Measuring research performance of individual countries : the risk of methodological nationalism

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Abstract

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. The analytical point of departure in the paper is the ongoing debate on methodological nationalism within the social sciences, initiated by German sociologist Ulrich Beck. The paper shows that this discussion is also highly relevant for the field of comparative research studies. These studies are often carried out as country comparisons with no or little focus on the growing transnationality of what is measured. However, as we show in the paper research is today a transnational activity and must be understood as such. Researchers collaborate more and more with researchers in other countries and thereby make research publications transnational products. Also the national research institutions are to a higher and higher degree transnationalised due to the growing mobility of researchers. In the paper we use Denmark as our primary case but we also include 16 other countries in our study. Based on an examination of all the papers registered in the Thompson Reuter's Web of Science-database we thus follow the development in research collaboration from 1980 to 2014 for 17 leading research countries.

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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 where knowledge, human capital and information technology is seen as the foundation of the economy (OECD, 1996), a renewed focus on national research performance and country comparisons has emerged. According to the idea of the

knowledge-based economy research together with education and innovation are key elements in doing well 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 a population is, the more patents a country can produce, the better a country will likely do in the knowledge-based society. Future economic performance is in other words understood as intimately linked to such factors as for example the amount of money spent on higher education and R&D, the educational standard of the population, the research and innovation performance of the country.

This development – together with the upcoming 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. 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. After 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).

In this paper we will focus 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 historically such comparisons have been infrequent and small-scaled compared to the all-encompassing multi-national performance comparisons of the recent two decades (e.g., May, 1997; Adams, 1998 and King, 2004). Such comparisons have often been commissioned by international organisations such as the EU[1], but single countries also use a lot of energy to find out how they are doing in terms of research performance, regularly publishing indicator reports, e.g. USA[2], Netherlands[3], Norway[4] and Denmark[5]. One, 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; 2013b; Sørensen et al. 2015). Here the level of scientific and technological research excellence in the different EU-countries are judged by four indicators: the share of highly cited publications, the number of top scientific universities and public research organizations, the number of patent applications and the value of ERC grants.

Nevertheless, the question is how meaningful it is to make these country comparisons 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? As the Danish science historian Helge Kragh once said in relation

[1] https://ec.europa.eu/research/innovation-union/pdf/state-of-the-union/2012/innovation_union_progress_at_country_level_2013.pdf
[2] http://www.nsf.gov/statistics/seind14/
[3] http://www.wti2.nl/introductie/publicaties-2
[4] http://www.nifu.no/en/statistics/
[5] http://ufm.dk/publikationer/2014/forskningsbarometer-2013

to H.C. Ørsted and the discovery of electromagnetism: the fact that Ørsted discovered electromagnetism in Copenhagen doesn't mean there is something particularly Danish about electrical currents effect on magnets (Kragh, 2002: 11).

We will discuss the question of country comparisons in the following with a special focus on comparisons of 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 by publication output, mainly international journal articles. While production and impact go hand in hand, citation impact is considered the most important research performance indicator as citations on an aggregate level of analysis is seen as a proxy for research 'quality' (Gläser & Laudel, 2007). Numerous indicators have been suggested for measuring impact but there is a growing consensus on focusing on a country's share of the top 10% most cited papers (e.g., Tijssen et al., 2002; Bornmann, De Moya-Anegón & Leydesdorff, 2012; Waltman et al., 2012).

Our analytical point of departure will be the growing international discussion on *methodological nationalism* (Chernilo, 2011). One of the strongest voices in this discussion, German sociologist Ulrich Beck, has e.g. warned us against 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 isolated from other containers (e.g. Beck, 2000; 2005; 2006, 2007, 2009; Beck & Sznaider, 2006; Beck & Grande, 2010). This to Beck represents a distorted version of reality (Sørensen & Christiansen 2012: 80-83). Holding on to this view of society in an increasingly interconnected world will therefore 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, social scientists should according to Beck be careful not to use antiquated understandings of society when they study social phenomena. In other words, Beck wants us to pay attention to possible traces of methodological nationalism in our comparisons, and methodological nationalism occurs when the nation-state unconsciously and uncritically is treated as the natural frame of society and thus in our case the natural entity to study when we look at societal phenomena such as science and research performance.

Regarding the fields of higher education and science studies, methodological nationalism has so far only been discussed in relation to higher education (Shahjahan & Kezar, 2013; Kosmützky, 2015). However, as we will try to argue in this paper the discussion of methodological nationalism is also highly relevant when it comes to measuring research performance of individual countries. While nation-states have been main patrons of scientific research, the latter is to a large extent a phenomenon that is difficult to understand in relation to nation-states. As we will show in the following, research is to a very great extent a transnational phenomenon. Research always builds on preceding ideas, methods and discoveries of other scholars both from within and outside a given national entity. This has always been the case. However, as we will show in the following the research process also often involves collaboration with scientists placed in other countries, and locally – in the different research institutions where the research is produced – there are often many different scientists with different national backgrounds working together. The transformation of "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 Manhatten or the Human Genom projects, but also the changing funding

landscape, especially after the end of the Cold War, where international funding institutions have emerged, have also been a driver or perhaps a multiplier in 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 looking at the general development in cooperation among researchers in 17 of the most essential 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 national state like Denmark is. We have chosen Denmark as our case because Denmark is among the top-performing countries within research. The development in Denmark's research performance has also been taken up by other scholars who have discussed 'the Danish miracle' (Öquist & Benner, 2012; Aagaard & Schneider, 2015) – a reference to the fact that Denmark apparently has outperformed its Nordic neighbouring countries as well as most other countries (apart from Switzerland and the Netherlands, see Schneider and Aagaard, 2015). But the question is *how Danish Danish research actually 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 methodical nationalism and the acute methodological challenges involved in measuring research performance of individual countries.

