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Article

Studies of national research performance: A case of 'methodological nationalism' and 'zombie science'?

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Abstract

The analytical point of departure in this paper is the ongoing debate, initiated by Ulrich Beck, on methodological nationalism within the social sciences. Based on a comprehensive study of research collaboration and mobility of researchers this paper discusses possible traces of methodological nationalism in comparative studies of research performance. These studies are often carried out as country comparisons with no or little focus on the growing transnationality of what is measured. However, research is a transnational activity and must be understood as such. Researchers increasingly collaborate with researchers in other countries. The national research institutions are increasingly transnationalised due to the growing mobility of researchers. Based on an examination of all the papers registered in the Thompson Reuter's Web of Science database we follow the development in research collaboration in the period 1980–2014 for 17 leading research countries.

Key words: methodological nationalism; mobility; collaboration; national research performance.

1. Introduction

Following the shift in the understanding of the economy from an industrial economy based on natural resources, work division and machine technology to a new, knowledge-based economy in which knowledge, human capital and information technology are seen as the foundation of the economy (OECD 1996), a renewed focus on national research performance and country comparisons has emerged. According to the notion of the knowledge-based economy, research together with education and innovation are the key elements needed to thrive in the new economy. Research, education and innovation performance are thus understood as important indicators of a country's economic competitiveness. The more research a country can produce, the more impact this research has, the better educated the population is, the more patents the country can produce, the better the country will likely fare in the knowledge-based society. In other words, future economic performance is understood to be intimately linked to factors such as: the amount of money spent on higher education and R&D, the educational standard of the population, and the research and innovation performance of the country.

This development—together with the rise of New Public Management (Hood 1991) and related ideas, such as 'the audit society' (Power 1997), 'the evaluative state' (Neave 1988) and 'the competition state' (Cerny 1997)—has led to a growing number of country comparisons of performance within these areas. The OECD has headed this development, and its PISA measurements (Program for International Student Assessment, cf. PISA 2015) are prime examples of cross-country comparisons of education performance. The EU adopted the idea of the knowledge-based economy in 2000, declaring that it wanted to be:

> . . . the most competitive and dynamic knowledge-based economy in the world. . . (European Council 2000: 2)

It has likewise shown a growing interest in cross-country comparisons within the areas of education, research and innovation (Sørensen et al. 2015).

This paper focuses on the measurement of research performance. National comparisons of research performance are not new. An early example is Charles Babbage's concern about the decline of science in England relative to Germany (Nye 1984), but such comparisons have historically been infrequent and on a small scale compared to the all-encompassing, multi-national performance comparisons of the last two decades (May 1997; Adams 1998; King 2004). Such comparisons have often been commissioned by international organisations such as the EU,[1] but individual countries also invest considerable energy to shed light on how they are doing in

terms of research performance, regularly publishing indicator reports (e.g. the USA,[2] the Netherlands,[3] Norway[4] and Denmark[5]). A good example from the EU of a cross-country comparison of national research performance can be found in the newly developed 'Composite Indicator for Scientific and Technological Research Excellence' (European Commission 2013a,b; Sørensen et al. 2015). Here, the level of scientific and technological research excellence in the various EU countries is judged using four indicators: the share of highly cited publications, the number of top scientific universities and public research organisations, the number of patent applications and the value of European Research Council grants.

Nevertheless, one asks how meaningful these country comparisons are in the field of science. Can we ascribe research results and performance to individual countries? Is science not a prime example of an activity that always crosses national boarders? We will discuss the question of country comparisons in Section 4 with a special focus on comparisons of the research performance of individual countries. National research performance is traditionally understood as the scientific production and citation impact of a given country. Production is measured in terms of publication output, mainly international journal articles. While production and impact go hand-in-hand, the citation impact is considered the most important research performance indicator as citations on an aggregated level of analysis are seen as a proxy for research 'quality' (Gläser and Laudel 2007). Numerous indicators have been suggested for measuring impact, but there is a growing consensus that we should focus on a country's share of the 10% most cited papers (Tijssen et al. 2002; Bornmann et al. 2012; Waltman et al. 2012).

Our analytical point of departure will be the growing international discussion of methodological nationalism (Wimmer and Glick Schiller 2002; Chernilo 2011). One of the strongest voices in this discussion has been Ulrich Beck, a German sociologist. According to Beck (and Sznaider), the problem with methodological nationalism is that it:

> . . . equates societies with nation-state societies and sees states and their governments as the primary focus of social-scientific analysis. It assumes that humanity is naturally divided into a limited number of nations, which organise themselves internally as nation-states and externally set boundaries to distinguish themselves from other nation-states. And it goes further: this outer delimitation as well as the competition between nation-states, represents the most fundamental category of political organisation. (Beck and Sznaider 2006: 3)

Thus, here and elsewhere, Beck warns of a tendency within the social sciences to assume that the world can be divided into nation-state containers that can be studied more or less in isolation from other containers (cf. Beck 2000, 2005, 2006, 2007, 2009; Beck and Grande 2010). To Beck, this represents a distorted version of reality (Sørensen and Christiansen 2013: 80–3). Holding on to this view of society in an increasingly interconnected world will only result in what he calls 'zombie science' or a fruitless 'science of unreality' (Beck 2006: 21). In the same way that zombies live on in our imagination after they are actually dead, according to Beck, social scientists should be careful to avoid using antiquated understandings of society when studying social phenomena. In other words, Beck wants us to pay attention to the possible traces of methodological nationalism in our comparisons, and methodological nationalism occurs when the nation-state is unconsciously and uncritically treated as the natural frame of society and, thus, in our case is the natural entity to study when examining societal phenomena such as science and research performance.

In the fields of higher education and science studies, methodological nationalism has thus far only been discussed in relation to higher education (Shahjahan and Kezar 2013; Kosmützky 2015). As we will try to argue in this paper, the discussion of methodological nationalism is also highly relevant when it comes to measuring the research performance of individual countries. As shown below, research is a highly transnational phenomenon. Research always builds on the existing ideas, methods and discoveries of other scholars, both from within and outside a given national entity. This has always been the case. As we will show, the research process also often involves collaboration with scientists working in other countries, and locally—in the different research institutions where the research is produced—scientists with different national backgrounds work together. The shift from 'Little Science' to 'Big Science' during and after World War II, with huge concentrations of researchers of many different national origins working on specific research efforts such as the Manhattan and Human Genome projects, but also the changing funding landscape, especially since the end of the Cold War, where international funding institutions have emerged, have likewise been a driver—or perhaps multiplier—of the transnationalisation of research activities (Strasser 2008).

In order to explore the transnational character of research in relation to collaboration and institutions, we will start by examining the general development in cooperation among researchers in 17 of the most important research countries in the world. Hereafter, we will focus on the research production and performance ascribed to Denmark. We want to see how 'national' the research production of a single nation-state like Denmark is. We have chosen Denmark as our case because Denmark is among the top-performing research countries. The development of Danish research performance has also been addressed by other scholars, who refer to 'the Danish miracle' (Öquist and Benner 2012; Aagaard and Schneider 2015). This is a reference to the fact that Denmark has apparently outperformed its Nordic neighbours as well as most other countries (apart from Switzerland and the Netherlands (Schneider and Aagaard 2015)). But the question is how 'Danish' Danish research really is? The question of the national-versus-transnational character of the current research production will be at the centre of our paper. Based on our findings, we will further discuss the issue of methodological nationalism and the acute methodological challenges involved in measuring the research performance of individual countries. Our main argument is that there are considerable theoretical and operational discrepancies between the perceived discrete units of analysis and what is actually measured when it comes to national research performance.

2. Methods

Throughout the paper we use the terms transnational and transnationalisation instead of international and internationalisation, respectively, because, in our view, these terms more accurately describe what is currently at stake. Etymologically speaking, the term *inter*national describes things happening *between* nations, whereas the term *trans*national describes phenomena that go *across* or *beyond* nations. Contemporary research is precisely a phenomenon that goes across and beyond the state apparatus of the single nation-states. As Wagner has argued, nation-states dominated

cross-national science collaboration in the 20th century, but more recently we have experienced a shift from a:

> . . . nationally centred scientific system to a global one in which researchers, not national authorities, set the rules. (Wagner 2008: 9)

International science collaboration activities such as the International Space Station and similar megascience projects still exist. However, cross-national research collaboration is no longer primarily driven by such government-controlled, international projects but to a greater and greater extent by collaboration among individual researchers and research groups in a new global network (Wagner 2008: 31–2, 51–68). By using the concepts *transnationalisation* and *transnational*, we want to emphasise the non-state organised character of this development. This is also in line with the literature on methodological nationalism (Beck 2000; Wimmer and Glick Schiller 2002).

Empirically, collaboration has been examined using different designs, the most predominant of which has for decades been to use journal publications in bibliographic databases and then measure collaborative activity by counting multiple author contributions (Luukkonen et al. 1992; Georghiou 1998; Wagner and Leydesdorff 2005). Journal by-lines include author names and their institutional affiliations together with the countries of such institutions. Such data appear to open up to a variety of different analyses of supposedly 'collaborative' activities, such as patterns of individual or international collaboration, where the latter simply examines the number of different countries mentioned in the by-lines. Such bibliometric analyses of co-authorships are valuable in the sense that they are invariant, verifiable and relatively inexpensive and not least practical to do, but they are by no means perfect and have clear limitations. Katz and Martin (1997) have suggested that measures of co-authorship are best seen as partial indicators of collaboration.

