French Research Performance in Context

A report prepared for the CURIF

(Coordination of French Research-Intensive Universities)

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"There is no national science,

just as there is no national multiplication table;

what is national is no longer science."

Anton Chekhov (1921)

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Executive Summary

This report aims at contributing to the ongoing policy reflection on the French research system. It is structured in two main parts, each of which seeks to answer a simple question:

- Is the performance of the French research system satisfactory?
- If not, why is this the case?

The main conclusions are summed up at the beginning of each section of the text, followed by a presentation of key evidence.

Part 1. Contextualising French research performance

The first part provides a broad overview, comparing French research output across a wide set of indicators with that of a set of ten benchmark countries: Australia, China, Denmark, Germany, Japan, Netherlands, Spain, Switzerland, UK and US.

Global performance indicators

The first set of data compares benchmark countries in terms of (a) share of production and citations and (b) research focused university rankings. It enables us to identify three types of countries: high performing, emerging and low performing.

Within continental Europe, the data clearly distinguishes:

- Denmark, the Netherlands and Switzerland, which are not only highly performing but are continuing to improve their performance;
- Spain, which has low performances but is catching up;
- France and Germany, whose performance is both low and declining.

The performance of France and Germany is worse in the case of more selective indicators (top 50% is better than top 10%; ranking in top 500 is better than ranking in top 100) and their decline is true not only when compared to emerging countries such as Spain but also when compared to high-performing countries.

Globally, the overall picture is similar:

- countries such as Australia (to which one could add Canada or Singapore) are performing similarly to leading European countries such as Denmark;
- a large and increasing number of countries are on a similar trend to Spain; amongst these, China is a case apart and should now be considered a global powerhouse with a research potential, which will soon be comparable to the US;
- Japan is performing even worse than France and Germany, with truly dramatic drops in global share of both production and citations;

Finally, although the US and the UK still dominate on size-dependent criteria such as total production and total citations, their overall performance is declining and they are below high-performing countries according to most size-independent criteria.

Excellence indicators

The second set of data looks in greater detail at the performance of benchmark countries on excellence indicators. To do this, we have selected three groups of indicators:

- general bibliometric data with field-weighted citation impact, citations in PP Top1% and PP Top 10% and fine-grained performance across 251 fields;
- performance in cutting-edge fields such as biotechnology or fast evolving technological topics
- Indicators of individual performance such as highly-cited researchers and ERC awards

Despite the use of very specific indicators, the global results are perfectly aligned with those from the first set of data and confirm the three groups of countries, which we defined above.

Denmark, the Netherlands and Switzerland perform very well on all indicators (with a few exceptions for Denmark). The UK and US perform better on more selective indicators. Interestingly, China performs better in cutting-edge fields than in more traditional ones.

The French performance is particularly weak in cutting-edge fields, at an institutional level (rather than a country level) and on very selective indicators. The same is true of Germany but to a lesser extent.

Comparing results in Horizon 2020

Our third set of data compares country performance in Horizon 2020.

In this case, France and Germany both stand out with cumulative losses of well over 1 billion Euros, whereas a country such as the Netherlands has gained close to 1 Billion Euros from H2020 over the same time period.

As in the case of other indicators, despite the fact that the results of France and Germany are already very poor, their market share is continuing to decline both when compared to the previous framework programme and on a yearly basis. On the contrary, countries such as Denmark, with excellent results, continue to improve.

Reframing the problem

The “European Paradox” assumes that Europe’s research is strong, while its innovation is weak. It has been at the heart of European Research policy since 1995 and continues to guide framework programmes, as we move towards Horizon Europe.

This European paradox is clearly a myth. Europe does not have *a comparative advantage in producing knowledge*. It has difficulties turning knowledge into innovation and growth precisely because the proportion of truly world-class research it produces is low and its expertise in cutting-edge fields is poor.

However, the problem is not that of a “transatlantic gap” between Europe and the US, but one of intra-european divergence. And the main issue within Europe is not North versus South or East versus West but the weakness of Franco-German research performance.

Part 2. Why is the French research system underperforming?

The second part of this report proposes a multifactorial analysis of the reasons for which the French research system seems to be performing less well than it could. It examines five key factors or, better said, families of factors:

- funding of the research system;
- connection to the global research system;
- structure of the French research system;
- human resource model;
- autonomy, accountability and governance.

Together these five factors provide a coherent and robust narrative which will hopefully make it possible to define a set of policy recommendations that will succeed in making the French research system truly competitive.

Factor 1: Funding of the research system

The first Factor is, of course, funding: without money there could be no research. This leads to two questions.

1. Does the French research system have enough money?

The answer to this is clearly “no”. Two key arguments support this perspective:

- French investment in Research and Development (GERD) is below the OECD average, just above the EU average and lower than key competing countries.
- Even more significantly, France is losing ground compared with nearly all our benchmark countries. Indeed, investment in research is increasing rapidly not only in emerging research countries like China or Spain, but also in both low performing research countries such as Germany and Japan and high performing ones such as Denmark and the Netherlands.

This trend has been clear for nearly twenty years and urgently needs to be addressed.

2. Is the money well distributed?

This said, the quantity of money is not the only important parameter. Indeed, the way money is distributed is at least as important as the amount.

High performing countries share a number of characteristics:

- they concentrate research funding on research intensive universities;
- they have dual funding mechanisms, which differentiate teaching and research funding;
- research funding is dependent on performance-based indicators;
- they privilege competitive funding mechanisms over block grants.

High performing national research systems are thus “vertically-segmented” systems, which clearly distinguish between the missions that different kinds of higher education and research institutions are supposed to fulfill, and allocate funding on this basis.

Unlike these countries, French universities are constrained by a budget allocation model that:

- does not distinguish a research stream from a teaching stream;
- accords little weight to performance indicators;
- allocates only limited amounts on a competitive project-based basis.

In a world in which universities are the key hubs that ensure global visibility, this has major consequences on the performance of the French research system as a whole.

Factor 2: Connection to the global research system

For reasons outlined in the introduction, the scientific system essentially acts as a huge machine for internally filtering out interesting from less interesting endeavours. As a result, being performant in research supposes not only to be intrinsically good but also to be connected to the rest of the network in an efficient way: interesting science needs to be noticed in order to become effectively relevant. This is why being connected is so important.

Factor 2 examines three key questions that measure the degree of integration of the French research system within the global research system:

1. Language and history

Science has always been global, but until the 1970s major national research systems continued to be reference points in terms of prestige. The emergence of a single global research system was comparatively easy for countries that had always looked abroad (Denmark, the Netherlands, Switzerland) and for countries whose system became the core of the global system (UK, US) but it was very hard for countries, which used to be major references in their own right such as France, Germany or Japan.

The consequences of this continue to have an impact on performance (for example, attracting leading researchers implies switching to English not only for publishing, but also as a working language in the lab and for teaching).

2. Connections

Co-publication data clearly shows that French researchers are increasingly working with international colleagues. However, these co-publication networks are not correlated with excellence - the strongest scientific affinities of France are with Belgium, Italy and Spain, three neighbouring countries, two of which have relatively low research performances. Furthermore, France has the lowest co-publication rate of all our benchmark countries with China, the key emerging research powerhouse.

And, reinforcing the warning signs, the share of French researchers who have had short-terms stays in foreign institutions is surprisingly low compared to other countries.

3. Hubs

However, to truly understand the impact of connections, it is necessary to look not just at raw data but at the networks behind these connections. These underline two facts:

- first and foremost, the research potential and visibility of hubs is key because it is there that new trends emerge, cutting-edge research is produced and connections at a global level are forged;
- secondly, the rest of the country needs to be well connected with these global hubs to enable global research results to be assimilated at a local level.

This is why most countries strive to reinforce a few key hubs rather than to promote the countries research potential as a whole.

Factor 3: Structure of the French research system

Factor 3 addresses the structure of national research systems. To do this, we distinguish three main features:

- the presence or absence of large national research organisations ;
- the degree of integration of universities and national research organisations;
- the degree of institutional differentiation among research intensive universities and institutions with a more local and/or educational focus.

The French national research system can be characterised as (a) weakly segmented with a low degree of institutional differentiation and (b) hybrid, with large national research organisations partly integrated within large research and teaching universities.

We then analyse the impact of this structure on the performance of the French research system in two steps:

1) The impact of vertical segmentation on performance

The first part of the discussion is closely linked to Factor 2 and shows that weakly segmented systems in which research in general and top research in particular is being performed by a greater fraction of institutions, tend to perform less well because they do not benefit from the knock-on effect of strong hubs.

2) The impact of strong national research organisations on performance

The second part of the discussion looks at the impact of strong national research organisations on the overall visibility and performance of a country when the global research system is structured around research intensive universities. It notably argues that:

- in a global system there is a premium for systems based on a "simpler" architecture. As a result, national research organisations have a measurable negative impact on:
    - rankings and visibility of universities,
    - strategic decisions taken by potential international partners,
    - student choices;
- national research organisations perform well in purely quantitative terms but not as well in qualitative terms. They are behind the world's leading universities in per researcher performance and, in some cases, behind research-intensive French universities on indicators such as citations per paper;
- the mixed research unit system is structurally costly because it implies large transaction costs and inhibits strong strategic profiling and planning;
- just as problematic, the two-track recruitment system differentiates the long-term mission and status of individual researchers for no good reason and on no strong basis;
- finally, the size and geographic dispersion of large umbrella type national research organisations does not favour the emergence of cutting-edge fields.

Our analysis of Factor 3 ends with a short description of some recent evolutions of national research systems, which could be interesting to consider in a French context.

Factor 4: Human Resource model

At the end of the day, research performance depends on individuals: researchers publish articles, which are cited, they are awarded ERCs and become Highly Cited Researchers. Attracting talented researchers is thus key, which is why our fourth factor explores the main features that makes a research system attractive.

France currently experiences a brain drain towards high performing countries, a balanced brain circulation with Germany, and a brain inflow from lower performing countries. This brain circulation is not only linked to working conditions but also to research performance: studies show that a researcher with an ERC will obtain better results if she chooses to move to a high performing country.

Brain circulation has a major impact because research performance depends primarily on talent: fostering internal development of excellence is far harder and less efficient. This is why attracting talent is so important for national research systems.

Studies show that researchers are attracted first and foremost to:

- "outstanding faculty, colleagues or research team";
- and "excellence/prestige of the institution".

Better research infrastructure and access to research funds are important, but less so. The same is true of better salaries, quality of life and working conditions.

In other words, leading researchers are attracted to vertically segmented research systems and perform better within them, thus reinforcing the impact of structure described previously in Factor 3

To attract the best researchers, high performing countries have launched specific funding programmes, or “talent schemes”. These aim to support the emergence of national lighthouses by providing long term research autonomy to successful applicants.

The French research system is unable to compete with these countries because universities do not have the necessary autonomy and power to define their Human Resource policy. Close to half of the academic staff working in research intensive universities are still employed by national research organisations who define their own Human Resource rules. The university has no power to define their workload (balance between teaching and research) or incentives to foster strategic objectives.

Within the university itself, staff promotion and hiring decisions depend on national agencies such as the CNU, that have strict national rules, which dramatically limit each university’s autonomy. Universities cannot even freely modulate the time an employee spends on research, academic and administrative duties.

Factor 5: Autonomy, accountability and governance

All four previous factors underline how high performing countries have segmented research systems in which a relatively low number of research intensive universities play a key strategic role.

This implies that the leadership of these research universities must be able to define and implement an ambitious global strategy. And this, in turn, requires autonomy, accountability and good governance.

Today, despite the important reforms of the last decades, French institutions are in the paradoxical situation of being *accountable* without having real *autonomy*.

The 2017 EUA scoreboard on university autonomy shows that France still lags behind the rest of Europe on all indicators: financial autonomy, organisational autonomy, staffing autonomy and academic autonomy. Indeed, globally, France ranks last of all 29 research systems analysed.

This said, the solution is not simply to increase autonomy on each indicator: autonomy cannot be isolated from accountability or governance as a whole. Indeed, for autonomy to be meaningful entails *a minima* 3 requirements:

- autonomy must not be merely legalistic, but effective: it is not (only) about statutes, but about the factual political system of university governance;
- governance must have true authority over all domains of activities;
- accountability must ensure alignment with general sectoral policy objectives and foster professionalisation.

There is no magic formula which demonstrates that the election or nomination of leaders is necessarily better, nor is there one, which defines the ideal proportion of external members in the governing bodies. However, there is a logical relation between (a) how resources come to an institution, (b) how much power the leadership has in terms of decision-making, and (c) how this leadership is appointed.

Epilogue: "getting to Denmark"

All through this report, one factor stands out: France does not trust its research intensive universities enough. The situation has improved but remains far from that of neighbouring countries.

Throughout the world, research intensive universities are the key hubs of the research system. They define research strategy, they host the best students, they concentrate leading researchers, they have dedicated funding mechanisms.

France, on the contrary, combines a highly stratified higher education system in which the most prestigious institutions are not the main research centres with a weakly stratified research system in which the key research actors are not universities. This leads to a paradoxical result: France ends up with both the social stratification of elitist education systems, and the disappointing research performance of low performing research systems.

In a famous paper, Land Pritchett and Michael Woolcock quipped that the problem of getting to strong, reliable, transparent public institutions could be summed up as the problem of "getting to Denmark" (2004). This image is particularly apt for the French research system.

Danish, Dutch and Swiss systems of higher education are good examples of how to balance the competitive, and intrinsically elitist game of "world-class" research with the demand to provide a higher education and research system which promotes openness, inclusiveness and comprehensive social well-being. The fact that they increasingly outperform the UK and US on size-independent research indicators demonstrates that the anglo-saxon model is not necessarily the most performing one.

It is time for France to accept that the model already exists, time to reinforce research intensive universities, to create excellent university colleges and polytechnics, to rethink the role of national research organisations and to end the distinction between *grandes écoles* and universities. It is time, in other words, to look at what other European countries are doing right.

Introduction

Structure and objective

This report aims at contributing to the ongoing policy reflection on the French research system by analysing the performance of the system and exploring five factors which help explain this performance. The main conclusions are summed up at the beginning of each section of text, followed by a presentation of key evidence.

The first part of the report provides a broad overview, comparing French research output to a set of benchmark countries. It takes into account macro level data such as total production, total number of citations and university rankings, as well as more detailed data from a wide range of bibliometric and project indicators of top performance seen from various angles, both globally and for specific fields. The combination of different perspectives and indicators increases the robustness of overall conclusions. These paint a surprisingly coherent picture, which shows that French research is less competitive, not only than US research but also, more importantly, than that of European countries such as Denmark, the Netherlands or Switzerland.

Taken together this data confirms that the “European Paradox” (good European research versus poor innovation) is not sustained by facts and that the “Transatlantic gap” (poor European research and poor innovation) is not a useful paradigm either. The problem is clearly intra-European and more precisely Franco-German.

The second part of the report examines five factors that help explain why this might be the case: quantity and distribution of funding, integration into the global research system, structure of the research system, Human Resource system, and finally autonomy and accountability of the key actors. Each factor corresponds to a potential weak spot of the French higher education and research system.

This system can be (somewhat simplistically) represented as follows:

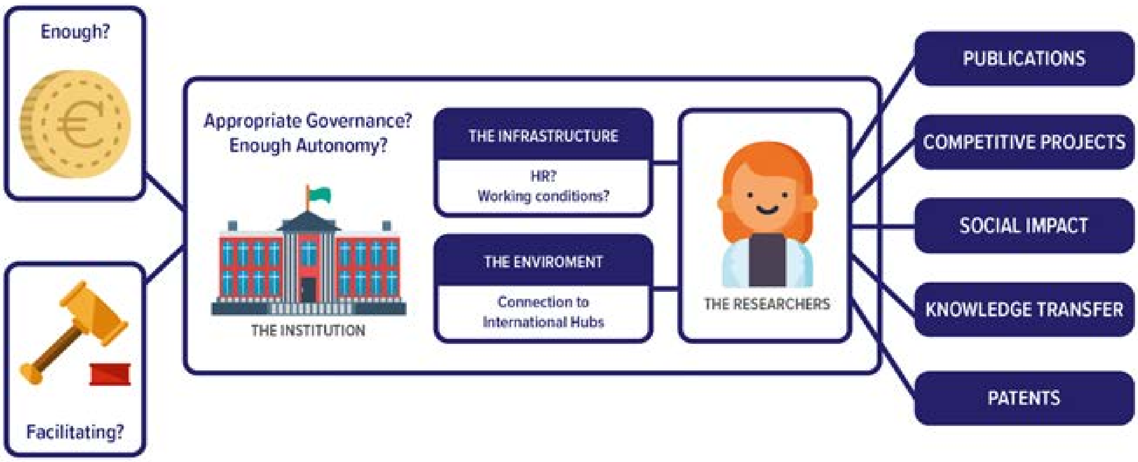

Fig. 1: Rough representation of the higher education and research system, from input to output

Methodology

This report relies largely on existing literature, data and contextualised elements of comparison.

The first part is chiefly descriptive, whereas the second part is structured more like an essay with each of the five factors illustrated by examples. Each individual argument can be contested; however, taken together, we think that they form a robust narrative.

Both parts combine two main approaches:

- the first approach is *analytical*. It relies on qualitative and quantitative analyses of the French system itself, systematically motivated by data, research articles and reasoning;
- the second approach is *comparative*. Selecting a set of countries sufficiently similar to France on certain dimensions, and different in other relevant aspects, makes it possible to propose hypotheses on the impact that key variables have on research production.

We systematically compare French performance to those of ten other countries: Australia, China, Denmark, Germany, Japan, the Netherlands, Spain, Switzerland, the United Kingdom and the United States[1]. Occasionally, other countries are considered for specific indicators or comparisons, such as Belgium, Canada, Italy, Singapore, South Korea or Sweden.

Although certain arguments are more conclusive than others, we have tried to follow some basic rules throughout the report:

- making explicit the major assumptions underlying the notion of research performance and their connection to policy decisions;
- reviewing and analysing existing data and information to see how far they enable us to prove or disprove some of these assumptions;
- clearly stating how far each argument goes, and what is a matter of conviction, interpretation or intuition, when it comes to formulating policy decisions;
- including counterarguments when these were available in the literature and sufficiently robust.

We are aware that some of the hypotheses may generate controversy, especially when they are perceived as having implicit consequences in terms of public policy. To limit this, we have chosen not to include a list of recommendations in the report.

[1] The colour coding is coherent throughout the report.

Methodological note on correcting for size of countries

Our biggest benchmark country, China, has over 200 times the population of Denmark, our smallest one. Comparing the total number of citations of Denmark to that of China is therefore of limited interest: input or output data on research production needs to be scaled to a meaningful measure if we want to analyse efficiency- or density-related questions.

For this purpose we used data from the UNESCO data portal monitoring data relevant for Sustainable Development Goal 4: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all":

- http://data.uis.unesco.org

This data is produced by the OECD and based on Frascati methodology (2015a):

- https://www.oecd.org/sti/inno/frascati-manual.htm

Our main options for adjusting measures for size are population, number of researchers, GDP and GERD. Given the question being addressed in this report, we chose the number of researchers per country as our baseline for normalisation, rather than the entire population or purely economic indicators such as GDP or GERD.

The definition of a "researcher" is, of course, open to question and data is not always directly comparable from country to country (see OECD 2015a, 151 onward), but we are confident that the results are robust. France has almost 300,000 researchers[2] or just over 0,4% of total population. Our benchmark countries have similar numbers of researchers per population (c. 4,500 per million inhabitants), apart from China (c. 1,000) Denmark (c. 8,000) and Spain (c. 3,000). These numbers are consistent with other sources (notably Eurostat[3]). We further checked for distortions that might result from this choice of default baseline but did not detect any and were able to replicate key results using different baselines.

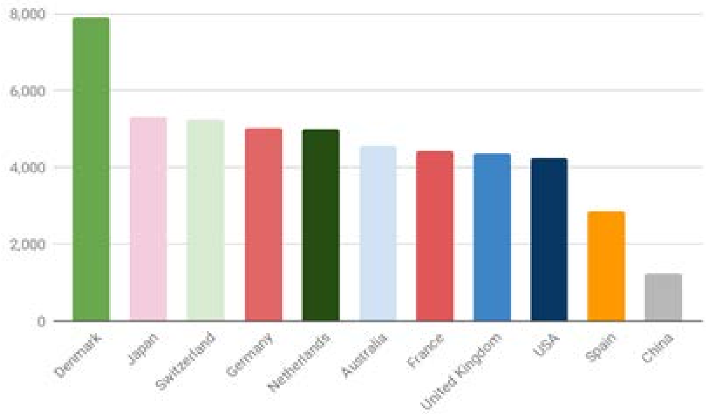

Fig. 2: Researchers per million inhabitants (data source: UNESCO STI indicators)

[2] UNESCO data, with Full Time Equivalent of researchers, defined as "professionals engaged in the conception or creation of new knowledge". Adding persons engaged directly in R&D, the total number of R&D personnel is 435 000 (http://data.uis.unesco.org/index.aspx?queryid=64)

[3] https://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_personnel#R.C2.A0.26.C2.A0D_personnel

Critical assumptions

The first part of this report shows that the French research system is less efficient than other research systems in converting its considerable assets into highly visible research. Whereas the second part explores possible reasons for which this could be the case.

For the argument as a whole to be robust, three conditions must be met: first that the assumptions underlying the factual analysis are solid; second that the question is of strategic importance to the French state and third that acting will not have negative counter effects.

Before we begin the actual analysis, we will examine these conditions by:

- testing two important assumptions:
  - research visibility is a proxy for research performance;
  - science is a deeply skewed game;
- analysing how research has evolved:
  - in historical terms;
  - in terms of competition;
- exploring if a highly performing research system can be compatible with greater social equity.

The last condition is perhaps the most important of all because it acts as a counterpoint to the rest. It is also highly controversial and goes well beyond the scope of the report. For this reason, we formulate it as a question.

Research visibility and research performance

Most of the present report is concerned with evaluating "research performance". However, to paraphrase Raymond Carver (2016), it is important to know "what we talk about when we talk about research performance".

The only data available for an overall assessment of research performance actually measure research *visibility* rather than intrinsic *quality*: Nobel prizes, citations, and other indicators discussed in this report tell us that a given researcher or paper has attracted the attention of a significant part of the community. They cannot tell us whether such attention was correct or misplaced, the results of robust analysis or a fad. And they obviously tell us nothing about the intrinsic value of the rest of research.

There is no perspective from Sirius, which would enable us to see whether prizes or citations are correctly attributed.

Classical social theory of science highlights the metaphor of the science community as a gigantic forum to direct attention. The scientific system essentially acts as a huge machine for internally filtering out interesting from less interesting endeavours: "the institution of science has developed an elaborate system for allocating rewards to those who variously lived up to its norms" (Merton 1973, 297), or more bluntly: "Academics publish their work in exchange for scientific recognition" (Kwiek 2018). The point is not that this filtering machine is never wrong, but rather that there is no alternative standpoint to judge how well it fulfills its mission[4].

Gaming indicators

Defining indicators gives individuals an incentive to game these indicators. This principle is known as Goodhart's law - "Any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes" (Goodhart 1984) - or Campbell's law - "The more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social processes it is intended to monitor." (D. T. Campbell 1976).

It is particularly true of bibliometric indicators and has been used to describe the perverse impact that monitoring can have on research for over 20 years (Strathern 1997; Fire and Guestrin 2019).

The gaming of indicators is usually linked to individual or institutional behaviour but it can have a visible impact at a country level. Bacchini et al. thus study how:

> *the Italian scientific community responded, at the national level, to the introduction of a research evaluation system, in which bibliometric indicators play a crucial role. Our results show that the behavior of Italian researchers has indeed changed after the introduction of the evaluation system following the 2010 university reform. Such a change is visible at a national scale in most of the scientific fields. The comparative analysis of the inwardness indicator showed that Italian research grew in insularity in the years after the adoption of the new rules of evaluation* (2019).

The following graph shows how Italian researchers increased the number of citations amongst themselves to boost their citation scores from 2010 onwards (Italy in red).

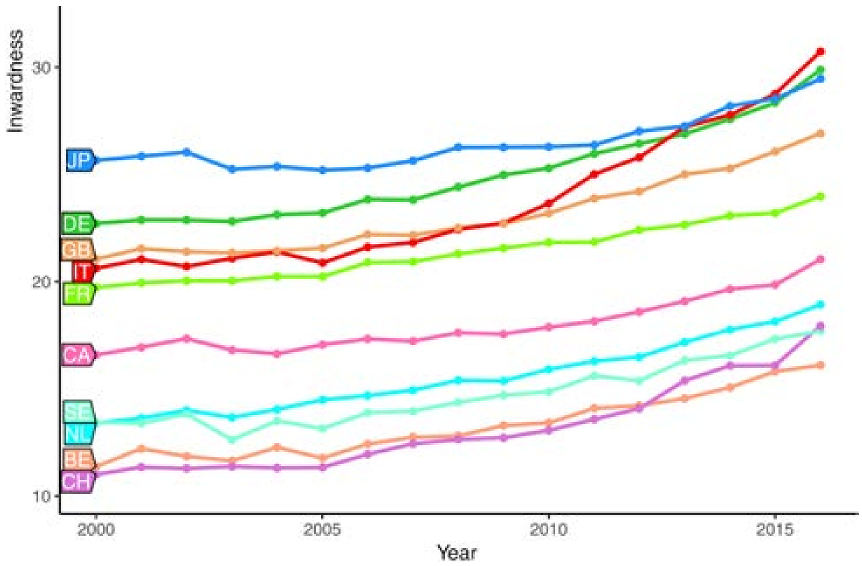

Fig. 3: Inwardness for G10 countries, 2000-2016; US removed from graph (reproduced from Baccini et al. (2019), SciVal data)

[4] The scientific system continuously rediscovers forgotten research articles and reassesses their value, but this is part of the way the machine works, it does not provide an external perspective.