Methods

Throughout the paper we use the terms transnational and transnationalisation instead of for example international and internationalisation because these terms in our view more accurately describe what is at stake today. Etymologically speaking we could say that the term *inter*national can be used to describe things that happen *between* nations whereas the term *trans*national can be used to describe phenomena that go *across* or *beyond* nations. As we will try to show in the following, research today is exactly a phenomenon that goes across and beyond the single nation-states.

Empirically, collaboration has been examined with different designs but the most predominant one has for decades been to use journal publications in bibliographic databases as the unit of analysis and then measure collaborative activity by counting multiple author contributions (e.g., Luukkonen, Persson & Sivertsen, 1992; Georghiou, 1998; Wagner & Leydesdorff, 2005). The byline of journal publications includes author names and their institutional affiliations together with the countries of such institutions. Such data seemingly open up for a variety of different analyses of collaborative activities such as individual collaboration patterns or international collaborations, where the latter simply examine the number of different countries mentioned in the bylines. 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. While this seems straightforward it is not without theoretical and technical challenges. The main challenges are to define the central concept of research "collaboration" and subsequently examine the validity of co-authorships as a measure of such research activities (Katz & Martin, 1997). First of all, in turns out that the concept of research "collaboration" is not so well understood as is generally assumed (cf. Katz & Martin (1997) for a thorough discussion); and second, we are not necessarily dealing with the same phenomenon when units of analysis

switch between individuals, groups, institutions, sectors or nations. Considering these challenges a straightforward translation of co-authorships to "collaboration" is crude.

Obviously, co-authorships can only be used to count collaborations or contributions where the collaborating or contributing participants have put their names on a joint article. We acknowledge that on the level of individual articles, co-authorship in itself does not mean that "collaboration" has actually occurred, whatever "collaboration" means (Woolgar, 1976). But as Narin (1976) has asserted the submission of a manuscript containing new knowledge claims is a crucial outcome of science, representing findings that the authors collectively are willing to claim as notable. So claiming authorship serves as a socio-cognitive filter on the multitude of relations in the social context of discovery (Melin & Persson, 1996), and does indicate that mutual activities of importance has taken place, be it "collaboration", "cooperation", "contribution" or the like.

We use co-authorships at the level of countries as a proxy of "transnationalisation". We are cautious when interpreting co-authorship trends as "collaboration"; while co-authorships certainly capture "collaborative" actives, 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 why authors are represented in the byline 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 bylines as an indication of "transnationalisation" and collaborative efforts of some sort.

We use Thompson Reuter's Web of Science (WoS) database to analyse the development in transnationalisation. We use the customized in-house version of the database at CWTS, Leiden University. While the database in principle covers all research areas, the social sciences and especially the humanities are poorly covered. The findings therefore mainly relate to the natural, life, medical and technical sciences. Our focus in the present analysis is upon 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 from 1980 to 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. Notice, as we do not weight contributions to individual articles it makes no difference in this context whether a country has one or more author affiliations on a given transnational research article, i.e., the article is either national or transnational. Further, in order to examine the developments in transnationalisation and relate it to research performance, we also examine publication output and citation impact for the chosen countries for a specific year.

In relation to analyses of transnational collaboration using co-authorships means that the institutional affiliation decides the country of origin for the examined publication. 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 transnational collaboration analyses 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 Franzoni et al.'s (2012) study on mobility in order to be able to compare results. However, as we especially focus on Denmark we supplement Franzoni et al.'s (2012) survey 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 & Martin, 1997; Laudel, 2002). Despite the limitations of co-authorship measures, many studies have used this technique to investigate research collaboration and especially at aggregate levels of analysis, results seem valid, valuable and seems to be upheld by theory (e.g., Price, 1963; Crane, 1972; Luukkonen, Persson & Sivertsen, 1992; Melin & Persson, 1996; Wagner & Leydesdorff, 2005; Leydesdorff & Wagner, 2008).