Obviously, co-authorships can only be used to count author contributions to publications assuming that such mutual authorships imply some form of 'collaboration'. At the level of individual articles, however, co-authorship in itself does not necessarily mean that 'collaboration' has actually occurred—whatever 'collaboration' really means (Woolgar 1976). Narin (1976) has asserted that the submission of a manuscript containing new knowledge claims is a crucial outcome of science, representing findings that the authors are collectively willing to claim as notable. So, claiming authorship serves as a socio-cognitive filter regarding the multitude of relations in the social context of discovery (Melin and Persson 1996) and indicates that mutual activities of importance have taken place, be they 'collaboration', 'cooperation', 'contribution' or the like. The unit of analysis in this article is countries, so we examine co-authorships at the country level. We no longer examine the individual author and their potential collaborative efforts but aggregate to the political/geographic construct of countries. Hence, the meaning of collaboration is clearly different from that at the individual level. One could argue that while the concept might become more abstract, as an indicator it becomes simpler: that is, a proxy for a country's internationalisation through participation in formal knowledge production processes. The fact that we can measure this through co-authorships for all countries for the same time period strengthens the interpretative value of such a proxy.

But it is also important to acknowledge that research collaboration can have many manifestations, co-authorships being but one. For example, Bozeman et al. (2013: 3) define collaboration as:

> . . . social processes whereby human beings pool their human capital for the objective of producing knowledge.

They also argue that co-authorship is neither necessary nor sufficient to such collaboration.

Besides the conceptual challenges linking co-authorships to collaboration, a further important challenge is the actual distribution of credit among the authors of a publication. In practice, two counting methods exist: full counting, where all of the participating units (i.e. authors, institutions, countries) receive one full credit each, and fractional counting, where all of the participating units divide one credit among them (i.e. 1/n), meaning that more units mean less credit per unit (Gauffriau and Larsen 2005). It has been suggested that the counting approaches measure different constructs, where full counting measures a unit's participation and fractional counting a unit's contribution (Waltman and van Eck 2015). However, both approaches are essentially flawed, as they both disregard the fact that credit, be it participation or contribution, is usually unevenly distributed among the units represented in the by-line, leading to what is known as inflationary bias when it comes to full counting, or equalising bias when it comes to fractional counting (Hagen 2015). While the latter has been demonstrated in small-scale studies, the challenge currently seems unsolvable, as it requires statements of actual shares of contributions among units, something which is very rarely visible in publications and indeed difficult to quantify precisely. This bias should be taken into consideration when discussing national performance, because what we end up measuring with co-authorships is not the precise aggregated research effort. At the moment, and in the foreseeable future, this seems to be unquantifiable.

We use co-authorships at the level of countries as a proxy for 'transnationalisation'. We are cautious when interpreting co-authorship trends as 'collaboration'. While co-authorship certainly captures 'collaborative' activities, we agree that it is best seen as a partial indicator of such activity. Hence, we use it here to document the growing transnational character of research. Consequently, the individual reasons for authors being represented in the by-line and their actual contributions to the work are disregarded in the present analysis. We simply interpret the empirical phenomenon that authors from institutions in two or more countries are mentioned in author by-lines as an indication of 'transnationalisation' and collaborative efforts of some sort, and similar to other large-scale studies we are not able to address the differential contributions among participating countries in a publication. We use full counting at the country level in our analyses, meaning that each unique country affiliation in a publication is given one credit. Thus, in line with the reasoning of Waltman and van Eck (2015), our analyses examine the countries' transnational participation and not necessarily their respective contributions to the research efforts.

Our analysis of the development in transnationalisation is based on bibliographic data from the Web of Science database produced by Thomson Reuters. We use data from the Science Citation Index Expanded, the Social Sciences Citation Index and the Arts & Humanities Citation Index. We use the in-house enriched version of the database at CWTS, Leiden University. CWTS enrich the database in several ways: most importantly, they perform their own citation and address matching. In principle, the database covers all research areas, but the social sciences and especially the humanities are poorly covered. Therefore, the findings mainly relate to the

natural, life, medical and technical sciences. Our focus in the present analysis is on Denmark, a small, rich, western European country, with a highly developed welfare state. In order to contextualise the Danish development we include 16 other countries in the analysis. We examine the development in international co-authored journal articles in the period 1980–2014 (the entire duration of the database) by examining for each of the countries the proportion of annual articles where at least one other country affiliation is also present. It should be noted that we do not weigh contributions to individual articles. Thus, it makes no difference in this context whether a country has one or more author affiliations on a given transnational research article: the article is either national or transnational. Furthermore, in order to examine the developments in transnationalisation and relate them to research performance, we also examine the publication output and citation impact for the chosen countries for a specific year.

In relation to analyses of transnational collaboration using co-authorships, this means that the institutional affiliation decides the country of origin for the publication being examined. Hence, articles from researchers of different national origins working in the same institution in a foreign country will be credited to the country of the institution and not to the authors' national origin. Consequently, to augment the analysis of transnational collaboration based on co-authorships, with their inherent limitations, in the second part of our findings we also examine the mobility of researchers for the same countries as those included in the co-authorship analyses (except for China), as this also indicates the degree of transnational collaboration. In fact, the countries included in co-authorship analyses are chosen based on the basis of the study by Franzoni et al. (2012) on mobility in order to be able to compare results. As we especially focus on Denmark, however, we supplement the survey by Franzoni et al. (2012) with register data from Denmark, collected from various official sources, on mobility and the accompanying transnationalisation of Danish research institutions.

Counting co-authorships is only one among several measures of collaboration, and scientific collaboration may lead to a number of outcomes of which co-authored articles are only one (Katz and Martin 1997; Laudel 2002). Despite the limitations of co-authorship measures, many studies have used this technique to investigate research collaboration. Especially at the aggregate levels of analysis, the results seem to be valid, valuable and upheld by theory (de Solla Price 1963; Crane 1972; Luukkonen et al. 1992; Melin and Persson 1996; Wagner and Leydesdorff 2005; Leydesdorff and Wagner 2008).

3. Findings

3.1 Transnational research collaboration

In the first analysis we examine the long-term developments in the degree of transnational research collaboration for 17 countries. As indicated above, we have chosen 16 of these countries in order to be able to compare our findings on mobility with those of Franzoni et al. (2012). These 16 countries are among the core countries with respect to research productivity, performance and collaboration, measured in international bibliographic databases. They satisfy our aims as we have some main typologies of research countries among them. However, we have also included China due to the special circumstances surrounding it, its growing research system and international influence (Leydesdorff et al. 2014).

Three inter-linked findings are shown in Figs 1–3 and discussed on the basis of these figures. Fig. 1 presents the long-term development in the proportion of transnational journal articles for the 17 countries based on the international bibliographic Web of Science database. After establishing and discussing this development, we focus on one recent year, 2010, in order to characterise and categorise the countries in relation to their size and degree of transnational research collaboration, and relate that to their relative performance measured by citation impact. We further elaborate on this in Fig. 3, where we map the countries according to their mutual collaborative efforts in 2010 in order to be able to examine the relation between a country's impact and its collaborative partners. Together, these findings will illuminate the challenges of measuring and claiming national research performance in a highly transnational setting.

Several interesting patterns emerge from Fig. 1. Twelve of the 17 countries, including Denmark, have seen a rather steep—almost linear—growth in the period 1980–2014 in the proportion of articles resulting from transnational research collaboration. For these countries, the origin of the time series in 1980 was roughly in the range 10–20%, whereas in 2014 this interval had risen to the range 50–70%. In the Danish case in 2014, 6 out of 10 research articles with at least one Danish institutional address also had at least one international address affiliated with them; only 4 out of 10 could be considered purely 'national' research articles. The absolute visibility in the database for the individual countries has also changed dramatically from 1980 to 2014. The USA was the largest country in 1980 and is still so in 2014 in terms of the annual number of publications: its annual visibility has more than doubled during the period. The case of a small country like Denmark is more dramatic. Its annual visibility has increased five-fold in the period 1980–2014. But the most dramatic increase comes from the emerging countries, which have experienced more than a 20-fold increase in visibility in the database. However, such increases in visibility cannot only be ascribed to increases in productivity: some of the increase is also the result of the expansion of the database. That said, all of the countries have seen a large increase in their publication activities over this period (cf. Adams 2013).