Overall, we nonetheless think that our methodology is sufficiently robust to warrant the use of the term "research performance" for three reasons. First, because, despite gaming, there is a "general consensus on the notion that the scientific output can be measured by examining the distributions of the count of publications (volume) and of the citations received (impact)" (Bonaccorsi, Cicero, et al. 2017); secondly because we balance classical generic indicators (such as total country production) with narrow-focus, specialised indicators (such as those used by the Global Research Benchmarking System); thirdly, and most importantly, because the results we find are surprisingly consistent and coherent, across all indicators[5].

Science as a deeply skewed game

Lotka's law, or the inverse square law of productivity, states that the number of scientists producing n papers is $1/n^2$ of those producing one paper.[6]

Science is a skewed game[7] in which individual performance follows a power law distribution whereby a small minority of researchers produce the majority of articles and receive the most citations. Research in the field clearly proves that:

- this has always been true[8];
- it is true whatever the nature of the research system[9];
- it is true not only of individual scholars but also of institutions and countries[10].

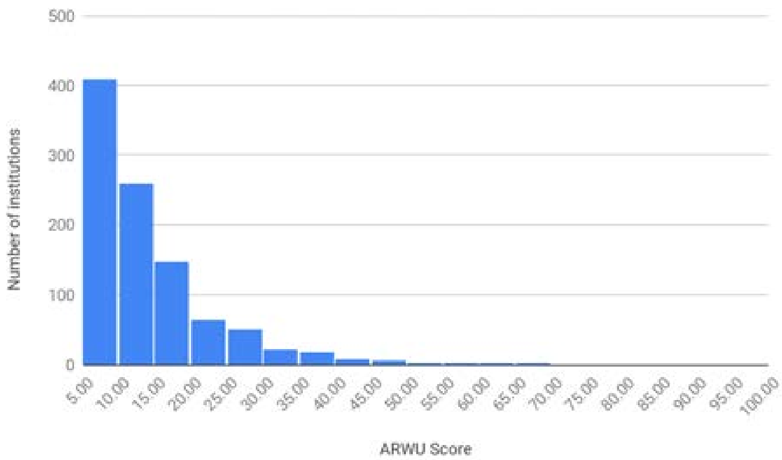

Fig. 4: Histogram of ARWU Scores (data source: ARWU 2019)

[5] Gaming as described by (*Baccini et al. 2019)* results in above-expected performance on an indicator (i.e. number of citations) but this usually has an impact on another indicator (i.e. inwardness of citations).

[6] Kwiek (2018). Lotka was the first to study the distribution of scientific production (Lotka 1926).

[7] For a recent discussion, see Kwiek (2018). See also Crane (1965) and O'Boyle and Aguinis (2012); Bauwens et al. (2008).

[8] The Ortega hypothesis is sometimes presented as an opposing theory because it argues that it is the large mass of modest, narrowly specialised scientific contributions that enable breakthroughs. This is an important point to acknowledge, however it simply means that the 1% would not exist without the 99%, it does not diminish the importance of the 1%. (Cole and Cole 1972).

[9] Even in internally uncompetitive and vertically undifferentiated higher education systems such as Poland, in which top researchers are scattered across the whole system. See Kwiek (2018).

[10] The distribution of HiCi per country also follows a power law as we show later in this document.

The previous graph illustrates the power law distribution applied to the Shanghai rankings. Harvard (rank 1, 100 points) and Stanford (rank 2, 75 points) are separated by 25 points, as are Stanford and Cornell (rank 13, 50 points), and Cornell and University of Utah (rank 110, 25 points). After that follows a long tail of 890 institutions scoring within the lowest quarter.

A likely explanation for this is the preponderant importance of breakthroughs, which helps explain why global science organises itself into highly concentrated nodes capable of disruptive, and not only incremental, progress (Rodríguez-Navarro and Brito 2019).

Science is thus, by construction, a highly competitive, "star-system" game, with a strong cumulative advantage effect. "Elitism" is not an option in this game - it is intrinsic to the game in the same way as it is for both competitive endeavors such as professional sports or performance arts such as acting. An excellent researcher does not only have a greater impact than an average researcher, she has a greater impact than x average researchers - and, in certain cases, x can represent dozens or hundreds of researchers.

As a result, science can be analysed as a social network, which answers the general rules of behaviours of social networks, and in particular the disproportionate role played by powerful hubs. Being performant in research supposes not only to be intrinsically good but also to be connected to the rest of the network in an efficient way: interesting science needs to be noticed in order to become effectively relevant.

This means that effects tend to be massively cumulative, leading to a strong "Matthew effect", whereby the way papers are cited, researchers connected and institutions perceived is linked to reputation as much as intrinsic quality:

> *[The] complex pattern of the misallocation of credit for scientific work must quite evidently be described as "the Matthew effect," for, as will be remembered, the Gospel According to St. Matthew puts it this way: For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath. Put in less stately language, the Matthew effect consists of the accruing of greater increments of recognition for particular scientific contributions to scientists of considerable repute and the withholding of such recognition from scientists who have not yet made their mark. (Merton 1968, 159)*

This in turn has major consequences in terms of research policy both at the country level and the institutional level.

The golden age of Research

As a sector, Research and Development is remarkably recent[11]. The first attempts to measure how much money is invested in research date to the late 1930s when J. D. Bernal's "budget of science" attempted to calculate how much money was being spent on science by combining government data, industrial data and university grants committee reports (Bernal 1939). His conclusion was that the UK spent 0,1% of their GDP on R&D in 1934 and he added that: "The scale of expenditure is probably less than one-tenth of what would be reasonable and desirable in a civilised country."

[11] For a detailed description, see Godin (2003).

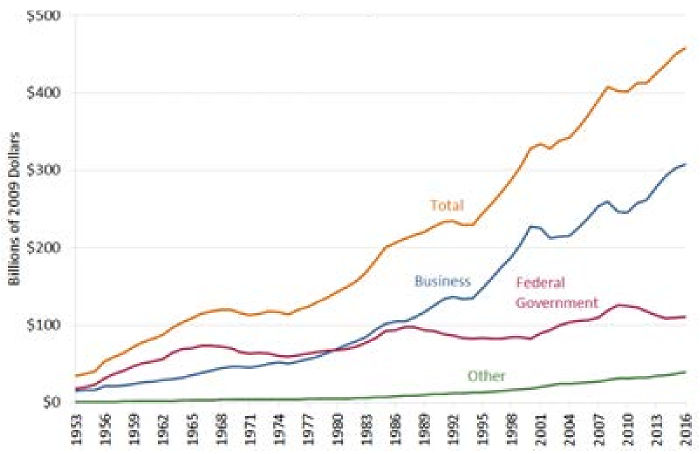

Fig. 5: R&D spending in the US since 1953 in 2009 US$ (reproduced from Santacreu and Zhu (2018))

R&D spending truly takes off with the Manhattan project to build the atomic bomb. At a governmental level, its importance is enshrined in policy with the publication of Vannevar Bush's report to the US President Truman: *Science, The Endless Frontier (1945)*[12], which argued for a massive increase in public funding of basic research. The allied victory in the Second World War, the beginning of the Cold War and increasing globalisation and competition in a number of industrial sectors lead to a true explosion in spending from the 1950s onwards.

The increase in spending on R&D is forecast to continue over the next 30 years and, potentially, to accelerate.

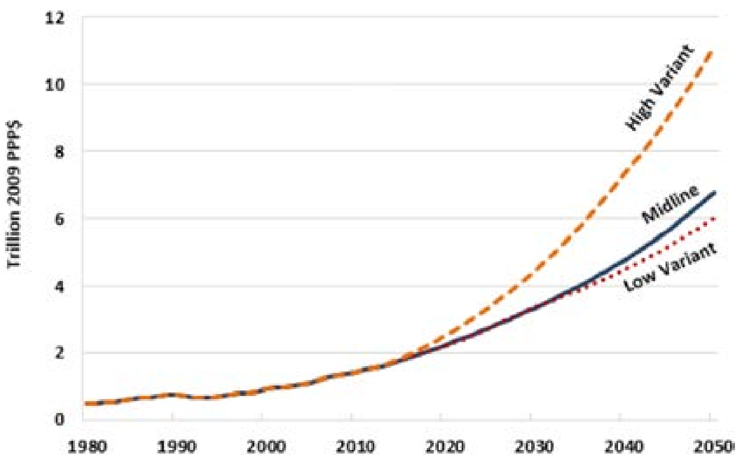

Fig. 6: increase in R&D spending with forecasts (reproduced from Dehmer et al. (2019))

This acceleration in R&D spending is happening simultaneously to a shift in the global R&D landscape. This shift is marked by the remarkable emergence of China (which will become the biggest contributor to R&D spending within a couple of years) and will continue in the coming years when countries such as India take off.

[12] https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm

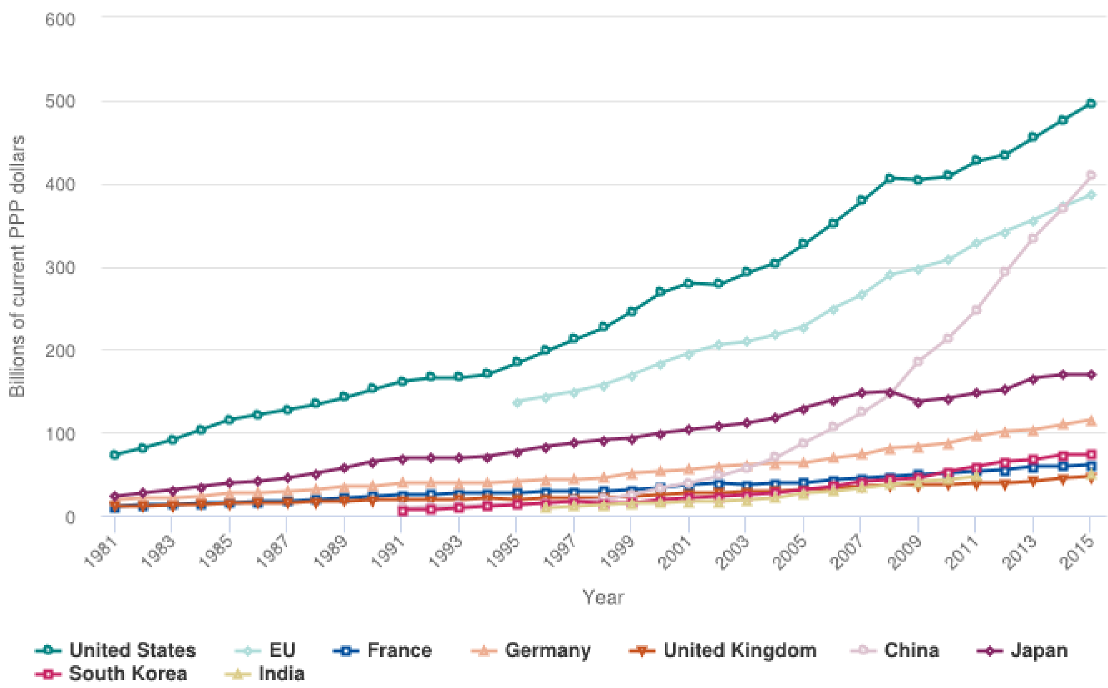

Fig. 7: Spending in R&D and GERD (reproduced from (National Science Board, NSF 2019)

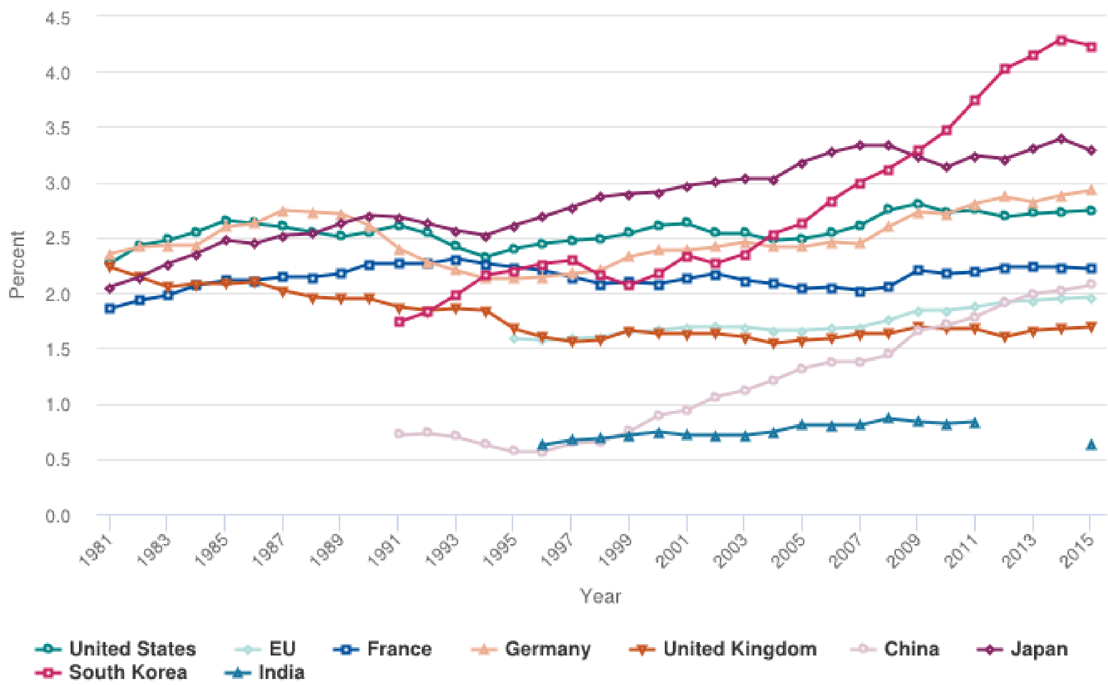

Fig. 8: Spending in R&D and GERD as share of GDP (reproduced from (National Science Board, NSF 2019)

These trends mark the ongoing shift towards a knowledge economy. They are exhilarating from the perspective of research *per se* but pose numerous questions from a national public policy perspective. They define the context of this study.

Globalisation and research performance

> *To achieve sustainable global competitiveness, the EU has no choice but to become a vibrant knowledge economy. Innovation and research policies are central to this*. (European Commission 2006)

Globalisation in the Higher Education and Research sector is nothing new.

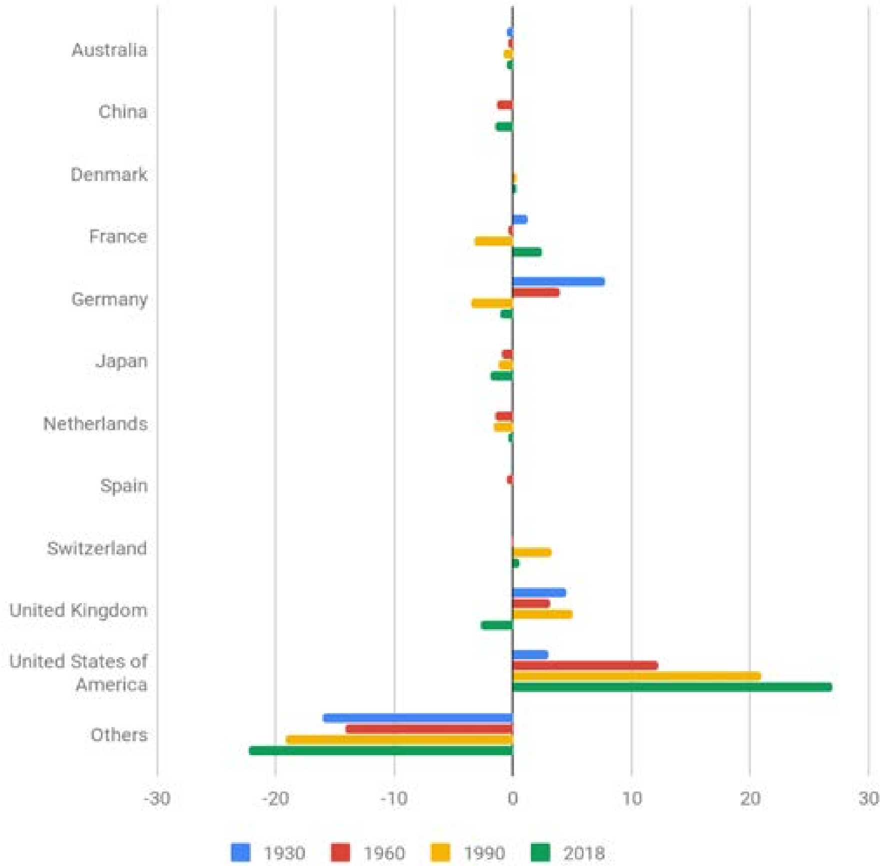

Fig. 9: Net gain/loss of Nobel prizes based on the cumulative shares of the previous 30 years (data source: nobelprize.org)

As the previous chart shows, up until the 1930s, Germany was able to attract scholars, who would be awarded Nobel Prizes,[13] whereas since the Second World War, the only country with that capacity has been the US.[14]

Nonetheless, over the last 30 years, the globalisation of higher education and research has accelerated rapidly[15] with increasing competition for the best scholars and PhD students.

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[13] The chart depicts the difference between the prize shares per organisation country and birth country of the laureates. Most of the times the Prize is shared, so that we deal in fractions of Prizes. E.g. Chemistry in 2017 was shared between Jacques Dubochet (⅓ of the prize, birth country Switzerland, organisation country Switzerland), Joachim Frank (⅓ of the prize, birth country Germany, organisation country USA), Richard Henderson (⅓ of the prize, birth country Scotland, organisation country USA) – Chemistry 2017 thus counts 0 for Switzerland, -0.33 for each Germany and Scotland and 0.66 for the USA.

[14] The total number of Nobel Prizes is small, so minor positive or negative changes are statistically not significant (e.g. France or UK from the 90s to the 2010s).

[15] Waltman et al. (2011) have, for example, shown that the average collaboration distance per publication increased from 334 km in 1980 to 1553 km in 2009.

A good (and controversial) illustration of this is shown on the following map:

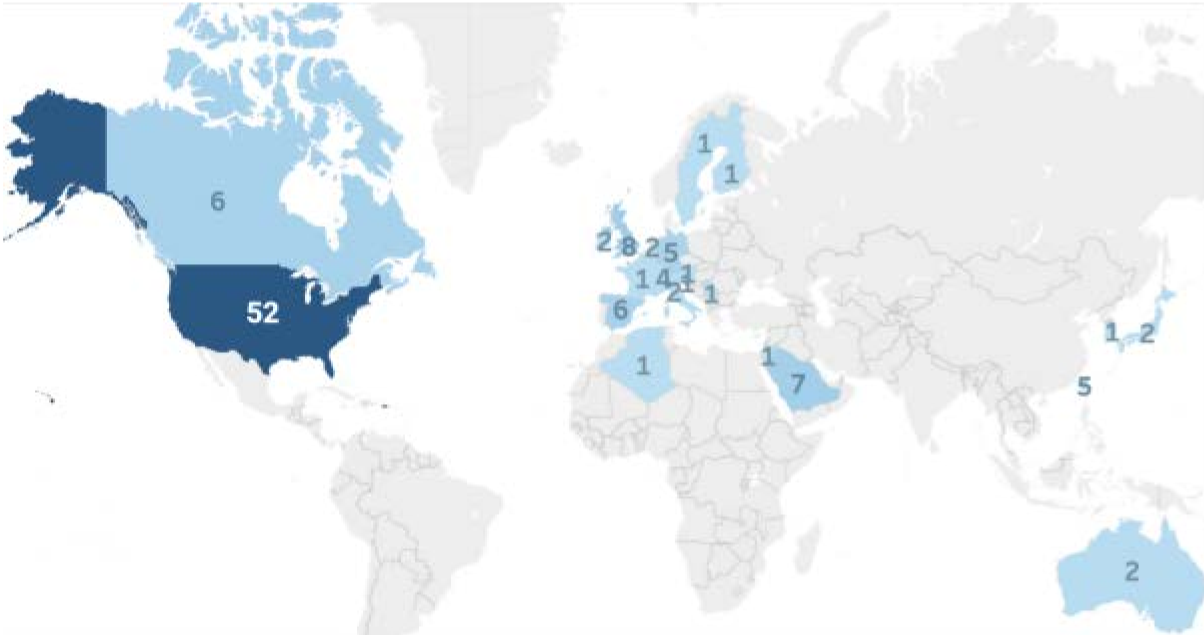

Fig. 10: Affiliations to King Abdulaziz University among Highly Cited Researchers, 2014 (data source: https://hcr.clarivate.com)

In 2014, over 120 Highly Cited Researchers (HCR) accepted a job contract from King Abdulaziz University as part-time researchers and added it as secondary affiliation on their HCR profiles. This was a (quite effective) attempt to "game" a key indicator of the Shanghai ranking (Academic Ranking of World Universities, ARWU). The researchers in question, all world leaders in their fields, defended themselves by arguing that this is "just capitalism" and "no different from Harvard hiring a prominent researcher"[16]

Beyond questionable individual institutional initiatives such as that launched by KAU, the

[16] Until 2014, ARWU took into account secondary affiliations in the Highly Cited list in their HiCi indicator. In that year, 8 HCR included KAU as primary affiliation and 123 as secondary affiliation. In 2015, due to increasing occurrences of this, ARWU decided to stop including secondary affiliations in their HiCi indicator. As a result, in 2013, 27 HCR were registered as primarily affiliated to KAU, and 43 as secondary. KAU changed their policy to make it more attractive for HCR to resign from their current positions and accept a primary affiliation to KAU, whilst decreasing the size of their offer to scholars who took a secondary affiliation. The result is clearly visible: in 2015, some scholars switched to KAU as their primary affiliation, some retained their KAU secondary affiliation and half stopped referring to KAU. (Bornmann and Bauer 2015; Bhattacharjee 2011)

For a detailed understanding of how this works and some of the consequences it is worth reading the contracts proposed by KAU (http://kamounlab.dreamhosters.com/pdfs/KAU_contract.pdf) and the mail exchange between J. A. Eisein (a HCR professor at UC Davis) and a researcher at KAU (https://phylogenomics.blogspot.com.es/2014/12/some-notes-on-citations-for-sale-about.html) (both acc. 01/10/2019). Reading this exchange and seeing the number of researchers contacted who accepted to sign a contract based on exactly this type of exchange, makes one both realise the depth of the problem and the fact that competition and globalisation in the Higher Education sector are here to stay.

See also the blog post of Lior Pachter on KAU's results in the USNWR ranking of Mathematics: KAU was ranked 7th in the world, thanks to employing as adjunct faculty more than a quarter of the world's HCRs in mathematics (!): https://liorpachter.wordpress.com/2014/10/31/to-some-a-citation-is-worth-3-per-year/ (acc. 01/10/2019).

We previously published a detailed analysis of such gaming attempts (SIRIS Academic 2016b).

increase in competition has led countries worldwide to reform their legal systems and to launch excellence initiatives with one shared goal: produce world-class research that enables innovation (and hopefully the creation of the next Apple or Google).

France is not an exception. The French research system has been undergoing a systemic process of change, with a succession of new laws[17], the creation of a national funding agency in 2005 (ANR), a national evaluation agency in 2006 (AERES, later replaced by Hcéres), new university systems in 2007 (PRES followed by ComUE), the launch of a national investment programme of 57 Billion Euros from 2009 onwards with the explicit aim of boosting French R&D[18] and a series of ongoing mergers and institutional reforms.

Can a highly performing research system be compatible with greater social equity?

This whole document is written from a very one-sided point of view: that of optimising a system to produce "highly-performant research", measured by citations, prestigious awards and highly cited researchers. This objective is, however, only one among the various goals that a research and higher education system should be aiming for. It does not justify an "all-in" approach in favour of vertical segmentation of the Higher Education and Research system as a whole. Indeed, it could legitimately be argued that if better performance comes at the price of social equity, then it should not be pursued.