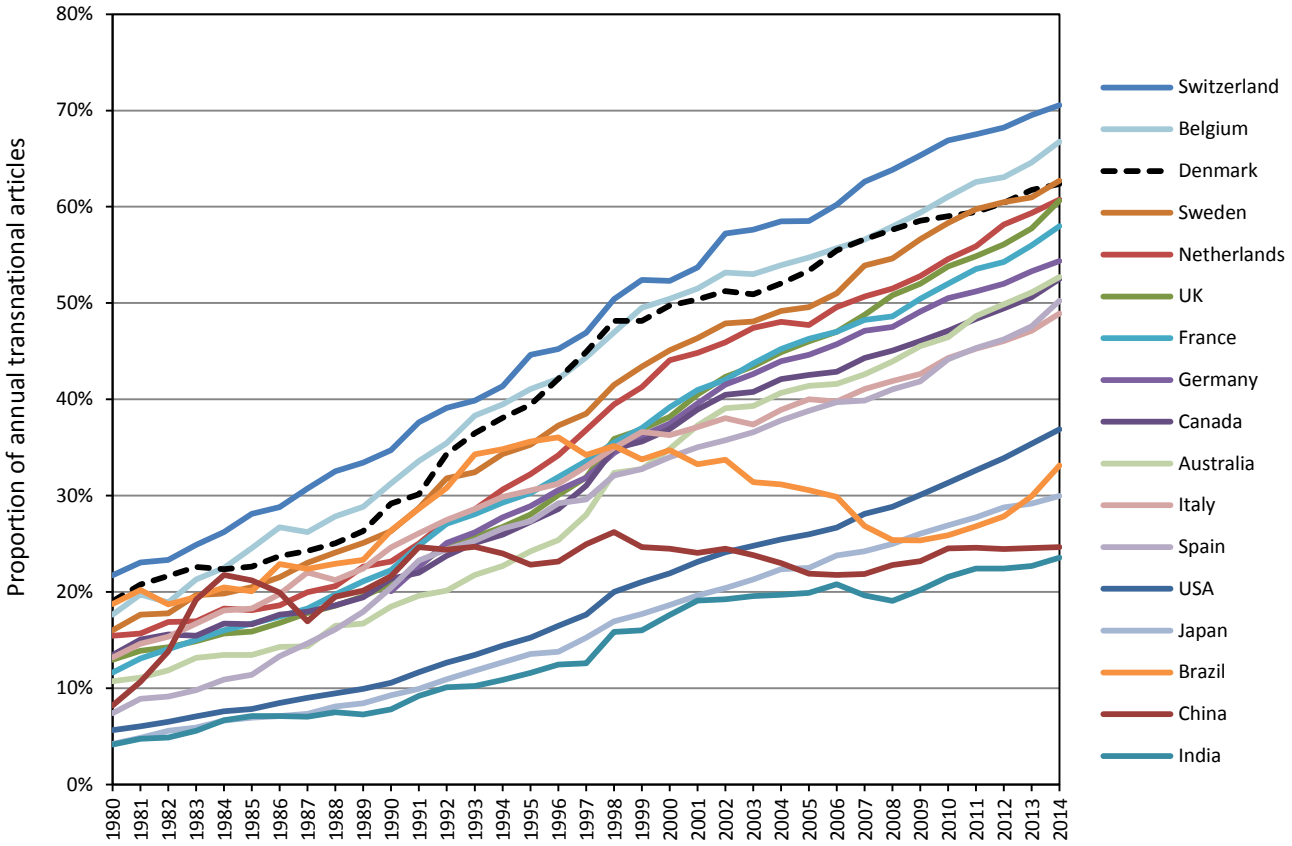
Findings

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 with those of Franzoni et al. (2012) on mobility. These 16 countries are among the core countries when it comes to research productivity, performance and collaboration, measured in international bibliographic databases. They satisfy our aims as we among them have some main typologies of research countries. However, we have included China as well due to the special circumstances surrounding China, its growing research system and international influence (Leydesdorff, Wagner & Bornmann, 2014).

Three inter-linked findings are illustrated in Figures 1, 2 and 3 and discussed based on these figures. Figure 1 presents the long-term development in the proportion of transnational journal articles for the 17 countries based on the international bibliographic database Web of Science. After establishing and discussing this development, we focus on one recent year, 2010, in order to characterize and categorize the countries in relation to their size and degree of transnational research collaboration, and relate that to their relative performance measured by citation impact. This we further elaborate in Figure 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.

Figure 1. *Annual developments in 17 countries' proportion of journal articles with transnational collaboration. The country legends to the right are ordered according to their rank in the graph in 2014, so that Switzerland is first and India last. Source: Web of Science, CWTS, Leiden University.*



Several interesting patterns emerge from Figure 1. For 12 of the 17 countries, including Denmark, the period from 1980 to 2014 has seen a rather steep almost linear growth in the proportion of articles resulting from transnational research collaboration. For these countries, the origin of the time series in 1980 was roughly between 10 and 20 percent, whereas in 2014 this interval had risen to between 50 and 70 percent. In the case of Denmark 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 United States was the largest country in 1980 and is still so in 2014 when it comes to annual number of publications; the annual visibility has more than doubled during the period. The case of a small country like Denmark is more dramatic; the annual visibility has increased five-fold from 1980 to 2014, but the most dramatic increase comes from the emergent countries which have experienced more than a twenty-fold increase in visibility in the database. However, such increases in visibility cannot only be ascribed to increase in productivity; some of the increase is also an effect of the database expanding. That being said, all countries have seen a large increase in their publication activities over this period (cf. Adams, 2013)