Fig. 1 also shows that the five countries with the highest share of transnational papers are also the smallest countries when it comes to population numbers and journal articles. Their research systems are relatively smaller than the other countries, but if we consider this situation from an efficiency perspective, Switzerland, Denmark, the Netherlands and Sweden clearly have a higher publication output *per* 100,000 *capita* compared to the mid-sized group of countries (e.g. the UK, France and Germany) and especially to the large-sized countries (e.g. China, India and Brazil). For example, Denmark 'produced' 222 journal articles *per* 100,000 *capita* in 2014 compared to 132 for the UK and 17 for Brazil. While this might say something about the efficiency of the national research systems, it should also be noted that this degree of efficiency correlates well with the degree of transnational collaboration. For the group of smaller countries, the degree of transnationalisation is in the range 60–70%, whereas the group of mid-sized countries are in the range 45–50% and the group of large countries are in the range 20–30%. 'Efficiency' therefore seems to be linked to the degree of transnationalisation and, if so, 'efficiency' should also be interpreted in light of this.

The other main finding that can be seen from Fig. 1 is the clear categorisation between the group of small and mid-sized countries—the 12 countries discussed above and the group of 5 large countries—and the seemingly different developments for these countries. The group is heterogonous, containing two rich Western countries (USA and Japan) and three emerging countries (China, India and Brazil). Clearly, the research systems and their efficiencies in these countries are very different and their heterogeneous

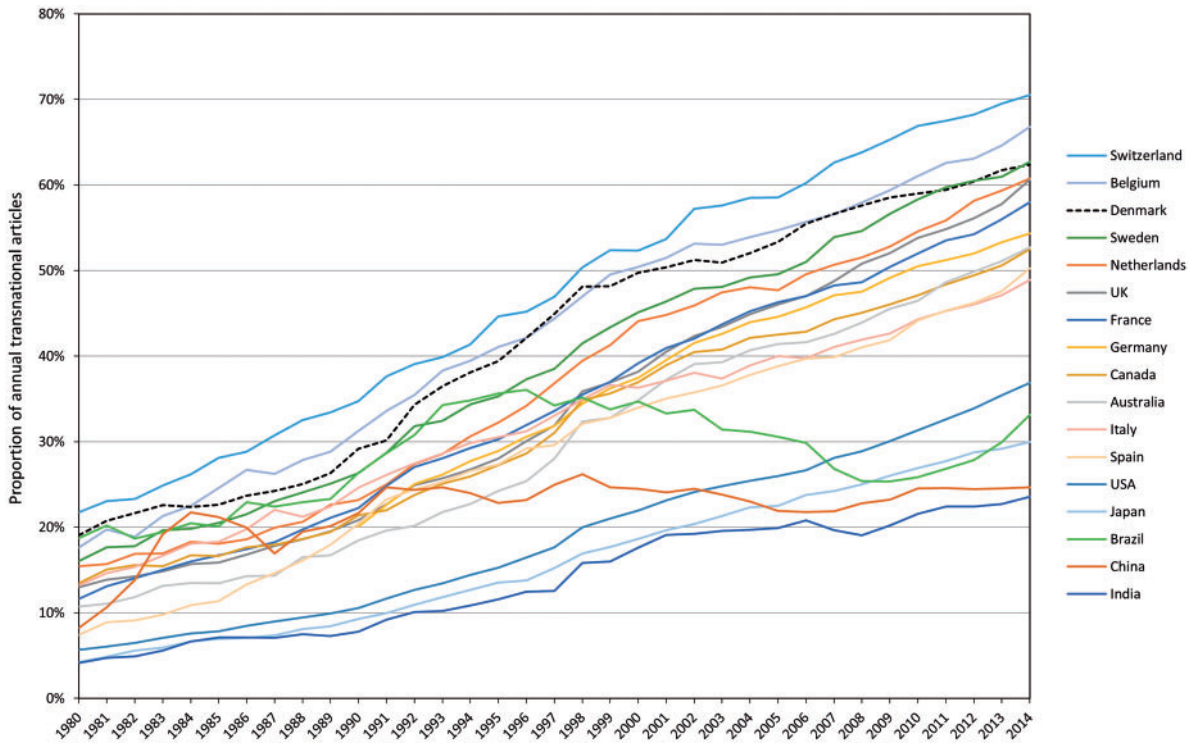

Figure 1. Annual developments in 17 countries' proportion of journal articles with transnational collaboration.

Country legends on right-hand side are ordered according to their rank on graph in 2014. Thus Switzerland is first and India last.
Source: Web of Science, CWTS, Leiden University

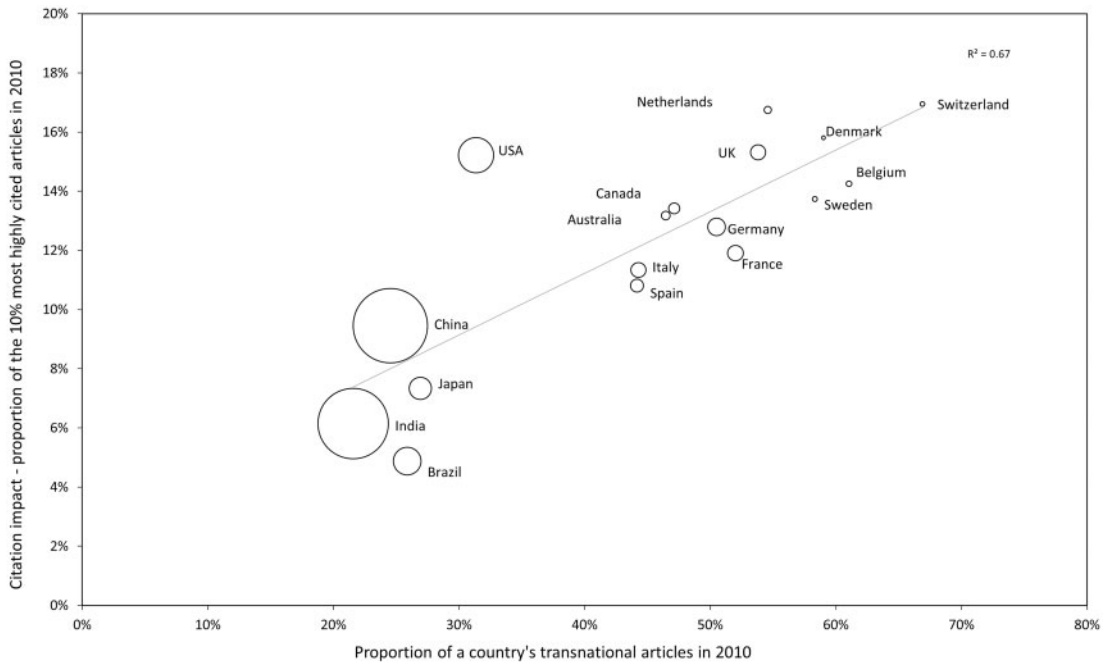

Figure 2. Relation between 'national' citation impact and a country's degree of transnational journal publication activity in 2010

y-axis shows total citation impact for a country's articles in Web of Science published in 2010. Citation impact is measured as proportion of articles among 10% most cited in database for that particular year. It is expected that a unit will have around 10% of its articles among those most cited; more means that impact levels are higher than expected
x-axis indicates proportion of 2010 articles that can be considered transnational. Size of circles indicates size of country depicted using 2010 population statistics from World Fact Book[7]

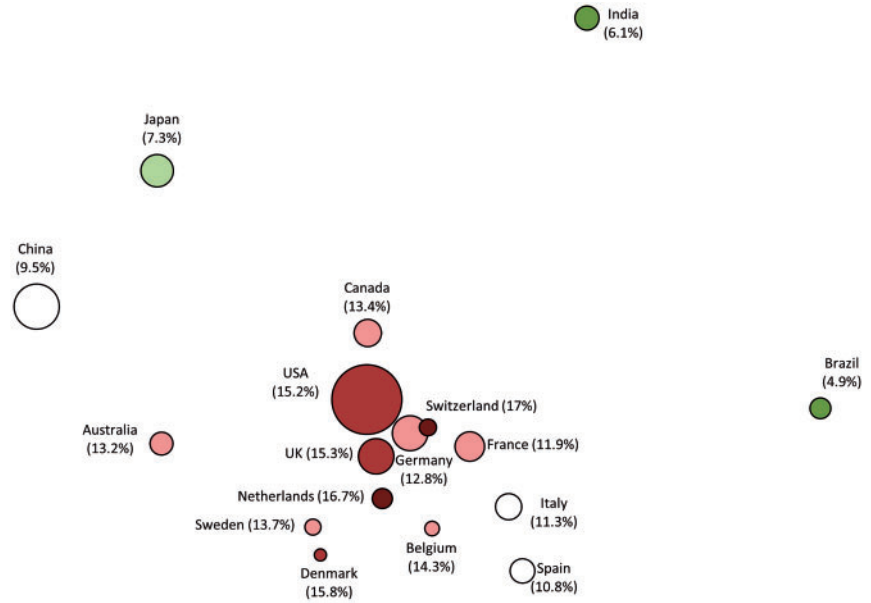

Figure 3. Transnational collaboration patterns between 17 countries in 2010. Countries are placed on map according to their mutual collaboration patterns measured by common co-authorships in articles published in 2010. Countries close to each other have stronger collaborative links between them. Countries placed towards centre of map have broader collaborative patterns, whereas those on fringe have more insulated collaborative patterns

Size of circles indicates 2010 publication output for individual countries relative to one another. Citation impact for each country is shown in brackets and colour code of circles indicates strength of impact: white (average impact); shades of green (light: low impact; dark: very low impact); shades of red (light: good impact; darker: high impact; darkest: very high impact)

developments in the proportion of transnational journal articles testify to this. The USA and Japan also experienced a seemingly linear growth in the degree of transnationalisation, albeit from a clearly lower base, rising from 5–6% in 1980 to 30–37% in 2014. For these two countries, the developments are similar to the groups of small and mid-sized Western countries discussed above, apart from the fact that both countries had clearly lower bases in 1980 (and still have considerably lower degrees of transnationalisation in 2014)[6] and that the American system is by far the largest when measured in terms of the absolute number of publications in the database per year. In 2014, more than 320,000 journal articles had at least one US address in the database, whereas the second largest country, China, had roughly 136,000 articles. The development for India, while initially almost linear, flattens out from 2000 onwards. India had the lowest base of 6% in 1980 and still has the lowest degree of transnationalisation in 2014 at 24%. At face value, the developments for China and Brazil seem to fluctuate much more than those in the other countries. Much of this fluctuation may be an artefact of the developments in the database.

