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Citation Elites in Polytheistic and Umbrella Disciplines: Patterns of Stratification and Concentration in Danish and British Science

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Abstract The notion of science as a stratified system is clearly manifested in the markedly uneven distribution of productivity, rewards, resources, and recognition. Although previous studies have shown that institutional environments for conducting research differ significantly between national science systems, disciplines, and subfields, it remains to be shown whether any systematic variations and patterns in inequalities exist among researchers in different national and domain specific settings. This study investigates the positioning of citation elites as opposed to 'ordinary' researchers by way of examining three dimensions of concentration (accumulation of publications and citations, specialisation, and institutional concentration) in biology, economics and physics in Denmark and the UK. Across all three dimensions, we put Richard Whitley's bipartite theory to the test, suggesting a nexus between the intellectual structure of a discipline and the configuration of its elite. The study draws on a dataset of researchers who published most of their publications in either physics, biology, or economics over the 1980–2018 period and with at least one publication in 2017–2018 while affiliated to either a British or a Danish university. We find higher degrees of concentration in the UK compared to Denmark, and that physics and biology respectively display the greatest and lowest degree of concentration. Similar patterns in disciplinary differences are observed in both countries, suggesting that concentration patterns are largely rooted in disciplinary cultures and merely amplified by the national context.

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Introduction and Background

One of the most salient trends in the contemporary science system is the sharpened stratification and the growing inequality in the distribution of resources, impact, influence, and visibility (see i.a. Ioannidis 2006; Ma and Uzzi 2018; Nielsen and Andersen 2021). The rise in concentration of research funding, rewards and scientific honours and the pronounced skew in citation scores, manifested in a small minority of researchers garnering a disproportionately large share of citations, has contributed to a widening status gap between a narrow stratum of elite scientists and the rank-and-file of the scholarly community (Lotka 1926; Merton 1968; Cole 1970; Reskin 1977; Allison 1980; Lariviere et al. 2010; Parker et al. 2010; Mongeon et al. 2016; Ma and Uzzi 2018; Aagaard et al. 2020; Katz and Matter 2017; Fox and Nikivincze 2020). Inequality in the science system may foster 'creative competition' but can also lead to great resource concentration on a few successful researchers, which may inhibit the efficient use of the global talent pool in science (cf. Nielsen and Andersen 2021). While great author-level disparities in citation distributions are well-described in the science studies literature (Price 1963; Cole and Cole 1972; Lariviere et al. 2010), recent studies point to widening author-level inequality over time and suggest a rising citation concentration in global science (Petersen and Penner 2014; Nielsen and Andersen 2021).

As evidenced in a number of studies, a primary source of stratification in the scholarly community is the concentration of publications and citations (see i.a. Price 1963; Cole and Cole 1973; Knorr-Cetina et al. 1979; Lariviere et al. 2010; Parker et al. 2010). Studies as far back as Lotka (1926) report that a relatively small pool of elite scientists accumulate a disproportionally large number of publications and citations (see also Zuckerman 1967; Allison and Stewart 1974; Mulkay 1976; Long 1978; Allison 1980; Fox 1983; Münch and Schäfer 2014). Cumulative career advantages accentuate inequalities in science and play an important role in reinforcing the tendency towards publication and citation concentration (Merton 1968; Zuckerman 1970; Reskin 1977). In relation to publications and citations, the essential features of cumulative advantage can be expressed as follows: (1) each publication increases a scientist's propensity for future publications and (2) each citation increases a scientist's propensity for future citations (Allison et al. 1982: 619).

Although studies have shown that institutional settings for carrying out research vary considerably between national higher education systems and scientific domains, it remains unclear whether any systematic variations exist in the degree of inequality between researchers in different country and disciplinary settings (Whitley 2003; Hollingsworth 2006; Heinze et al. 2020; Miao et al. 2022). Not many studies have investigated variations and potential patterns in inequalities among researchers and the degree to which research organisations are ordered into stable hierarchies of prestige across national science systems, disciplines, and subfields (Whitley 2003; Nielsen and Andersen 2021). Indeed, national institutional frameworks differ significantly when it comes to research funding arrangements, employment and promotion structures, and the degree to which funders and employers of researchers are willing to delegate control over intellectual goals, management of research programs and performance assessment through peer review procedures (Whitley 2003; Hollingsworth 2006; Münch and Schäfer 2014). Moreover, considerable national particularities exist when it comes to authority relations within research organisations, access to research infrastructure and resources, the average size of groups and labs, whether collaboration and communication occur formally or informally and whether scientific work is organised hierarchically or in an egalitarian manner (Whitley 2003; Yair 2019: 225–226). Similarly, significant disciplinary and subdisciplinary differences exist in terms of cognitive consensus, intellectual flexibility, productivity patterns, publication norms, citation practices and degree of inequality in the distribution of publications and citations (Reskin 1977; Lee and Bozeman 2005; Parker et al. 2010; Balietti et al. 2015; Hoenig 2017).

The present study explores aspects of stratification in two national science systems in Europe that are both predominantly structured by university institutions as opposed to larger non-university research organisations. More specifically, we investigate the positioning of citation elites compared to 'ordinary' researchers by way of examining three dimensions of concentration across researchers in Denmark and the UK within biology, economics, and physics. First, we examine to what extent citations and publications are concentrated among the citation elite and how unequal the distribution of citations is across researchers. Second, we explore concentration in terms of location within research specialties, i.e., the degree to which the citation elite is concentrated in selected subfields in relation to researchers in general. Third, we explore institutional concentration understood as the degree to which the citation elite is concentrated among top tier universities as opposed to researchers in general. We examine commonalities and differences in the top 5% most cited biologists, economists, and physicists with affiliations to either Danish or British institutions of higher education. To contrast results, we compare the top-most cited researchers with the remaining population of scientists in the three disciplines. Our dataset spans the period 1980–2018 and consists of researchers with at least one publication indexed in the Web of Science (WoS) in 2017–2018 who have published most of their publications in either physics, biology or economics and published at least one publication in 2017–2018 while affiliated to either a British or a Danish university (see section on Data and Methods).

The main argument for choosing a population of top-cited scientists based in Denmark and the UK is that we want to contrast the characteristics of citation elites in a Scandinavian welfare state, characterised by a small egalitarian science system, with traits of elite researchers in a large, highly stratified, and elitist British science system (Esping-Andersen 1990; Ellersgaard et al. 2013; Münch and Schäfer 2014). Hence, a primary motivation for selecting the Danish case is that highly cited researchers have seldom been studied in smaller country contexts and juxtaposed to their counterparts in larger science systems such as the British. Despite differences in size and degree of stratification, we find that the two science systems allow for meaningful comparisons across national samples.

The rationale behind making a cross-comparison of highly cited scientists in several disciplines, in this case three, relies on the notion that there are profound differences across scientific domains, with regard to research cultures, problem definitions, modes of knowledge production, collaboration, productivity patterns and (publication) norms (Braxton and Hargens 1996 in Hermanowicz 2012; Korom 2020b; Lee and Bozeman 2005). The three case disciplines were chosen because they have substantial variations in epistemic characteristics, and all have fairly clearly demarcated disciplinary boundaries separating them from other domains (Laudel and Bielick 2018). While physics is the perhaps most firmly institutionalised scientific discipline, economics is characterised by a strong internal hierarchy with shared standards of excellence and reputation (Cole 1970; Becher and Trowler 2001; Fourcade 2006; Balietti et al. 2015; Rossier et al. 2017; Korom 2020a). Finally, biology has been described as a fractious discipline with an ambiguous reputation hierarchy and heterogeneous reputation standards, although a recent study by Benz and Rossier (2022) points to a considerable internal hierarchy between functional and organic biology, in particular (Mulkay 1976; Becher and Trowler 2001).

At the same time, it is important to note that neither disciplines nor subfields can be assumed to be homogenous in terms of their epistemic characteristics. The conceptual characterisations presented here should be seen more as a stylised view of disciplines on a broader scale.