The main difficulty can be expressed as follows:

- it is true that science is skewed and that all scientific production is not of equal value. It is also undeniable that national research systems are faced with growing global competition and that this is reinforcing the value of the top 1% of research. "High level" research (getting citations, awards and generally speaking peer-recognition) is a competitive, zero-sum game: if someone else goes faster or is better, then you lose;

- but developing socially relevant knowledge, producing research with a strong local impact and educating students are all crucial objectives of higher education and research systems which are blatantly not zero-sum games. Those are typically endeavours where the results are not relevant only in comparison, but very much intrinsically: educating a student is an achievement in itself, whether or not you are trying to compare yourself to others. In this case, relative comparison matters only in so far as they can give you good ideas but they don't define your success, Matthew

[17] Loi de programme pour la recherche in 2006, loi relative aux libertés et responsabilités des universités in 2007, loi relative à l'enseignement supérieur et à la recherche in 2013 and the ordonnance 2018-1131 in 2018.

[18] It is too early to judge the success of these initiatives. Jalmi Salmi thus writes: "Measuring the effectiveness and impact of excellence initiatives on the beneficiary universities is not an easy task for at least two reasons: time and attribution. First, upgrading a university takes many years, eight to ten at the very minimum. Since many excellence initiatives are fairly recent, attempts at measuring success could be premature. It is indeed unlikely that the scientific production of beneficiary universities would increase significantly within the first few years of an excellence initiative. A thorough analysis would therefore require looking at a reasonably large sample of institutions for comparison purposes, either within a given country or across countries, over many years. The second challenge is related to attribution. Even if a correlation could be established from a large sample of institutions, it would be difficult to demonstrate that the excellence initiatives actually caused the observed change". *(Salmi 2016).*

effects don't hold, and noone should actually care whether they are at the center or of the margins of the networks. In a nutshell, top researchers are top athletes, but sports is not limited to the Olympics (indeed, the number of olympic gold medalists is well correlated with the strength of local sports clubs);

- Research and higher education systems must therefore somehow decide how to balance both aims: playing the competitive zero-sum game of attracting peer recognition, and providing intrinsic value to citizens and societies where they are and independently of any comparison.

The arguments that will be presented in this report therefore depend on a conditional sentence: *if* your aim is to perform in the zero-sum game of prestigious research, *then* certain rules apply - such as concentration of resources, vertical segmentation, a certain kind of incentive system, specific flavors of "autonomy + accountability" governance, a minimal capacity at playing the mercato to attract talented individuals, etc.

However, the conclusions must necessarily be balanced with the other aims that the higher education and research system as a whole is pursuing.

This is fundamental because the literature also shows that vertically-segmented and highly concentrated research systems can produce strong adverse effects in other areas, such as:

- a limitation of the diversity of talents, because the underlying Matthew effects mean that small initial differences of talent can have massive effects in terms of future outcome and citations;
- an increasing stratification of access to higher education: "The realization that *it may not be so easy to divorce stratification in research outcomes from social stratification of the student body* has come at a time where general concern about inequality has been reaching peaks not seen since before the Second World War. If there were solid and durable economic growth, one might be able to argue that some social stratification was a price to pay for a rising tide lifting all boats; the problem is that this argument hasn't held water for over a decade". (Usher 2019a)

Increasing stratification of the research system can thus lead to other kinds of stratification which are much less acceptable from the point of view of the overall system. Luckily, as we will show in this report, this does not necessarily have to happen.

Indeed, although A. Usher highlights the potentially negative effect of completely Malthusian research universities, he also underlines the importance of distinguishing between research- and education-focused institutions. This seems to be a major factor in the capacity of a higher education and research system to both produce visible research and to care for the needs of education:

> *One of the most striking conclusions from some recent work we at HESA have done on parents' views of higher ed is how many parents believe "all Canadian universities are reasonably good". It's not that they don't see variations in quality, or believe that some institutions might be better than others for their kids: it's just they don't see the gaps in quality as being very large. There are very few other countries where this is true. New Zealand, maybe. The Netherlands. Germany. After that, forget it: high stratification of prestige is the norm in the world. But not here. Broad access, strong community colleges and polytechnics, and a university system where excellence is not confined to a tiny*

> *elite. It's not a complete recipe for success, but it's a good start, and one we should acknowledge more publicly*. (Usher 2018)

As we will see in Part I of this report there is a big difference in terms of research performance between higher education systems. But, surprisingly, this difference in performance is not correlated with the degree of stratification of the respective higher education systems.

Germany and the Netherlands both have relatively open and equal higher education systems, yet the German research system underperforms whereas the Netherlands has one of the world's highest performing research systems. On the contrary, France and the UK have highly stratified higher education systems, yet France underperforms whereas the UK is a high performer in research.

By showing that very different national systems can be equally excellent in terms of performance, we are thus able to answer the initial question positively: a highly performing research system can be compatible with greater social equity.

In other words, the Anglo-Saxon model is not the only destination.

Part 1. Contextualising French research performance

The first part of this report provides a broad overview, comparing French research output with that of a set of ten benchmark countries: Australia, China, Denmark, Germany, Japan, Netherlands, Spain, Switzerland, UK and US.

It takes into account macro level data such as total production, total number of citations and university rankings, as well as more detailed data from a wide range of bibliometric and other performance indicators, both globally and for specific fields.

The combination of different perspectives and indicators increases the robustness of overall conclusions. These paint a surprisingly coherent picture, which shows that the French and German research systems are less competitive, not only than the UK or the US but also, more importantly, than that of European countries such as Denmark, the Netherlands or Switzerland.

Taken together this data confirms that the “European Paradox” (good European research versus poor innovation) is not sustained by facts and that the “Transatlantic gap” (poor European research and poor innovation) is not a useful paradigm either.

The problem is clearly intra-European and more precisely Franco-German.

Global performance indicators

Our first set of data compares the benchmark countries according to two classical performance indicators: (a) share of production and citations and (b) research focused university rankings. It enables us to clearly distinguish three types of countries: high performing, emerging and low performing.

Within continental Europe, the data clearly distinguishes:

- Denmark, the Netherlands and Switzerland, which are not only highly performing but are continuing to improve their performance;
- Spain, which has low performances but is catching up;
- France and Germany, whose performance is both low and declining.

The performance of France and Germany is worse in the case of more selective indicators (top 50% is better than top 10%; ranking in top 500 is better than ranking in top 100) and their decline is true not only when compared to emerging countries such as Spain but also when compared to high-performing countries.

Globally, the overall picture is similar:

- countries such as Australia (to which one could add Canada or Singapore) are performing similarly to leading European countries such as Denmark;
- a large and increasing number of countries are on a similar trend to Spain; amongst these, China is a case apart and should now be considered as a global powerhouse with a research potential, which will soon be comparable to the US;
- Japan is performing even worse than France and Germany, with truly dramatic drops in both production and citation share;

Finally, although the US and the UK still dominate on size-dependent criteria such as total production and total citations, their overall performance is declining and they are below high-performing countries according to most size-independent criteria.

This overall picture shows that the decline of the French research system is not only linked to the emergence of new actors such as China or to a so-called “Transatlantic Gap” between Europe and the US, but to a growing gap with high-performing European countries.

Total share of publications and citations

The share of research production of traditional powerhouses is diminishing proportionally with the rise of emerging research centres, chief of which is, by far, China (the other example from our benchmark is Spain). The share of citations follows a similar trend, but with a marked delay in time. Both the UK and especially the US are surprisingly vulnerable, with the share of US production diminishing faster than that of any other country.

Surprisingly, when correlated by number of researchers, countries such as Denmark, the Netherlands and Switzerland (or Australia) perform better than the UK or the US and much better than France and Germany (or Japan).

Even more surprisingly, these high-performing countries are actually increasing their advantage on all key indicators when compared to low performing countries.

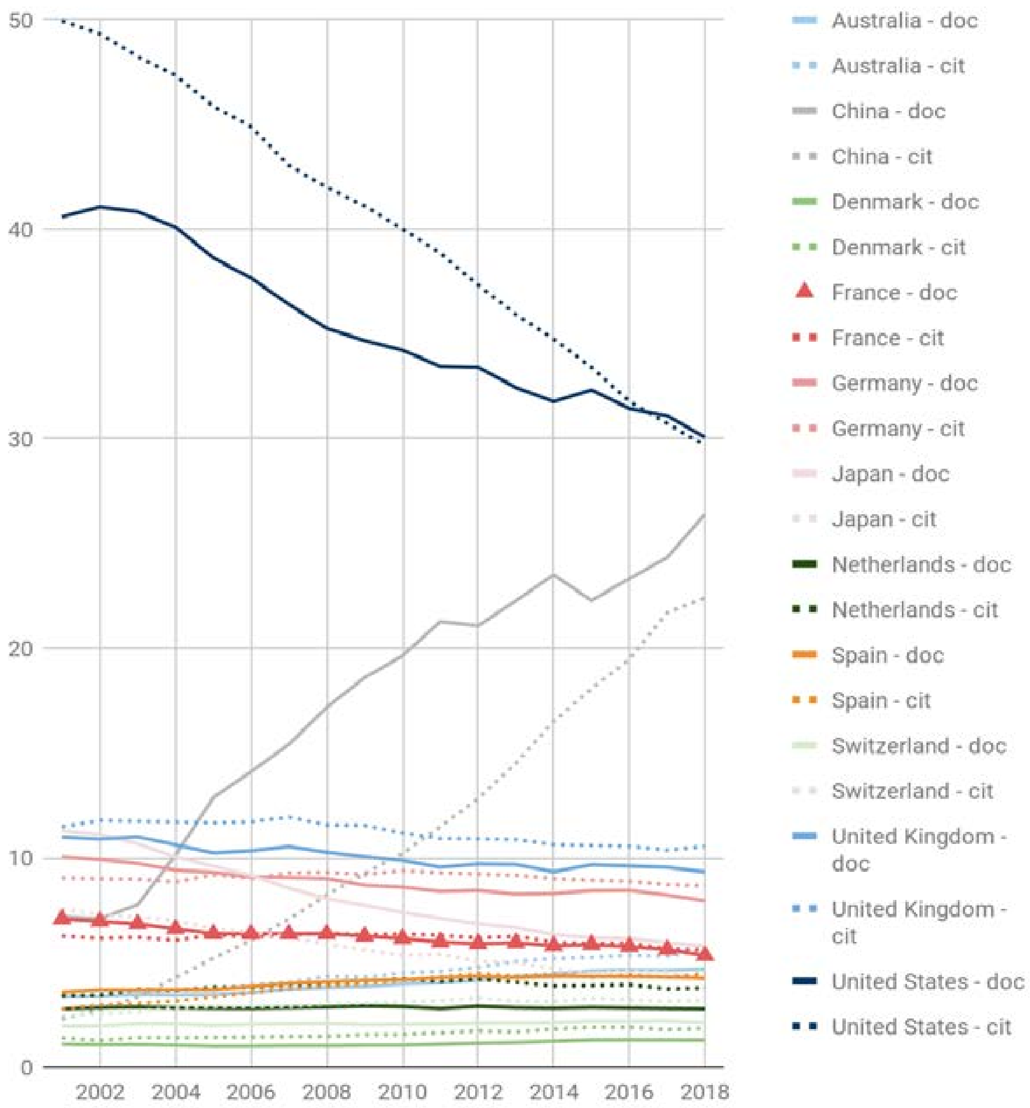

Fig. 11: Share of documents and citations - World Total
(data source: Scimago Country Ranking 2018)

The first graph tells a very simple story: whereas in 2001, the US dominated world research with over 40% of total production and over 50% of total citations, today this is no longer the case. China has massively increased its share not only of publications but also citations and looks likely to become the leading scientific producer within 2 years and the leading country for citations within 5, whereas the share of the US is now under one third in terms of both production and citations.

This story repeats itself with traditional powerhouses such as the UK, Germany, Japan or France also losing share whilst emerging scientific centres all increase it. Typically, this increase initially concerns only production (this is currently the case for India for example), before citations in turn start increasing (as in South Korea or Singapore).

Beyond this general trend, there are interesting differences between countries as shown when looking at the magnitude of change in share of production and citations.

Country	Evolution in share of Documents	Evolution in share of Citations
Australia	+38.19%	+66.81%
China	+267.27%	+878.91%
Denmark	+18.02%	+31.63%
France	**-24.74%**	**-10.49%**
Germany	-20.82%	-4.21%
Japan	-48.86%	-43.90%
Netherlands	+0.11%	+10.77%
Spain	+18.19%	+61.12%
Switzerland	+8.71%	+28.60%
United Kingdom	-15.09%	-8.16%
United States	-25.90%	-40.59%

Fig. 12: Evolution in share of documents and citations (data source: Scimago Country ranking 2001-2018)

The differences between individual countries within Europe is surprising:

- The increase in total share of Spain is clearly mainly due to the low starting point in 2001, when the Spanish research system was just beginning to become competitive.
- Much more impressive is the fact that countries such as Denmark, Switzerland and the Netherlands have all succeeded in increasing market share in both production and, especially, citations.
- On the contrary, France, Germany and the UK have lost market share, with France being the worst performer in terms of both production and citations in Europe.

One apparently positive trend for France is the fact that market share of citations overtook market share of production between 2006 and 2008. This is mostly due to two factors: the large increase in market share of countries like China, whose share of citations is increasing faster than that of production but with a lag of a few years, and the surprisingly strong drop in US performance, which is harder to explain but may be linked to a “return to the norm” whereby the central nodes are more widely distributed globally and US researchers not necessarily better connected to them[19].

When measured in terms of production and citations per researcher, the picture changes quite dramatically. Switzerland stands out in both production and citation. In number of citations per researcher, it is followed by the Netherlands, the UK, Australia, Denmark, the US and Spain (in production the order is slightly different but similar).

[19] Our hypothesis is that the production of mid ranked US researchers is being cited less than previously because they no longer benefit from such a strong US premium or from privileged access to high impact journals. Thus, 8 out of the top 10 universities in the Shanghai rankings are from the US, but since 2005 the US has lost 32 universities in the top 500 (from 168 to 132).

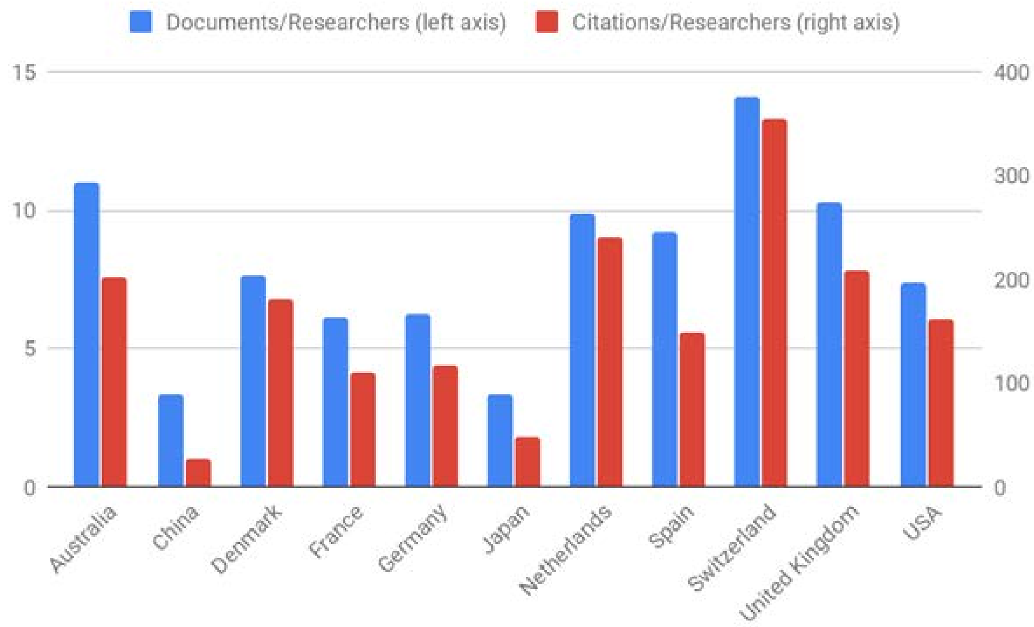

Fig. 13: Documents/Researchers and Citations/Researchers (data source: Scimago Country Ranking 2018; UNESCO STI indicators)

Both France and Germany perform clearly less well (especially in terms of citations). They remain ahead of Japan and China but well below all other benchmark countries.

International university rankings

University rankings confirm the picture provided by country-level production and citation numbers: overall there are fewer universities per researcher in France and Germany than in Denmark, the Netherlands and Switzerland in both the top 500 and the top 100 lists.

France and Germany, like emerging scientific hubs such as China and Spain, perform far better in the top 500 than in the top 100, whereas the reverse is true of the UK and the US.

The picture is true whatever the indicator but it is particularly stark for more selective indicators. Thus, the list of top 100 universities on CWTS Leiden PP Top10% indicator is dominated by Switzerland, the UK, the Netherlands and the US, whereas most other countries are completely absent.

Although international university rankings are said to measure the performance of the higher education as a whole, in practice, many of them exclusively measure research performance[20]. This is particularly true of ARWU, which explicitly states that it only measures research performance[21] and CWTS Leiden, which exclusively uses bibliometric indicators.

[20] QS and THE include criteria not directly related to research performance such as reputational surveys, which is why we do not refer to them in this report.

[21] ARWU focuses on research performance because : “If one wants to construct a reliable ranking of the world’s universities, the only possible ranking will be a comparative display of research performance”. (Liu and Cheng 2005)

Although most rankings (ARWU included) do not take into account national research organisations (NRO), they include the production of NRO researchers affiliated with joint research laboratories, who correctly sign their scientific papers.

They also have a growing impact on the research performance of countries because (a) policy makers explicitly use them when taking decisions[22]; (b) they are increasingly used by leading young scholars when choosing to accept a position or not[23]; (c) they enable comparisons and therefore encourage the concentration of excellence in top performing countries and institutions.

ARWU rankings

The disappointing performance of French institutions in the Shanghai rankings were one of the reasons for which France launched the *Programme d'Investissement d'Avenir* (PIA) and more specifically the IDEX initiative in 2010.[24]

They have been used to defend the idea that France should switch to an Anglo-Saxon model, because of the impressive domination of US universities amongst the best ranked, as shown by the following two tables:

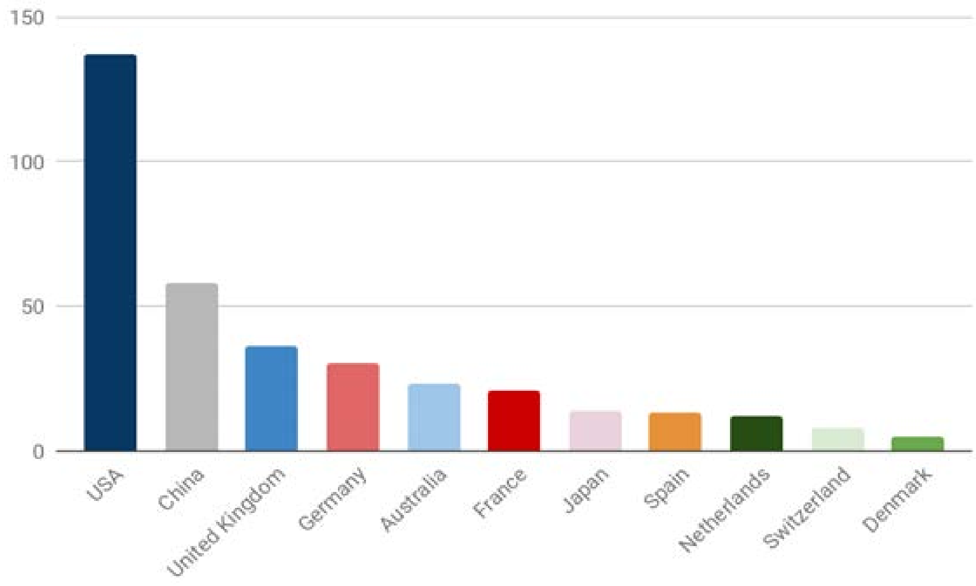

Fig. 14: ARWU Top-500 universities by country (data source: ARWU)

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[22] For example, the Indian Science and Engineering Research Board takes them into account when awarding grants to both PhD and PostDoc Indian researchers at Foreign institutions - http://www.serb.gov.in/home.php

[23] There is an extensive literature on this topic - see for example Hazelkorn et al. (2014).

[24] Juppé and Rocard cite Shanghai as a key diagnostic element for recommending massive public investment in higher education, research and innovation: "Ainsi, pour critiquables qu'ils soient, les classements et indicateurs internationaux font état de prestations médiocres: le classement de Shanghai ne place que trois universités françaises dans les cent premières (dont la première à la 40e place seulement en 2009), tandis que le classement du *Times Higher Education Supplement* considère que seuls quatre établissements français figurent parmi les deux cents meilleurs mondiaux. La part de la France dans la production mondiale de publications scientifiques (toutes disciplines confondues) est tombée de 5,4 % à 4,7 % au cours de la dernière décennie." (Juppé and Rocard 2009, 27)

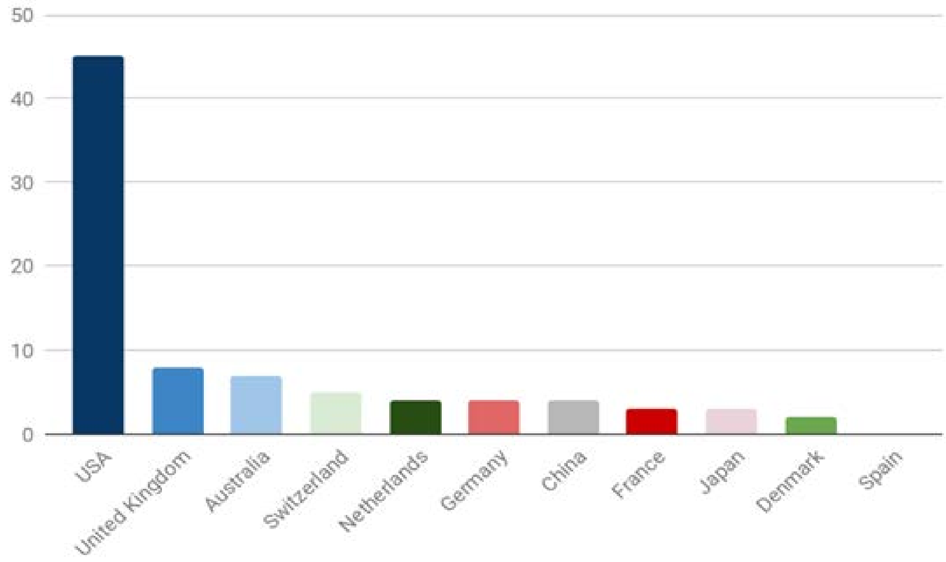

Fig. 15: ARWU Top-100 universities by country (data source: ARWU)

This domination of US universities is often taken at face-value and used to confirm the assumption that the US research system outperforms European research systems. This is, however, no longer true and when one looks at the data not in absolute terms but by number of researchers, the picture changes quite dramatically.

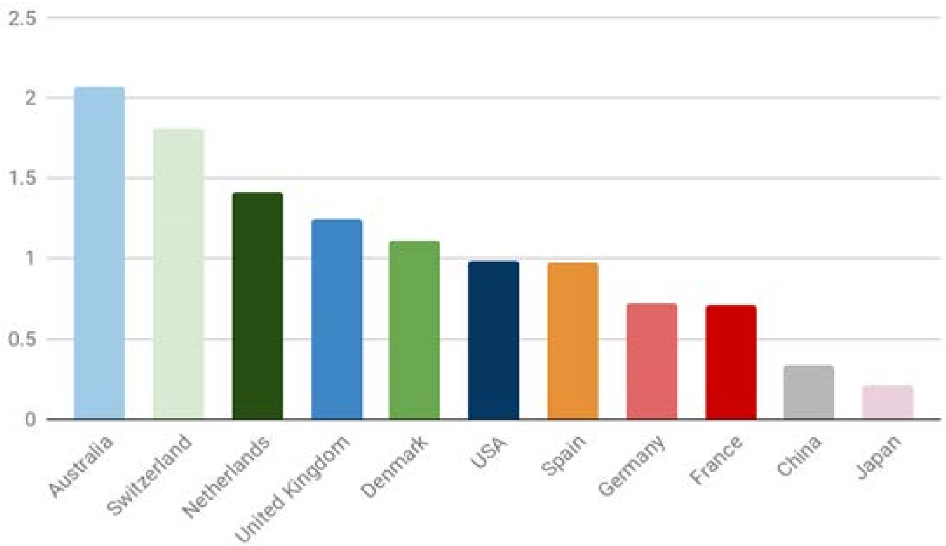

Fig. 16: ARWU Top-500 univ. per 10,000 researchers (data source: ARWU, UNESCO STI)

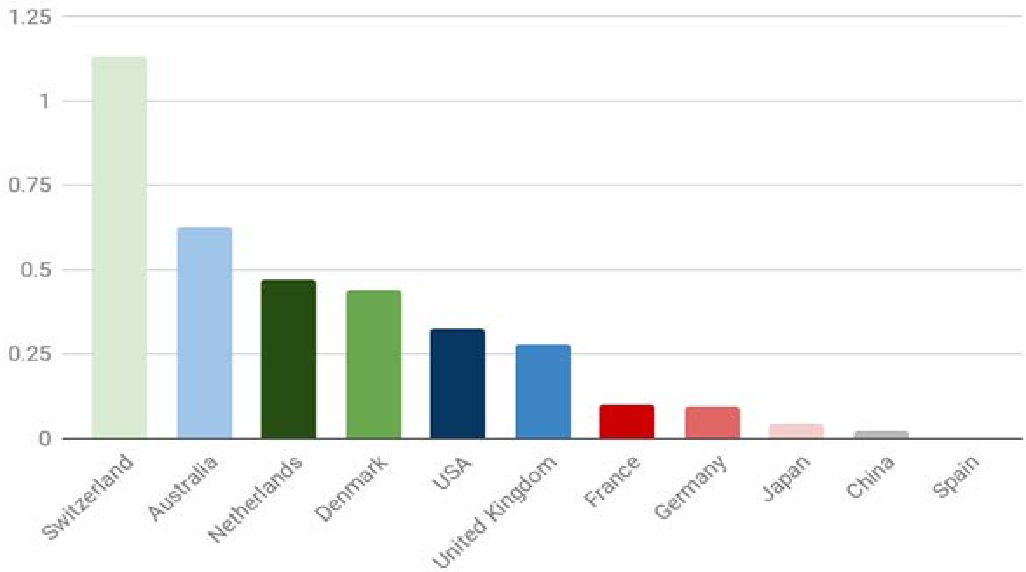

Fig. 17: ARWU Top-100 univ. per 10,000 researchers (data source: ARWU, UNESCO STI)

Both the French and the German performances are, once again, disappointing (as is the Japanese). But the most interesting story lies elsewhere: Switzerland, Australia, the Netherlands and Denmark clearly outperform both the US and the UK in number of top universities adjusted for number of researchers and this is true both in terms of top 500 and top 100 institutions.