What is also characteristic from Figure 1 is that the top five countries are also the smallest ones when it comes to population numbers and journal articles. Their research systems are relatively smaller than the other countries, but if we consider it from an efficiency perspective, Switzerland, Denmark, Netherlands and Sweden

clearly have a higher publication output *per* 100,000 *capita* compared two both the middle-sized group of countries, such as the UK, France and Germany, and especially the large-sized countries such as China, India and Brazil. For example, in 2014 Denmark "produced" 222 journal articles *per* 100,000 *capita* compared to 132 for the UK and 17 for Brazil. While this may say something about efficiency of the national research systems it is also noticeable that this degree of efficiency correlates well with the degree of transnational collaboration. For the group of smaller countries, the degree of transnationalisation is between 60 to 70 percent, whereas the group of middle-sized countries has a degree between 45 to 50 percent and the group of large countries between 20 to 30 percent. So "efficiency" 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 visible in Figure 1 is the clear categorization between the group of small and middle-sized countries, i.e. the 12 countries discussed above, and the group of 5 large-sized countries and the different developments for them. The group is heterogonous containing two rich Western countries, USA and Japan, and three BRIC or emergent countries, China, India and Brazil. Clearly, the research systems and their efficiencies in these countries are very different and their heterogeneous developments in the proportion of transnational journal articles testify to this. The Western countries, USA and Japan, actually also experience a linear growth in the degree of transnationalisation, albeit from a clearly lower base and with a lower slope, rising from 5-6 percent in 1980 to 30 to 37 percent in 2014. For these two countries the developments are similar to the groups of small and middle-sized Western countries discussed above, apart from the facts that both countries had clearly lower bases in 1980 (and still have considerably lower degrees of transnationalisation in 2014) and that the American system by far is the largest when measured as 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 almost linear at first flattens out from 2000 onwards. India had the lowest base of 6 percent in 1980 and still has the lowest degree of transnationalisation in 2014 at 24 percent. At face value, the developments for China and Brazil seem to fluctuate much more than the other countries, but much of this is most likely 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. Today the database covers some 14,000 journals and many of the "new" journals are regional outlets from Latin America and Asia (especially China) (Testa, 2011). Regional journals, even if their language is English, are characterized 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 obviously influence the calculation of the degree of transnationalisation. Hence the sudden changes and drops for China and Brazil should most likely be ascribed to this phenomenon. Nevertheless, some interesting recent patterns are visible. The degree of transnationalisation seems to be rising for Brazil, and the development for China has been very stable around 25 percent for close to 15 years.

What is not shown in Figure 1 but documented by Adams (2013), and our data confirm his findings, is the fact that while all countries experience considerable increases in transnational collaborations compared to the origin in 1980, emergent countries, such as China, Brazil and India, both see a marked absolute increase in national and transnational research articles, whereas the western countries in fact experience a stagnation of national research output and a considerable increase in transnational output.

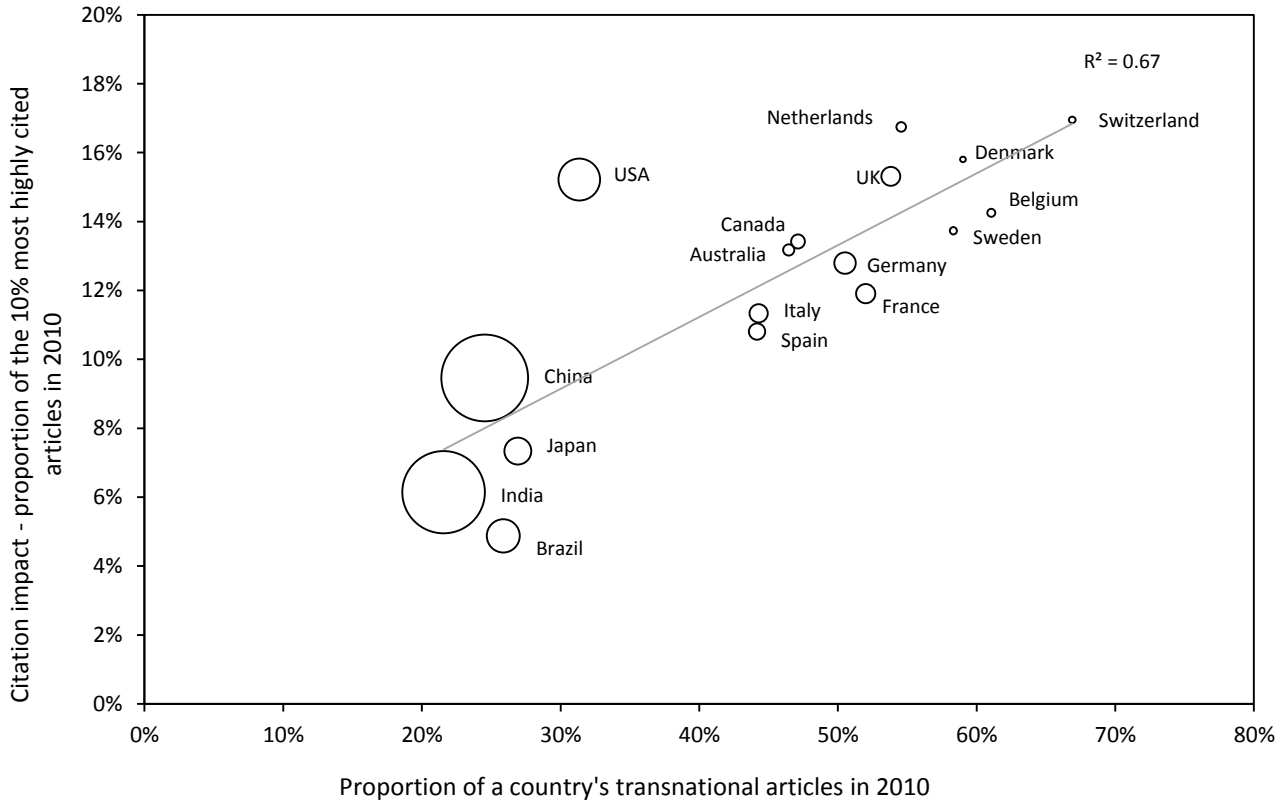
From the findings in Figure 1 we can conclude that all countries have experienced an increase in the degree of transnationalisation. The development has been most intense for a number of small-sized Western countries which at the same time also seems to be most efficient when it comes to research output *per capita*. The degree of transnationalisation is seemingly lower for larger countries, but the reasons for this may vary considerably between the countries. The fact that only a little more than 1 in 3 articles with a US address also has 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 it in many ways does not need to turn its attention to collaborative efforts abroad. Some US universities, for example Harvard, have a larger research output per year in the Web of Science than some of the small western European countries, e.g., in 2010 Danish output (i.e. publications with at least one Danish institutional address) was roughly 12000 whereas Harvard University alone had an output of more than 25000 publications. In fact, geographically the US system sees a lot of collaborative activity, albeit across federal state borders and not so much across national borders. But perhaps most interesting, the US science system can indeed be considered to be transnational, not so much visible in its publication patterns, but much more visible when one studies the composition of faculties at US universities. Junior and senior researchers from around the globe go the US to work, most likely because the US science system is still considered to be the center of gravity in the world science system. We return to this below.