The paper will proceed as follows: First, we provide the theoretical backdrop for our study of citation elites in distinct national and disciplinary settings. Second, we outline our theoretical expectations and analytical strategy. Third, we describe the data and indicators used. Next, we report the results of the analysis. Finally, we conclude and discuss caveats of this type of study, while also calling for more empirical research on scientific elites in different national and disciplinary contexts.

(Trans)national Elites in High and Low Consensus Disciplines

Citations as Currency and Closure in Science

Scientific elites have considerable control over specialty formation (usually through work in core specialties) since they are the developers—or at least the legitimators of epistemic developments in research domains (Whitley 1976: 488). The ability of elites to control the intellectual evolution and direction of scientific advances can be expressed through Weber's (1978) notion of closure[1] (Bourdieu 1988; Azoulay et al.

[1] Social closure is a process of exclusion by which a limited circle of eligibles maximise rewards and monopolises advantages by closing off opportunities to another group of subordinate outsiders (Weber 1978: 638; Parkin 1979: 44; Murphy 1988: 88). Science contains mechanisms that makes such exclusion possible. To highlight some examples, mechanisms of closure can e.g. be at play in male academic networks (Noordenbos 2002), in PhD exchange networks (Burris 2004), in the socioeconomic profiles of students, doctoral students and professors (Blome et al. 2019) and more generally in the maintenance of positions endowed with institutional power both inside and outside academia (Bühlmann et al. 2017).

2019). Alongside their capacity to erect barriers to entry into scientific domains by way of control over e.g. financial and editorial resources[2], elites can also maintain their elevated standing through strong collaborative ties that link them together in elite networks. Such ties combined with the tendency for researchers from both the higher and the lower strata to predominantly be influenced by and cite a few highly visible luminaries, inevitably contribute to citation inequalities (Cole 1970; Mulkay 1976; Knorr-Cetina et al. 1979; Leimu et al. 2008).

Elites in science can be defined in multiple ways, for instance according to their roles and functions, their esteem and reputation, their access to funding and research facilities, their ties to other influential researchers and their productivity, impact, or visibility (de Beaver and Rosen 1979; Laudel 2005; Korom 2020a; Nielsen and Andersen 2021). Citations are essential for building a successful career in science and high citation scores is one of several indices of elite status (Korom 2020b: 193; Nielsen and Andersen 2021). This study will focus on one specific segment of scientific elites, namely, citation elites (Cole 1970; Parker et al. 2010; Korom 2020a). We understand citation elites as the numerical minority of scholars that amass the most citations in a given national and field-specific setting. Citations are a valuable asset in the research community and a critical source of scientific and symbolic capital (Bourdieu 1988; Kladakis et al. 2022). In this paper, we use the accrual of citations (symbolic capital) as a measure of impact, influence, and inequality in science (Mulkay 1976: 382; Deville et al. 2015).

Nationally Distinct Institutional Arrangements for Conducting Research

There are significant national differences in how science is organised, and national research environments offer differential material and intellectual conditions and opportunities for carrying out scientific work (Gaston 1970; Whitley 2003: 1016; Münch and Schäfer 2014: 5; Heinze et al. 2020: 2). National science systems may differ in terms of research culture, norms, practices, the average size of research teams, equality across institutions, access to education, relations between junior and senior staff, as well as management and governance systems (Yair 2019). Science systems can also vary in their degree of centralised control over conditions and decision-making for individual universities. Heinze et al. (2020) argue that countries with weak institutional control, such as the UK and the US, are more conducive to change that can in some cases facilitate breakthrough research. The American and the British science systems also attract more talented early-career researchers as well as established elite researchers internationally than countries with strong institutional control, such as France and Germany (Heinze et al. 2020: 1). Denmark can be seen as an intermediate case where reforms have resulted in greater decentralisation, though to a lesser degree than in the UK (Brøgger et al. 2023).

[2] Contrary to the widespread view that elites use their financial and editorial resources to block entry in their field, a study by Azoulay et al. (2019: 2890) suggests that it is rather the prospect of challenging the luminaries in the field that discourages outsiders from entry.

Although scientists are nationally bound and careers and employment remain structured by nationally distinct institutional arrangements, top scholars are highly mobile and flexibly move around the world to take up positions and affiliations at the universities that can offer them the best conditions and research opportunities (Zuckerman 1977: 154; Whitley 2003; Laudel 2005). Despite the considerable attention given to the national origins and geographic location of scientific elites, the careers of elite scholars are highly international as research activities and collaboration patterns are conspicuously transnational in nature (Gaston 1970; Zuckerman 1970, 1977: 14; Sørensen and Schneider 2016; Hoenig 2017: 126; Korom 2020a). Furthermore, as Laudel (2005: 381) points out, scientific specialty areas are international. Thus, the degree to which work is conducted in these specialties is unevenly distributed across countries. In line with this perspective, national elites are not equally scattered across disciplines and specialty areas, both due to differences in the size and stratification of science systems as well as variations in the relative standing and strength of fields, depending on the particular national context (Münch and Schäfer 2014; Miao et al. 2022).

The Intellectual Structure of a Discipline and the Composition of its Elite

As Lee and Bozeman (2005) suggest, "*field* is one of the most important control variables in science studies" (p. 691, emphasis added). Correspondingly, Whitley (1976) points out that the discipline, as a unit of analysis that institutionalises and socialises researchers and research work, is an important arena for studying scientific elites.

According to Whitley (1976), the composition of a discipline's elite is tied to its overall intellectual structure (see also Korom 2020b). Whitley (1976) distinguishes between two types of disciplines: 'polytheistic' and 'umbrella' disciplines. Polytheistic disciplines are weakly coordinated, have a low degree of consensus over theoretical and methodological issues, multiple beliefs on what constitutes good science, specialties that are unlikely to be firmly institutionalised, and a heterogenous elite scattered across multiple specialties (Cole 1970; Allison and Stewart 1974; Becher and Trowler 2001; Hermanowicz 2012). Umbrella disciplines are unified under core cognitive goals and methods, have firmly institutionalised specialties, and a homogenous elite concentrated in a few core specialties that hold the cognitive authority over the discipline (Balietti et al. 2015; Korom 2020b). In these disciplines, work in central specialties is expected to be concentrated in a few prestigious universities because of the "inequitable allocation of resources across universities" (Whitley 1976: 489). Furthermore, the high degree of consensus in umbrella disciplines makes mobility among researchers easier and facilitates their concentration in a few highly prestigious organisations (Whitley 1976). By comparison, the lack of agreement on what counts as academic excellence makes elites in polytheistic disciplines more likely to circulate between departments of varying prestige (Korom 2020b).

A key postulate of Whitley's theory is that epistemic factors specific to disciplines affect the career trajectories of academic elites and the influence they gather (Korom 2020a: 361). According to Whitley (1984), disciplines can be further distinguished according to two basic parameters: the degree of 'task uncertainty' confronted with in research work and the degree of 'mutual dependence' between researchers (Fuchs 1993). Technical task uncertainty refers to the extent to which the methods and techniques used to solve research problems and the reliability of results produced within a discipline are agreed upon (Whitley 1984: 781). By comparison, strategic task uncertainty concerns variation in the stability of problem formulations and the degree of consensus regarding which research problems are the most important to pursue (Whitley 1984: 781). Functional dependence reflects the need for coordination of research, common standards, and methods, while strategic dependence refers to the importance of coordination of strategies and collegial acceptance of research methods or results (Whitley 1984: 779).

The distribution of discipline-specific national elites in different research specialties offers a rough indication of the prestige hierarchy in a given discipline (see i.a. Whitley 1976; Laudel 2005). Authors in the field have not only pointed to the existence of (inter)disciplinary status hierarchies between disciplines, but also (intra)disciplinary prestige hierarchies, i.e., status differences between different branches within the same discipline (Cole and Cole 1973; Cole 1983; Burris 2004; Gingras and Wallace 2010; Korom 2020a; Benz and Rossier 2022). For instance, Gaston (1970) observed that greater repute was attached to contributions in theoretical high energy physics as opposed to advances made in the experimental branch of the discipline (Blume and Sinclair 1973). Along similar lines, Mulkay (1976) recounts a study by Cole and Cole (1968), showing that scientists working in elementary particle physics were more visible on average than those in atomic and molecular physics, while solid-state physicists were the least visible. More recently, Benz and Rossier (2022: 199–200) found empirical support for the existence of a hierarchy of subdisciplines within biology, suggesting that molecular biology is situated at the top while traditional botany and zoology is located towards the bottom.