Emerging countries are already performing well in terms of top 500 universities (with Spain in front of France for example), whereas the US and the UK continue to perform much better proportionally in the top 100 than in the top 500 when compared to France and Germany. Like in all other indicators, China is improving extremely fast[25] and will likely equal the French performance even on a size-independent criteria such as this one within a few years.

The one positive result from the perspective of the French research system is that the number of French universities in the top 500 has remained stable since the list was first published in 2003 (with only one less), whereas the US or Japan have lost respectively 22 and 12 institutions in this ranking, Germany has lost 12 and the UK 6.

CWTS Leiden PP Top 10% and PP Top 1%

ARWU is often criticised because of the weight of past performance (such as Nobel Prizes) and the weight of size-dependent criteria (such as PUB). This is why we have done the same exercise using CWTS Leiden's ranking based on the PP Top 10% and PP Top 1% indicators[26].

The following chart shows the number of universities with more than 10% / 1% of their scientific production belonging to the top 10% / 1% most cited publications in their respective fields, per 10,000 researchers. It thus simply highlights the number of universities that perform better than the world average.

[25] With an increase from 8 to 58 universities in the top 500 since 2005 and in 2019, for the first time, 4 universities in the top 100.

[26] CWTS Leiden is often misused: it is not a ranking per se, but a series of indicators. The user must select the indicator, otherwise the default view is total number of publications, which is not the most relevant indicator. CWTS Leiden's methodology is far more robust than most other citation indicators.

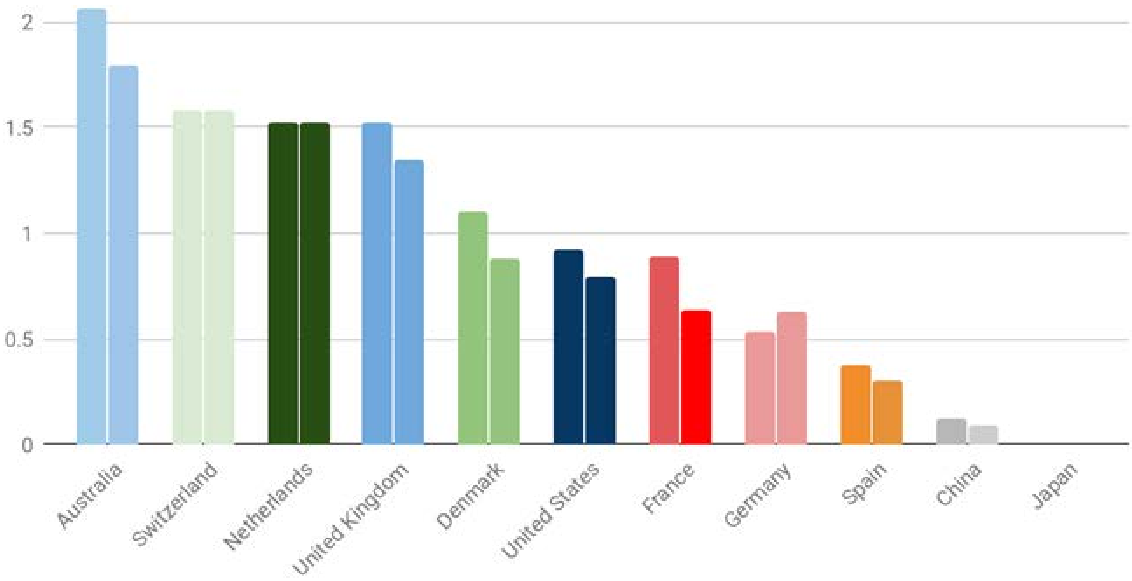

Fig. 20: N° of univ. per 10,000 researchers with 10% of production in the top 10% most cited, and with 1% within the top 1% (data source: CWTS Leiden 2013-2016, UNESCO STI Indicators)

Australia, Switzerland, the Netherlands and Denmark again outperform the US (the UK is here above Denmark) with Australia having four times more institutions as France producing top10% research per 10,000 researchers.

China is improving[27] and outperforms Japan, whose universities are all under the world average on these indicators. France and Germany perform better than on previous indicators but remain behind leading countries.

The number of universities in the top 500 per researcher according to PP Top 10% is similar:

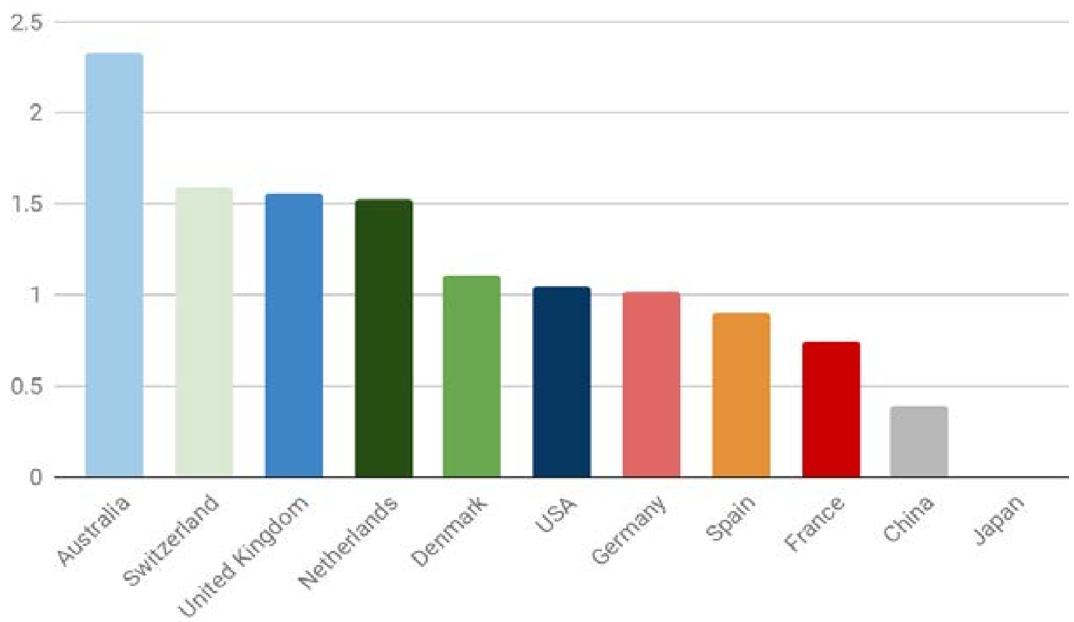

Fig. 18: CWTS Leiden Top-500 universities per 10,000 researchers (data source: CWTS Leiden, UNESCO STI indicators)

[27] With an increase from 8 to 21 universities (from 2006-2009 2013-2016 in PPTop10%), and from 9 to 16 institutions in PPTop1%.

In terms of Top 500 universities, the list is almost identical in CWTS Leiden and ARWU, with Germany performing a little better, once again the surprisingly weak performance of the US and, once again, Spain performing better than France. However, the top 500 is not particularly selective because less than 1000 institutions publish enough to be taken into consideration by CWTS Leiden.

This is why the most relevant graph is the following one, which measures the number of institutions per researcher ranked in the top 100 worldwide on the PP Top 10% criteria

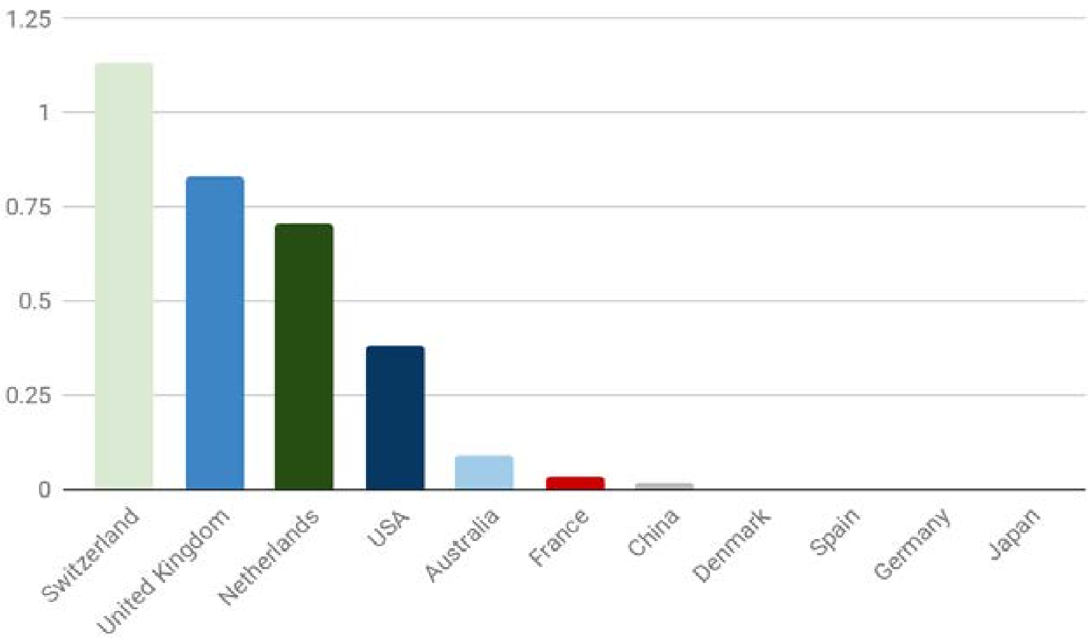

Fig. 19: CWTS Leiden Top-100 universities per 10,000 researchers (data source: CWTS Leiden, UNESCO STI indicators)

In this case, the differences between ARWU and CWTS Leiden PP Top 10% are dramatic. Whereas Switzerland and Netherlands still perform very well (better than the UK and US), most other countries disappear from the list.

Excellence indicators

Our second set of data looks in greater detail at the performance of our benchmark countries on excellence indicators. To do this, we have selected three groups of indicators:

- general bibliometric data with field-weighted citation impact, citations in PP Top1% and PP Top 10% and fine-grained performance across 251 fields;
- performance in cutting-edge fields such as biotechnology or fast evolving technological topics
- individual indicators such as highly-cited researchers and ERC awards

The fact that some indicators are very specific explains that there is a greater variation in performance from indicator to indicator. However, globally results are perfectly aligned with those from the first set of data and confirm the three groups of countries, which we defined above.

Denmark, the Netherlands and Switzerland perform very well on all indicators (with a few exceptions for Denmark). The UK and US perform better on more selective indicators. Interestingly, China performs better in cutting-edge fields than in more traditional ones.

The French performance is particularly weak in cutting-edge fields, at an institutional level (rather than a country level) and on very selective indicators. The same is true of Germany but to a lesser extent.

Bibliometry

Bibliometric data is perfectly aligned with the results from the first set of data.

In terms of basic field-weighted citation impact, Denmark, the Netherlands and Switzerland stand out, above the UK and the US. Whereas France and Germany perform above the world average but clearly below most western countries.

CWTS Leiden's PP Top10% indicator clearly shows the general downward trend of French institutions with a drop of 27 places in the median rank of the top 10 institutions from 112th to 139th since 2010. This drop is due only in part to the rise of Asian competitors (with 11 places lost, mostly to institutions from Singapore or Hong Kong) and largely to a loss of competitiveness when compared with high-performing Western countries.

Finally, a look at fine-grained indicators in 251 fields highlights both the fact that the US remains the runaway leader (the list is size-dependent), the remarkable performance of the Netherlands (basically on par with that of the UK), as well as excellent performances of Switzerland and Denmark. The French performance is particularly weak, considering that the indicator takes size into account.

Indicators based on citations are the most widely used indicators to measure research performance because they enable a quantitative measure of peer recognition. They must, nonetheless, be used with great care both because researchers continuously game them (with self-citations and citation cartels (Fister, Fister, and Perc 2016)), because citations do not necessarily privilege important articles (controversial articles often get many citations, as do state of the art reviews) and because citation practices vary widely both between and within disciplinary fields (Crespo, Li, and Ruiz-Castillo 2012).

Here we look at three different studies, first a fairly generic comparison of country performance using field-weighted citation impact, secondly an institutional level approach using CWTS Leiden's indicators and thirdly an in-depth study using a set of carefully thought out indicators to measure scientific excellence.

Field-weighted citation impact (country performance)[28]

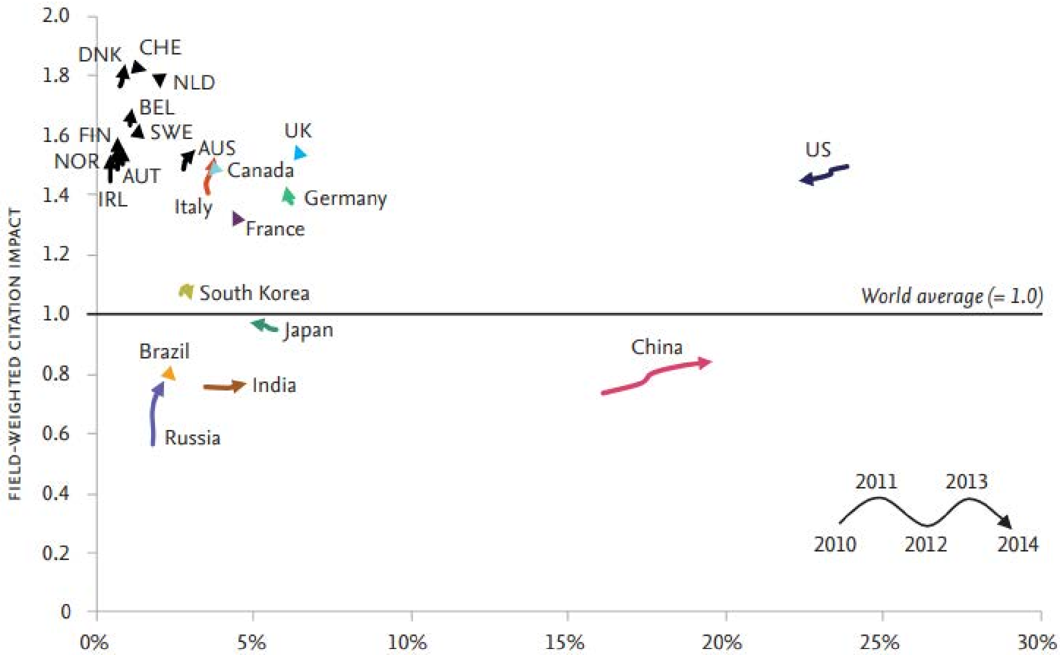

Fig. 21: Article share and field-weighted citation impact, 2010-14 (Elsevier 2016)[29]

The figure confirms previous indicators. In terms of basic field-weighted citation impact:

- three countries stand out: Denmark, the Netherlands and Switzerland;
- both the UK and the US perform well but much less well than these three countries;

[28] "Field-Weighted Citation Impact (FWCI) is an indicator of mean citation impact, and compares the actual number of citations received by a document with the expected number of citations for documents of the same document type (article, review, book, or conference proceeding), publication year, and subject area." (Purkayastha et al. 2019)
[29] The report from Elsevier 2016 explains: "The UK and comparator countries plus top ten countries with the highest field-weighted citation impact in 2014 among OECD countries with at least 5,000 publications in 2014 (including the US and China)".

- France and Germany perform above the world average but clearly below most western countries (including Italy in this case[30]).

The methodology behind this analysis is not particularly robust because Scopus uses journals to classify publications into large heterogeneous fields, which in turn feed field-weighted citation comparisons. The results are, nonetheless, meaningful because, overall, citation practices do not vary massively from country to country.

CWTS Leiden PP Top 1% and 10% (institutions)

CWTS Leiden's approach is more robust[31]. However it is institution rather than country based and does not take into account publications from non university actors or from universities with less than 1000 publications in CWTS Leiden core journals (a subset of Web of Science) over the last 4 years.

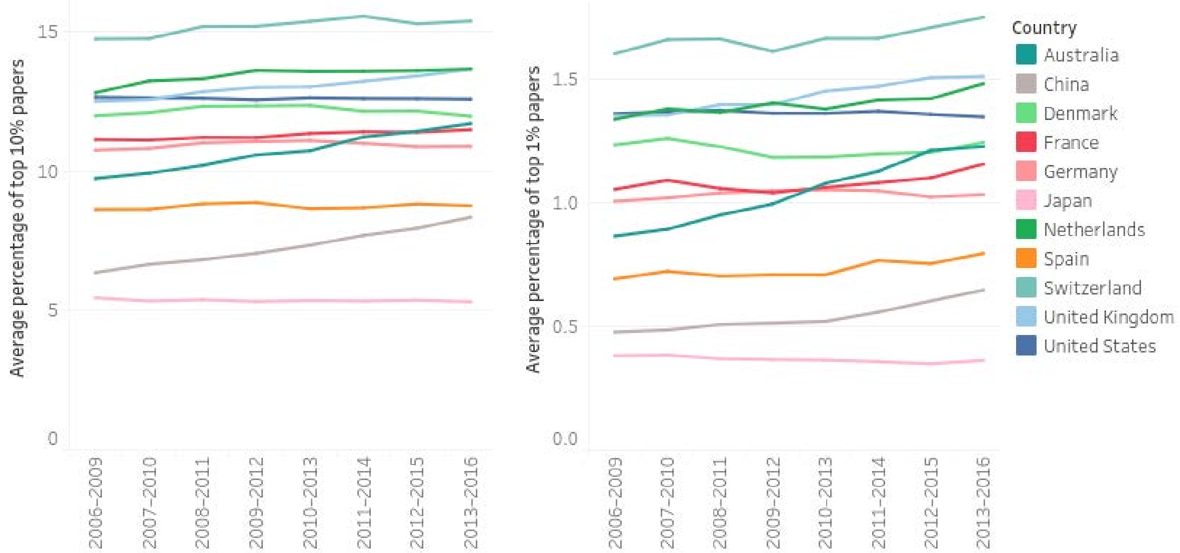

Fig. 22: Percentage of top 10% (and top 1%) most cited papers - average of institutions (data source: CWTS Leiden)

The two graphs above illustrate the evolution of the average performance of an institution in a given country[32]. They reinforce the previous analysis with Switzerland, ahead of the field by quite a distance, then the UK, Netherlands, US and Denmark, Australia, France and Germany, followed by Spain and China, with Japan as the worst performer by far within the benchmarked countries.

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[30] As indicated in the introduction to this report, this is probably due to an increase in gaming by Italian researchers, as a result of the introduction of a new national evaluation system in 2010.

[31] Unlike Scopus, which defines 35 areas and over 300 fields based on journals, CWTS Leiden defines around 4500 fields at the level of individual publications by using a text mining algorithm, which assigns each publication in Web of Science to a field based on its citation relations with other publications. https://www.leidenranking.com/information/indicators

[32] This should not be confused with country performance: the graph only includes data from institutions taken into account by CWTS Leiden and averages are calculated at an institutional level, without taking into account institutional size.

The overall evolution is also interesting[33]: the countries with the greatest, sustained increase in average percentage of both Top1% and Top 10% papers are China (31,4% and 35,9% increases) and Australia (20,3% and 42% increases). France performs relatively well in terms of improvement, alongside Spain, the UK and Switzerland, whereas Denmark and Germany are stable, the US is losing ground slightly and Japan rapidly.

Even more interesting is the progression of top ranked individual institutions, because this gives a much sharper idea of the level of competition at the very top of the global research table.

The table below shows the evolution of the percentage of publications in the top 10% and the global rank of individual French institutions according to this criteria from 2010 to 2019[34].

	2010		2019		Trend	
	Score	Rank	Score	Rank	%	Rank
ENS	16,2%	37	17,8%	19	+ **1,6%**	↑18
Paris Diderot	14,3%	70	13,6%	108	- **0,7%**	↓38
Paris Sud	12,9%	119	13,4%	119	+ **0,5%**	→0
Paris Descartes	12,6%	129	13%	136	- **0,4%**	↓7
Polytechnique	13,0%	115	12,9%	147	- **0,1%**	↓32
Sorbonne U	12,5%	133	12,8%	148	+ **0,3%**	↓15
Nice	13,2%	107	12,7%	152	- **0,5%**	↓45
Grenoble Alpes	11.9%	168	12,5%	171	+ **0,6%**	↓3
Paris-Est Créteil	12,2%	151	12,3%	183	+ **0,1%**	↓32
Toulouse 3	10.4%	294	12,0%	206	+ **1,6%**	↑88
Bordeaux	11.8%	177	12.0%	210	+ **0,2%**	↓22
Versailles SQ	13,0%	117	11.4%	257	- **0,6%**	↓140
Montpellier	12,3%	147	11.6%	244	- **0,7%**	↓97
Median performance of the top 10	**112th**		**139th**		+ **0,15%**	↓27

Fig. 23: Evolution of French performance in PP-Top10% (data source: CWTS Leiden)

The general downward trend is clear, with France losing a combined total of 336 positions since 2010 and a drop of 27 places in the median rank of the top 10 institutions from 112th to 139th.

This loss of positions is due only in small part to the rise of Asian competitors (with 11 places lost, mostly to institutions from Singapore or Hong Kong) and largely to a loss of competitiveness when compared to Western countries. The small increase in total score (+0,15%) is due to new (mostly Chinese) institutions passing the threshold to be ranked but,

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[33] Here it is important to underline that the share of Chinese publications has been increasing by almost 1% every 2 years at the global level! Since Chinese publications are currently, on average, less cited than those being published by most other countries, other countries share of citations mathematically increases every year.

[34] All institutions that were ranked in the French top 10 at some point during the last 10 years are included.

generally, with low performances - it is not an indication of an improvement in performance. This is well illustrated by A. Usher's recent comments on the performance of Canadian universities on the same indicator: "every single Canadian university has increased its share of papers in the global top-ten percent [...] for the most part the gains are on the order of 1.5 percentage points" (Usher 2019b).

In other words, every single French institution has lost on average 1,35% in total score compared to every single Canadian institution, which translates into an overall loss of 10% in terms of performance in under 10 years. This is highly significative.

A fine grained approach to bibliometric comparisons

One of the problems of the previous indicators is that they measure global performance throughout an institution or a country. By definition, they do not take into account variation in quality and overlook focused pockets of excellence, which can be crucial for taking strategic decisions in terms of research priorities (Haddawy et al. 2017).

This said, tools which enable fine-grained analysis are improving. The best-known of these are commercial solutions developed by Clarivate (InCites) and Elsevier (SciVal). Here we will use the Global Research Benchmarking System[35], developed by a consortium of institutions (using Scopus bibliometric data) and applied notably by Bonaccorsi et al (2017) to compare country performances[36]. The results are as follows:

Country	Fine-grained areas in top 10% in all indicators	Publications	Percent publications in top 25% SNIP	Citations	Percent publications in top 25% highly cited	4-year-h-index
USA	195	1601	1956	2171	2184	2612
UK	22	296	511	411	628	503
Netherlands	19	202	294	238	220	266
Switzerland	6	60	122	97	153	131
China	3	1170	134	597	166	601
Germany	1	184	182	190	294	243
Denmark	1	52	66	61	48	67
Japan	0	278	30	147	32	140
Australia	0	138	157	136	123	172
France	0	70	196	56	153	70
Spain	0	31	182	35	85	55

Fig. 24: Performance of benchmark countries (data source: Global Research Benchmarking System)

Each column lists the total number of times one of 251 fine-grained areas[37] is ranked amongst the top 10% worldwide within a university of a given country for a given indicator. The first

[35] www.researchbenchmarking.org

[36] GRBS enables a 3-level hierarchical structure of subject areas and measures performance at each level.