Considering our main question of the meaningfulness of country comparisons in relation to research performance, it is already clear that claims of national output and performance is “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. Below in Figure 2 we do that for the year 2010. Within the field of Scientometrics it is well-known that transnationally co-authored articles on average have higher citation rates compared to national articles, co-authored or not (e.g., van Raan, 1998; Glänzel & Schubert, 2001; Persson, Glänzel & Danell, 2004). The difference in impact is usually substantial. For example, the citation impact for the around 5000 national Danish articles from 2010 is 10.9%, i.e. some 11 percent of these articles are among the most highly cited in the database, whereas the total impact of the remaining 7000 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 which we will discuss below.

With this in mind, we would expect a good correlation between impact and degree of transnational collaboration which is also the case as shown in Figure 2 below. The caption explains the axes and circle sizes. 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, an article’s status as transnational is only 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 for disseminating the knowledge presented in the article. If then these authors are spread-out across countries this tendency is amplified. Transnational research effort is also often characterized by investigating topics of considerably interest or hype. The latter often results in publication in journals where citation activities are generally higher which eventually will benefit such research. And then there is the more controversial perspective that transnational research efforts in general is of better quality (see Adams, 2013); the latter claim is to a large extent questionable especially when quality claims are based on citation impact alone.

***Figure 2**. The relation between "national" citation impact and a country's degree of transnational journal publication activity in 2010. The y-axis shows the total citation impact for a country's articles in Web of Science published in 2010. Citation impact is here measured as the proportion of articles among the 10% most cited in database for that particular year. It is expected that a unit will have around 10% of its articles among the most cited; more means that the impact levels are higher than expected. The x-axis shows the proportion of the 2010 articles which can be considered transnational. The size of the circles indicates the size of the country depicted with 2010 population statistics from the World Fact Book[6].*



[6] https://www.cia.gov/library/publications/the-world-factbook/.

Returning to Figure 2, USA is clearly an outlier in as much as the impact is high but the proportion of transnationally co-authored articles are modest compared to the other countries with high impact. Since the end of World War II the United States has been considered to be the world leader in science (Hollingsworth & Gear, 2013). Scientific hegemony means that a country such as the US dominates multiple scientific fields and establishes the standards of excellence in most scientific fields. The US scientific elite, scholars and institutions, are considered the most prominent in the world and consequently the US attracts more foreign young people for training than any other country. Finally, and important for the present analysis, today the language of the dominating scientific communication systems is English and the databases used for scientometric analyses is dominated by Anglo-American journals. These characteristics obviously increase the likelihood for receiving citations. If we then consider that the US is the largest country in the Web of Science database, measured by annual publication volumes, then it becomes less surprising that not only does US articles receive a considerable number of citations from foreign articles, considerable citation traffic does also go on between articles with only US addresses. This is an important reason for the generally high citation impact of the US. Figure 1 showed that the degree of so-called "national" research output is decreasing as a function of country size, i.e., smaller countries have larger shares of transnational research collaborations. Figure 2 established that there clearly is a good correlation between the degree of transnational collaboration and impact, with the notable exception of the US, and that country size is clearly an indicator for 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. But there is more to it as we show in Figure 3 below. Seemingly, everybody wants to collaborate with the US.