While the notion of 'discipline' has been central to the science studies literature, it has also been associated with a great deal of ambiguity, both due to difficulties in properly defining the term and its blending with a variety of similar terms such as 'field', 'domain', 'specialty' and 'subject' (Sugimoto and Weingart 2015). This is even more the case for subfields, which are both more fluid in their definition and more apt to change over time. While physics, biology and economics are widely considered identifiable as disciplines (Laudel and Bielick 2018), they are more difficult to delineate in practice. In this paper, we rely on available bibliometric methods used to group publications in the WoS database. Disciplines are based on WoS subject categories, which are based on relations between journals. Subfields are based on 'micro fields' that are constructed using an algorithm that clusters publications according to journal and keywords. These methods are described in more detail in the Data and Methods section.

Research Objectives and Theoretical Expectations

Using all WoS publications over the 1980–2018 period, this study uses bibliometrics to compare and contrast the distribution of (1) *publications* and *citations* across the citation elite and the broader population of researchers in the chosen country and domain-specific settings. We will also examine the distribution of the citation elite across (2) *subfields* and (3) *universities*, and how these compare with distributions of researchers in general. Across all three dimensions, we put Whitley's bipartite theory—about a nexus between the intellectual structure of so-called polytheistic and umbrella disciplines and the configuration of elites in those disciplines—to the test (Engwall 1995; Korom 2020b). Obviously, Whitley's distinction between polytheistic and umbrella disciplines is ideal typical and thus not empirically clear-cut. Rather, our three case disciplines (biology, economics, physics) move along an imaginary continuum ranging from cognitively fragmented disciplines such as sociology and psychology at one end of the pole to high consensus disciplines such as physics at the other end (Hoenig 2017; Korom 2020b; Beyer 2022: 12).

Physics is a firmly institutionalised, high consensus discipline that in many ways epitomises Whitley's notion of an umbrella discipline (Korom 2020b). Similarly, economics is considered to have a low degree of fragmentation, a strong internal hierarchy with shared standards of excellence and reputation and is the social science discipline that comes the closest to meeting the key criteria of an umbrella discipline (Balietti et al. 2015; Becher and Trowler 2001; Fourcade 2006; Rossier et al. 2017; Korom 2020b). By contrast, biology is a decent exemplar of a polytheistic discipline with an ambiguous reputation hierarchy and a relatively low degree of consensus over theoretical and methodological issues (Cole 1970; Allison and Stewart 1974; Mulkay 1976; Becher and Trowler 2001; Hermanowicz 2012; Korom 2020b).

The British and the Danish higher education systems exhibit significant variation in national institutional frameworks for conducting research. Differences, which may be manifested in the degree of stratification and concentration among researchers in the two countries. While the British higher education system is characterised by weak institutional control and is one of the most stratified globally, the Danish higher education system is by contrast considered to be significantly less stratified and is characterised by a relatively high degree of institutional control (Aagaard 2011; Münch and Schäfer 2014; Bloch et al. 2018). An additional difference between the two systems is in sheer size. In 2018, there were in all 164 universities in the UK, compared to only eight in Denmark (Statista 2022; DK Uni 2022).

Reforms of the UK system in the 1980s allowed younger universities to challenge the position of the older elite institutions. However, meanwhile, the introduction of the Research Assessment Exercise (RAE) and its successor, the Research Excellence Framework (REF) has meant a further consolidation of the stratified UK system (Lee et al 2013). As a partial consequence of decades of competitive resource allocation and the resulting performance ranking of universities, the concentration of funds and research activity into a handful of the largest and leading departments and universities in the UK, has accelerated (Lee et al 2013). In 2009, Denmark also introduced a performance-based funding model, the Danish Bibliometric Research Indicator (BFI). The BFI is a publication-based model, where research funding is distributed according to number publications, which are weighted according to two levels (e.g. a top-level article is weighted three times higher than a bottom-level) (Sivertsen and Schneider 2012). However, a much smaller share of funding is distributed with the BFI than for the REF (in 2022 6% of total institutional research funding was distributed through the BFI) (UFM 2022).

RQ1: To what extent are citations and publications concentrated among the citation elite?

To examine this question, we use three indicators of concentration and inequality in productivity and influence across our case countries and disciplines: the share of total citations and publications that involve the citation elite, and the Gini coefficient that measures inequality across researchers in the number of citations per year. Based on our theoretical framework, we expect that physics has the greatest concentration of publications and citations among the citation elite, followed by economics, with biology being the least unequal.

In general terms, physics is considered to be a high consensus discipline characterised by low task uncertainty implying a high degree of uniformity among its practitioners about success norms and general agreement about the validity of research results (Fuchs 1993; Hermanowicz 2012). According to theory, resources in physics are heavily concentrated on the elite and the control over reputation is highly centralised (Fuchs 1993). Moreover, studies find that the elite in physics is highly visible, exercises discipline-wide influence and makes lasting research contributions that are frequently used and cited by other physicists (cf. Cole 1970; Mulkay 1976; Leimu et al. 2008). Taken together, this leads us to assume high degrees of publication and citation concentration in physics. Similarly, economics is thought of as being extremely hierarchical in structure, is characterised by shared standards of excellence and discipline-wide agreements over the ranking of economics journals, departments, and individual researchers (Engwall 1995; Fourcade et al. 2015). Economics has relatively low technical task uncertainty, reflecting broad acceptance of methods and techniques, but greater strategic uncertainty due to a lack of consensus on the validity of results. We accordingly expect considerable concentration in economics, although to a lesser extent than physics. Following Allison et al. (1982), biology, as opposed to economics and physics in particular, has weaker cumulative advantage and thus less inequality in publications and citations. Allison et al. (1982) suggest that disagreements over the evaluation of accomplishments of individual researchers and the lack of a core system of journals in biology, "limit an individual's ability to obtain discipline-wide recognition for his work" (p. 602). Moreover, biology can be viewed to have high technical uncertainty due to broad variation in methods used, but often greater consensus on the validity of results. We would thus expect publications and citations to be more evenly spread in biology.

In terms of country-level concentration we expect that the citation elite in a highly stratified science system such as the British on average garners a higher share of publications and citations than that of the citation elite in the Danish science system, even after accounting for population size. Another factor suggesting even further publication and citation concentration in the British system, is the language bias of UK researchers, i.e., their advantage due to easier access to American and English journals with higher impact and international visibility (Münch and Schäfer 2014: 72).

RQ2: To what degree is the citation elite concentrated in a small number of specialties in the discipline?

As pointed out by Whitley (1976), research activity, as a general rule, concentrates in the specialties that are more fundamental to a discipline. Correspondingly, it can be assumed that research activity in core specialties concentrates at the wealthiest and most prestigious universities. The scientific elite is in turn concentrated in these major science centres and tend to work in the most fruitful areas that also receive the lion's share of resources (Whitley 1976; Laudel 2005). For instance, it is described how particle physics, econometrics-centred specialties and macro/monetary economics attract more resources and elite members than more 'marginal' specialty areas in the two disciplines (Whitley 1976: 488; Claveau and Gingras 2016: 580 in Korom 2020b).

In line with theory, we would expect a polytheistic discipline such as biology to have both elites and non-elites scattered across multiple specialties (cf. Whitley 1976). This would in turn imply that it is relatively easier to become top cited in any of the specialties in biology though potentially with less influence over the discipline as a whole. By comparison, we expect physics and economics (both umbrella disciplines) to have firmly institutionalised specialties and a homogenous elite concentrated in a smaller number of core specialties (cf. Balietti et al. 2015; Korom 2020b). While it is less clear what differences can be expected between economics and physics, the organisation of much experimental physics research in large teams often with extensive infrastructure needs could imply a natural tendency towards even further concentration of elite researchers in selected research specialties.