The Web of Science database is not a closed system. For many years the database was stable, indexing around 3,500 of the most 'important' scholarly journals. If new journals were included, others most probably went out. This has changed considerably since the late 1990s. The database currently covers some 14,000 journals, many of the 'new' journals being regional outlets from Latin America and Asia (especially China) (Testa 2011). Regional journals, even if written in English, are characterised by mainly containing articles with authors from the same (regional) country. Consequently, such an influx of regional journals and therefore more national-authored articles in the denominator will influence the calculation of the degree of transnationalisation. While the sudden changes and drops for China and Brazil might well stem from this phenomenon, this has proven not to be the case. We have established a fixed set of approximately 3,200 journals which are indexed consistently from 1980 to 2014 in the Web of Science database. We have isolated these journals and their articles and recalculated the degrees of transnationalisation during that period for the same 17 countries as in Fig. 1. The results are very clear and corroborate the findings in Fig. 1. The trends are basically identical, although the actual shares of transnationalisation in the fixed set of journals seem to be slightly higher compared to Fig. 1. It should be noted that we see the same fluctuations for Brazil and China, suggesting that these are not artefacts caused by the considerable expansion of the database in the last 15–20 years. Interestingly, the patterns for Brazil and China clearly deviate from those of the other countries. The degree of transnationalisation seems to be increasing slightly for Brazil at the end of the period, while the development for China has been very stable (around 25%) for almost 15 years. The developments for the fixed set of journals are presented in the Appendix (see Fig. A.2).

What is not shown in Fig. 1 but is documented by Adams (2013) is that while all countries experienced considerable increases in transnational collaborations compared to the origin in 1980, emerging countries, such as China, Brazil and India, saw a marked absolute increase in both national and transnational research articles. Our data confirm his findings. In contrast, the Western countries actually experienced a stagnation of national research output and a considerable increase in transnational output.

From the findings in Fig. 1 we can conclude that all of the countries have experienced an increase in the degree of transnationalisation. The development has been intense for most countries, raising their annual share of transnational papers from 3 up to 7 times the reference value in 1980 (see Fig. A.2 and Table A.1 in the Appendix). A number of small-sized Western countries seem to be most efficient when it comes to *per capita* research output. The

absolute degree of transnationalisation would appear to be lower for larger countries, but the reasons for this may vary considerably between them. The fact that only slightly more than 1 in 3 articles with a US address also have an international address does not in itself indicate that the US science system generally is less transnational. The US science system is so large that, in many ways, it does not need to turn its attention to collaborative efforts abroad. Some US universities, such as Harvard, have a larger research output per year in the Web of Science than some of the small western European countries. For example, the Danish output for 2010 (i.e. publications with at least one Danish institutional address) was roughly 12,000, whereas Harvard University alone had an output of more than 25,000 publications. In fact, geographically, the US system sees a lot of collaborative activity, albeit across state borders and not so much across national borders. Perhaps most interesting, however, the US science system can indeed be considered transnational. This is less visible in its publication patterns, but much more visible when studying the composition of faculties at US universities. Junior and senior researchers from around the globe are drawn to the USA to work, probably because the US science system is still considered to be the centre of the world science system.

Considering our main question about the meaningfulness of country comparisons in relation to research performance, it is already clear that claims of national output and performance are 'polluted', especially for smaller countries. It is therefore interesting to try and correlate citation impact and the degree of transnational research activity for the 17 countries. In Fig. 2 we do this for the year 2010. Within the field of scientometrics, it is well-known that, on average, transnationally co-authored articles have higher citation rates compared to national articles, co-authored or not (van Raan 1998; Glänzel and Schubert 2001; Persson et al. 2004). The difference in impact is usually substantial. For example, the citation impact for the roughly 5,000 national Danish articles from 2010 is 10.9% (i.e. some 11% of these articles are among the most highly cited in the database), whereas the total impact of the remaining 7,000 transnationally co-authored articles is 16.7%, clearly a much higher rate of highly cited articles. The pattern is similar for other countries, albeit the US case is somewhat different.

With this in mind, we would expect a good correlation between the impact and degree of transnational collaboration, which Fig. 2 also indicates to be the case. Estimating a simple linear function, where impact is a function of the degree of transnational co-authored articles, explains 67% of the variance in the dataset and can be considered a reasonable fit, but there are notable outliers: USA, UK and the Netherlands. Obviously, the status of an article as transnational is merely a proxy for a number of underlying factors or characteristics of such articles that, on average, give them a higher citation rate. For a start, having several authors increases the likelihood of disseminating the knowledge presented in the article. If these authors are then spread out across countries, this tendency is amplified. Transnational research effort is also often characterised by investigating topics of considerable interest or hype. The latter often results in publication in journals in which citation activities are generally higher, which will in turn benefit such research. And then there is the more controversial perspective—that transnational research efforts in general are of better quality (Adams 2013). This claim is questionable, especially when basing quality claims on citation impact alone.

Returning to Fig. 2, the USA is clearly an outlier in as much as the impact is high but the proportion of transnationally co-authored articles is modest compared to the other high-impact countries. Since the end of World War II, the USA has been considered the world leader in science (Hollingsworth and Gear 2013). Scientific hegemony means that a country such as the USA dominates multiple scientific fields and establishes the standards of excellence in most of them. The USA scientific elite, scholars and institutions are considered the most prominent in the world. Consequently, the USA attracts more foreign young people for education than does any other country. Finally, and importantly for the present analysis, English has become the language of the dominant scientific communication systems, and the databases used for scientometric analyses are dominated by Anglo-American journals. These characteristics obviously increase the likelihood for being cited. If we then consider that the USA is the largest country in the Web of Science database, measured by annual publication volumes, then it becomes less surprising that not only do US articles receive a considerable number of citations from foreign articles, considerable citation traffic also goes on between articles with only US addresses. This is an important factor explaining the generally high US citation impact. Fig. 1 showed that the degree of so-called 'national' research output is decreasing as a function of country size: that is, smaller countries have larger shares of transnational research collaborations. Fig. 2 established that there is clearly a good correlation between the degree of transnational collaboration and impact, with the notable exception of the USA, and that country size is clearly an indicator of the degree of transnational collaborative activities. From these two findings, we can already deduce that, especially for smaller countries, the so-called 'national' performance is clearly to a large extent a shared one. There is more to it, however, as illustrated in Fig. 3. Seemingly, everybody wants to collaborate with the USA.

Fig. 3 shows the mutual 'research collaboration' between the 17 countries when examining their transnational co-authorship patterns. We have constructed a symmetric matrix in which the number of co-authored articles in 2010 between any pairs of the 17 countries is represented in the cells. The diagonal contains the total number of articles for each country. Hence, a country's collaboration profile is represented as a row vector and the mutual collaborative patterns of all countries can be examined using multidimensional scaling (MDS). MDS basically correlates the vectors and finds the most optimal, two-dimensional solution for representing all 17 countries in relation to each other. Countries close to each other have stronger collaborative links between them. Countries placed towards the centre of the map have broader collaborative patterns, whereas those on the fringe have more insular collaborative patterns. Further details concerning the interpretation of the map are given in Fig. 3 and some technical details and diagnostics are given in the Appendix.

Clearly, the USA is at the centre of the map. Looking at the individual countries and their share of co-authored articles with the other countries in the matrix, the result comes as no surprise. Of 16 countries, 14 have the largest share of transnational articles with the USA, and for 11 countries this share is in the range 10–23%. The share for countries in second place is usually considerably lower, the exceptions being Switzerland, the Netherlands and Belgium. These countries have equally large collaboration shares with at least one other country. Other countries likely to be involved in transnational research collaborations are the UK and Germany. Indeed, what is noticeable from Fig. 3 is the clique of countries in the centre of the map: they have significant mutual transnational collaboration activities. It should also be noted that most of these countries have good, high or very high impact, as depicted by the red colour code of the circles. In a sense everything revolves around the USA, the so-called 'outlier' in Fig. 2.