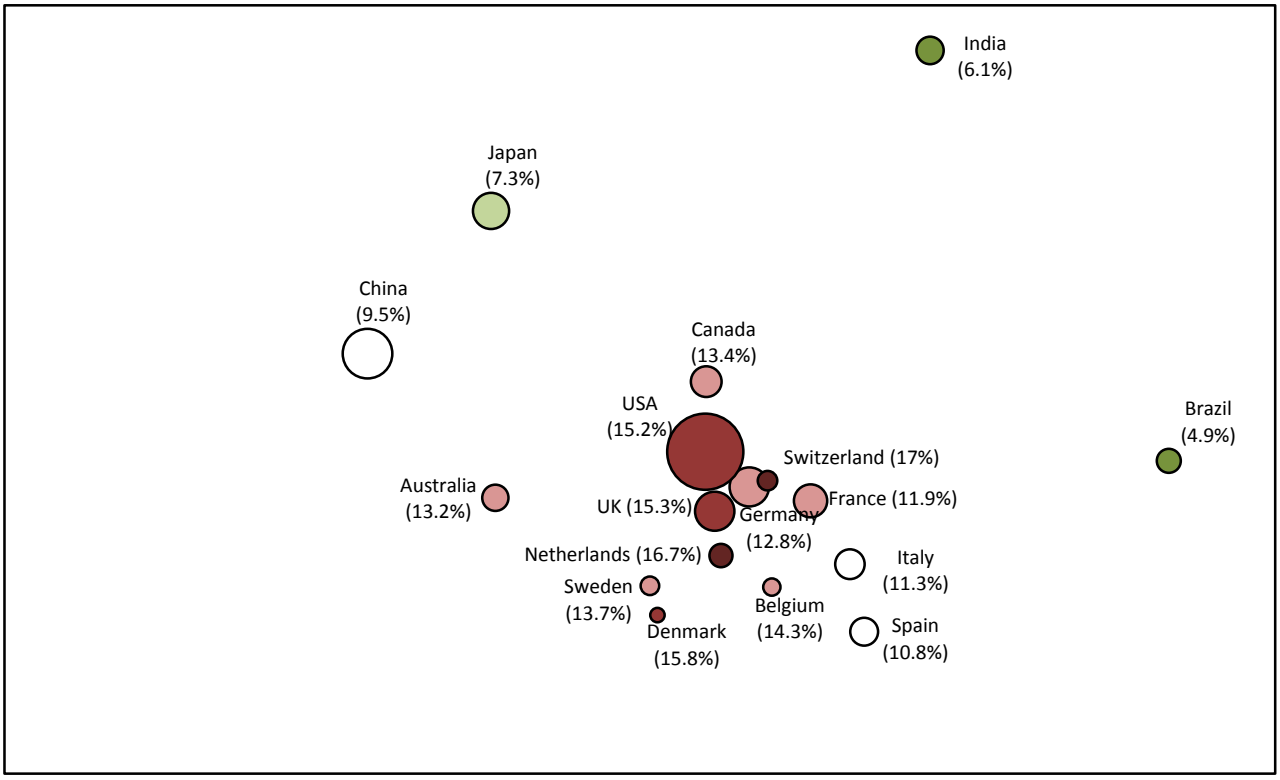
Figure 3 below visualizes the mutual "research collaboration" between the 17 countries when examining their transnational co-authorship patterns. We have constructed a symmetric matrix where the number of co-authored articles in 2010 between any pairs of the 17 countries is represented in the cells. 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 by use of 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 center of the map have broader collaborative patterns, whereas countries on the fringe have more insulate collaborative patterns. Further details concerning the interpretation of the map is given in the caption to Figure 3.

Clearly, the US is at the center of 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 US, and for 11 countries this share is between 10 and 23 percent. The share for countries in second place is usually considerably lower; exceptions are Switzerland, 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 United Kingdom and Germany. Indeed what is noticeable from Figure 3 is the clique of countries in the center of the map; they have significant mutual transnational collaboration activities. What is also noticeable is that most of these

countries have good, high or very high impact, as depicted by the red color code of the circles. In a sense everything revolves around the US, the so-called "outlier" from Figure 2.

Figure 2 showed that 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 Figure 3 we see that these countries are on the periphery on 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 US are between 14 and 23 percent. The four countries with modest or low transnational collaborative activities in Figure 2 are naturally placed on the fringe of the map in Figure 3. While they all have their highest share of transnational collaboration with the US, the relative numbers are markedly lower with China's 10 percent as the highest. These are relatively large countries, both in population and publication numbers, but their transnational collaborative activities when it comes to journal publication is low and so is their impact.

Figure 3*. Transnational collaboration patterns between 17 countries in 2010. Countries are placed in the 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 the center of the map have broader collaborative patterns, whereas countries on the fringe have more insulate collaborative patterns. The size of the circles indicates the 2010 publication output for the individual countries relative to each other. The citation impact for each country is shown in brackets and the color code of the circles indicate the strength of the 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).*



It is natural to conclude that a country's degree of transnational co-author activity is more or less proportional to its citation impact. But we should qualify this since whom you collaborate with seem to matter a great deal. Everybody collaborates with the US, but some more than others and the performance of these countries are clearly the highest. Further, a strong clique of mainly Western countries not only collaborates extensively with the US, they also collaborate with each other. Interestingly, these countries all show high performance levels.