It is fair to assume that neither the general population of researchers nor the top-most cited biologists, economists and physicists are equally scattered across specialty areas in Denmark and the UK. We assume that variations in size and degree of stratification between the two science systems as well as differences in national funding priorities and positions of strength will inevitably result in varying intensity in research activity across specialty areas.

RQ3: To what degree is the citation elite concentrated among selected universities?

Extant research has highlighted the tendency of elite scientists and future members of the scientific elite to concentrate at a few elite universities globally, notably in the US and the UK (Gaston 1970; Blume and Sinclair 1973; Mulkay 1976; Zuckerman 1977; Bennett and Glasner 1982; Laudel 2005; Parker et al. 2010; Korom 2020a, 2020b; Nielsen and Andersen 2021). Similarly, studies have pointed to great inequalities in the distribution of highly cited researchers and citations on a few elite institutions (Münch and Schäfer 2014: 65; Deville et al. 2015).

No doubt, the prestige attached to the Universities of Oxford and Cambridge continues to exert a great attraction on academics from all over the globe (Halsey and Trow 1971: 233 in Blume and Sinclair 1973: 135). The ability of such top institutions to attract top (cited) researchers is apart from their great reputation in large part due to their privileged access to research funds and facilities as compared to research institutions of lesser repute (Mulkay 1976; Münch and Schäfer 2014: 65–66; Ma et al. 2015). Hence, in academic systems such as the British, characterised by a stable hierarchy of academic prestige, prestige, and control over the distribution of resources will tend to concentrate in the hands of a small elite at the few leading academic institutions (see also Whitley 2003). In contrast, Denmark boasts a higher education system with a small number of relatively equally equipped universities, to which only moderate institutional prestige is attached (cf. Bloch et al. 2018). The Danish science system, characterized by a number of non-public funding sources, namely private research foundations and non-profit organisations, can be expected to exhibit greater pluralism in the criteria applied when making funding allocation decisions (Whitley 2003: 1023). Such national institutional features may in turn likely result in greater dispersal of research resources across fields and a more equal distribution of funds across universities. Thus, whereas the stable prestige hierarchy and the great concentration of resources leads us to assume a greater clumping together of the citation elite at the more prestigious universities in the UK, the fairly egalitarian allocation of resources from central hold, combined with a great number of non-state charities and foundations, would tend to suggest a more equal spreading of the national citation elite across the Danish universities.

In umbrella disciplines such as economics and physics, core work is expected to be concentrated in a few prestigious institutions because of the great disparity in research facilities and resources across universities (cf. Whitley 1976: 489). Moreover, the relatively cohesive cognitive structure and high degree of consensus in the two disciplines makes mobility among researchers easier and is likely to facilitate the concentration of elites at the most reputable universities (cf. Whitley 1976; Korom 2020a, 2020b). While economics does not have high strategic dependence, it has high functional dependence, which may be a strong factor for institutional concentration. Similarly, physics has a strong degree of both types of dependence and may have infrastructure needs that can only be fulfilled in the strongest research environments (cf. Whitley 1984: 779). We would thus expect the strongest institutional concentration of citation elites in physics, sharply followed by economics. By comparison, theory suggests that both elites and the average academic in internally fragmented, polytheistic disciplines such as biology, will tend to circulate more between institutions of varying prestige, especially because of the lack of discipline-wide consensus on what counts as academic excellence (cf. Korom 2020b).

Data and Methods

This section describes the data and indicator construction used in the analysis. As noted above, we will seek to examine the above questions using bibliometric data. Citation-based measures have a number of shortcomings which should be kept in mind when interpreting results (see Concluding Observations for an elaborated discussion of these limitations). Bibliometric indicators, albeit an imperfect measure of achievement, are useful to measure the individual research performance of scientists (Garcia and Sanz-Menéndez 2005; Ma et al. 2015), to make disciplinary and national rankings of scientists (Gaughan and Robin 2004; Hoenig 2017) and to identify elites (Mulkay 1976; Hermanowicz 2016). In this study, the primary bibliometric measure used for ranking the performance of scientists is the total number of citations per year (Cole and Cole 1967; Blume and Sinclair 1973; Allison and Stewart 1974; Corley 2005; Fukuzawa 2014; Deville et al. 2015).

Our dataset covers researchers who published the majority of their publications in physics, biology, or economics, over the period 1980–2018, which is the entire period covered by the database we used (a relational database version of the WoS hosted by the Centre for Science and Technology Studies (CWTS) at Leiden University). We selected all researchers with at least one publication in the WoS in 2017–2018 with an affiliation in either the UK or Denmark. We also include scientists that are retired or deceased as long as they had publications and an affiliation in Denmark or the UK during the period under study. We then retrieved the entire publication record (limited to articles, notes, and reviews) of the identified researchers using a disambiguated list of authors and publications based on the disambiguation algorithm of Caron and van Eck (2014). We used the National Science Foundation (NSF) classification (NSF 2006) of WoS journals to assign a discipline to the identified researchers. This classification groups journals in one of 143 specialties (including economics) and 14 disciplines (including biology and physics). While biology and physics are thus classified at a higher level than economics, we consider all three to be well-defined disciplines that, as argued above, make good candidates for comparison. We define the main specialty and discipline of researchers as the ones where they published the most papers and limit our dataset to the researchers who published the majority of their publications in physics, biology, or economics.

Operationalising Citation Elites

The citation elite is measured as the top 5% in their discipline and country in terms of number of citations per year. A narrower definition of the citation elite, e.g. the top 1%, would have resulted in a very small sample of researchers for Denmark, and within economics in both countries, making the results overly dependent on the performance of single researchers. For comparison, we show concentrations of publications and citations for both the top 5% and the top 1% below.

The total number of citations is of course influenced greatly by the age of the researcher, where some researchers in our sample may have been active during the entire period while others only for a few years. In order to ensure that our measure of the citation elite also includes younger researchers that have a certain degree of influence in their discipline, we control for the number of researcher years, defined as the number of years from first to last publication in our sample.

Note that we use full counts for both number publications and number citations. An alternative would be to use fractional counts, which account for the number of co-authors and hence seek to isolate the individual researcher's own contribution.

However, we choose to use full counts for two reasons in particular: First, full counts make sense as they capture all publications and citations that the researcher is involved in, and hence has some degree of influence over. Second, the information we typically have on the achievements of researchers, such as from CVs, Google Scholar, H-indices, or biographical descriptions, is seldom if ever fractionalised, implying that general assessments of who is elite are typically based on full counts. Note also, that since our measures are based on full counts, multi-authored publications (and their citations) are counted for all co-authors, meaning that total numbers of publications and citations can greatly overstate actual aggregate sums.

Operationalising Specialisation

Our analysis of specialisation draws on the CWTS classification system, where the entire population of WoS publications is classified in over 4000 micro fields, which we here refer to as subfields. Publications are clustered into subfields based on direct citation relations between publications and topics used in titles and abstracts (Waltman and van Eck 2012). For each researcher, we have identified the subfield that is most common among their publications. In cases where there are ties, one of these most common subfields is randomly chosen. A number of publications span more than one of these subfields. Within economics 4.5% of publications from the UK and 6.3% from Denmark had ties, 6.9% (UK) and 8.6% (DK) within biology and 10.4% (UK) and 13.3% (DK) within physics. Based on the list of the five journals with the largest number of publications and the list of five characteristic terms extracted from the titles of the publications in a micro-level field, we have sought to identify the most appropriate name for each subfield. Given that subfields are constructed by a computer algorithm, they do not always correspond to a specific subfield (CWTS Leiden Ranking 2023). In the few cases where it was not possible to conceptually distinguish between them, selected subfields were combined. It is important to point out that our categorisation of subfields is based on citation relations and topic similarity among articles and thus not on conceptual definitions or epistemic characteristics of subfields. As with the three disciplines, there is variation in the size of each subfield (in terms of publications), as well as the number of subfields within physics, biology, and economics. For this reason, the analysis of specialisation is most suited for comparison across countries, while comparison across disciplines should be done with greater caution.