[37] The fine-grained areas in this table correspond to the 251 areas defined in the All Science Journals Classification of Scopus for 2011.

column is the most important: it lists the number of times that one of these labs performs in the top 10% in every one of the four indicators listed in the four columns. In other words, the table is comparing country performance at a lab level[38]. Logically, results depend on both the size of the country[39] and the excellence of the labs.

The following table focuses on the number of universities per country for two indicators: top research performance and most cited:

Country	No. of institutions with top 10% research performance across all indicators in at least one fine-grained area	No. of institutions in the top decile in the world distribution of number of citations 2007-2010 by scientific field
United States	43	80
Netherlands	7	12
China and Hong Kong	6	35+
United Kingdom	6	16
China	3	35
Switzerland	3	4
Denmark	2	3
Germany	1	16
France	0	6
Australia	0	2
Spain	0	3
Japan	0	n/a

Fig. 25: Number of institutions with top 10% research performance and number of citations (data source: Global Research Benchmarking System; (Bonaccorsi, Cicero, et al. 2017))

Unlike previous graphs, both these graphs are size-dependent. As a result, the US appears as a runaway leader, whereas China is higher up the list. This fact reinforces the truly remarkable performance of the Netherlands (basically on par with that of the UK), as well as excellent performances of Switzerland and Denmark. The French performance is particularly weak[40].

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[38] Labs typically specialise on topics, which correspond in terms of disciplinary scope (and number of researchers involved) to fine-grained areas. Of course, the correspondence is not exact.

[39] They take into account the 251 fine grained categories of all universities that perform above a certain threshold of excellence.

[40] Bonaccorsi et al. (2017) explicitly discuss the possibility that the French system of multi-affiliations causes problems with the datasets but, even if this is the case, it is unlikely that it is enough to explain the overall performances (and it is a further argument against the current French model, which promotes multi-institutional affiliation).

Cutting-edge fields

The difference in performance between high-performing countries and low-performing countries is even greater in cutting-edge fields than in mainstream fields.

For example, in the ARWU ranking for Biotechnology, in terms of per researcher results, the leaders are, once again Switzerland (top 300) and Denmark (top 100). However, whereas the US performs more or less the same as in the general rankings, China performs better and France worse.

Indeed, within Europe, recent studies show a major gap in performance in cutting-edge biomedical and technological research between Germany, France, Italy and Spain on the one hand, and the UK, the Netherlands and Switzerland on the other.

This gap in performance extends to Fast Evolving Technological Topics were France is one of the weakest overall performers, alongside or below Spain, Portugal, Greece and Italy.

A fine-grained approach, such as the one discussed above, naturally leads to look at how different countries are performing in different fields and, maybe most interestingly, how they are performing in cutting-edge fields.

Bonaccorsi et al. do not go into this question in detail, but they do state that:

> *the European position is strong only in smaller scientific areas and in Medicine, while it is weak in large areas of the life sciences, information sciences, and material sciences, as well as in Engineering and in fundamental disciplines such as Chemistry, Mathematics, and Physics. Few European universities are at the top in fundamental science disciplines such as biology, biochemistry, molecular biology (hence biotechnology), that is, in the fields in life sciences that have promoted the most dramatic scientific revolution in the 20th century. [...] Few European universities are at the top in fundamental science in computer science, software, artificial intelligence, or systems. (Bonaccorsi, Haddawy, et al. 2017, 441)*

We would argue that this is particularly true of France and Germany. To test this proposal, we chose to look into the field of biotechnology[41] for which ARWU publishes a specific subject ranking[42].

[41] We singled out Biotechnology because it is the one cutting-edge field identified by Bonaccorsi et al. (2017) and also the one field for which ARWU has two related subject specific rankings. Looking into other cutting-edge fields such as neuroscience, artificial intelligence, etc. would be important.

[42] This ranking is methodologically relatively robust and based on three key indicators (total publications in Web of Science, Category Normalised Citation Impact and total publications in Top Journals (Biomaterials) / the fourth indicator on International Collaboration has a weight of one fifth of the other three) and the Awards indicator, that is present in some of the Subject Rankings is not used for the Biotechnology ranking.

	Top 100		Total ranked (300)	
	Number	Per 10,000 researchers	Number	Per 10,000 researchers
Australia	3	0.27	12	1.07
China	18	0.11	81	0.47
Denmark	2	0.44	5	1.10
France		0.00	17	0.57
Germany	6	0.14	37	0.89
Japan	2	0.03	16	0.24
Netherlands	2	0.23	10	1.17
Spain	3	0.22	17	1.27
Switzerland	1	0.23	7	1.58
United Kingdom	6	0.21	20	0.69
United States	39	0.28	96	0.69

Fig. 26: ARWU Subject Ranking "Biotechnology" 2018 (data source: ARWU)

The results should not be overinterpreted, but the differences with the general rankings or rankings of more classical fields are interesting.

The US has about the same number of universities ranked as in the general rankings (39 versus 44 and 96 versus 94). Whereas China performs far better in Biotechnology with 18 universities in the top 100 (versus 4 in the general rankings) and 81 in the top 300 (versus 27). In terms of per researcher results, the leaders are once again Switzerland (top 300) and Denmark (top 100).

In this specific ranking, France performs weakly with 0 universities in the top 100 and 17 in the top 300, below Spain (3 in the top 100 and 17 in the top 300), whereas Germany performs better, in particular in terms of top 300 universities.

This disappointing performance is confirmed by a recent study by Alonso Rodríguez-Navarro and Ricardo Brito, which covers a larger subset of biomedical research (Rodríguez-Navarro and Brito 2019)[43], as well as Technological research and compares performance between two subsets of countries: Germany, France, Italy and Spain (GFIS) on the one hand, and the UK, the Netherlands and Switzerland (UKNS) on the other, using the Ep index (efficiency based on percentiles or excellence based on percentiles index)[44].

[43] The field is defined by the following query: "BIO-MED searches we used (SU=((biochemistry & molecular biology OR biotechnology & applied biotechnology OR cell biology OR microbiology) NOT (computer science OR mathematical & computational biology)) OR TS=((cancer OR crispr* OR microbiota OR stem cell* OR immunity OR inflamma*) NOT (statistics OR trial OR survey)))"

[44] "The e_p index is a derivative of the exponent of the power law that percentile frequencies obey; i.e., a mathematical parameter that characterizes the distribution of local papers among the global papers. It reveals the research efficiency or breakthrough potential". The aim of the Ep indicator as follows: "We use efficiency in the sense of intrinsic efficiency or breakthrough potential, i.e., independent of inputs. This definition could be seen as the capacity of a research system to produce revolutionary science with the minimum possible amount of normal science, using Kuhn's terms (Kuhn [1962] 2012)". (Rodríguez-Navarro and Brito 2019, 3)

Country set/funding	TECH publications			BIO-MED publications		
	Number	Percent	e_p	Number	Percent	e_p
GFIS						
All papers published	20080	100	0.062	26828	100	0.066
EU funded not (ERC or MC)	2813	14.0	0.066	2305	8.6	0.075
ERC funded	726	3.6	0.143	510	1.9	0.166
UKNS						
All papers published	6250	100	0.104	10884	100	0.103
EU funded not (ERC or MC)	751	12.0	0.145	592	5.4	0.144
ERC funded	534	8.5	0.191	414	3.8	0.271

Fig. 27: "Publications in TECH and BIO-MED from Germany, France, Italy, and Spain (GFIS) and from the UK, the Netherlands, and Switzerland (UKNCH). Year 2014." (reproduced from Rodríguez-Navarro and Brito, (2019))

The study clearly demonstrates a massive gap in performance, that is true not only of average papers but even of papers published with EU funding (excluding ERC or MC) and of papers funded by the ERC[45].

In a previous article, Rodríguez-Navarro and Brito (2018) applied their analysis to what they term FETT (Fast Evolving Technological Topics) of which they identify 14 based on high citation rates and current technology importance[46] and which they compare to SETT (Slow Evolving Technological Topics)[47].

They calculated results for USA, ERA (European Research Area), EU (so as to exclude Switzerland) and EU without the UK again using the Ep index as well as the P'top0,01% indicator that "indicates the capacity of the system to publish papers with a certain citation level, which implies the production of breakthroughs of certain relevance".

The results are very instructive both at a global level and at a country by country level:

	SETT fields		FETT fields	
	Ep	**P'top0,01%**	**Ep**	**P'top0,01%**
US	0.115	3.40	0.128	6.28
ERA	0.093	3.44	0.08	1.58
EU without UK	0.089	2.34	0.068	0.66

Fig. 28: SETT and FETT performance for US, European Research Area and UK in 2014 (reproduced from (Rodríguez-Navarro and Brito 2018))

[45] We will return to this last point in the second part of the report.

[46] Graphene, solar cells, nanotechnology, electronics, Li+ or Na+ batteries, metal-organic frameworks, superconductors, transistors, semiconductors, wireless communications, composite materials, quantum dots, fuel cells, and energy transfer.

[47] They include here the following 10 fields: mechanics, engineering, materials science, energy & fuels, electrochemist, robotics, metallurgy & metallurgical engineering, automation & control systems, instruments & instrumentation, operation research & management science, and telecommunications.

Country	Number of papers	Fractional counts[b]		Domestic counts	
		e_p index	$P'_{top\ 0.01\%}$	e_p index	$P'_{top\ 0.01\%}$
Netherlands	1499	0.118	0.250	0.111	0.141
Ireland	497	0.087	0.026	0.095	0.029
Austria	774	0.068	0.012	0.077	0.013
Germany	7480	0.078	0.259	0.076	0.13
Finland	781	0.077	0.022	0.076	0.015
Denmark	804	0.076	0.027	0.073	0.017
Sweden	1402	0.072	0.034	0.069	0.019
Belgium	1227	0.061	0.017	0.060	0.01
Spain	4061	0.060	0.051	0.057	0.032
Portugal	968	0.067	0.018	0.052	0.005
Greece	735	0.058	0.007	0.049	0.003
Italy	4320	0.051	0.037	0.048	0.024
France	5373	0.054	0.042	0.048	0.022
Czech Republic	909	0.047	0.003	0.046	0.002
Hungary	388	0.008	1.3E-06	0.007	5.6E-07
Singapore	3066	–	–	0.196	2.19
Switzerland	960	–	–	0.151	0.49
UK	3114	–	–	0.107	0.45

Fig. 29: FETT performance for selected countries in 2014; fractional counts only took into account EU countries (reproduced from (Rodríguez-Navarro and Brito 2018))

The results clearly show that the EU performs far worse in Fast Evolving Technological Topics than in Slow Evolving Technology Topics (SETT). Indeed, whereas performance is almost identical in SETT fields for the US and the European Research Area as a whole (including UK and Switzerland), it is over four times weaker in terms of P'top0,01% in FETT fields.

In terms of country level performance, Switzerland once again stands out and the Netherlands also perform well. Denmark performs less well than on previous indicators and Germany better. France performs very poorly (below countries such as Spain, Portugal or Greece).

This is true not only on e_p indicators but even on P'Top0,01%, which is size dependant. As the authors state: "Even considering the size of the system, the likelihood of publishing a domestic paper in the Ptop 0.01% layer was 10 times higher for Singapore than for the four biggest EU countries combined, even though the total number of publications was ≈ 7 times lower in Singapore. This implies that, normalizing by the number of publications, Singapore is 70 times more efficient (in the sense of providing visibility to research results) than the four biggest EU countries as a whole" (Rodríguez-Navarro and Brito 2018).

The implications of this for current French research in these fields is shown in the following figure, which shows the number of publications that would be in the top 0.01% most cited layer supposing a total production of 10,000 publications:

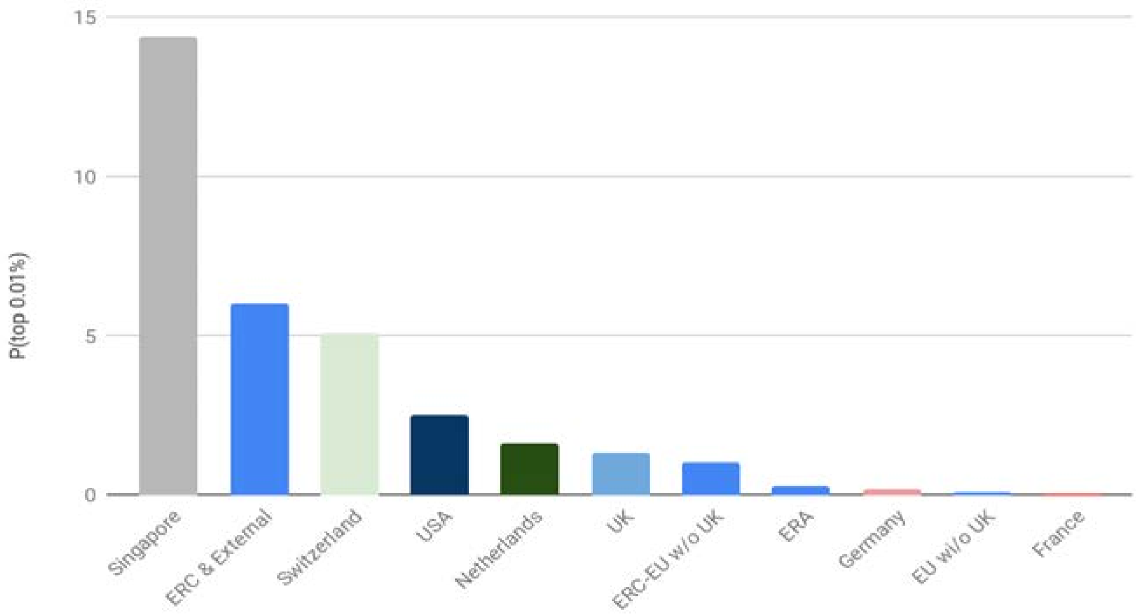

Fig. 30: Number of publications that would be in the top 0.01% most cited layer supposing a total production of 10,000 publications (adapted from (Rodríguez-Navarro and Brito 2018))

Individual awards

The same overall trend is true when measuring the performance of individual researchers, with the Netherlands, Denmark and Switzerland performing better than Germany and France.

In the case of HCR, normalised by number of researchers, Switzerland is the stand out performer, followed by the Netherlands, UK, US and Denmark. Once again, Germany, France and Spain are well behind.

At an institutional scale, the stand-out performers are all Anglo-Saxon, but French and German institutions rank below their competitors in Switzerland, Denmark or the Netherlands.

In the case of ERC, France and Germany have relatively good success rates but this still translates to a comparatively lower number of ERCs per researchers because of much lower applications rates.

There are numerous ways of evaluating individual performance. We have chosen two measures, based on different assessment methods:

- Highly Cited Researchers (HCR). HCR are determined continuously purely via bibliometric analysis by Clarivate Analytics;
- ERC Grants (Starting, Advanced and Consolidator) for European countries. ERC are evaluated by peers and are project based.

Highly Cited Researchers

Since 2014[48], Clarivate Analytics has compiled an annual list of the most highly cited researchers in 22 disciplines, with their institutional and country affiliation[49]

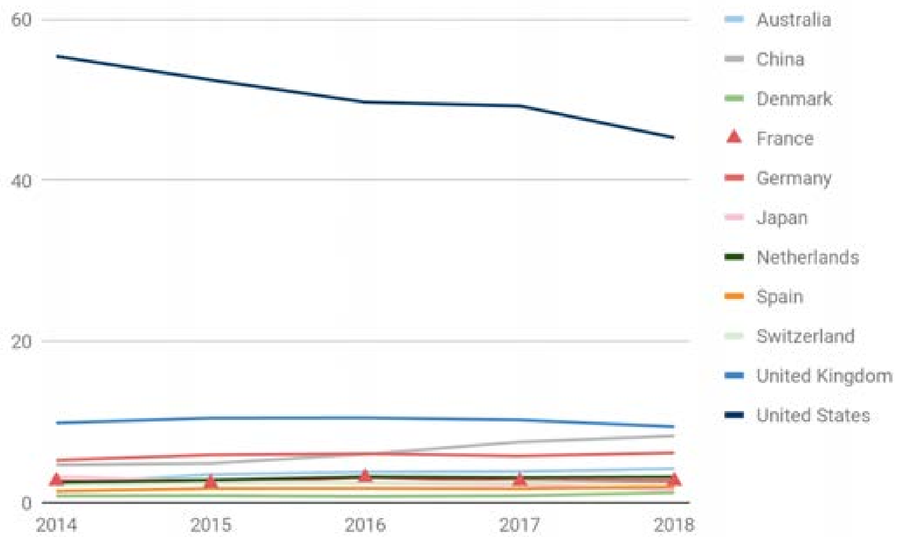

Fig. 31: Share of HCR by country - World total (data source: Clarivate Highly Cited Researchers 2018)

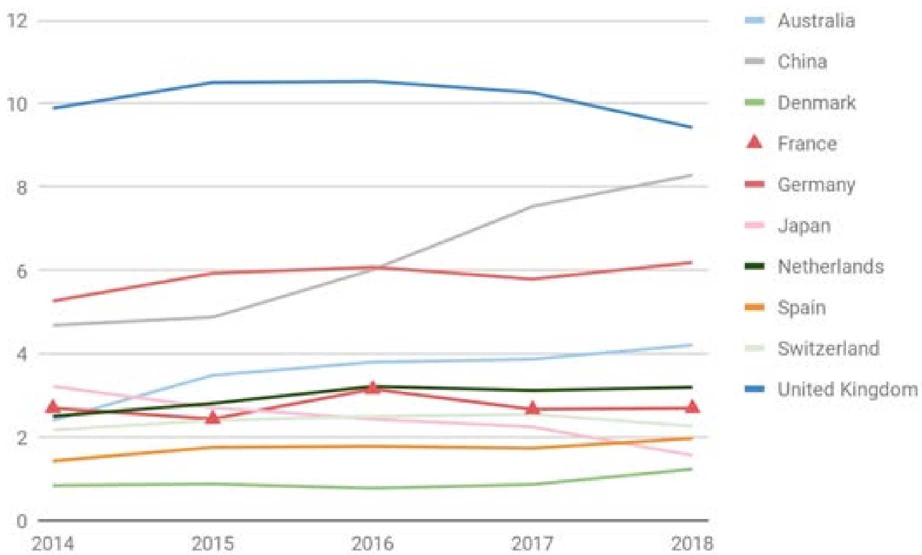

Fig. 32: Share of HCR by country - without USA (data source: Clarivate Highly Cited Researchers 2018)

The US dominates the list, even if the number of HCRs affiliated to US institutions is decreasing significantly on a year to year basis. The number of HCR affiliated to Chinese

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[48] A list was produced in 2001 but it is difficult to use due to data problems with the affiliations. ARWU assigns 20% of total score to the HiCi indicator, i.e. last year's number of HCR in a given institution.
[49] The list is often criticised - see, for example, Étienne Ghys in Le Monde, *A Shanghaï, une obsession pour la racine carrée,* in which he remarks that there are no French mathematicians https://www.lemonde.fr/campus/article/2019/09/03/a-shanghai-une-obsession-pour-la-racine-carree_5505962_4401467.html. This said, no one claims that HCRs are not excellent.

institutions has just started increasing but will soon pass the UK. The rest of countries are fairly stable.

The Lorenz curve, showing the distribution of HCR at the country-level is heavily skewed:

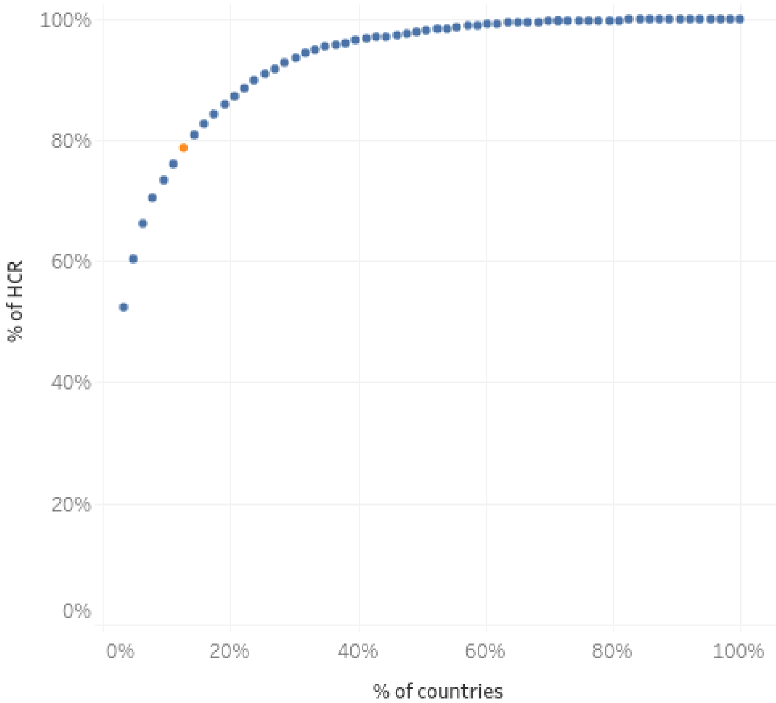

Fig. 33: Lorenz curve - HCR per country, France highlighted (data source: Clarivate Highly Cited Researchers 2018)

The top decile (USA, UK, China, Germany, Australia and the Netherlands) accounts for 73% of all HCR; the top quarter (the above plus Canada, France, Switzerland, Spain, Italy, Japan, Saudi Arabia, Denmark and Singapore) for 90%; the top half for 98%; and the bottom decile for just 0.1% of all HCR.

However, once again, the really telling graph is that which is normalised by number of researchers.

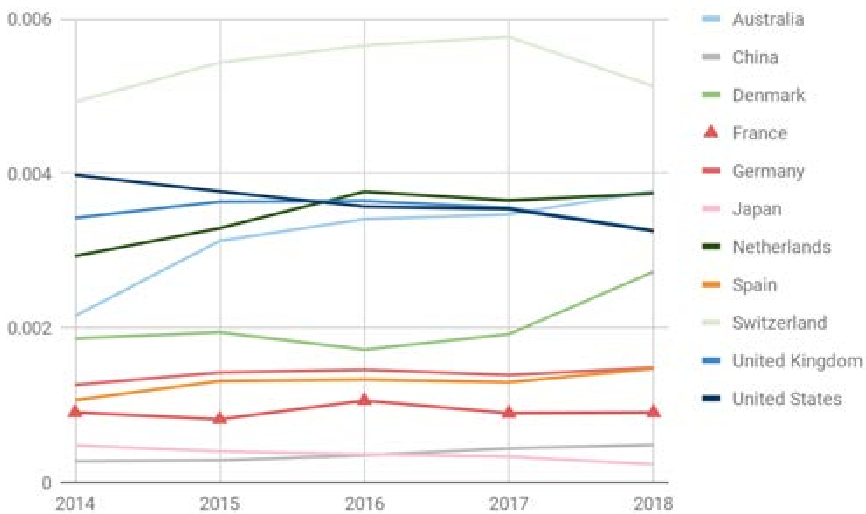

Fig. 34: Ratio of HCR by researcher (data source: Clarivate Highly Cited Researchers 2018)

Here, Switzerland outperforms both the UK and the US by a fair margin, whilst the Netherlands equals the latter and Denmark is close to catching up. These countries perform almost twice as well as Germany, Spain and France, with France just above China and Japan.

In terms of highly cited researchers per institutions, the picture is even more skewed than when we looked at it at the country level, when normalising by the size of the academic body of the respective institutions.

Harvard thus has 170 highly cited researchers for a staff of about 4,700 whilst Sorbonne University has 4 for a staff of roughly the same size and the CNRS has 23 for 11,000 statutory researchers.