Fig. 2 illustrated how Italy and Spain had slightly lower proportions of transnational collaboration as well as slightly lower impact levels compared to the other Western countries (except Japan). In Fig. 3 we see that these countries are on the periphery of the 'inner circle' or clique of Western countries with high proportions of transnational collaboration activities and high impact. Indeed, the collaborative activities of the 'inner circle' countries with the USA are between 14 and 23%. The four countries with modest or low transnational collaborative activities in Fig. 2 are naturally placed on the fringe of the map in Fig. 3. While they all have their highest share of transnational collaboration with the USA, the relative numbers are markedly lower, China's 10% being the highest. These are relatively large countries, both in population and publication numbers, but their transnational collaborative activities when it comes to journal publications are low, as is their impact.

It is natural to conclude that a country's degree of transnational co-author activity is more or less proportional to its citation impact. However, we should qualify this, since who you collaborate with seems to matter a great deal. Everybody collaborates with the USA but some more than others, and the performance of these countries is clearly the highest. Furthermore, a strong clique, consisting primarily of Western countries, not only collaborate extensively with the USA, they also collaborate with each other. Interestingly, these countries all display high performance levels. Obviously, the US research system, as measured in these analyses, is the largest and geographically the USA is comparable to Europe. Geographic distance is important when it comes to potential research collaboration. This becomes apparent in Fig. 3, where the European countries are closely linked. Interestingly, a recent report suggests that if the USA is broken down to its federal states, collaboration patterns between US states are broadly similar to trans-country collaboration in Europe (Kamalski and Plume 2013). Likewise, the citation performance of the trans-country/state collaborations is higher than national publications but lower than 'outside region' collaborations, such as the transnational collaboration between the USA and European countries.

It is clear from Figs 1–3 that the comparison of national research performance between countries is indeed challenging. For smaller countries, up to 70% of the so-called 'national' articles can also be described as 'national' for at least one other country. This becomes further complicated when we consider that citation impact, the main performance parameter, is largely influenced not only by the degree of transnationalisation but also by whom you collaborate with. Looking at the 17 countries examined here, the close clique of western European countries revolving around the USA are also the top-ranked countries with respect to impact. When comparing them, however, we should remember that a considerable number of the articles promoting these countries to the highest ranks are mutual collaborative works claimed by each country as national research output. Multiple counting is rife, yet technical fixes such as fractional counting do not necessarily solve the essential problem. They only displace the problem, since fractional counting 'punishes' transnational research collaboration and an equalising bias becomes apparent (Aksnes et al. 2012).

3.2 Transnational research institutions

If we now turn to the research institutions, some of the same trends become apparent. As we have seen, not only do research institutions and researchers collaborate with colleagues from abroad to a great (and greater and greater) extent—the research institutions themselves are also to a very large extent transnational units. In their comprehensive study of the mobility patterns of researchers in 16 countries, Franzoni et al. (2012) found that around half of the research staff within the fields studied (biology, chemistry, materials and earth and environmental sciences) in Switzerland (56.7%), Canada (46.9%) and Australia (44.5%) came from abroad (i.e. lived in another country at age 18). Also in the USA (38.4%), Sweden (37.6%) and the UK (32.9%), a huge share of the researchers had a foreign background. According to this study, 21.8% of the researchers in Denmark in the four fields under study in 2011 came from other countries. Apparently, however, there are still countries that do not have transnational research units. For example, there are very few foreigners working in academia in India (0.8% in the four fields studied), Italy (3.0%) and Japan (5%). However, many researchers from India (39.8%) and Italy (16.2%) work abroad.

This in- and outflow of researchers is not a new phenomenon. According to Dedijer (1964), it is as old as science itself. Researchers have always been pulled towards better research conditions and pushed away by bad conditions. Historically, this has benefitted the USA, which has long been able to attract many of the best scholars from around the world. In the years 1952–1961 alone, more than 9,000 scientists together with 30,000 engineers and 14,000 physicians and surgeons came from other countries to settle in the USA (Dedijer 1964: 965). The current (cf. Franzoni et al. 2012) flow of researchers from countries such as India and Italy towards the USA thus fits with historical trends. However, Dedijer (1964) has noted that the USA was not alone in benefiting from this traffic. According to him, the migration of scientists can be described as follows:

> The migration of scientists has certain preferred directions: from the less-developed to the more-developed countries, from countries developing slowly to countries developing rapidly, from small countries with developed science to large countries with developed science, and, most important, from countries with less-developed science and education policies to those with more-developed ones. (Dedijer 1964: 966)

Without going into further detail regarding the development, we can say that Denmark has clearly been one of the countries benefitting from the global migration of researchers. This development goes way back. One of the best examples of a transnational research environment in Denmark can thus be found as early as the 1920s and 1930s, when scientists from around the world came to Copenhagen to work at Niels Bohr's famous institute (Aaserud and Nielsen 2006; Nielsen and Nielsen 2008: 424–33).

Today we also see a huge flow of PhD students and scientists from other countries to Denmark. Of the new PhD students who started a PhD programme in Denmark in 2010, 34% came from abroad (Statistics Denmark 2011). Here we can even speak of a genuine transnationalisation: the new PhD students came from no fewer than 82 different countries! If we look at the faculty members, we can see that 21% of all new positions (academic staff at all levels) at Danish universities in the period 2011–2013 went to researchers from outside Denmark (Ståhle 2014: 23). Especially at the postdoctoral/assistant professor level, very significant numbers of people from abroad have been recruited to Danish universities. In 2011–2013, 29% of this group lived outside Denmark before obtaining a postdoctoral/assistant professor position at a Danish university. Among the researchers recruited from abroad to Danish universities are both foreigners and Danes (87% foreigners and 13% Danes) (Ståhle 2014: 24).

If we look at the main areas within the universities, the science departments clearly have the highest level of transnationalisation.

Table 1. Number and share of recruitments of foreign citizenship researchers (professors, associate professors, and assistant professors/post docs) at Danish universities in period 2011–2013

	Professor level		Associate professor level		Assistant professor/post-doctoral level		Total	
	Number	Share	Number	Share	Number	Share	Number	Share
All Danish universities	186	22%	457	34%	1,220	46%	1,863	38%

Source: Ståhle (2014: 26)

Within the science departments, 34% of all the new academic jobs in the period 2011–2013 went to researchers from abroad (Ståhle 2014: 26). If we only look at the postdoctoral/assistant professor levels, the figure is 43%. This is much more than the other main areas. In the social sciences, the corresponding figures are 18% and 23%, within the arts they are 15% and 20%, and within health sciences 14% and 19%. However, more than half of the new post-doctoral positions at Danish universities in that period (2011–13) went to the science departments. These departments therefore contributed strongly to the increasing transnationalisation of Danish universities.

Finally, if we look at the aggregated figures (foreigners recruited from abroad plus recruited foreigners already working at a Danish university), 1,863 research positions, corresponding to 38% of the recruitment of all new research staff at Danish universities in the period 2011–2013, went to non-Danish citizens (cf. Table 1).

This increasing recruitment of foreign researchers to Danish universities has also led to an increase in the total share of foreign researchers at Danish universities. If we look at the three Danish universities that contribute the most to the overall Danish research production (more than 80% of the annual total output registered in Web of Science), then the overall share of foreign researchers employed at the University of Copenhagen has increased from 18% of the total academic staff in 2009 to 22% in 2013, at Aarhus University the share has grown from 18% to 20% within the same period, and 35% of all of the researchers employed at the Danish Technical University in 2013 were foreign citizens (Svansø 2013). This means that the leading Danish research institutions have largely become transnational units.

There is no reason to think, however, that Denmark is an extreme case in this regard. We know that scientists now regularly move across national borders to visit or work in other countries for shorter or longer periods of time. A survey study on the mobility of researchers in the 27 EU countries found that 61% of the 9,588 respondents had worked in or visited (at least once in their career and at least for three months) a research institution outside of the country in which they attained their highest educational degree (Børing et al. 2015). More than half of them had even done so within the last three years. This study also showed that mobility rates are highest within the natural sciences (69%) and humanities (62%), and lowest in the social sciences (52%) and engineering and technology (51%) (Børing et al. 2015: 818, Table 7). According to Fernandez-Zubieta et al. (2015), the USA remains the preferred destination for researchers from around the world, but countries such as the UK also attract many researchers from abroad. Of the researchers working in the UK, 28% were non-UK citizens in 2012/2013 (Fernandez-Zubieta et al. 2015: 5). Furthermore, the mobility study by Franzoni et al. (2012) seems to suggest that the share of foreign researchers working in Denmark is actually lower than in other high-performing research countries. Thus, Danish research institutions had fewer researchers with a foreign background working within the four examined fields of their study than eight other countries (Switzerland, Canada, Australia, USA, Sweden, UK, the Netherlands and Germany).

4. Discussion

How Danish is Danish research? And what can even be considered to be 'Danish' research? Our findings demonstrate that these questions are difficult to answer precisely. If it is difficult in the first place to determine what is in fact 'national research', then it is obviously also difficult to measure and compare such an entity with other countries in a meaningful manner. Using co-authorships, the measure most often used for examining international collaboration, we have shown that for a small country such as Denmark, what is claimed as 'Danish research' can today, in 6 out of 10 cases, also be claimed as research belonging to at least one other country. Our results also show that close to 40% of new recruitments to Danish universities are researchers with foreign citizenship. Mobility data (Franzoni et al. 2012) further show that a large minority of the active researchers in high-performing Western countries have a foreign background. This means that some of the so-called Danish articles, whether transnational or national, are probably authored by non-Danish researchers. Since they are affiliated to a Danish research institution, however, their research is considered 'Danish'. This further complicates matters, but also testifies to the claim that contemporary research has become a highly transnational activity.