After having chosen a single most common subfield for each researcher, we compare the distribution of the citation elite across subfields with the distribution for non-elite researchers. As opposed to examining the overall distribution, we focus on a set of the largest subfields, in order to examine whether the citation elite is more likely to specialise in selected subfields in comparison with researchers in general. While this method of identifying the main subfield of researchers is far from perfect, we view it as a very useful way to systematically categorise individual research areas and to compare degrees of specialisation for elite and non-elite researchers across country and discipline.

Table 1 Basic statistics by country and discipline

Country	Discipline	Total citations	Total publications	Total number researcher	Average citations per researcher	Average citations per researcher per year	Average publications per researcher	Average number researcher years
DK	Biology	2,127,289	86,817	3,252	654.1	39.6	26.7	13.2
	Econ.	130,347	7,111	424	307.4	20.0	16.8	12.9
	Physics	3,725,777	126,666	2,939	1,270.3	97.7	43.1	11.3
UK	Biology	12,545,543	453,313	17,581	715.6	42.2	25.8	14.1
	Econ.	1,442,459	75,193	3,925	368.4	21.3	19.2	14.8
	Physics	53,123,147	1,768,974	27,664	1,924.1	149.9	63.9	11.7

Operationalising Institutional Specialisation

Institutional specialisation seeks to examine whether the distribution of the citation elite across universities in the given national context differs from that of researchers as a whole within each discipline and country. More specifically, we are interested in whether and the degree to which the citation elite is more concentrated among a select set of top universities and to what extent we see any interesting differences at the country and disciplinary level. Measurement here is complicated by the fact that our sample runs over close to 40 years and many, if not most, researchers have likely moved around over time. We measure affiliation as the organisation for which the researcher has most publications over the period. In cases, where this affiliation is not in the UK or Denmark, and the last known affiliation is in the UK or Denmark, the latter is chosen. This measurement may not fully capture the dynamics of stratification in cases where researchers move towards top universities as they become more successful. However, we believe that this can provide a reasonably accurate picture of where the citation elite is located in comparison with researchers overall.

Table 1 shows some basic statistics for each of the six samples of researchers. Economics is by far the smallest discipline measured in terms of number of researchers, and also has the lowest average number of publications per researcher and number of citations per publication. Physics has the highest number for all three counts. In contrast, the average number of researcher years (measured as number years from first to last WoS publication) is lowest for physics.

Analysis and Results

We here present an analysis of publication and citation patterns across researchers as well as the degree to which the citation elite in our samples are concentrated in selected subfields and universities.

Publication and Citation Distributions

Figure 1 shows Gini coefficients as a measure of inequality in number of citations per year for each country and discipline. Coefficients are clearly highest for physics, indicating greater inequality in the distribution of citations across physicists. Note also that the Gini coefficient for physics is substantially higher in the UK (0.81) compared to Denmark (0.72). For both the UK and Denmark, Gini coefficients in economics are higher than in biology, though differences are less pronounced than for physics. Coefficient estimates are also slightly higher in the UK for both economics and biology, though differences are relatively small. Taken together, these results confirm our expectations as outlined earlier about the greatest inequality across researchers being in physics, followed by economics and biology as well as Gini coefficients being higher for the UK than for Denmark.

Figure 2a, b show the share of citations and publications that can be attributed to the top 5% and 1% cited researchers, respectively. As Figure 2a attests to, the citation elite in physics has by far the highest shares of both publications and citations among the three disciplines. In the UK, the top 5% most cited physicists are involved in 42% of publications and nearly two-thirds of citations (63%), indicating a very high degree of involvement of the citation elite in the country's research output. The same pattern is found for physics in Denmark, though the elite accounts for somewhat lower shares of citations and publications.

The share of publications by the citation elite is much lower for economics compared to physics, with 14% of publications for the UK and 16% for Denmark, which may likely be due to smaller teams and author groups in economics (cf. Nielsen and Andersen 2021: 5). However, the share of citations for the citation elite in economics is much higher than publication shares. Citation shares for the elite within biology are lower than for economics, while shares of publications are slightly higher. Hence, while overall shares of citations are somewhat similar for economics and biology, the average citations per paper appear to be larger for economics. A possible interpretation here, is that the highly cited economists, on average, are not significantly more productive than the bottom 95%, since especially researchers located in branches of the discipline using advanced mathematical modelling have a relatively low publication output. This is in contrast, to the productivity patterns of researchers in many branches of biology where author groups tend to be larger than in economics (cf. Lee and Bozeman 2005: 691; Cook et al. 2015). Our findings on disciplinary variation in the share of total citations and publications, that involve the top 5% cited researchers, are partially in line with our theoretical expectations. While citation concentration, as predicted, follow the same pattern in both countries, i.e., physics being the most unequal, followed by economics and then biology, publication inequalities go somewhat against our original hypothesis. Although we in both countries do see the greatest concentration of productivity in physics, the top-cited biologists in Denmark and the UK, on average account for a larger share of publications than their colleagues in economics. Surprisingly, aside from UK physics and citation rates for UK biology, the Danish citation elite in economics and biology on average amass a larger share of publications and citations than their UK counterparts, although differences are marginal.

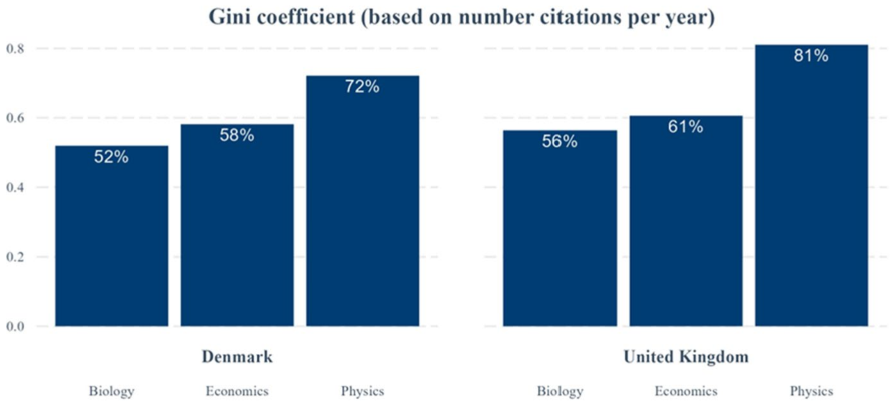

Fig. 1 Gini coefficient of the distribution of citations per year across researchers

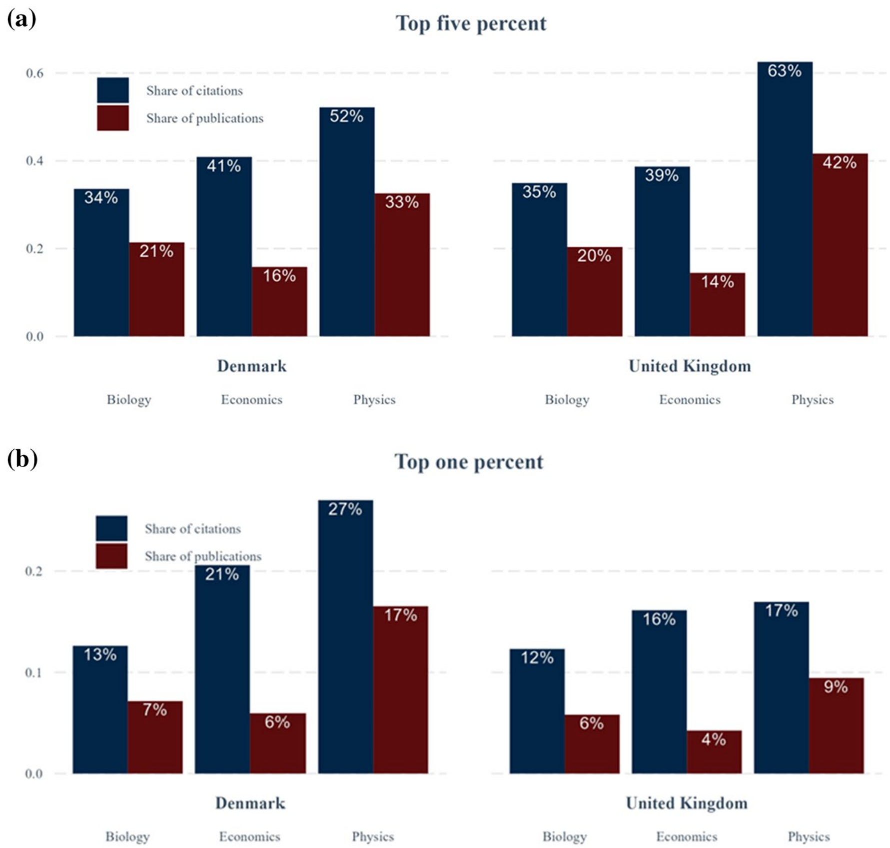

Fig. 2 **a** Share of citations and publications attributed to the top five percent most highly cited scientists. **b** Share of citations and publications attributed to the top one percent most highly cited scientists