The following figure represents the ratio of highly cited researchers per academic staff of 17 institutions, each either at the top of the ARWU general ranking or top-ranked in their (benchmark) country. The CNRS is added for comparison:

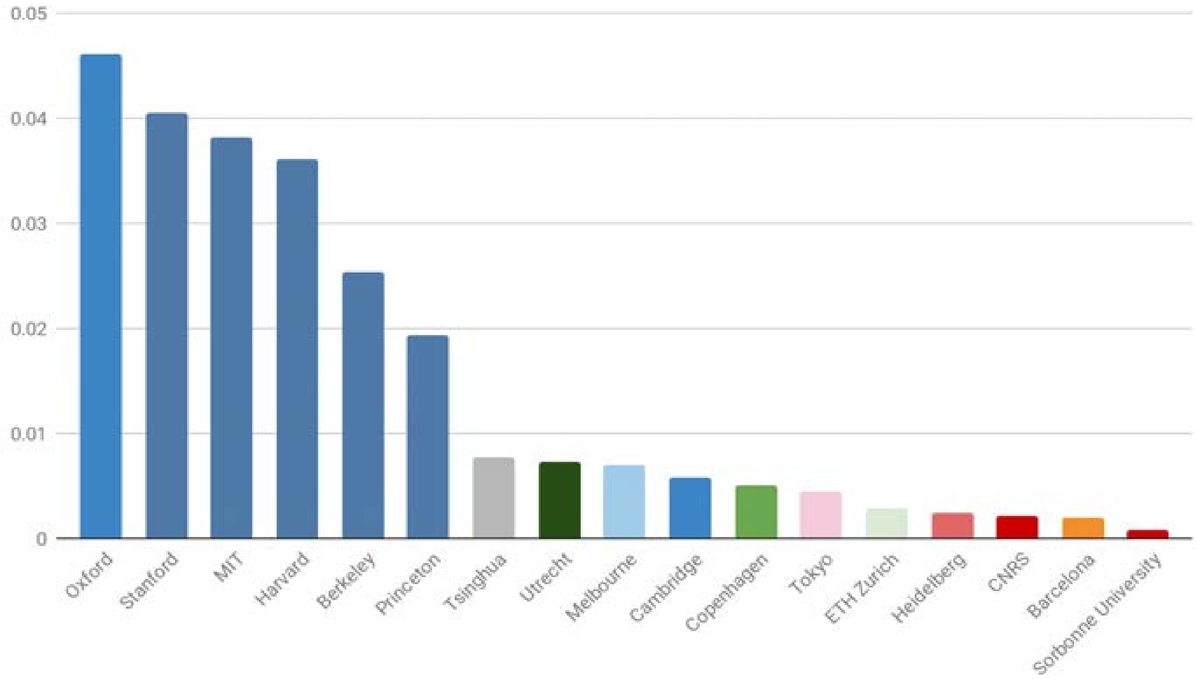

Fig. 35: Highly Cited Researchers per academic staff (data source: Clarivate Analytics 2018)

The list remains dominated by a small number of Anglo-Saxon institutions[50], which basically correspond to the "elite of the elite". Leading European universities (as well as Melbourne or Tsinghua) have scores between twice and four times higher than the CNRS. The scores of universities such as Sorbonne University will increase a lot with the re-affiliation of national research organisation researchers but they will remain far behind their key competitors.

ERC grants

ERC grants tell a different story from HCR, since they evaluate projects, not publications and are selected on the basis of peer-review rather than bibliometrics. This avoids the biases of bibliometrics but limits the sample to researchers who have chosen to apply, thus introducing a form of auto-selection.

[50] It would be interesting to look into the top 10 institutions on highly selective size independent indicators to see if non UK or non US institutions are any closer than they were twenty years ago.

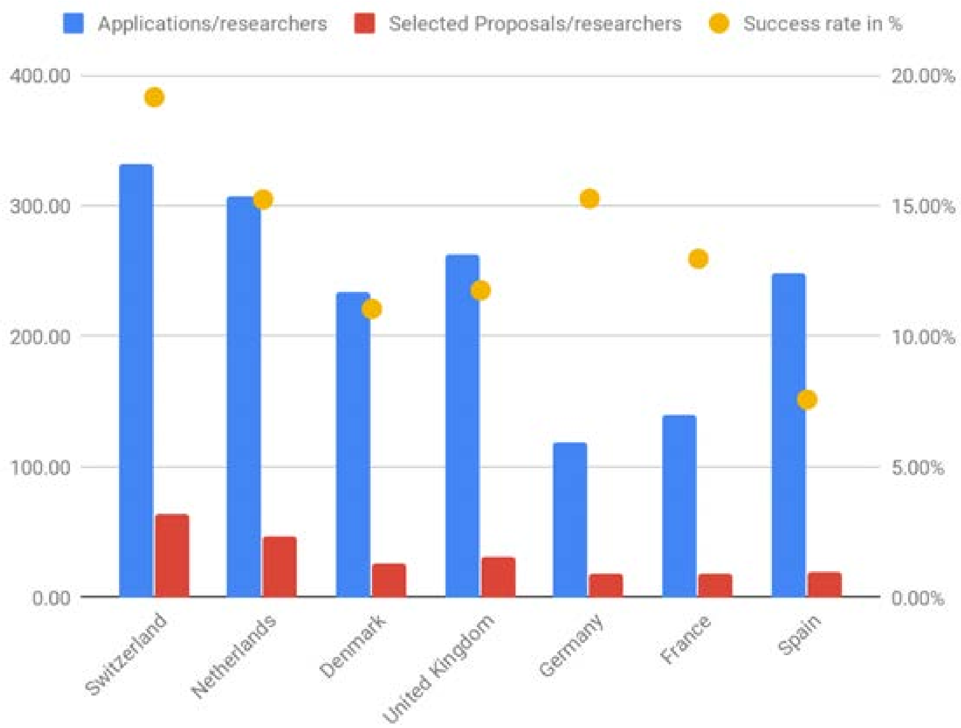

Fig. 36: ERC - applications, selected proposals and success rates, each per 10,000 researchers (data source: CORDIS)

The overall, country-level picture is similar to that provided by the HCRs with the Netherlands and Switzerland being the most performant countries in terms of both applications and proposals awarded by a margin of between two and three times more than Germany, France or Spain. The UK, Denmark and Spain all perform better than France and Germany.

A striking feature is that success rates based on normalised values, are remarkably similar: apart from Switzerland (with very high success rates) and Spain (with very low success rates).

This clearly means that one of the reasons for which Denmark has more ERCs when accounting for number of researchers, is that it files more applications.[51] Its success rate is in fact slightly lower than that of Germany and France.

This said, it is likely that an increase in application rates of French researchers would lead to a decrease in success rate. What would be interesting would be to see if the success rate stabilised at a similar percentage to Denmark or if it diminished to one closer to Spain.

[51] Cf. on this point Piro (2019), p. 1118 as well as the previous tables.

Comparing results in Horizon 2020

Our third set of data compares country performance on Horizon 2020.

In this case, France and Germany both stand out with cumulative losses of well over 1 billion Euros, whereas a country such as the Netherlands has gained close to 1 Billion Euros over the same time period.

Like for various other indicators, despite the fact that the results of France and Germany are already very poor, their market share is continuing to decline both when compared to the previous framework programme and on a yearly basis. On the contrary, countries such as the Netherlands or Denmark, with excellent results, continue to improve.

We end this analysis by turning from ERCs to the wider question of Horizon 2020 performance, about which Peter Fisch[52] has provided a set of clear and insightful analyses.

The following figure illustrates the position of each member state in terms of absolute amounts benefited from Horizon 2020:

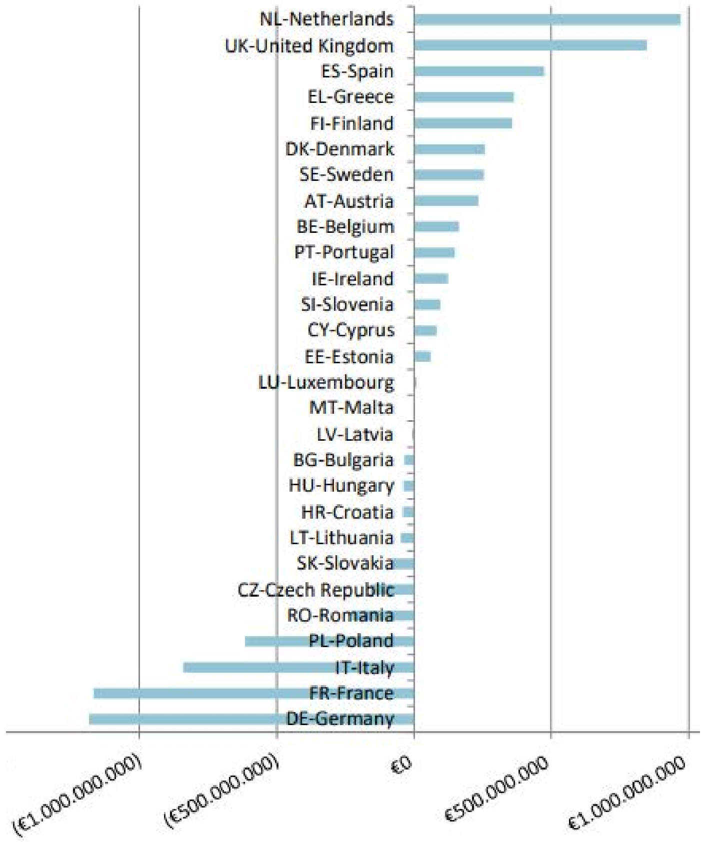

Fig. 37: H2020 (up to mid-2018), Net distribution effect (reproduced from Fisch (2019))

France and Germany have each accumulated well over 1 Billion € of losses so far on Horizon 2020 as a whole. They, of course, contribute far more than most other countries, but not more per capita than the Netherlands who have gained almost 1 Billion € over the same time frame.

[52] See https://www.peter-fisch.eu/european-research-policy/think-pieces/

In this sense, the following graph, which simply calculates per capita funding received, independently from the amount contributed by each member state, is perhaps even more instructive.

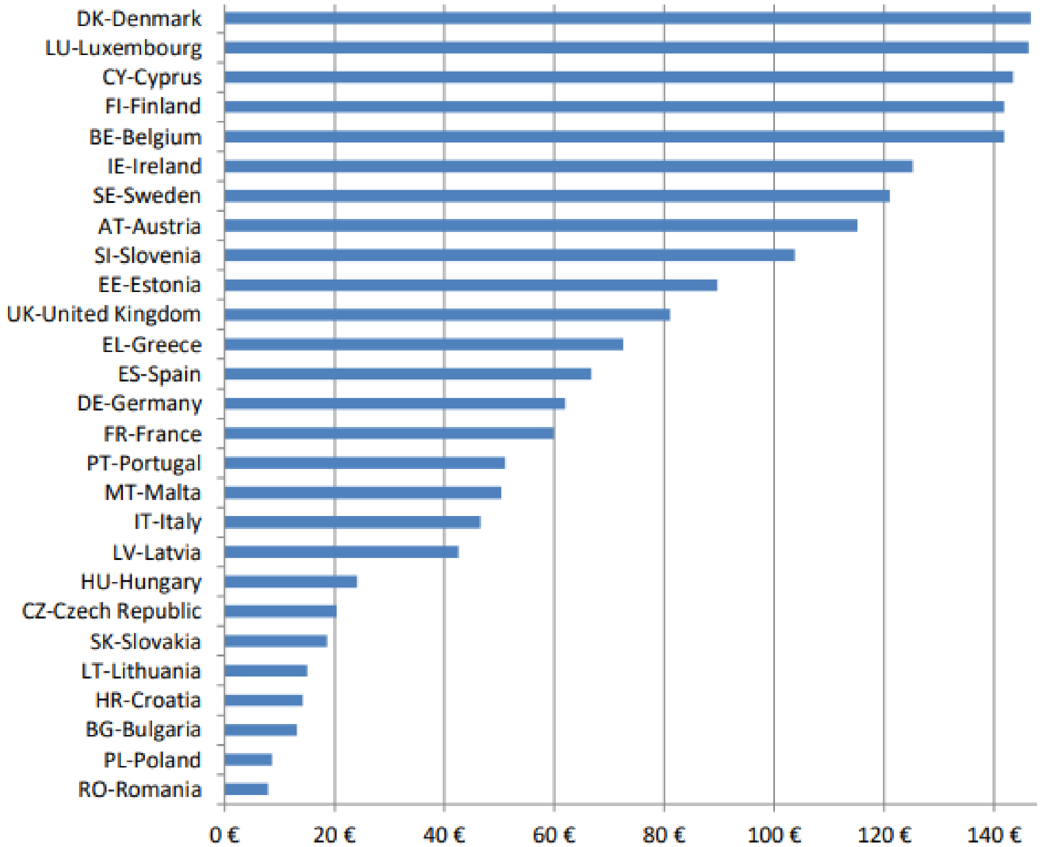

Fig. 38: H2020 (up to mid-2018), Funding received per capita (reproduced from Fisch (2019))

The Netherlands[53] and Denmark are both well above 140€ in income per capita from Horizon 2020. France and Germany are for their part at around 60€ per capita, which is below all countries except Portugal, Italy and most (but not all) Eastern European countries.

The relatively good performance of countries such as Greece and Spain is partly due to the massive decline in public funding, which followed the 2008 economic crisis. This forced researchers to apply to Horizon 2020 because there were no other sources of funding available.

However, if this argument were sufficient to explain the weak performances of France and Germany, it is difficult to understand why it has had no impact on the performance of countries such as Denmark or Belgium.

[53] The Netherlands are just above Denmark - they have mistakenly been omitted from the graph.

In terms of market share, France and Germany are continuing to decline (-7% and -11%). Whereas Denmark continues to improve (+8%), the UK and Switzerland stay stable and Spain's market share has increased by a massive 24%.

Member State	*FP7 Funding Received 2007 - 2013*	*FP7 Market Share %*	H2020 Funding Received 2014 until mid 2018	Horizon 2020 Market Share %	Change in Market Share from FP7 to Horizon 2020
AT-Austria	*1.114.900.000 €*	*2,99%*	889.168.622	3,03%	1%
BE-Belgium	*1.806.300.000 €*	*4,84%*	1.409.460.210	4,80%	-1%
BG-Bulgaria	*95.200.000 €*	*0,26%*	61.975.896	0,21%	-17%
CY-Cyprus	*78.900.000 €*	*0,21%*	120.164.872	0,41%	94%
CZ-Czech Republic	*249.300.000 €*	*0,67%*	196.516.796	0,67%	0%
DE-Germany	*6.967.400.000 €*	*18,68%*	4.860.021.425	16,57%	-11%
DK-Denmark	*978.200.000 €*	*2,62%*	828.063.197	2,82%	8%
EE-Estonia	*90.200.000 €*	*0,24%*	106.415.064	0,36%	50%
EL-Greece	*924.000.000 €*	*2,48%*	724.129.973	2,47%	0%
ES-Spain	*2.947.900.000 €*	*7,91%*	2.881.069.497	9,82%	24%
FI-Finland	*898.100.000 €*	*2,41%*	776.094.405	2,65%	10%
FR-France	*4.653.700.000 €*	*12,48%*	3.389.735.087	11,56%	-7%
HR-Croatia	*74.200.000 €*	*0,20%*	55.462.052	0,19%	-5%
HU-Hungary	*278.900.000 €*	*0,75%*	200.817.588	0,68%	-8%
IE-Ireland	*533.000.000 €*	*1,43%*	560.403.497	1,91%	34%
IT-Italy	*3.457.100.000 €*	*9,27%*	2.583.406.034	8,81%	-5%
LT-Lithuania	*55.100.000 €*	*0,15%*	41.543.580	0,14%	-4%
LU-Luxembourg	*39.800.000 €*	*0,11%*	80.749.580	0,28%	158%
LV-Latvia	*40.700.000 €*	*0,11%*	47.912.484	0,16%	50%
MT-Malta	*18.600.000 €*	*0,05%*	19.951.075	0,07%	36%
NL-Netherlands	*3.152.500.000 €*	*8,45%*	2.477.806.142	8,45%	0%
PL-Poland	*399.400.000 €*	*1,07%*	299.265.645	1,02%	-5%
PT-Portugal	*470.900.000 €*	*1,26%*	521.570.867	1,78%	41%
RO-Romania	*148.700.000 €*	*0,40%*	110.178.760	0,38%	-6%
SE-Sweden	*1.595.000.000 €*	*4,28%*	1.122.083.097	3,82%	-11%
SI-Slovenia	*164.300.000 €*	*0,44%*	184.927.467	0,63%	43%
SK-Slovakia	*72.300.000 €*	*0,19%*	81.279.796	0,28%	43%
UK-United Kingdom	*5.984.700.000 €*	*16,05%*	4.705.403.497	16,04%	0%
All Member States	*37.289.300.000 €*	*100,00%*	29.335.576.205	100,00%	0%

Fig. 39: "Market Shares" in FP7 and H2020 for EU Member States (reproduced from Fisch (2019))

Despite strong statements of intention, Horizon 2020 funding has not been evolving towards a more equal distribution, on the contrary.

Reframing the problem

The "European Paradox" assumes that Europe's research is strong, while its innovation is weak. It has been at the heart of European Research policy since 1995 and continues to guide framework programmes, as we move towards Horizon Europe.

This European paradox is clearly a myth. Europe does not have *a comparative advantage in producing knowledge*. It has difficulties turning knowledge into innovation and growth precisely because the proportion of truly world-class research it produces is low and its expertise in cutting-edge fields is poor.

However, the problem is not that of a "transatlantic gap" between Europe and the US, but one of intra-european heterogeneity. And the main issue within Europe is not North versus South or East versus West but the weakness of Franco-German research performance.

Neither "European Paradox" nor "Transatlantic Gap"

The "European Paradox" assumes that Europe's research is strong, while its innovation is weak. It has been at the heart of European Research policy since 1995 (European Commission 1995) and continues to guide framework programmes, as we move towards Horizon Europe:

> *When looking ahead to the future of Europe in a globalising world, the contrast is striking between Europe's comparative advantage in producing knowledge and its comparative disadvantage in turning that knowledge into innovation and growth. [...] Europe is a global scientific powerhouse. (Lamy et al. 2017)*

This European paradox has long been shown to be a myth. Europe does not have a comparative advantage in producing knowledge. It has difficulties turning knowledge into innovation and growth precisely because the proportion of truly world-class research it produces is low and its expertise in cutting-edge fields is poor. Giovanni Dosi demonstrated this in a seminal paper (2006) and our report simply builds on the large volume of existing literature on the topic[54].

The fact that the notion remains present in official discourse and continues to shape public policy is the real issue: "it is highly worrying that the European Commission continues to apply a research policy that ignores academic findings, which indubitably demonstrate the weakness of EU research" (Bonaccorsi, Cicero, et al. 2017).

The "Transatlantic Gap" is the term used in numerous articles, reports and documents to address this question by showing "the gap between Europe and the US in the quality of academic research in terms of its excellence, as measured by the share of scientific publications that are highly cited" (Bonaccorsi, Cicero, et al. 2017).

[54] For a recent example, see Jean-Pierre Bourguigon's speech to the Royal Swedish Academy of Sciences (2019). See also the comments of Jean-Michel Catin in his blog (2019).

As such it has replaced the notion of “European Paradox” but has had limited impact on policy makers, despite official reports to the European Commission underlining that it is a key issue (D. Campbell et al. 2013).

Our hypothesis is that this is because the notion of “Transatlantic Gap” obscures the true problem, which is one of intra-european heterogeneity or, more precisely, one of Franco-German failure.

The Franco-German illusion

The most important cause of the decline in European research has been the decline of German and French research (Rodríguez-Navarro and Brito 2019).

The fact that the performance of the French Research System should be sub-optimal is no surprise: many official French reports mention it:

> *La France n’est pas positionnée sur la « frontière d'efficience » de la dépense de recherche publique, que l’on peut estimer en reliant les niveaux de dépense aux indicateurs de performance d'un échantillon de pays. De ce point de vue, elle n’est toutefois pas significativement différente de la moyenne des pays de second rang (qui incluent l'Allemagne et le Japon). La situation s'est améliorée depuis 2004, ce qui signale une dynamique positive. (Demenet 2018)*

The problem is that this official discourse is nuanced (as above) by two assumptions: first that the French research performance is similar to that of second rank countries such as Germany and Japan and secondly that the situation is getting better.

As we have shown throughout this first part, the first assumption is correct: France performs similarly to Germany and, in fact, according to most indicators, better than Japan.

The problem is that, in terms of research performance, the situation is not getting better and that the so-called second-rank performers are in danger of becoming third-rank performers:

- France and Germany are rapidly being caught and in some cases passed by emerging scientific powerhouses such as China but also Australia or Spain.
- They are continuing to lose ground to strong performers such as Denmark, the Netherlands or Switzerland.
- Furthermore, French and German research performance is strongest in mainstream fields and according to generic indicators, such as the total number of publications. When looking at indicators, which seek to capture truly exceptional research or that which takes place in cutting-edge fields, then the French performance is even weaker.

This has deep consequences in terms of the way research policy is discussed at both a French and a European level.

At a European level, the classical divisions of Europe (South Europe versus North Europe, EU 15 versus EU 13 and anglo-saxon model versus continental European model) are not relevant for describing research performance. Of course, France and Germany benefit from their long-standing status as research powerhouses, from their relatively high level of investment in R&D and from their size. But in terms of pure, size-independent, research performance, they are surprisingly similar to Spain, Italy or Slovenia and, on some indicators, perform even less well than these countries. The best performers are countries such as Denmark, the Netherlands or Switzerland.

The oft-discussed problem of knowledge and technology transfer in France is not a question of quality of tools and mechanisms for transfer but a problem of research: knowledge and technology transfer depends on excellent research in cutting-edge fields and French research is simply not excellent enough and not focused on the right fields for it to enable a high level of breakthrough innovation. France has a problem with research performance.

These two facts have major consequences in terms of policy design:

- At a European level, the priority should be to address the research performance of France and Germany, because these two countries are the powerhouse of Europe. This becomes even more vital in the light of Brexit.
- In France, the state should concentrate its efforts on improving the performance of the French Research System, not attempting to kick-start innovation.

Finally, it is worth underlining that the most highly performing countries in the world in terms of research are not Anglo-Saxon countries. The leaders are at the heart of Europe, they are countries that combine excellent research with social impact and social equality. And this is important for Europe in general and for France and Germany in particular.

Part 2. Why is the French research system underperforming?

The second part of this report proposes a multifactorial analysis of the reasons for which the French research system seems to be performing less well than it could. It examines five key factors or, better said, families of factors:

- funding of the research system;
- connection to the global research system;
- structure of the French research system;
- human resource model;
- autonomy, accountability and governance.

Together these five factors provide a coherent and robust narrative which will hopefully make it possible to define a set of policy recommendations that will succeed in making the French research system truly competitive.

The Anna Karenina principle

> *According to the Anna Karenina principle, for something to succeed, several key aspects or conditions must be fulfilled. Failure in any one of these aspects leads to failure of the undertaking. That is, the success of complex undertakings always depends upon many factors, each of which is essential; if just one factor is lacking, the undertaking is doomed.* (Bornmann and Marx 2012)[55]

The Anna Karenina principle has been applied to science by Lutz Bornmann and Werner Marx who list eleven prerequisites for scientific breakthroughs to occur and argue that if only one of these conditions is not fulfilled, then the scientific breakthrough cannot happen.

It is useful because it helps explain why it is so hard to reproduce the conditions which enable a concentration of excellence to emerge.

The Anna Karenina principle should not be taken to mean that all high performing research systems are equal but simply that all high performing research systems fulfill a set of prerequisites. If only one part of the system is underperforming, then the whole system will underperform: in a highly competitive system, success requires a perfect alignment of all factors. This is why it is so hard to transform a national research system.

The fact that after 15 years of continuous reforms and Billions of Euros of investment the French research system should be underperforming does not mean that the reforms and investment were mistaken: the creation of the ANR to boost competitive funding and the AERES/HCERES to improve accountability, the launch of the Programme d'Investissement d'Avenir, with the Idex, Labex and other calls, the new laws and bylaws to increase autonomy and improve the competitiveness of the French research system were probably all necessary but they remain insufficient.

A change in public policy can be fundamental and yet only have an impact when all the necessary factors are aligned, when all the necessary changes have been made.

In the second part of this report we will analyse five factors which could help explain why the French research system seems to be performing less well than it could:

- funding of the research system;
- connection to the global research system;
- structure of the French research system;
- human resource model;
- autonomy, accountability and governance model.

Together, they provide a comprehensive, cohesive and robust narrative that helps explain why the French research system underperforms and how it could improve.

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[55] The Anna Karenina principle comes from the opening sentence of L. Tolstoy's novel Anna Karenina - "All happy families are alike; each unhappy family is unhappy in its own way". It was popularised by Jared Diamond (1997).

Factor 1: Funding of the research system

The first Factor is, of course, funding: without money there could be no research. This leads to two questions.

1. Does the French research system have enough money?

The answer to this is clearly "no". Two key arguments support this perspective:

- French investment in Research and Development (GERD) is below the OECD average, just above the EU average and lower than key competing countries.
- Even more significantly, France is losing ground compared with nearly all our benchmark countries. Indeed, investment in research is increasing rapidly not only in emerging research countries like China or Spain, but also in both low performing research countries such as Germany and Japan and high performing ones such as Denmark and the Netherlands.

This trend has been clear for nearly twenty years and urgently needs to be addressed.

2. Is the money well distributed?

This said, the quantity of money is not the only important parameter. Indeed, the way money is distributed is at least as important as the amount.

High performing countries share a number of characteristics:

- they concentrate research funding on research intensive universities;
- they have dual funding mechanisms, which differentiate teaching and research funding;
- research funding is dependent on performance-based indicators;
- they privilege competitive funding mechanisms over block grants.

High performing national research systems thus have "vertically-segmented" systems, which clearly distinguish between the missions that different kinds of higher education and research institutions are supposed to fulfill, and allocate funding on this basis.

Unlike these countries, French universities are constrained by a budget allocation model that:

- Does not distinguish a Research stream from a Teaching stream;
- Depends far less on Performance indicators;
- Allocates only limited amounts on a competitive project-based basis.

