'. In Steve Bradley and Colin Green (eds), (2nd ed.), *The Economics of Education*, pp. 161–170. London: Elsevier Academic Press.

Harman, G. (2002). 'Producing PhD graduates in Australia for the knowledge economy', *Higher Education Research & Development*, **21**, pp. 179–190.

Horner, S., D. Jayawarna, B. Giordano and O. Jones (2019). 'Strategic choice in universities: managerial agency and effective technology transfer', *Research Policy*, **48**, pp. 1297–1309.

Horta, H., V. Dautel and F. M. Veloso (2012). 'An output perspective on the teaching–research nexus: an analysis focusing on the United States higher education system', *Studies in Higher Education*, **37**, pp. 171–187.

Jang, H. (2024). 'Impact of funding size on research outputs: evidence from South Korea's government-funded programme', *Asian Journal of Technology Innovation*, **33**, pp. 1–22.

Johnson, B. (2017). 'HEFCE: the road to the responsible research metrics forum', The Bibliomagician.

Joseph, J. and A. J. Wilson (2018). 'The growth of the firm: an attention-based view', *Strategic Management Journal*, **39**, pp. 1779–1800.

Kellard, N. M. and M. Śliwa (2016). 'Business and management impact assessment in research excellence framework 2014: analysis and reflection', *British Journal of Management*, **27**, pp. 693–711.

Khoo, S.-Y., P. Perotti, T. Verousis and R. Watermeyer (2024). 'Vice-chancellor narcissism and university performance', *Research Policy*, **53**, art. 104901.

Krieger, B. (2024). 'Heterogeneous university funding programs and regional firm innovation: an empirical analysis of the German Excellence Initiative', *Research Policy*, **53**, art. 104995. https://doi.org/10.1016/j.respol.2024.104995.

Lee, Y. S. (1996). '"Technology transfer" and the research university: a search for the boundaries of university-industry collaboration', *Research Policy*, **25**, pp. 843–863.

Lockett, A., M. Wright and A. Wild (2015). 'The institutionalization of third stream activities in UK higher education: the role of discourse and metrics', *British Journal of Management*, **26**, pp. 78–92. https://doi.org/10.1111/1467-8551.12069.

Lodahl, J. B. and G. Gordon (1972). 'The structure of scientific fields and the functioning of university graduate departments', *American Sociological Review*, **37**, pp. 57–72.

Moore, B., T. Ulrichsen and A. Hughes (2010). 'Synergies and trade-offs between research, teaching and knowledge exchange', www.pacec.co.uk.

Morgan-Thomas, A., S. Tsoukas, A. Dudau and P. Gąska (2024). 'Beyond declarations: metrics, rankings and responsible assessment', *Research Policy*, **53**, art. 105093.

Papatsiba, V. and E. Cohen (2020). 'Institutional hierarchies and research impact: new academic currencies, capital and position-taking in UK higher education', *British Journal of Sociology of Education*, **41**, pp. 178–196.

Pidd, M. and J. Broadbent (2015). 'Business and management studies in the 2014 Research Excellence Framework', *British Journal of Management*, **26**, pp. 569–581. https://doi.org/10.1111/1467-8551.12122.

Rhee, L. and P. M. Leonardi (2018). 'Which pathway to good ideas? A n attention-based view of innovation in social networks', *Strategic Management Journal*, **39**, pp. 1188–1215.

Ridge, J. W., D. Kern and M. A. White (2014). 'The influence of managerial myopia on firm strategy', *Management Decision*, **52**, pp. 602–623.

Salter, A., R. Salandra and J. Walker (2017). 'Exploring preferences for impact versus publications among UK business and management academics', *Research Policy*, **46**, pp. 1769–1782.

Sarrico, C. S. (2022). 'The expansion of doctoral education and the changing nature and purpose of the doctorate', *Higher Education*, **84**, pp. 1299–1315. https://doi.org/10.1007/s10734-022-00946-1.

Sealy, R., E. Doldor, S. Vinnicombe, S. Terjesen, D. Anderson and D. Atewologun (2017). 'Expanding the notion of dialogic trading zones for impactful research: the case of women on boards research', *British Journal of Management*, **28**, pp. 64–83. https://doi.org/10.1111/1467-8551.12203.

Sengupta, A. and A. S. Ray (2017). 'Choice of structure, business model and portfolio: organizational models of knowledge transfer offices in British universities', *British Journal of Management*, **28**, pp. 687–710. https://doi.org/10.1111/1467-8551.12224.

Stremersch, S., R. S. Winer, and N. Camacho (2021). 'Faculty research incentives and business school health: A new perspective from and for marketing', *Journal of Marketing*, **85**, pp. 1–21.

Tassey, G. (2005). 'The disaggregated technology production function: a new model of university and corporate research', *Research Policy*, **34**, pp. 287–303.

Taylor, J. (2011). 'The assessment of research quality in UK universities: peer review or metrics?', *British Journal of Management*, **22**, pp. 202–217. https://doi.org/10.1111/j.1467-8551.2010.00722.x.

The Russell Group. (2024). 'Research-intensive universities generate nearly £38 billion for UK economy through research, innovation and the creation of new businesses, new analysis reveals', https://russellgroup.ac.uk/news/research-intensive-universities-generate-nearly-38-billion-for-uk-economy/.

UK Research and Innovation. (2023). 'How we fund higher education providers', Research England. https://www.ukri.org/publications/research-england-how-we-fund-higher-education-providers/how-we-fund-higher-education-providers/.

Yu, N., Y. Dong and M. de Jong (2022). 'A helping hand from the government? How public research funding affects academic output in less-prestigious universities in China', *Research Policy*, **51**, art. 104591. https://doi.org/10.1016/j.respol.2022.104591.

Zhang, S., K. H. Wapman, D. B. Larremore and A. Clauset (2022). 'Labor advantages drive the greater productivity of faculty at elite universities', *Science Advances*, **8**, art. eabq7056.

Vasilis Theoharakis is a Professor of Strategic Marketing and Director of the Centre of Strategic Marketing & Sales at Cranfield School of Management, and Visiting Professor at XJTLU, China. He combines academic research with venture and industry experience, including roles in venture capital and technology start-ups and leadership positions in Silicon Valley. His research focuses on strategic marketing, internationalization and entrepreneurship, with publications in journals such as *IJRM*, *JR*, *JPIM*, *GSJ*, *RP*, *JBE* and *JBR*.

Georgios Batsakis is a Professor of International Business at Alba Graduate Business School, The American College of Greece, and Reader in International Business at Brunel Business School, Brunel University of London. His research focuses on the internationalization processes of multinational enterprises. He has published in journals such as the *Journal of International Business Studies*, *Journal of World Business*, *Global Strategy Journal*, *Journal of Retailing* and *British Journal of Management*, among others. In 2022, he was included in the Poets&Quants Best 40-Under-40 Business School Professors.

Supporting Information

Additional supporting information can be found online in the Supporting Information section at the end of the article.