It is clear from the three figures that comparison of national research performance between countries is indeed challenging. For smaller countries up to 70 percent of the so-called "national" articles can also be described as "national" for at least one other country. The matter is further complicated when we consider that the main performance parameter, citation impact, to a large extent is 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 US is also the top ranked countries when it comes to impact. However, when we compare them we should remember that a considerable number of the articles that promote 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 does not necessarily solve the essential problem, it only displaces it since with fractional counting, transnational research collaboration is "punished" (Aksnes, Schneider & Gunnarsson, 2012).

Transnational research institutions

If we now turn to the research institutions, we can observe some of the same trends. Not only do research institutions and researchers, as we have seen above, to a great (and greater and greater) extent collaborate with colleagues from abroad – the research institutions themselves are also to a very large extent transnational units. In their comprehensive study of mobility patterns of researcher in 16 countries, Franzoni et al. (2012) found that around half the research staff within the studied fields (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 the age of 18). Also in the US (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 studied fields, in 2011 came from other countries. Apparently, however, it is still not all countries that have transnational research units. There are, for example, very few foreigners working in academia in India (0.8% in the four studied fields), Italy (3.0%) and Japan (5%). However, a lot of researchers from India (39.8%) and Italy (16.2%) work abroad.

This in- and outflow of researchers is not something new. 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. This has historically not least benefitted the USA that for a long time has been able to attract many of the best scholars from around the world. In the years between 1952-61 alone more than 9,000 scientists together with 30000 engineers and 14000 physicians and surgeons came from other countries to settle in the USA (Dedijer, 1964: 965). When we today (cf. Franzoni et al. 2012) see a flow of researchers from e.g. India and Italy towards the USA it thus fits with historical trends. However, already Dedijer (1964) noted that not only the USA benefitted from this traffic. According to him migration directions of scientists can be described in this way:

> "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 further into the details behind the development we can say that Denmark has clearly been one of the countries benefitting from the global migration of researchers. This development also goes way back. One of the best examples of a transnational research environment in Denmark can thus be found as early as in the 1920th and 1930th where scientists from all over the world came to Copenhagen to work at Niels Bohr's famous institute (Aaserud & Nielsen, 2006; Nielsen & Nielsen, 2008: 424-433).

Today we also see a huge inflow of PhD students and scientists from other countries to Denmark. 34% of the new PhD students starting a PhD education in Denmark in 2010 thus came from abroad (Danmarks statistik, 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 faculty members we can see that 21% of all the new positions (academic staff at all levels) at Danish universities between 2011 and 2013 went to researchers from outside

Denmark (Ståhle, 2014: 23). Especially at the post doc/assistant professor level a huge number of people from abroad has been recruited to Danish universities. In 2011-2013 29% of this group lived outside Denmark before getting the post doc/assistant professorship at a Danish university. Among the researchers recruited from abroad to Danish universities there are both foreigners and Danes: 87% are foreigners and 13% Danes (Ståhle, 2014: 24).

If we look at the main areas within the universities, it is clearly the Science departments that have the highest level of transnationalisation. Within the Science departments 34% of all the new academic jobs in 2011-2013 went to researchers from abroad (Ståhle, 2014: 26). If we only look at post doc/assistant professors 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 it is 15% and 20%, and within Health 14% and 19%. However, more than half of the new post doc positions at Danish universities in that period (2011-13) went to the Science departments. These departments therefore contributed strongly to a growing transnationalisation of Danish universities.

If we finally look at the aggregated figures (foreigners recruited from abroad plus recruited foreigners already working at a Danish university), 1863 research positions, corresponding to 38% of all new recruitments of research staff at Danish universities between 2011 and 2013, went to non-Danish citizens (cf. table 1).

Table 1: The number and share of recruitments of foreign citizenship researchers (professors, associated professors and assistant professors/post docs) at Danish universities in 2011-2013. Source: (Ståhle, 2014: 26)

	Professor level		Associated professor level		Assistant professor/post doc level		In total	
	Number	Share	Number	Share	Number	Share	Number	Share
All Danish universities	186	22%	457	34%	1220	46%	1863	38%

This growing 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 in Web of Science) then the overall share of foreign researchers employed at Copenhagen University has grown 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 in 2013 35% of all employed researcher at the Danish Technical University (DTU) were foreign citizens (Svansø, 2013). This means that the leading Danish research institutions to a relatively great extent have become transnational units.

Discussion

How Danish is Danish research and what can indeed be considered Danish research? The findings in this paper demonstrate that these are difficult questions to answer precisely, and 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 way. Using co-authorships, the measure most often used for examining international collaboration, we show that for a small country such as Denmark, what is claimed as "Danish research" can today, in 6 out 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 from Franzoni et al. (2012), while slightly lower for Denmark, generally corroborates our findings that for high-performing western countries a large minority of the active researchers have a foreign background. This likely implies that some of the so-called Danish articles, whether transnational or national, are authored by non-Danish researchers but since they are affiliated to a Danish research institution, the research is considered to be "Danish". This further complicates matters, but generally testifies to the claim that scientific research to a very high degree can be considered a multidimensional transnational activity, and this has important implications for governance and assessments of performance.