In a world in which universities are the key hubs that ensure global visibility, this has major consequences on the performance of the French research system as a whole.

Investment in R&D

According to OECD data from 2017[56], in terms of total intramural R&D expenditure (GERD), the United States remains the largest investor in R&D with a GERD of $543 billion (PPP). China follows with $495 billion, Japan is next with $170 billion and Germany with $132 billion. France is 6th overall with $64 billion followed by the UK with $49 billion. Eurostat has lower figures than OECD, but the proportions between countries and their positions are essentially similar[57]

In terms of share of GDP invested in Research and Development, France is in the average of our benchmark countries with 2,2%, just below the average of OECD countries (2,37) and just above the EU average of 2,03%. This is similar to the Netherlands and China, above Spain and (surprisingly) the UK but clearly below the US, Germany, Denmark and Japan.

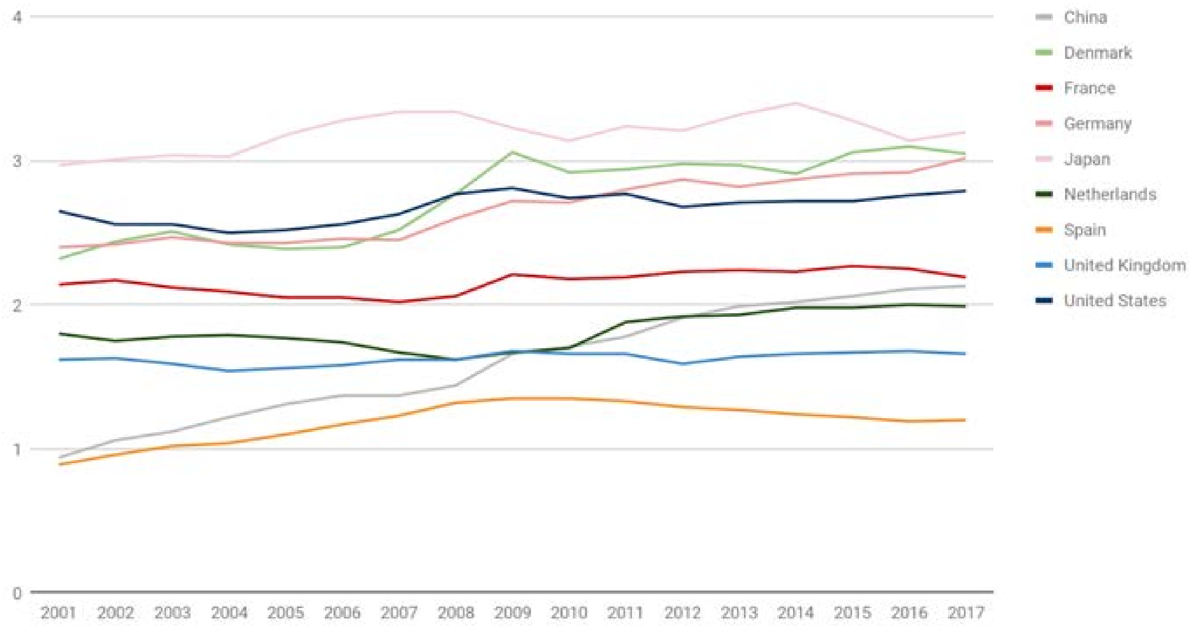

Fig. 40: GERD in % of GDP (data source: Eurostat)

Even if the percentage of French investment in R&D has slightly increased since 2001, it has done so far less than the rest of the benchmark countries:

[56] https://stats.oecd.org/Index.aspx?DataSetCode=GERD_SOF
[57] https://data.europa.eu/euodp/en/data/dataset/YJhH4ynFS54MJ6xRAzNFA, or in a more user friendly format: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_e_gerdtot&lang=en

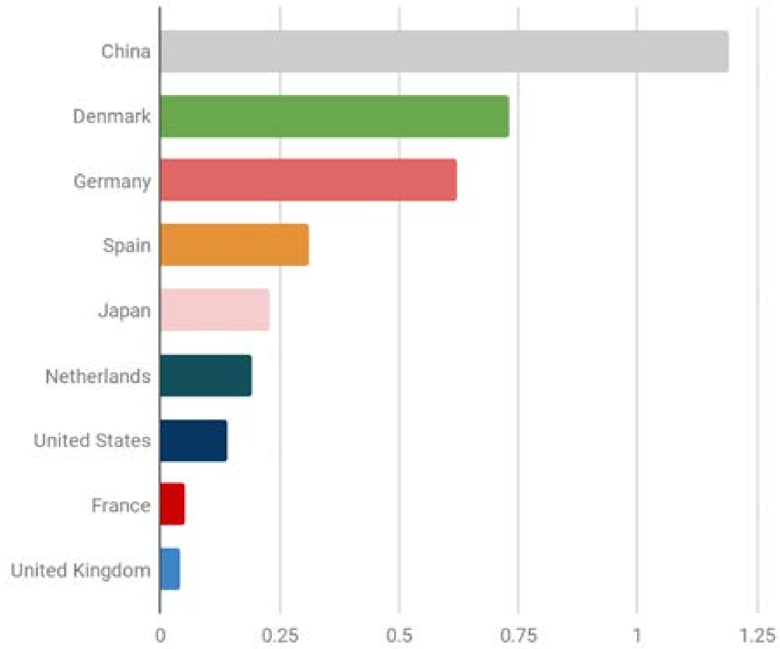

Fig. 41: % increase in R&D investment between 2001 and 2017 (data source: Eurostat)

In this category, the strongest performers include countries with low GERDs such as China and Spain, but also leading countries in percentage of GERD such as Denmark or Germany.

Compared to our benchmark countries, French R&D is thus slightly underfunded compared to key competing countries. More seriously, the increase in R&D funding since 2001 is well below than that of other countries.

France is losing ground in terms of R&D funding, both when compared to low performers such as China and Spain, which appear to be closing the gap to France, and to high performers such as Denmark, which are actually increasing it.

Comparing research expenditure and research performance

Piro (2019) has analysed the correlation between GERD as a percentage of GDP and research performance. He shows that a significant correlation can be seen between GERD and Intellectual Assets as defined by the EID[58], whilst the correlation between GERD and Citations is still noticeable[59], but less pronounced (e.g. the UK, Estonia, Ireland and Norway are among the highest cited countries while remaining below a GERD of 2%).

[58] The EID (Hollanders, Es-Sadki, and Merkelbach 2019) considers PCT patent applications, trademark applications and design applications as Intellectual assets.
[59] The correlation is 0.693. (Piro 2019)

Country	GERD as % of GDP	Intell. assets (EIS)	Citation Index
Israel (IL)	4.2	136.7	124.2
Sweden (SE)	3.3	176.5	144.6
Switzerland (CH)	3.3	169.2	168.1
Finland (FI)	3.2	163.5	138.1
Austria (AT)	2.9	142.7	137.8
Denmark (DK)	2.9	166.7	163.4
Germany (DE)	2.8	153.4	130.7
Belgium (BE)	2.3	85.7	147.8
France (FR)	2.2	93.0	127.1
Iceland (IS)	2.2	66.8	175.5
Slovenia (SI)	2.2	72.7	96.0
Netherlands (NL)	1.9	136.6	159.3
Czech Rep. (CZ)	1.7	53.2	99.5
Norway (NO)	1.7	53.2	140.6
Estonia (EE)	1.6	90.5	141.5
UK (UK)	1.6	83.2	144.3
Ireland (IE)	1.4	48.6	140.8
Italy (IT)	1.3	92.2	125.2
Luxembourg (LU)	1.3	128.2	133.1
Portugal (PT)	1.3	61.8	117.5
Hungary (HU)	1.2	39.3	104.5
Spain (ES)	1.2	65.1	120.5
Serbia (RS)	0.9	24.2	74.8
Croatia (HR)	0.8	27.0	79.7
Greece (GR)	0.8	30.3	116.6

Fig. 42: Main indicators by country - countries listed by GERD as % of GDP, Assets as assessed by the European Innovation Scoreboard (EIS) and Citation index (Piro 2019)

Piro concludes: "The most remarkable finding [...] is nevertheless that the Netherlands is the only country with less than 2% of GDP spent on GERD, that is both in the top-ten rank for EIS and citation indicators. Switzerland, Denmark and Sweden are the other countries that feature in both top-10 EIS and citation scores (and with some of the highest GERD shares of GDP)"

The lack of funding partly explains the relatively low French scores on EIS and citations but it is clearly not the only reason. Indeed, the available evidence seems to show that GERD and scientific performance are relatively weakly correlated.

Bauwens et al. (2008) provide further arguments in this direction within an analysis done at the European level. Starting from the comparatively bad performance of European universities within Clarivate's Highly Cited Researchers list by comparison with US universities, they run an econometric analysis to assess the weight of several possible causes, from monetary resources to English proficiency and governance culture. The result of their analysis heavily points towards institutional causes:

> *We have used our model to simulate the implications of possible policies to be implemented in order to reach a much higher research output. First, if the EU17 were to achieve the Lisbon objective of a GDP-share in R&D equal to 3%, its share of HCRs would just slightly increase from 24.3% to 27%, while the US would still account for 59.7% of HCRs. This sheds new light on the possible inappropriateness of the EU*

objectives and policies regarding European universities". (Bauwens, Mion, and Thisse 2008).

Hence their conclusion that *"the way the money is used is probably as critical as the amount of money itself."*

Distribution of research funding (between universities)

The total amount of money available is thus important, however the way this money is distributed can have almost as great an impact.

In the French case, two questions seem key to explore from a comparative perspective:

- the way funding is divided between national research organisations and universities;
- the way funding is distributed amongst universities.

For purposes of clarity, we concentrate in this chapter on the second question and discuss the role of national research organisations in chapter 3.

Dual funding systems versus single funding systems

Jean-Pierre Bourguignon (2019) recently highlighted the difference between Europe and the US by pointing out that in Europe there are 3000 institutions of higher education of which 1500 are research active and 850 award PhDs, whereas in the US there are 4000 institutions of higher education but only 300 award PhDs and research funding is heavily concentrated in the 108 institutions classified by the Carnegie Institute as "very high research" universities.

Today, most high-performing European countries have adopted a dual funding system for their universities which enables specific funding for research, sometimes combined with some degree of Research Performance Based Funding (RPBF).

For instance, the Netherlands, Sweden, the UK and Denmark all apply different formulas to allocate funding to the universities and distinguish a research and a teaching allocation.

- Netherlands: the funding of universities is divided into three parts: (1) block-funding from the state; (2) funding from research-funding agencies (NWO, KNAW) on a project-basis; (3) self-generated revenue. The second part obviously depends on research. But the first part also partly depends on it, since it includes a student-based allocation and a non student-based allocation (Melin et al. 2018).
- Sweden: two streams of government funding go to universities - one for teaching (related to the number of Bachelor and Master students) and the other for research (related to the number of PhD students as well as to the research activity). On top of this, national research funding is partially distributed through national funding agencies in a competitive fashion[60]:

  Since the 1990s Sweden has had a research funding system in which a larger share of funding to public research institutions and particularly

[60] https://english.uka.se/facts-about-higher-education/higher-education-institutions-heis/funding-of-swedish-heis.html

> *universities is allocated through competitive means: comprising project funding and organisational level funding linked to organisational assessment. A new system for the allocation and redistribution of the appropriations for research and postgraduate education to the university sector was introduced in Sweden in 2009 (Jacob, 2015), (Jonkers and Zacharewicz 2016)*

- UK: University funding from the government is also separated into two different streams - one for teaching and one for research (Universities UK 2016). Those streams are heavily influenced by performance exercises, with the REF serving as a reference to allocate a large part of the research funding (Sivertsen 2017; Manville et al. 2015).

  > *The UK was the first country to introduce a RPBF system in 1986 with the explicit goal of increasing selectivity in the allocation of public resources (Geuna and Piolatto 2015; OECD 2010). Organisational level funding in the UK is nowadays almost always allocated based on organisational assessment.* (Jonkers and Zacharewicz 2016)

  Within an institution, each research unit is assessed by its research output, societal impact, and research environment (de Boer et al. 2015).

- Denmark: funding mechanisms from the Ministry of Higher Education and Science similarly distinguish funding for education from funding for research[61]. Regarding the latter:

  > *45% of a given research fund is distributed according to the universities' education funding; 20% of a given research fund is distributed in accordance with the universities' external research funding, i.e. research funding which the universities' have obtained in the research councils, from the EU, etc.; 25 % of a given research fund is distributed in accordance with the universities' research publishing (bibliometrics); 10 % of a given fund is distributed in accordance with the number of students having completed their PhD thesis*[62].

  Until 2010, the redistribution was based on a 50-40-10 ratio. That is, 50% was based on the level of educational funding, 40% was based on the amount of external research funding, and 10% was based on the number of PhD graduates (Van Dalen et al. 2014; Jonkers and Zacharewicz 2016; Schmidt, Langberg, and Aagaard 2006).

  The weight of research performance has recently been increased. The 2018 strategic plan of the Danish Ministry of HE and Science thus declares that:

  > *The Government will introduce a new model for distribution of basic funding, which will advance the quality of Danish research even further. The model will advance high quality research as well as promote excellence on all levels and in all research fields. Moreover, the model will support in-demand education and research areas. The new model will also support universities' ability to take long-term action and be strategic in their research efforts.* (Danish Ministry of Higher Education and Science 2018)

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[61] https://ufm.dk/en/education/higher-education/danish-universities/the-universities-in-denmark/funding-for-danish-universities

[62] https://ufm.dk/en/education/higher-education/danish-universities/the-universities-in-denmark/funding-for-danish-universities/funding-for-research-1/funding-for-research

Project-funding versus block allocation

Compared to other countries, French research performing institutions have access to far less project-based resources. The graph below shows the proportion of project-based funding within the total budget of institutions - based on a study led by the JRC about the modality of allocation of publicly funded research:

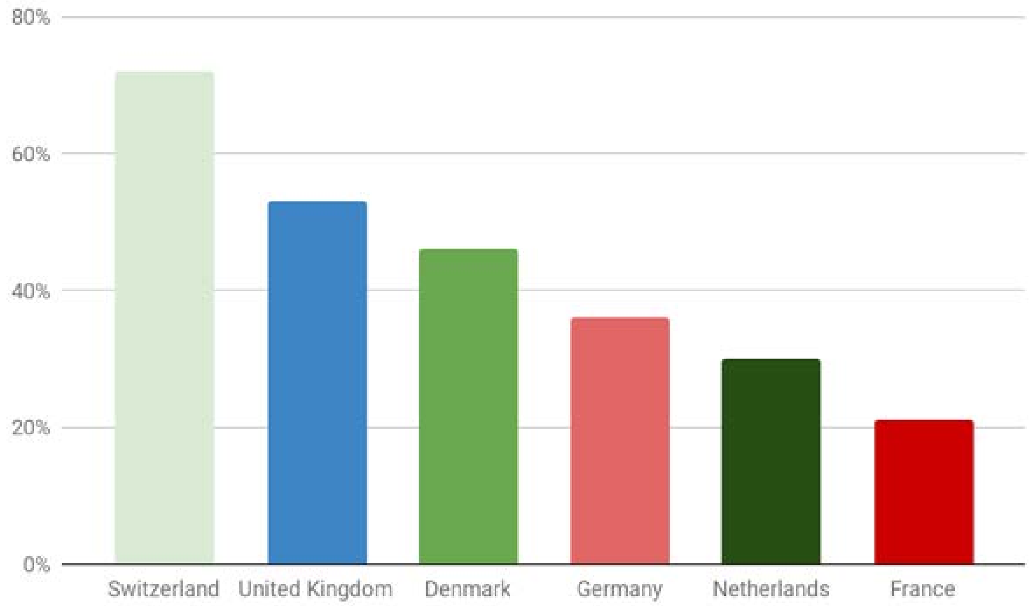

Fig. 43: Share of project-funding (data source: (Jonkers and Zacharewicz 2016))

Nearly 80% of the French research funding is allocated at the organisational level, by opposition to project-based funding: “France's public allocations for publicly performed research is allocated for 79 % and 21 % in the form of organisational level (institutional) funding and project funding respectively” (Jonkers and Zacharewicz 2016).

The French case

High performing national research systems thus have “vertically-segmented” systems that clearly distinguish between the missions that different kinds of higher education and research institutions are supposed to fulfill and allocate funding on this basis.

Unlike these countries, French universities are constrained by a budget allocation model that:

1. Does not distinguish a Research stream from a Teaching stream;
2. Depends far less on performance indicators;
3. Allocates only limited amounts on a competitive project-based basis[63].

In a world in which universities are the key hubs that ensure global visibility, this clearly has consequences on the performance of the French research system as a whole.

[63] This argument still holds even if all PIA funding is taken into account: the amounts involved are of a different order of magnitude.

Factor 2: Connection to the global research system

For reasons outlined in the introduction, the scientific system essentially acts as a huge machine for internally filtering out interesting from less interesting endeavours. As a result, being performant in research supposes not only to be intrinsically good but also to be connected to the rest of the network in an efficient way: interesting science needs to be noticed in order to become effectively relevant. This is why being connected is so important.

Factor 2 can be broken down into three key questions that measure the degree of integration of the French research system within the global research system:

1. Language and history

Science has always been global, but until the 1970s major national research systems continued to be reference points in terms of prestige. The emergence of a single global research system was comparatively easy for countries that had always looked abroad (Denmark, the Netherlands, Switzerland) and for countries whose system became the core of the global system (UK, US) but it was very hard for countries, which used to be major references in their own right such as France, Germany or Japan.

The difficulties that this implies continue to have an impact on performance (for example, attracting leading researchers implies switching to English not only for publishing, but also as a working language in the lab and for teaching).

2. Connections

Co-publication data clearly shows that French researchers are increasingly working with international colleagues. However, these co-publication networks are not correlated with excellence - the strongest scientific affinities of France are with Belgium, Italy and Spain, three neighbouring countries, two of which have relatively low research performances. Furthermore, France has the lowest co-publication rate of all our benchmark countries with China, the key emerging research powerhouse.

And reinforcing the warning signs, the share of French researchers who have had short-terms stays in foreign institutions is surprisingly low compared to other countries.

3. Hubs

However, to truly understand the impact of connections, it is necessary to look not just at raw data but at the networks behind these connections. These underline two facts:

- first and foremost, the research potential and visibility of hubs is key because it is there that science is defined and where connections at a global level are forged;
- secondly, the rest of the country needs to be well connected with these global hubs to enable global research results to be assimilated at a local level.

This is why most countries strive to reinforce a few key hubs rather than to promote the countries research potential as a whole.

Science has always been produced in hubs within networks, written in a language which enables it to be widely shared. This was true in the Aegean, the Huang He Valley and Northern India in the mid first millennium BCE, it was true in the Abbasid Caliphate, in Italian city-states during the Renaissance and in research intensive American universities after the second world war.

Of course, exceptions exist and serendipity and stubbornness sometimes lead to scientific breakthroughs in underperforming systems, but, even when this happens, it is high performing research systems that benefit most.

A recent example is the discovery of CRISPR by F. Mojica at the University of Alicante[64]. The discovery of CRISPR was key, but the following research steps happened in other cities. From Spain to France, the Netherlands, Germany and Austria, the Baltics and Scandinavia and finally the US. The story of each discovery is unique but the fact that the final step of biological engineering to enable genome editing took place in Boston, not in Alicante, is not surprising: we know of no cases where the reverse is true.

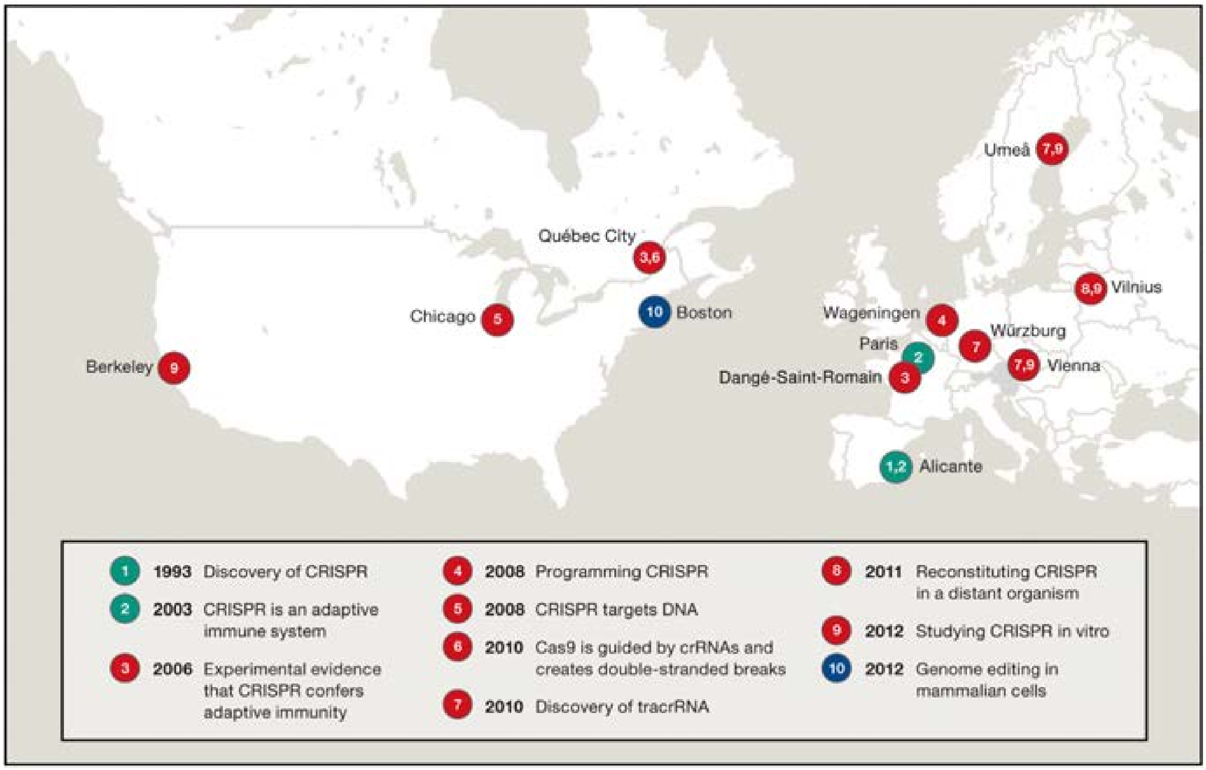

Fig. 44: "The Twenty-Year Story of CRISPR Unfolded across Twelve Cities in Nine Countries For each 'chapter' in the CRISPR 'story', the map shows the sites where the primary work occurred and the first submission dates of the papers. Green circles refer to the early discovery of the CRISPR system and its function; red to the genetic, molecular biological, and biochemical characterization; and blue to the final step of biological engineering to enable genome editing" (Lander 2016)

The quality of a national research system not only enables excellent science and breakthroughs but also ensures that these breakthroughs have strong impact beyond fundamental research. It explains why over the last 60 years most Nobel Prizes have been awarded to researchers working in the US, even if they started their career elsewhere, and why Google, Amazon, Facebook and Apple were born in the US.

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[64] The story is recounted in Lander (2016).

During the first half of the twentieth century, key hubs included France, Germany, Japan, Russia, the UK and the US. The role of each hub shifted with time[65] and through time each hub coexisted with smaller hubs such as Scandinavia, the former Austro-Hungarian world and many more. In each hub, the language of publication was different and prestige came from different events or publications (typically those of the national academy of sciences). Only very few global indicators of prestige existed and even these were just emerging - Nobel Prizes are the most famous example, yet even they long kept a strong Scandinavian bias[66].

The Second World War marks a radical shift: first and foremost, it is then that public investment in science truly takes off around the world; second the allied victory clearly puts the US at the forefront of scientific research; third scientific publishing starts becoming global. These three factors enable the emergence of a single global scientific network, structured around hubs, which connect researchers in universities (e.g. Harvard) and scientific journals (e.g. Nature and Science) and in which the *lingua franca* is English. The global scientific network becomes clear by the mid 1970's. This is when, for better or worse, Impact Factor appears[67], when where you publish becomes as important as what you publish[68], when Global Scientific publishing houses consolidate[69] and when the foreign language abstracts in the journals of the Soviet Academy of Science switch from French to English, to take some examples.

Progressively, the structure of the network itself starts shifting from a national model (dominated by the US) to a truly global model in which for "more than half of the countries, the international network has become the better predictor of the national participation at the global level than vice versa" (Wagner, Park, and Leydesdorff 2015).

Our hypothesis is that during the second half of the twentieth century, minor scientific hubs such as the Nordic countries, Switzerland or the Netherlands found it easier to integrate the global system because their institutions and languages had never been global hubs: learning Danish and moving to Copenhagen were never the ultimate aspiration for a budding young scientist, whereas learning English and spending time at Oxford or learning French and attending the Collège de France were. Sharing English as a common language made it easy for the UK to integrate the global system that was born in the US. But the same was not true of France, Germany or Japan, whose languages and institutions were (and sometimes are) still imagined to be globally prestigious within each country[70].