For comparison, Fig. 2b shows the shares of citations and publications for the top 1% highest scoring researchers. We note again the small number of researchers in some of the groups of the 1% citation elite, which means that single persons can have a rather large influence on aggregated results. With this caveat, there are still a number of interesting results to note here. First, citation shares for physics and economics are essentially the same for the UK, in large contrast with results for the top 5%. Note also that the share of citations for the top 5% in UK physics is 3.7 times higher than the citation share for the top 1% (i.e., 5 times as many articles received 3.7 times as many citations). Hence, the difference in citation rates for articles in the top 5% compared to the top 1% in UK physics is relatively smaller than in the other disciplines.

Second, when considering the top 1%, citation shares are greater in Denmark than in the UK, the largest difference being in physics. This result goes against our expectations that a more stratified and elitist science system such as that of the UK, would tend towards greater inequality in citation concentration and in turn visibility among the elite (cf. Münch and Schäfer 2014). A possible alternative explanation is that country size plays a role here. For instance, a large science nation such as the UK will tend to have influential researchers in a larger number of specialities (cf. Laudel 2005: 381; Münch and Schäfer 2014; Miao et al. 2022).

Distribution of Elites and Non-elites across Subfields

Figure 3 shows the share of researchers in subfields, where for simplicity only specialty areas with at least 1% of researchers in the discipline overall are displayed. Given this cut-off, the smaller number of subfields for biology in the UK, combined with the fact that all of these subfields have small shares, suggests that researchers spread more evenly across a larger number of specialties, which to some degree can be expected given the much larger size of the UK research environment. This result also partially confirms our expectation that researchers in polytheistic disciplines such as biology will tend to spread across multiple specialties (cf. Whitley 1976), though we also find relatively greater concentration among elites. For conservation biology, marine ecology, soil biology and meat science in Denmark, and for conservation biology, ecology and soil biology in the UK, shares for citation elites are much larger than for the remaining 95% of researchers. For the UK, ornithological science is the second most populated research area with slightly more elites than the bottom 95%. It is also worth noting that the citation elite is underrepresented in marine biology research in Denmark given the large number share of scientists in that subfield overall. These results thus run somewhat counter to our theory, suggesting that both elites and non-elites in polytheistic disciplines tend to scatter across multiple specialty areas (cf. Cole 1970; Becher and Trowler 2001; Hermanowicz 2012). While this seems to be the case for the bottom 95% of biologists in both countries, the share of elites located in selected subfields is much higher than for the remaining researchers. Also, we see a higher share of top-cited Danish biologists in a few specialties than for the UK elite when comparing to the remaining population of biologists in the two countries.

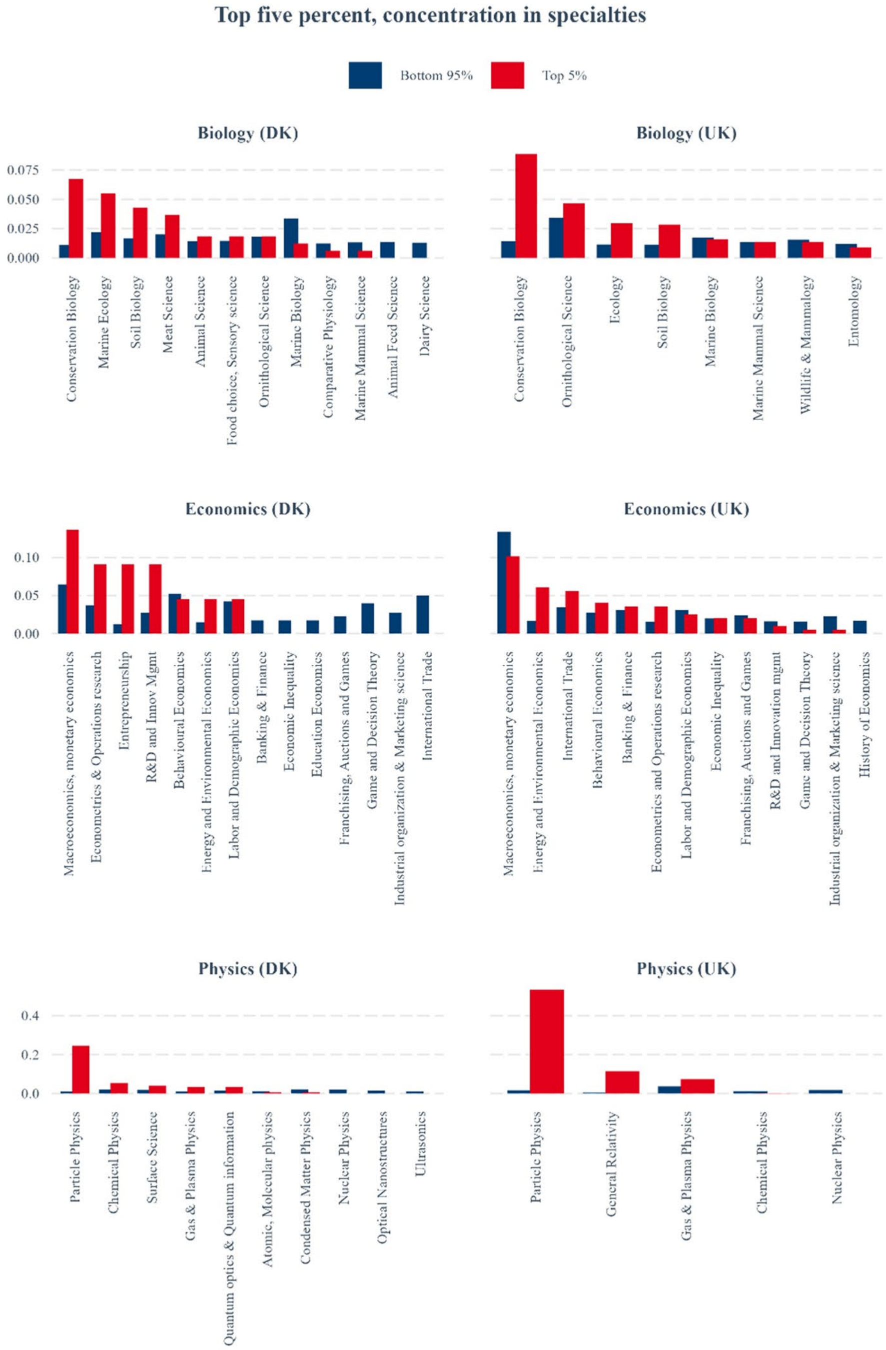

Fig. 3 Distribution of elite (top 5% most cited) and non-elite scientists across subfields

The distribution of elites relative to researchers overall in biology and economics appears to be somewhat similar. The concentration of citation elites in a single subfield, namely macroeconomics, monetary economics—traditionally considered to be a core research area in economics (Lee et al. 2013: 706)—is high for both Denmark and the UK. However, while the share of elites is much larger than non-elites in Denmark, the opposite is the case in the UK. Other areas popular among the elite in Denmark are econometrics & operations research, entrepreneurship and R&D and innovation management. Interestingly, these results are in line with theory suggesting that econometrics-centred specialties and macro/monetary economics attract more resources and elite members than other more 'peripheral' specialties in economics (cf. Whitley 1976: 488; Korom 2020b). Hence, while there in Danish economics, appears to be a strong overrepresentation of elites in a few 'elite' specialties, the share of UK elites in subfields is closer to the share of scientists overall in those subfields. One notable exception for the UK is energy and environmental economics, where the share of elites is more than three times higher than for non-elites.