It is understandable and legitimate that policymakers want to know how the public money spent on research is expended and following more recent public managerial trends also know how the funded science is performing. This exercise is difficult and to some extent meaningless given the fact that research is to a large extent a transnational phenomenon. What does it mean 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 research versus German research, but *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. This is important to comprehend, because the performance of transnational research papers is considerably higher than the national ones.

We have also demonstrated that the degree of transnationality is somewhat different among the countries we examine. When examining co-authorships, the degree is lowest for the emergent countries and highest in the smaller western European countries. In the latter countries, including the United States, transnational collaboration basically represents all the growth in publication output, whereas both national and transnational output has increased intensely in the emergent countries, most likely indicating that these countries have experienced a general rise in their scientific capacity. Whereas western countries both experience growth in transnational collaboration and transnational mobility, mobility in emergent countries seem to a large extent to be a one way affair, with researchers moving abroad.

Adams (2013) argues that research historically has progressed through three ages (the individual, the institutional and the national) and 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 this contributed to the wider economy through knowledge, new processes and products. However, the new age of international collaboration will in his view challenge the ability of nations to conserve

their scientific wealth in the form of intellectual property and research talent. Although we don't 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 a national enterprise to be nationally governed 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 to some extent legitimate seem misdirected and far from the reality of science that we have tried to show above must be understood as a transnational activity and a more or less "invisible global network" (Wagner, 2008). There are in our view, however, no signs of this competition and way of thinking now coming to an end. Quite on the contrary, nations still very much seem to be thinking of themselves and acting as competing entities in a global knowledge-based economy.

With its inherent transnational nature, we see science as a complex, self-organising adaptive system or systems which to a large extent can only indirectly be governed by states or institutions. The latter provide the context, yet scientific endeavours go beyond serving such patrons. Transnational collaboration and mobility has grown for reasons mostly 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 decoupling from the goals of national science policies – and establishing research ownership becomes muddled and almost synthetic.

The question is then where this leaves us in terms of the discussion on methodological nationalism that we briefly touched upon in the introduction. Are country comparisons of research performance the result of what Ulrich Beck has 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 …". They further write:

> "Methodological nationalism takes the following premises for granted: 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 organize 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, represent the most fundamental category of political organization." (Beck & Sznaider, 2006: 3)

This is also frequently what happens in comparisons of research performance. In such comparisons we often start with the 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 – that, in other words, the nation-state itself (its policies, institutions, funding bodies etc.) is the source of this country's research performance.

As already mentioned above in the introduction the pressure for knowing how a given nation-state is doing in terms of research performance gets stronger the more we adopt the idea of the competition state and the

deeper we get into the 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 have to be careful how we interpret the results of such comparisons of research performance. If we again take Denmark as an example we can on the one side say that Danish research is doing extremely well, that Denmark is a top-performing country when it comes to research production and impact. However, on the other side the evidence presented above also show that these results to a greater and greater extent is created in collaboration with non-Danish researchers working outside as well as inside Denmark. And this is not just the case for Denmark. This development takes place globally.

The concept 'Danish research' – as well as Swedish research, German research, US American research etc. – hereby changes meaning. Danish research today means research that involves Danes but also to a great extent non-Danish researchers (working outside and inside Danish research institutions). Instead of speaking of *either* Danish research *or* research from other countries we therefore have to start thinking about Danish research as something that involves *both* Danish researchers *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 funding bodies *and* non-Danish funding bodies.

If we want to avoid making 'zombiescience' or 'science of unreality' (Beck, 2006: 21) in this field of science we therefore have to start by recognizing that research is a transnational activity and that research performance probably has more to do with transnational collaboration than national efforts. Even though nation-states can still play an active role in creating attractive conditions for research in a given country – by supplying sufficient funding, creating attractive research institutions etc. – research performance today is deeply dependent on transnational cooperation in the form of cross national mobility of ideas, methods and researchers as well as researchers' collaboration across borders on research projects and papers. Future research within this field ought therefore to pay more attention to these transnational factors when measuring research performance.

This is also very much in line with Beck's thoughts on methodological nationalism. According to him social science can only be a 'science of reality' in so far as it recognizes that we today live in an increasingly interconnected world (Beck, 2000; 2005: 10-50; 2006: 24-44). Beck here talks about 'banal cosmopolitanism' or 'real cosmopolitanization' meaning that behind our backs, unnoticed, as a side-effect of other activities we have created a world in which we everywhere on the planet are deeply dependent on developments in other parts of the world. We can thus observe, also in the field of science, a somewhat paradoxical movement: The more effort and resources we use to make e.g. Denmark a world leading research nation, the less national the output (research results and papers) of such initiatives will be! Under the new 'cosmopolitan condition' (Beck & Sznaider, 2006) national research strategies and initiatives to heighten the quality and impact of a nation's research output will thus at the same time accelerate a transnationalisation of the same nation's research activities. The nation-state of course still plays a role and can still be analyzed, e.g. as a 'showcase of the global' (Beck & Grande, 2010: 430).

Wagner (2008) has argued that the "the invisible global network of science" is not best administered using old-fashioned strategies favouring national self-interests. Rather, broader governance should be introduced, aiming to nurture centres of local expertise adept at making contributions crucial to the entire community of their peers. By reversing a cliché, Wagner summarises her challenge to policymakers: "Think locally, act globally".

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