This has important implications for governance and research performance assessments. Obviously, it is understandable and legitimate that policy-makers want to know how the public money spent on research is expended and how the funded science is performing. This exercise is difficult and to some extent meaningless, given that contemporary research is a transnational phenomenon. What does it mean, for example, that 'Danish' research performs somewhat better than 'German' research? If we only look at production and impact comparisons, this would be the conclusion. However, what is compared in this case is not Danish versus German research, but rather transnational research partly taking place in Denmark and Germany, meaning research created by researchers stemming from many different countries but including a research institution placed in the given country. It is important to appreciate this, because the citation rates of transnational research papers are considerably higher than the national ones.

We have also demonstrated that the degree of transnationality is somewhat different among the countries we examined. When examining co-authorships, the degree is lowest for the emerging countries and highest in the smaller, western European countries. In the latter, together with the USA, transnational collaboration basically represents all of the growth in publication output, whereas both national and transnational output has increased intensely in the emerging countries, most likely indicating that these countries have experienced a general increase in their scientific capacity. Whereas Western countries experience growth in both transnational

collaboration and transnational mobility, mobility in emerging countries largely appears to be a one-way affair, with researchers moving abroad.

Adams (2013) argues that science has historically progressed through three ages (the individual, the institutional and the national) and that it has now entered a fourth age driven by international collaboration between elite research groups. According to Adams (2013), nations in 'the national age' competed to be at the cutting edge because it contributed to the broader economy through knowledge, new processes and products. In his view, however, the new age of international collaboration will challenge the ability of nations to conserve their scientific wealth in the form of intellectual property and research talent. Although we do not see transnational cooperation as something new—but rather as something that is growing and intensifying, for example due to developments in exogenous factors such as communication technologies and transportation factors—we agree with Adams that, hitherto, nations, especially Western nations, have mainly considered research as a national enterprise to be governed nationally and invested in and scientific output as some sort of wealth that can be measured and compared. We also agree with Adams that such parochial national economic interests, while legitimate to some extent, seem misdirected and far from the reality of science that we have tried to show must be understood as a transnational activity and global network (Wagner 2008). In our view, however, there are no signs of this competition and way of thinking coming to an end any time soon. Quite to the contrary, nations seem to continue to think of themselves and act as competing entities in the global, knowledge-based economy.

With its inherently transnational nature, we see science as a complex, self-organising adaptive system or systems which can only indirectly be governed by states and institutions. The latter provide the context, yet scientific endeavours go beyond serving such patrons. Transnational collaboration and mobility has increased for reasons that are generally independent of the needs and policies of the state. As political and economic shifts have occurred over the past three decades, we have seen the growth of transnational collaboration as a decoupling from the goals of national science policies. Establishing research ownership therefore becomes muddled and almost synthetic.

Thus, we ask where this leaves us in terms of the discussion of methodological nationalism that we briefly touched upon in Section 1. Are country comparisons of research performance the result of that which Beck and others have termed 'methodological nationalism'? According to Beck and Sznaider (2006: 2), we can talk about methodological nationalisms when social scientists:

> . . . in doing research or theorizing take it for granted that society is equated with national society.

This is also frequently what happens in comparisons of research performance. In such comparisons, we often start with a nation-state and ask how it is doing compared to other nation-states, as though research performance can be attributed to individual nation-states. We also often assume that the performance of a given country can be understood as a result of certain policies in that country. In other words, the nation-state itself (e.g. its policies, institutions and funding bodies) is the source of a country's research performance.

As already mentioned in Section 1, the pressure to know how a given nation-state is doing in terms of research performance becomes stronger the more we adopt the idea of the competition state and the deeper we move into global competition in the knowledge-based economy. The interest in research performance has grown because it is understood as an indicator of how well a country is doing in the new, knowledge-based economy. However, the findings in this paper show that we must be careful about how we interpret the results of such comparisons of research performance. Using Denmark as an example, we can say that Danish research is doing extremely well, that Denmark is a top-performing country when it comes to research production and impact. On the other side, however, the evidence presented above also shows that these results are largely created in collaboration with non-Danish researchers working outside as well as inside Denmark. And this is not just the case for Denmark, this is a global phenomenon.

Thus, the concept of 'Danish research'—which also applies to Swedish research, German research, US research and so on—changes meaning. 'Danish research' has come to refer to research involving Danes but, to a great extent, also non-Danish researchers (working outside and inside Danish research institutions). Instead of speaking of either Danish research or research from other countries, we must therefore start thinking about Danish research as something involving both Danish and non-Danish researchers. 'Danish research' is also something that takes place both in Denmark and outside Denmark—and it can furthermore be funded by both Danish and non-Danish funding bodies.

If we want to avoid making 'zombie science' or 'science of unreality' (Beck 2006: 21) in this field of science, we must therefore start by recognising that research is a transnational activity and that research performance probably has more to do with transnational collaboration than national efforts. Although nation-states can still play an active role in creating attractive conditions for researchers in a given country (by supplying sufficient funding, creating attractive research institutions etc.) research performance has become deeply dependent on transnational cooperation in the form of the cross-national mobility of ideas, methods and researchers as well as collaboration between researchers across borders on research projects and papers. Knowledge and research production is now taking place in what Wagner (2008) calls the 'new invisible college'—a global network of individual researchers and research groups. In order to better understand how this network functions, future research ought to focus more on the strategies and behaviour of individual researchers and research groups (the nodes and hubs in the network) as well as the collaboration and migration patterns of researchers (the links and paths of the network) instead of the performance of the nation-states. In other words, future research in this field could benefit from an increased focus on the micro-level of research production.

This is also very much in line with Beck's thoughts on methodological nationalism. According to him, social science can only avoid making 'zombie science' if it recognises that we live in an increasingly interconnected world (Beck 2000, 2005: 10–50, 2006: 24–44). Here, Beck is talking about 'banal cosmopolitanism' or 'real cosmopolitanisation', meaning that, behind our backs, unnoticed, as a side-effect of other activities, we have created a world in which, everywhere, we are deeply dependent on developments in other parts of the world. Thus, we can also observe a somewhat paradoxical movement in the field of science. The more effort and resources we use to make a single nation-state a world-leading research nation, the less national the output (research results and papers) of such initiatives will be. In 'the new invisible college' (Wagner 2008) under the new 'cosmopolitan condition' (Beck and Sznaider 2006) national research strategies and initiatives to heighten the quality and impact of a nation's research output will simultaneously accelerate a transnationalisation of the same nation's research activities.

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Notes

1. See <https://ec.europa.eu/research/innovation-union/pdf/state-of-the-union/2012/innovation_union_progress_at_country_level_2013.pdf> accessed 12 Aug 2016.
2. See <http://www.nsf.gov/statistics/seind14/> accessed 12 Aug 2016.
3. See <http://www.wti2.nl/introductie/publicaties-2> accessed 12 Aug 2016.
4. See <http://www.nifu.no/en/statistics/> accessed 12 Aug 2016.
5. See <http://ufm.dk/publikationer/2014/filer-2014/forskningsbarometer-2013.pdfhttp://ufm.dk/publikationer/2014/filer-2014/forskningsbarometer-2013.pdf> accessed 12 Aug 2016.
6. As a consequence of the lower base rate, the largest countries (except Brazil and China) seem to have a generally higher growth rate if we use 1980 as reference year (see Appendix, Fig. A.1 and Table A.1).
7. See <https://www.cia.gov/library/publications/the-world-factbook/> accessed 12 Aug 2016.

References

Aagaard, K. and Schneider, J. W. (2015) 'Research funding and national academic performance: Examination of a Danish success story'. *Science and Public Policy*, 43: 518–31.

Aaserud, F. and Nielsen, H. (2006) 'Niels Bohrs verdenscenter for teoretisk fysik' [transl.: Niels Bohr's global centre for theoretical physics] in *Viden uden grænser. 1920–1970. Dansk naturvidenskabs historie* [transl.: Knowledge without borders. 1920–1970. The History of Danish Natural Science], H. Nielsen and K. Hvidtfeldt Nielsen (eds), pp. 41–66. Aarhus, Denmark: Aarhus University Press.

Adams, J. (1998) 'Benchmarking international research'. *Nature*, 396(6712): 615–18.

——— (2013) 'Collaborations: The fourth age of research'. *Nature*, 497(7451): 557–60.

Aksnes, D. W., Schneider, J. W. and Gunnarsson, M. (2012) 'Ranking national research systems by citation indicators. A comparative analysis using whole and fractionalised counting methods'. *Journal of Informetrics*, 6: 36–43.

Beck, U. (2000) 'The cosmopolitan perspective: Sociology of the second age of modernity'. *British Journal of Sociology*, 51: 79–105.