In line with our original proposition about elites in umbrella disciplines and their concentration in a few core specialties (cf. Balietti et al. 2015; Korom 2020b), most elite physicists in our two national samples appear to be concentrated in a single subfield, namely particle physics. The concentration is dramatic for the UK, with over half of elite researchers yet under 2% of non-elite. Concentration is also very large in Denmark, at around 25%. Interestingly, these results correspond surprisingly well with a more than 50-year-old study by Cole and Cole (1968), suggesting that researchers in elementary particle physics on average were more visible than their colleagues in atomic and molecular physics, while solid state physics were the least visible. Similarly, our findings show that the top 5% in Denmark is neither well represented in atomic, molecular physics nor condensed matter physics of which solid state physics is a branch, while these two specialty areas are not even among the subfields with over 1% of scientists in the UK. Possible explanations for this heavy concentration of highly cited researchers in particle physics, are the extensive infrastructure needs for experimental particle physics and the huge author groups that receive high citation rates on individual papers, perhaps best exemplified by the mega teams at a few very large facilities such as the particle physics lab at CERN in Switzerland. As suggested earlier in this paper, neither elites nor the overall population of researchers will be equally scattered across specialty areas in different country contexts (cf. Laudel 2005: 381). Correspondingly, the citation elite in the two countries, with some exceptions, appears to be distributed in different specialty areas depending on discipline. Contrary to our expectations about country differences though, there appears to be greater concentration of top-cited economists in specific subfields in Denmark as opposed to the UK.

Distribution of Elites and Non-elites Across Institutions

Figure 4 shows distributions of elite and non-elite researchers across research institutions. Within biology, the share of elite and non-elite researchers across Danish universities is quite similar, though shares of researchers in the top 5% are slightly higher for the three largest universities. On the surface, these numbers do not indicate much further concentration among elite researchers, but rather a high concentration of researchers overall in 2–3 institutions. It is somewhat surprising that nearly three-quarters (73.6%) of the most highly cited biologists are based at only two Danish universities, namely the University of Copenhagen and Aarhus University. It should be noted though, that traditional biologists are not to be found at two out of the eight Danish universities, namely the Copenhagen Business School and the IT University of Copenhagen. The pattern is different for UK biology. Researchers are relatively evenly distributed among a number of universities, with the highest share at 3.1%. However, there are multiple institutions for which the share of elite researchers is much higher than the share of researchers overall. For 13 out of the 14 institutions shown, the share of elites is greater than the share of non-elites. Interestingly, two so-called Redbrick[3] universities, Sheffield, and Leeds, hold the highest proportions of highly cited biologists, sharply followed by what can be considered both new and old elite universities located in the Loxbridge triangle[4] (cf. Münch and Schäfer 2014; Savage et al. 2015). We note that the institutional concentration of the elite in the UK is generally much lower within biology than within physics and economics. In sum, we do not have data for Denmark supporting the assumption that both the elite and the average academic will be more evenly spread across a greater number of institutions in a polytheistic disciplines such as biology (cf. Korom 2020a). Rather the opposite is the case. For UK biology we only have partial empirical evidence supporting Whitley's (1976) theory. While the overall population of biologists are scattered across multiple institutions of varying size and standing, we do see a higher proportion of elites at both the Redbricks and universities in the Loxbridge area.

Concentration within economics in Denmark is somewhat similar to that for biology. Again, we see great inequalities among universities in the distribution of both highly cited economists and researchers overall. While Aarhus University hosts over one-third (36.4%) of researchers in the top 5%, the University of Copenhagen approximately hosts one-fourth (27.3%), with the Copenhagen Business School not surprisingly coming in on the third spot both for economists overall and for top-cited researchers. In the UK, concentration of elites in economics is mainly found among five universities, namely elite universities located in what is also known as the 'golden triangle', i.e., London: LSE (11.2%), UCL (9.1%) and University of London (7.6%) and Oxbridge: Oxford (10.2%) and Cambridge (9.1%) University. We see the highest overrepresentation of elites at the London School of Economics. Results for economics are very much in line with our theoretical assumptions about elites being affiliated to elite universities in umbrella disciplines (cf. Whitley 1976; Korom

[3] The six original Redbrick universities established in the early 20th century are: Birmingham, Bristol, Leeds, Liverpool, Manchester, and Sheffield (Breakwell and Tytherleigh 2008; Uni Guide 2023).

[4] The Loxbridge triangle refers to the University of Cambridge and the University of Oxford and four universities in London, including Imperial College London, University College London, King's College London, and the London School of Economics.

Fig. 4 Distribution of elite (top 5% most cited) and non-elite scientists across institutions

2020a, 2020b). While both the general population of economists and elites to an overwhelming extent are located at the two oldest and highest-ranking universities in Denmark, a bit under half of elite economists have ties to elite institutions in London, Oxford, and Cambridge.

Within Danish physics, there is a strong concentration of citation elites at one institution, University of Copenhagen, with over half (52.4%) of all elites and only around one-fifth (21.2%) of non-elites. The Technical University of Denmark has the second highest proportion of elites with 28% and 41% percent of physicists overall. These results are noticeable and correspond well with the reputable standing of the Niels Bohr Institute in international physics, attracting both young talented and well-established researchers from across the globe. Concentration in the UK is more evenly distributed across a larger range of universities, though in several cases with fairly large differences between elite and non-elite shares. It is worth noting that the University of Glasgow (9.8%) and the two younger Redbricks, University of Manchester (8.1%) and Birmingham (7.7%), apart from the University of Oxford (8.8%) hold the highest numbers and shares of highly cited physicists in the UK, relative to the bottom 95% of researchers in the discipline. Taken together, the results for economics and physics confirm our original hypothesis about the strongest institutional concentration of citation elites in physics, followed by economics. While concentration patterns are particularly stark for the Danish citation elite in physics, it is somewhat surprising that concentration on traditional elite universities is more pronounced for economics than for physics in the UK.

Arguably, a key factor influencing distributions in Denmark is simply the small number of universities, with eight universities in total and 2–3 main universities (Aarhus and Copenhagen, with the addition of the Technical University of Denmark). For the case of institutional concentration, this makes a comparison of Denmark and the UK difficult. Still, the share of citation elites in Danish institutions is closer to the overall share of scientists in these same institutions. More concentration of elites in some institutions is observed in the UK, however to a lesser extent than expected when consulting theory. For all samples it should be noted that larger shares of highly cited researchers at fewer universities can be observed for Denmark since elites and the rest of scientists are spread out on fewer universities. Hence, while the seeming egalitarian nature of the Danish higher education system suggests a more equal spreading of highly cited researchers across Danish universities, it is surprising to observe such strong concentration of the citation elite for all three disciplines at only two universities.

Concluding Observations

Accelerated competition over scarce resources has intensified funding concentration that in turn have had the unintended consequence of a widened status gap between the elite and the rest. A pressing question for current science policy is whether concentration is good or bad for science. Arguments have been made that some degree of inequality is desirable, as it places a greater share of resources and influence among top performers. However, recent increases in concentration, combined with a surge in the number of early career researchers in temporary positions suggest that this question should be given careful consideration. A key question here is at what point inequality goes from being desirable to a factor that has adverse consequences for how the science system functions and the development and diversity of new knowledge.

This paper provides documentation for how national science systems in select disciplines differ in their capacity to foster and attract highly cited researchers. Great inequalities exist in global science when it comes to each nations' capability to produce highly cited researchers (Parker et al. 2010). While both great national and subfield inequalities exist in the access to the material and intellectual resources necessary to produce research that eventually becomes highly cited, subfields also differ from one another in the amount of resources required to foster highly cited work (Parker et al. 2010). No doubt, the availability of research income matters for the ability of universities to attract top scientists. This is certainly also the case for higher education institutions in Denmark and the UK, where the most reputable and wealthy British universities are able to recruit internationally visible researchers with higher publication and citation rates than their Danish counterparts (see e.g., Weakliem et al. 2012; Münch and Schäfer 2014: 66; Maesse 2018). Moreover, in elitist and hierarchical academic systems like that of the UK, top performers are not only recruited and trained at the leading institutions but are also likely to remain in these same institutions for the majority of their careers (Whitley 2003). As already established, members of what Zuckerman (1977: 154) has termed the mobile international elite, govern access to key resources in their respective disciplines and can insist on their intellectual agendas to be followed (Whitley 1976, 2003). Moreover, high-achieving scholars are strongly embedded in elite networks, allowing them to obtain positions on editorial boards and getting in touch with PhD students, postdocs, and fellow colleagues with whom they can co-author papers that often receive considerable traction from peers (Maesse 2018).