——— (2005) *Power in the Global Age*. Cambridge, UK: Polity Press.

——— (2006) *The Cosmopolitan Vision*. Cambridge, UK: Polity Press.

——— (2007) 'Beyond class and nation: Reframing social inequalities in a globalizing world'. *British Journal of Sociology*, 58: 679–705.

——— (2009) *World at Risk*. Cambridge, UK: Polity Press.

——— and Grande, E. (2010) 'Varieties of second modernity: The cosmopolitan turn in social and political theory and research'. *British Journal of Sociology*, 61: 409–43.

——— and Sznaider, N. (2006) 'Unpacking cosmopolitanism for the social sciences: A research agenda'. *British Journal of Sociology*, 57: 1–23.

Bornmann, L., De Moya Anegón, F. and Leydesdorff, L. (2012) 'The new Excellence Indicator in the World Report of the SCImago Institutions Rankings 2011'. *Journal of Informetrics*, 6: 333–5.

Bozeman, B., Fay, D. and Slade, C. (2013) 'Research collaboration in universities and academic entrepreneurship: the-state-of-the-art'. *Journal of Technology Transfer*, 38: 1–67.

Børing, P., Flanagan, K., Gagliardi, D., Kaloudis, A. and Karakasidou, A. (2015) 'International mobility: Findings from a survey of researchers in the EU'. *Science and Public Policy*, 42: 811–26.

Cerny, P. G. (1997) 'Paradoxes of the competition state: The dynamics of political globalization'. *Government and Opposition*, 32: 251–74.

Chernilo, D. (2011) 'The critique of methodological nationalism: Theory and history'. *Thesis Eleven*, 106: 98–117.

Crane, D. (1972) *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Chicago, IL University of Chicago Press.

Dedijer, S. (1964) 'Migration of scientists: A world-wide phenomenon and problem'. *Nature*, (7 March 1964) 201: 964–7.

de Solla Price, D. J. (1963) *Little Science, Big Science*. New York: Columbia University Press.

European Commission (2013a) *Innovation Union Competitiveness Report: 2013*. Brussels: European Commission.

——— (2013b) *Research and Innovation Performance in EU Member States and Associated Countries: Innovation Union Progress at Country Level*. Brussels: European Commission.

European Council (2000) *Presidency Conclusions: Lisbon European Council 23 and 24 March 2000*. Lisbon: European Council.

Fernandez-Zubieta, A., Geuna, A. and Lawson, C. (2015) 'What do we know of the mobility of research scientists and of its impact on scientific production', Working paper 08/2015. Turin, Italy: Department of Economics and Statistics 'Cognetti de Martiis', University of Turin <http://dx.doi.org/10.2139/ssrn.2611203> accessed 12 Aug 2016.

Franzoni, C., Scellato, G. and Stephan, P. (2012) 'Foreign-born scientists: Mobility patterns for 16 countries'. *Nature*, 30: 1250–3.

Gauffriau, M. and Larsen, P. O. (2005) 'Counting methods are decisive for rankings based on publication and citation studies'. *Scientometrics*, 64: 85–93.

Georghiou, L. (1998) 'Global cooperation in research'. *Research Policy*, 27: 611–26.

Glänzel, W. and Schubert, A. (2001) 'Double effort = double impact? A critical view at international co-authorship in chemistry'. *Scientometrics*, 50: 199–214.

Gläser, J. and Laudel, G. (2007) 'The social construction of bibliometric evaluations' in *The Changing Governance of the Sciences*, R. Whitley and J. Gläser (eds), pp. 101–23. Dordrecht, the Netherlands: Springer.

Hagen, N. T. (2015) 'Contributory inequality alters assessment of academic output gap between comparable countries'. *Journal of Informetrics*, 9: 629–41.

Hollingsworth, R. J. and Gear, R. J. (2013) 'The rise and decline of the hegemonic systems of scientific creativity' in *Exceptional Creativity in Science and Technology: Individuals, Institutions, and Innovation*, A. Robinson (ed.), pp. 25–52. West Conshohocken, PA: Templeton Press.

Hood, C. (1991) 'A public management for all seasons?'. *Public Administration*, 69: 3–19.

Kamalski, J. and Plume, A. (2013) *Comparative Benchmarking of European and US Research Collaboration and Researcher Mobility*.SciVal, Elsevier <www.scienceeurope.org/uploads/PublicDocumentsAndSpeeches/SE_and_Elsevier_Report_Final.pdf> accessed 12 Aug 2016.

Katz, J. S. and Martin, B. R. (1997) 'What is research collaboration?'. *Research Policy*, 26: 1–18.

King, D. A. (2004) 'The scientific impact of nations'. *Nature*, 430(6997): 311–16.

Kosmützky, A. (2015) 'In defence of international comparative studies. On the analytical and explanatory power of the nation state in internation comparative higher education research'. *European Journal of Higher Education*, 5: 354–370.

Kruskal, J. B. (1964) 'Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis'. *Psychometrika*, 29: 1–27.

Laudel, G. (2002) 'What do we measure by co-authorships?'. *Research Evaluation*, 11: 3–15.

Leydesdorff, L. and Wagner, C. S. (2008) 'International collaboration in science and the formation of a core group'. *Journal of Informetrics*, 2: 317–25.

——, —— and Bornmann, L. (2014) 'The European Union, China, and the United States in the top 1% and top 10% layers of most-frequently cited publications: Competition and collaborations'. *Journal of Informetrics*, 8: 606–17.

Luukkonen, T., Persson, O. and Sivertsen, G. (1992) 'Understanding patterns of international collaboration'. *Science, Technology, and Human Values*, 17: 101–26.

May, R. M. (1997) 'The scientific wealth of nations'. *Science*, 275(5301): 793–96.

Melin, G. and Persson, O. (1996) 'Studying research collaboration using co-authorships'. *Scientometrics*, 36: 363–77.

Narin, F. (1976) *Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity*. Washington, DC: National Science Foundation.

Neave, G. (1988) 'On the cultivation of quality, efficiency and enterprise: An overview of recent trends in higher education in Western Europe, 1986–1988'. *European Journal of Education*, 23(1/2): 7–23.

Nielsen, H. and Nielsen, K. H. (2008) 'Peaks in Danish university research' in *Science in Denmark: A Thousand-Year History*, H. Kragh, P. Kjærgaard, H. Nielsen and K. H. Nielsen. (eds), pp. 423–57. Aarhus, Denmark: Aarhus University Press.

Nye, M. J. (1984) 'Scientific decline: Is quantitative evaluation enough?'. *Isis*, 75: 697–708.

OECD (1996) *The Knowledge-based Economy*, General distribution, OCDE/GD(96)102. Paris:OECD.

Öquist, G. and Benner, M. (2012) *Fostering Breakthrough Research: A Comparative Study*. Halmstad, Sweden: Royal Swedish Academy of Sciences.

Persson, O., Glänzel, W. and Danell, R. (2004) 'Inflationary bibliometric values: The role of scientific collaboration and the need for relative indicators in evaluative studies'. *Scientometrics*, 60: 421–32.

PISA (2015) <http://www.oecd.org/pisa/> accessed 12 Aug 2016.

Power, M. (1997) *The Audit Society*. Oxford, UK: OUP.

Schneider, J. W. and Borlund, P. (2007) 'Matrix comparison, Part 1: Motivation and important issues for measuring the resemblance between proximity measures or ordination results'. *Journal of the American Society for Information Science and Technology*, 58: 1586–95.

—— and Aagaard, K. (2015) 'Developments in Danish research performance. Scientometric mapping of developments in Danish research performance in the period 1980–2013 at macro- and meso-levels' http://ufm.dk/publikationer/2015/filer/dfir_scientometric_analysis_final.pdf accessed 12 Aug 2016.

Shahjahan, R. A. and Kezar, A. J. (2013) 'Beyond the "national container": Addressing methodological nationalism in higher education research'. *Educational Researcher*, 42: 20–29.

Sørensen, M. P. and Christiansen, A. (2013) *Ulrich Beck: An Introduction to the Theory of Second Modernity and the Risk Society*. London: Routledge.

——, Bloch, C. and Young, M. (2015) 'Excellence in the knowledge-based economy: From scientific to research excellence'. *European Journal of Higher Education*, Published online 16 March 2015: DOI:10.1080/21568235.2015.1015106

Statistic Denmark (2011) 'Hver tredje nye ph.d.-studerende er udlænding' [transl.: Every third new PhD student is a foreigner], Nyt fra Danmark Statistik, No. 276, 16 June 2011. Copenhagen: Danmarks Statistik.

Ståhle, B. (2014) *Forskerrekruttering på universiteterne 2011–2013*. Statistiknotat. [transl.: Recruitment of researchers at universities 2011–2013. A statistics memo] Copenhagen: Uddannelses- og forskningsministeriet (Ministry of Education and Science).

Strasser, B. J. (2008) 'The coproduction of neutral science and neutral state in Cold War Europe: Switzerland and international scientific cooperation, 1951–69'. *Osiris*, 24: 165–87.

Svansø, V. L. (2013) 'Udenlandske forskere strømmer til Danmark' [transl. Foreign researchers are flowing to Denmark], in *Berlingske Business*, 10 July 2013 <http://www.business.dk/arbejdsmarked/udenlandske-forskere-stroemmer-til-danmark> accessed 12 Aug 2016.

Testa, J. (2011) *The Globalization of Web of Science: 2005–2010*. Thompson Reuters.

Tijssen, R. J. W., Visser, M. S. and van Leeuwen, T. N. (2002) 'Benchmarking international scientific excellence: Are highly cited research papers an appropriate frame of reference?'. *Scientometrics*, 54: 381–97.

Van Raan, A. (1998) 'The influence of international collaboration on the impact of research results'. *Scientometrics*, 42: 423–28.

Wagner, C. S. (2008) *The New Invisible College: Science for Development*. Washington, DC: Brookings Institution Press.

—— and Leydesdorff, L. (2005) 'Mapping the network of global science: Comparing international co-authorships from 1990 to 2000'. *International Journal of Technology and Globalisation*, 1: 185–208.

Waltman, L. and van Eck, N.J. (2015) 'Field-normalized citation impact indicators and the choice of an appropriate counting method', *Journal of Informetrics*, 9: 872–94.

——, Calero-Medina, C., Kosten, J., Noyons, E. C. M. et al. (2012) 'The Leiden ranking 2011/2012: Data collection, indicators, and interpretation'. *Journal of the American Society for Information Science and Technology*, 63: 2419–32.

Wimmer, A. and Glick Schiller, N. (2002) 'Methodological nationalism and beyond: Nation-state building, migration and the social sciences'. *Global Networks*, 2: 301–34.

Woolgar, S. W. (1976) 'The identification and definition of scientific collectivities' in *Perspectives on the Emergence of Scientific Disciplines*, G. Lemaine, R. MacLeod, M. Mulkay and P. Weingart (eds), pp. 235–45. The Hague: Mouton & Co.

Appendix

A.1. Description of MDS techniques used to construct Fig. 3

Fig. 3 is based on MDS. MDS refers to a set of related ordination techniques used to visualise the level of proximity between individual cases in a dataset. In the present case, we constructed a symmetric matrix of full publication counts for 17 countries. Each cell contains the number of co-authored papers between any two countries in the year 2010, whereas the diagonal contains the total output of papers for a given country in that year. The matrix of full counts was subsequently transformed to a symmetric proximity matrix using the cosine similarity measure and further converted into a dissimilarity matrix, which is the input for the MDS algorithm (Schneider and Borlund 2007). We use non-metric MDS, meaning that only the order of the dissimilarities between the countries counts. We use the SMACOF MDS algorithm with a maximum number of 100 iterations to find an optimal configuration with the lowest stress value for two dimensions. A small stress value indicates a good fitting solution, whereas a high value indicates a bad fit. It should be noted that the higher the number of dimensions, the weaker the stress. We use Kruskall's Stress 1 to measure the goodness of fit resulting in 0.147 which according to Kruskall (1964) can be considered a fair fit.

A.2. Supplementary figures and tables to support findings in Fig. 1

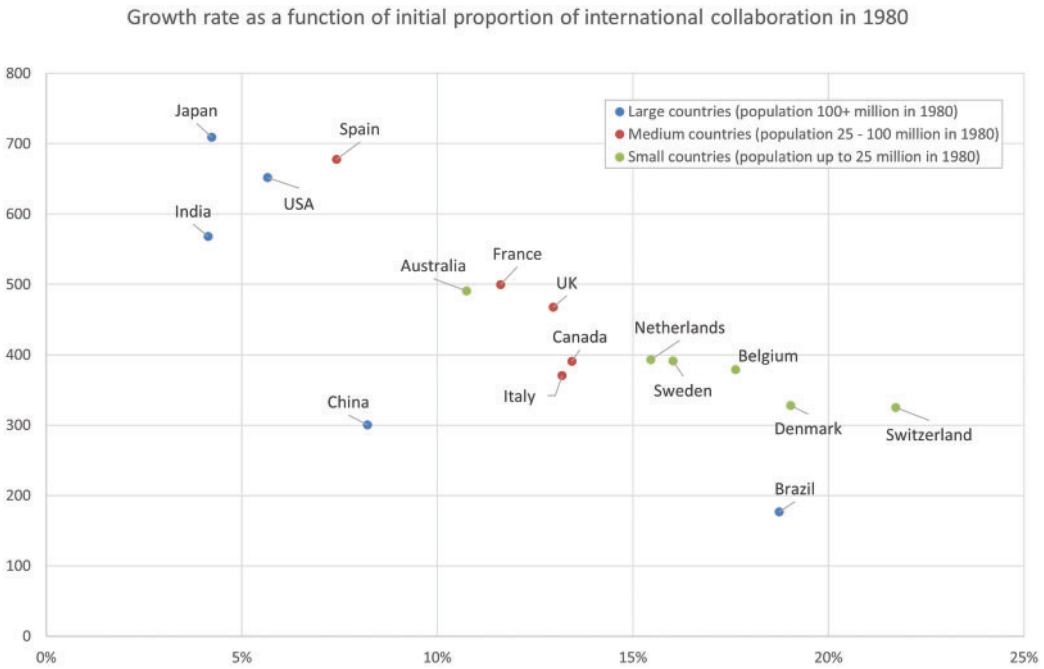

Figure A.1. Total growth rate from reference year to 2014 as a function of degree of transnationalisation in 1980 (i.e. reference value)

Country circles are colour coded according to three size groups: small, medium and large countries

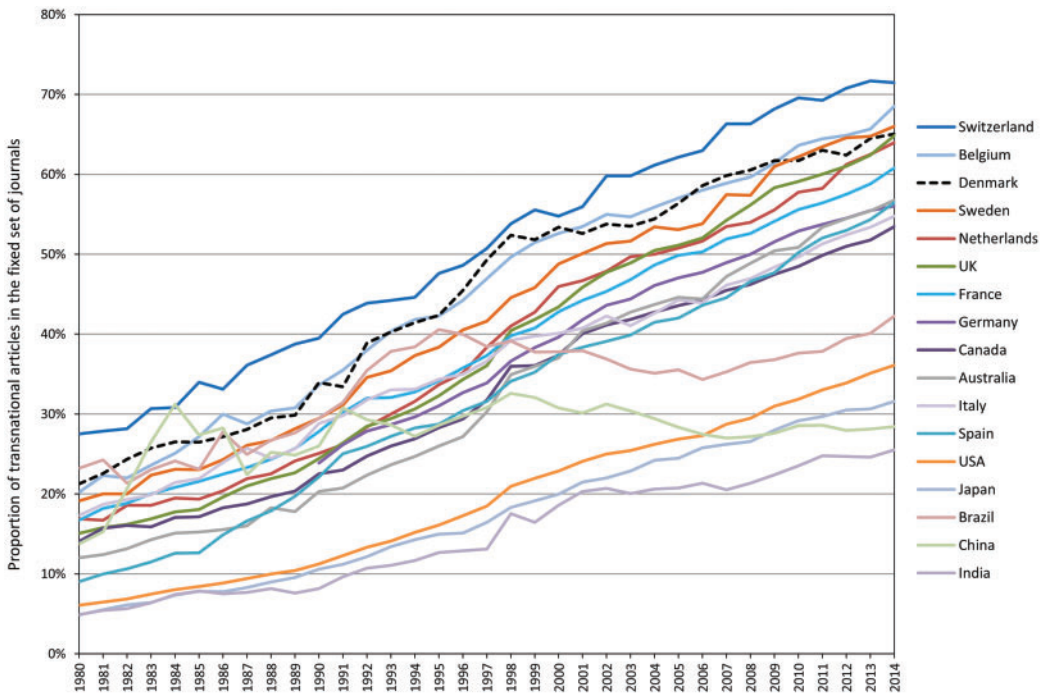

Figure A.2. Annual developments in 17 countries' proportion of journal articles with transnational collaboration calculated on a fixed set of approximately 3,200 journals indexed consistently in Web of Science database in period 1980–2014

Source: Web of Science, CWTS, Leiden University

Table A.1. Growth rates for all countries

Publication year	1980	1985	1990	1995	2000	2005	2010	2014
WoS database	100	135	188	280	363	432	495	564
China	100	258	263	278	298	266	299	300
India	100	172	188	280	425	480	521	568
USA	100	139	187	270	388	459	554	652
Brazil	100	107	141	190	185	163	138	177
Japan	100	164	219	321	441	532	637	709
Germany			100	144	187	222	252	271
Italy	100	139	187	231	275	303	336	371
UK	100	122	161	216	294	355	415	468
France	100	144	192	261	337	399	448	499
Spain	100	153	275	369	458	523	595	678
Canada	100	124	159	203	275	316	351	391
Australia	100	125	172	226	324	385	432	491
Netherlands	100	117	150	209	285	309	353	393
Belgium	100	139	177	233	286	310	346	379
Sweden	100	128	164	220	281	309	364	391
Switzerland	100	129	160	206	241	269	308	325
Denmark	100	119	153	207	261	280	310	328

Index year is 1980 except for Germany where it is 1990
Cumulative rate shown every fifth year