Our analysis indicates that differences in concentration patterns across disciplines can be substantial and related to variations in epistemic characteristics. Moreover, the present study offers an original approach to researching citation elites by contrasting their positioning vis-à-vis non-elite researchers. To our knowledge, this study is the first of its kind to investigate systematic variations in concentration at the level of citations, subfields, and institutions across national and disciplinary boundaries.

Overall Findings

Drawing on work by Whitley (1976, 1984) on how the overall intellectual structure of a discipline is tied to the composition of its elite, this paper aimed to account for how citation elites in Denmark and the UK (operationalised as the top 5% most cited in their discipline and country) concentrate on three distinct dimensions (accumulation of publications and citations, institutional concentration, and specialisation) within three disciplines: biology, economics and physics.

The general conclusion from this study is that patterns of concentration and inequality on the three above-mentioned dimensions appear to vary greatly across disciplines and to a lesser extent across countries. The greatest degree of inequality and concentration in the share of total citations and publications is found in physics, followed by economics and biology. These findings align well with theory. As for specialisation in biology, our results confirm that polytheistic disciplines tend towards lesser concentration in selected subfields. While we find that biologists tend to scatter across multiple specialty areas, our results show the greatest concentration of national elites in a few core specialties for physics, followed by economics. Partially in line with our expectations about national differences and our original proposition about elites in umbrella disciplines, the majority of elite physicists in our two samples are located in the same subfield, whereas we observe somewhat greater concentration of elite economists in a few specialties in Denmark as opposed to elite economists in the UK. Our findings on institutional affiliation confirm our theoretical expectation about the strongest institutional concentration of citation elites in physics, followed by economics. However, while we observe that institutional concentration of elite biologists is generally much lower for the UK than for the two other disciplines, we do not have data for Denmark supporting the assumption that both elites and non-elites are more evenly spread across a greater number of universities in biology.

Differences between economics and biology may also depend on varying degrees of uncertainty and dependence within the two disciplines. On the one hand, biology has less consensus on which methods and problems are most important, potentially implying that the sphere of influence for elite researchers will often be limited to their own specialty. On the other hand, new results may tend to gain broader acceptance in biology than within economics, which is a less exact science, leaving more room for the interpretation or dispute of new results. This thus implies that biology has greater consensus than economics for results *within* subfields, while economics has greater consensus in methods *across* subfields. This aligns well with our findings that concentration in general is slightly greater in economics, while concentration among the elite within subfields is greater in biology. In sum, we note that similar patterns in disciplinary differences are observed in both countries, suggesting that these patterns are largely rooted in disciplinary cultures and merely amplified by the national context.

Our expectation was that a hierarchical system such as that in the UK would tend towards greater concentration and inequality. However, we find that differences between Denmark and the UK are not as great as originally predicted. In fact, it is surprising to observe that the citation elite largely concentrates on only two Danish universities, in what on the surface appears to be an egalitarian higher education system. Overall concentrations in the two countries are similar within biology and economics, with a somewhat greater degree of concentration for the UK within physics. Specialisation of the elite within biology and economics appears to be more pronounced in Denmark, while the opposite is the case for physics, where almost half of all UK elite scientists are located in one subfield, particle physics. Differences between the two countries is clearer concerning institutional affiliation which appears to be greater in the UK within all three disciplines. This could suggest that the elitist nature of a national science system (e.g., the UK) is primarily manifested through institutional hierarchies and not in the disciplines themselves, whose epistemic cultures have a greater tendency to transcend national contexts. Hence, this would lead us to assume that elites in the UK are predominantly recruited through elite universities, while the lack of an exceptional cluster of elite universities in Denmark, suggests that certain disciplines and specialty areas enjoy a particular status in the recruitment of elites in the Danish science system (see Bühlmann et al. 2017; Rossier et al. 2017 for a similar discussion).

Limitations

While we have drawn on theory to motivate the design of our analyses, the three dimensions of concentration that we have sought to account for can nevertheless involve a number of facets that we are unable to capture concisely with the bibliometric measures that we have at our disposal. While we view that the data used here provides useful indications of trends in stratification and inequality, we are also careful to point out that these measures are far from able to capture the full gamut of concentration patterns. First of all, bibliometric delineation of disciplines and identification of researchers at the level of disciplines and subfields, is tricky. For instance, researchers that are classified in a specific discipline (i.e., biology, economics, or physics) may not necessarily have a training in this discipline, nor being based in a biology, economics, or physics department. Moreover, some specialty areas are larger and have greater citation traffic than others, meaning that some researchers are working in subfields where single contributions are cited more often than in other subfields (Korom 2020b). We are also aware that citations by no means are a perfect measure of achievement nor influence in science, but merely a proxy of peer recognition. It is thus possible for a researcher to be considered as being part of the elite by their peers without ranking in the top 5% of the field in terms of citations. However, we find that citation counts are useful as a tool to identify one particular segment of the scientific elite. We also agree with Korom (2020a) that "citations can be used as an approximate indicator of influence as they reflect evaluations of scientific contributions by qualified peers" (p. 146).

Citation patterns develop over time and vary according to field. Moreover, it should be borne in mind that evidence about highly cited researchers "is always specific to the discipline and time period under consideration" (Parker et al. 2010: 139–140). It is also worth noting that the WoS does not include all of the scientific literature, which means that our findings are somewhat contingent on this data source. This is especially the case for economics since social sciences tend to be less well covered in the WoS than e.g. biology and physics (Mongeon and Paul-Hus 2016). The coverage may not only differ across discipline but also over time as the WoS has been in constant evolution over its history. Similarly, while the micro fields used in this study are based on the entire period, some of them may have emerged in more recent years and some may have disappeared over time.

Finally, while our study suggests that citation concentration should be understood in the context of diverging trends in publication and collaboration activities for the elite compared to the ordinary scientist, we are unable to delve into the underlying drivers behind inequalities in citation impact. These differences in inequality trends across and within disciplines may reflect variations in the intensity of resource concentration and differences in publication and citation practices, i.e., the frequency with which papers are published, sizes of author groups and the average number of references per article (Hamann 2018; Nielsen and Andersen 2021: 5).

Prospective Research

The present study makes strides in helping to clarify issues related to the measurement of disciplinarity and the assignment of researchers to subfields while also paving the way for similar cross-country and cross-disciplinary studies comparing elites and non-elites in science. A promising avenue for further research would be to investigate the pathways to becoming highly cited and under which conditions researchers achieve elite status (see Parker et al. 2010; Korom 2020b). Moreover, we call for more empirical research comparing citation elites and degrees of intensity in stratification and concentration across different national and field-specific settings. Also, more cross-country comparisons are needed of the social and formal career traits of highly cited academics in different fields. Future research would also do well to explore possible associations between PhD origins and later academic appointment for elite researchers as well as the role played by multiple institutional affiliations in the careers of top performers (see Hottenrott et al. 2022 for a study on the extent and nature of multiple affiliations). Prospective research could also look into temporal developments in specialisation among the elite and the non-elite, in addition to differences in patterns of individual level publication and citation concentration across multiple disciplines over a longer time span. A prominent feature of scientific elites is their ability to reproduce themselves and pass on their intellectual legacy by way of recruitment and training of the next generation of would-be elites in their specialty (Mulkay 1976; Whitley 1976; Bennett and Glasner 1982). Future research could add to our work by examining data across age cohorts and the role played by 'dynastical elites' in producing future members of the scientific elite.

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Declarations

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

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