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[65] (Hollingsworth and Gear 2012) show how leadership shifts from France to Germany (19th century), to Britain (early 20th century) and the US (mid 20th century).

[66] Few historians of science would defend the idea that Sweden is a major scientific powerhouse, yet with 33 Noble prizes, Sweden is still today the 5th country with the most Nobel Prizes in the world (after the US, UK, Germany and France but in front of Japan or Russia/Soviet Union).

[67] Impact Factor is invented by Eugene Garfield in the 1960's. They are calculated yearly starting from 1975 for journals listed in the Journal Citation Report.

[68] "At the start of my career, nobody took much notice of where you published, and then everything changed in 1974 with Cell" - Randy Schekman, Berkeley molecular biologist and Nobel prize winner, cited in Buranyi (2017).

[69] The story of how Robert Maxwell creates Pergamon, the first global scientific publishing house (later brought by Elsevier) is brilliantly recounted by Stephen Buranyj (2017).

[70] This is illustrated by personal experiences of the authors of this report: in the 1990's students at UCL (London) were still encouraged to learn French and German when studying archaeology and the best students at Barcelona University were sent to do a Master or a PhD in Paris. By the 2010's neither were true. In 2013, professors of philosophy in a small French university department still considered the very idea that one of their students could be interested by a course in Oslo University as a joke.

English as a *lingua franca*

The fact that science is published and discussed in a *lingua franca* has frequently be seen as a major condition for the success of the endeavour globally. D'Alembert expresses this beautifully in the eighteenth century:

> *Les savants des autres nations à qui nous avons donné l'exemple, ont cru avec raison qu'ils écriraient encore mieux dans leur langue que dans la nôtre. L'Angleterre nous a donc imités ; l'Allemagne, où le latin semblait s'être réfugié, commence insensiblement à en perdre l'usage : je ne doute pas qu'elle ne soit bientôt suivie par les Suédois, les Danois et les Russes. Ainsi, avant la fin du XVIIIème siècle, un philosophe qui voudra s'instruire à fond des découvertes de ses prédécesseurs, sera contraint de charger sa mémoire de sept à huit langues différentes ; et après avoir consumé à les apprendre le temps le plus précieux de sa vie, il mourra avant de commencer à s'instrure*. (Gordin 2015)

D'Alembert's words mark the death of a global scientific language (latin) and the beginning of a multilinguistic scientific world, but this multilinguistic world itself would only last a couple of centuries.

The following graph shows the evolution of publishing languages - with English becoming the leading language of publication in the 1930's and the global *lingua franca* from the 1970's:

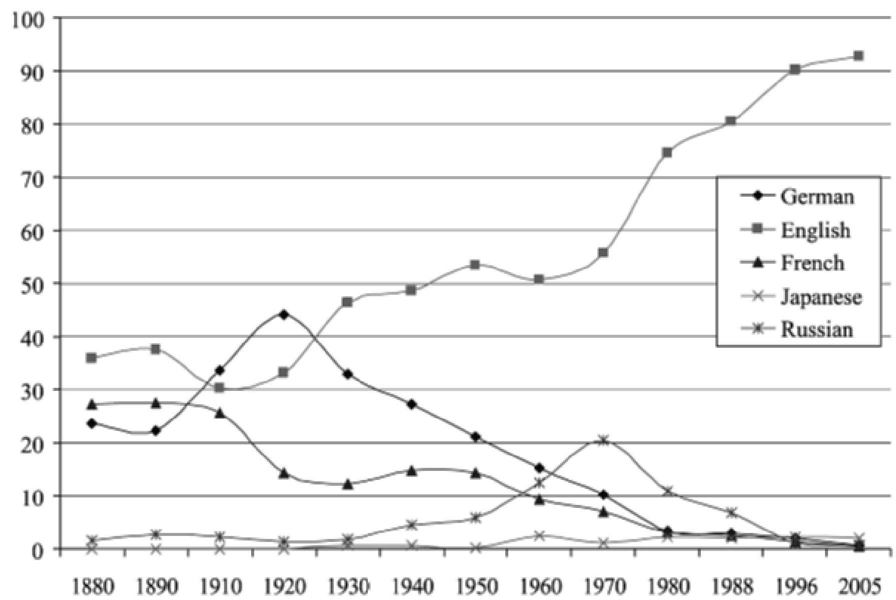


Fig. 45: Publishing languages in global scientific literature (Carli and Ammon 2007)

This dominance of English as a scientific *lingua franca* has clear implications:

- Career development is increasingly tied to English language publishing – Knowledge workers of any linguistic background see their career development increasingly dependent (explicitly or implicitly) on bibliometric indicators such as their capacity to publish in high-impact journals, the great majority of which are published in English. The official language of the overwhelming majority of labs is English in both the private and the public sector.

- Scientific productivity in terms of publication in high-impact journals correlates to English language proficiency.

> *There was a significant relationship of national spending on research and TOEFL scores to publication output of developed countries [...]. These two variables explained approximately 71.5% of the variation in publication rate across developed nations around the world [...]. Normalized for population size, English-speaking nations and certain northern European countries such as Denmark, The Netherlands, Switzerland, and Sweden had the highest rate of publication in the five highest ranked general medical journals, while Asian countries had generally low rates of publication. Research spending and English proficiency were strongly associated with publication output in the highest ranked general medical journals (Man et al. 2004).*

The following graph highlights how the shift is ongoing, even in countries such as the Netherlands, where over 95% of publications were already in English in the late 1990s. Countries like France and Germany where around 80% of publications are in English are changing more slowly than countries such as Italy or Russia.

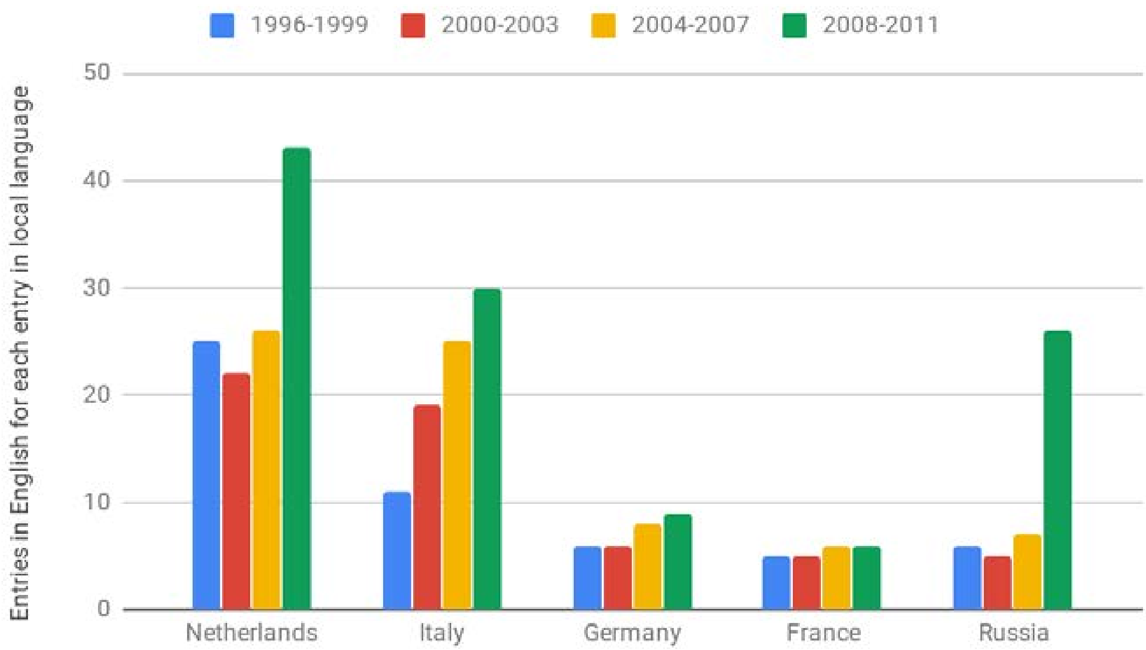


Fig. 46: Number of English to local language journal articles (data source: researchtrends.com 2012[71])

[71] https://www.researchtrends.com/issue-31-november-2012/the-language-of-future-scientific-communication/

The situation in the Social Sciences and Humanities

The shift to English is happening more slowly in the Social Sciences and Humanities but the overall trend is similar. French is still the second language at a global level with 7,1 % of articles published in French, but it has become a residual language of publication in all countries that are not francophone (Italy is the first non francophone country for articles published in French with 5,1%)

Fig. 47: Word cloud of main languages other than English in the SSH according to Scopus (reproduced from researchtrends.com 2013)

At a country level, France and Spain are now the only countries where English language publications count for less than 50% of the total and France is the only country where more articles are still being published in the local language than in English.

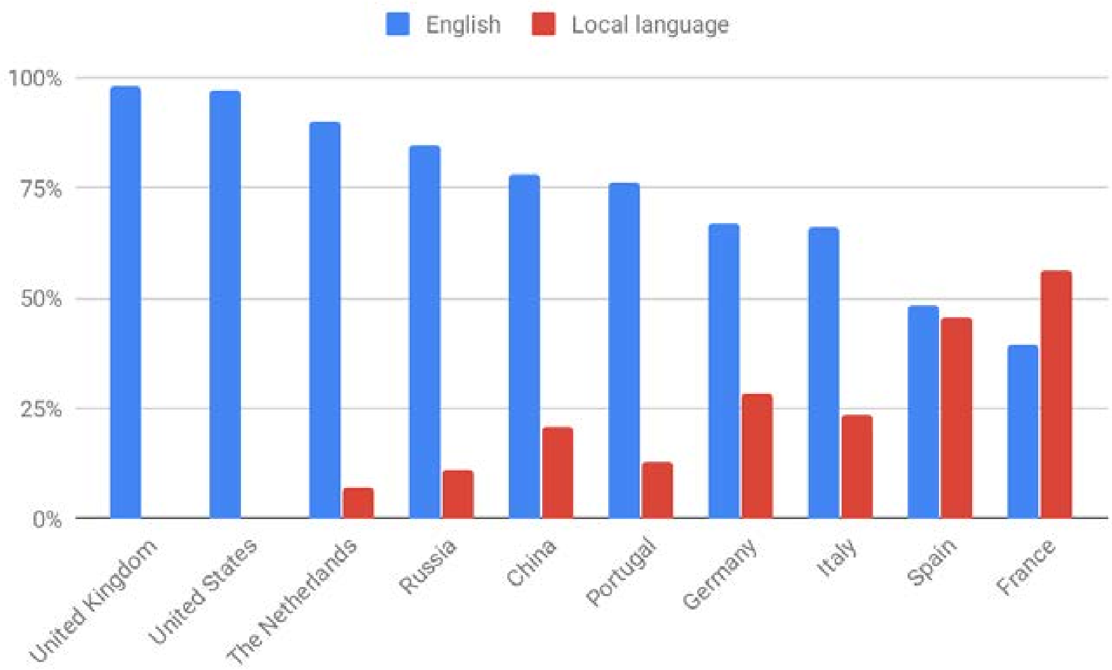
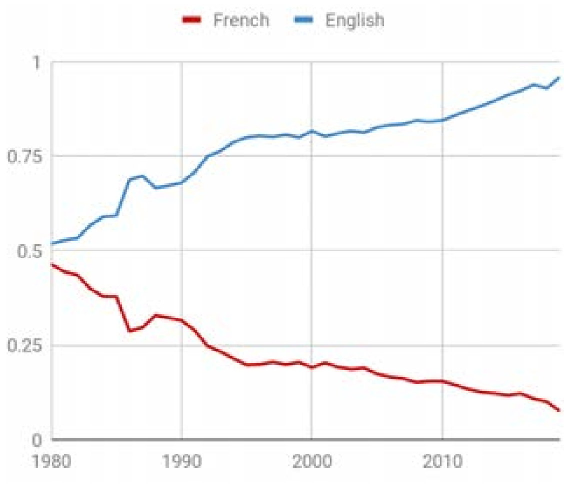


Fig. 48: Percentage of English and main local language journal articles in the SSH (data source: researchtrends.com 2013[72])

[72] https://www.researchtrends.com/issue-32-march-2013/publication-languages-in-the-arts-humanities-2/ In the case of The Netherlands, Russian, China and Portugal, local language includes other languages apart from French, German, Italian and Spanish - the red bar is thus slightly overestimated (less than 1%).

The following charts, inspired by Larivière and Desrochers (2016), represent the evolution in share of papers in the Social Sciences and Humanities in France, Germany and Quebec written in English (vs. French or German) between 1980 and 2019:



Fg. 49: Language of publications in France (data source: Scopus, total 2019: 80,855)

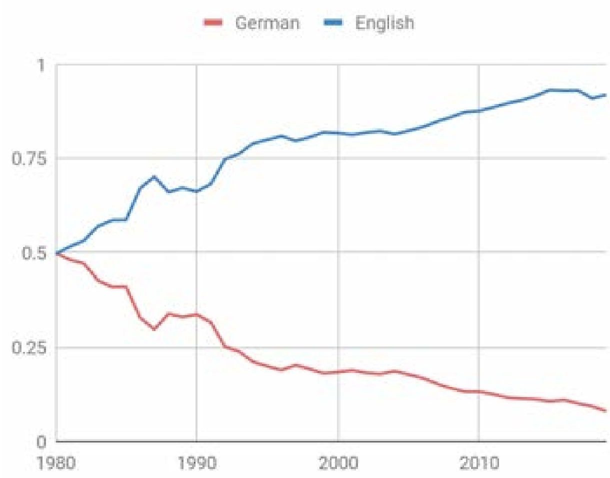


Fig. 50: Language of publications in Germany (data source: Scopus, total 2019: 121,416)

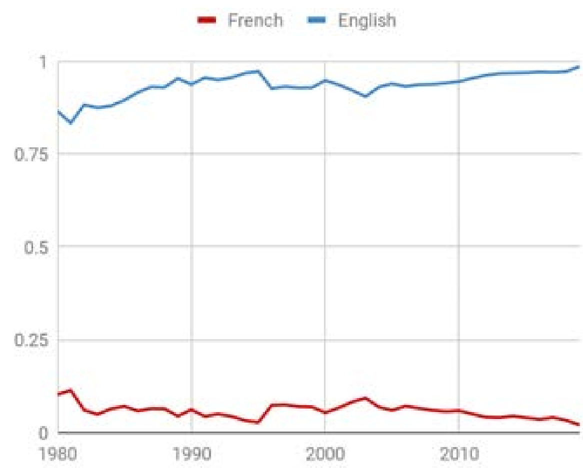


Fig. 51: Language of publications in Québec (data source: Scopus, total 2019: 4,965)

The graphs nicely illustrate the decline of publications in French and German from the 1980s onwards as well as the fact that in Quebec the shift had already occurred previously.

This shift is unavoidable because language means readership (and high impact journals), hence visibility and prestige, which is the currency of the scientific community. Countries which publish more in the dominant language enjoy a premium and their papers get more easily identified and noticed. But this shift takes time to occur, because, even if prestige is a universal currency, the way it is measured changes from country to country.

Because Danish and Dutch were never major scientific languages, research has long been published in other languages and this has bred a foreign language cultural capital. In these countries, prestige has always been linked with the fact of publishing in a foreign language.

In a country such as France in which the local language retains a high level of prestige and used to be a global scientific language, the process is much slower. A study from 1981, thus underlined that "Scholars disproportionately cite literature in the languages they feel most comfortable with, which are often their native languages [...] the French cited 29% French, Germans 22% German, Japanese 25% Japanese, Soviet researchers 67% Russian" (Gordin 2015). And in 2008, in a study of the factors explaining the distribution of Highly Cited Researchers, Bauwens et al. found that "if France were to improve its English proficiency by 10%, thus reaching the level of the Netherlands, the number of French HCRs would increase by 20%" (Bauwens, Mion, and Thisse 2008).

Furthermore, although this report is centered on research, in the case of language, research policy cannot be separated from higher education policy because most researchers are university professors and therefore expected to teach. For example, France is currently the only country in Europe in which universities can offer degree programmes/courses exclusively in the national language, thus making it impossible for universities to systematically recruit leading stars to all positions, irrespective of their knowledge of French[73].

Language is thus a critical factor in the visibility of scientific research and one which helps explain the apparent under performance of the French system of R&D. It is a factor which is diminishing because French research is now almost entirely published in English, but it remains a factor and we think that it helps explain why France and Germany underperform compared to Denmark or Netherlands.

It is however a particularly complex issue, because switching language in research intensive universities is not just a question of publication, it is a question of teaching, administration and daily communication.

From language to connections

The article on publication habits of French, German and Quebecois researchers (Desrochers and Vincent 2016) includes an interesting series of graphs, which shows that even if researchers in the Social Sciences and Humanities publish more and more in English, those in France and Germany tend to do so in English language journals published *in their own countries*.

[73] EUA autonomy scorecard's indicator - language of instruction at Bachelor level. https://www.university-autonomy.eu/

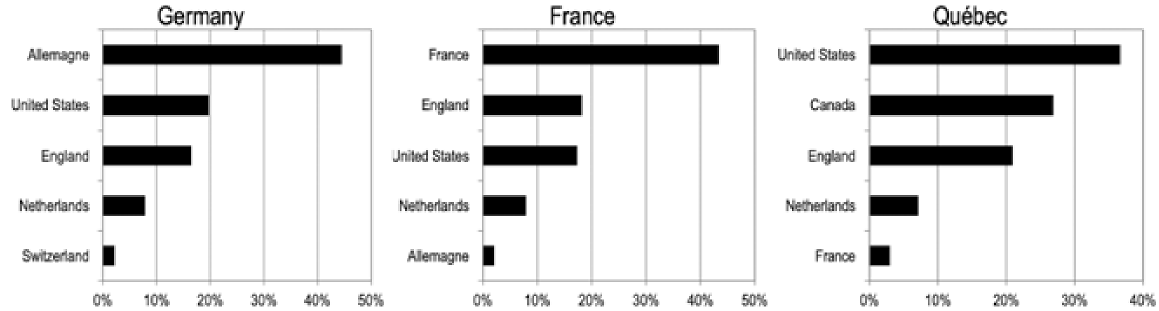


Fig. 52: "Country of journals in which the German, French, and Québécois researchers publish in the social sciences and humanities, in percentages, 1980-2014" (Desrochers and Vincent 2016)

In many cases, French and German researchers in the social sciences and humanities seem to have created their own journals in English (or changed the language of publication of their existing journals), they have not necessarily started publishing in global journals.

This is important, because a switch of language is not enough. English is important only because it is the language of the most prestigious journals. What is important is to publish in these prestigious journals, because they bring visibility and therefore prestige. What is important is the way you are connected to the world.

The classical approach to studying this question is to analyse international co-publication networks. At a macro level, these clearly show that France is both well connected and that the intensity of connections is growing.

The latest OST analysis of international collaborations thus shows that French researchers are increasingly working with international colleagues, with an important milestone reached in 2015, when the percentage of domestic co-publications fell for the first time, alongside the percentage of single address publications, which started falling in 2008:

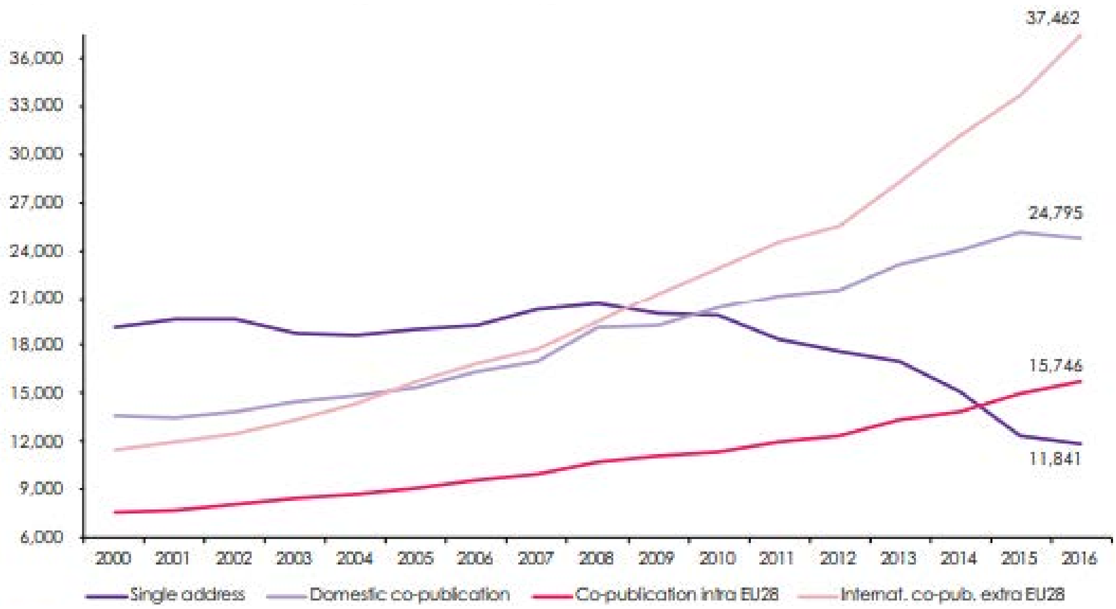


Fig. 53: Number of France publications by type of collaboration (OST 2019)

However, the OST report also includes a caveat:

> *With an international co-publication rate of 58%, France is close to the average for research-intensive countries of similar size, such as Germany. France's principal publishing partners are the USA and Europe's leading scientific nations. Nevertheless, co-publications with these countries are still not reaching their full potential, as measured by their share in total international co-publications. France has strong scientific affinity with Belgium, Italy and Spain, but low affinity with China. In this respect, France does not seem to have made the most of the boom in China's scientific capacities (OST 2019).*

Considering that China today accounts for one third of the global scientific output, this is a key issue, rendered all the more important by the fact that countries with whom France has strong co-publication networks (Italy or Spain) are clearly not global scientific leaders.

To measure the problem more precisely, we compared French co-publications with China with those of our other European benchmark countries, normalised by number of researchers.

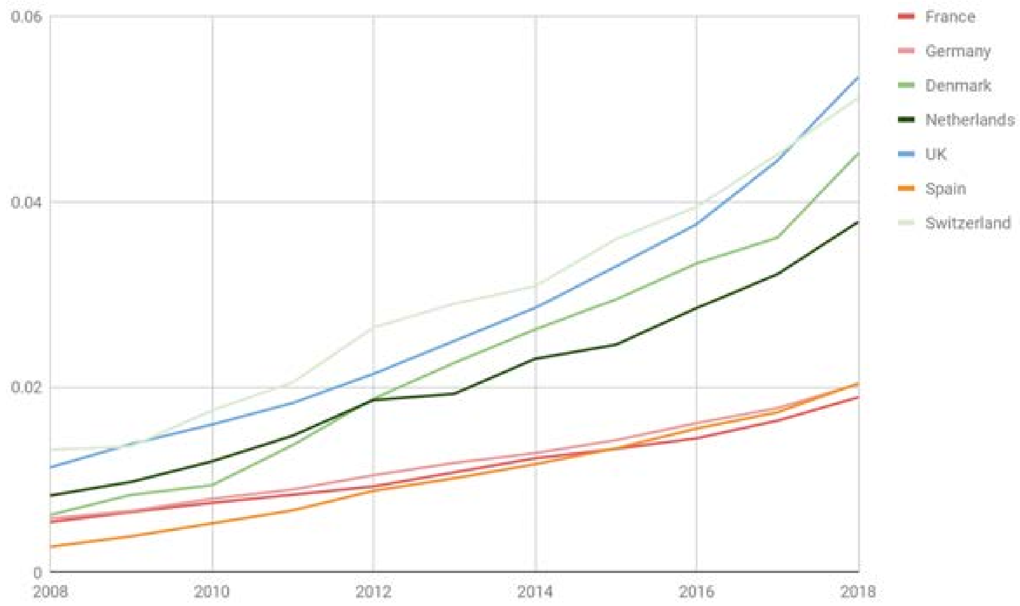


Fig. 54: Co-publications with China normalized per n° of researchers (data source: Scopus)

The resulting graph confirms the problem:

- Globally, Australia (not represented here) is a long way ahead of the rest of the world in terms of percentage of co-publications with China[74];
- Within Europe, Denmark, the Netherlands, Switzerland and the UK all have a high and growing percentage of co-publications with China. The same is true of the US;
- Finally, France and Germany (and, in this case, Spain) lag far behind and seem to be actually losing further ground with each passing year[75].

[74] This is linked to Chinese PhD and PostDoc mobility, to strong institutional policies and relative geographic proximity.
[75] The same is true of Japan, but this is linked to the remarkably low overall percentage of co-publications of Japan as a whole.

The problem might be specific to scientific collaboration with China but we think that it is indicative of deeper problems.

To test this hypothesis we chose a different approach and looked at researcher mobility rather than co-publication networks. For this, we used the GlobSci dataset[76] on researcher mobility in the fields of biology, chemistry, earth and environmental sciences and materials science and normalised results.

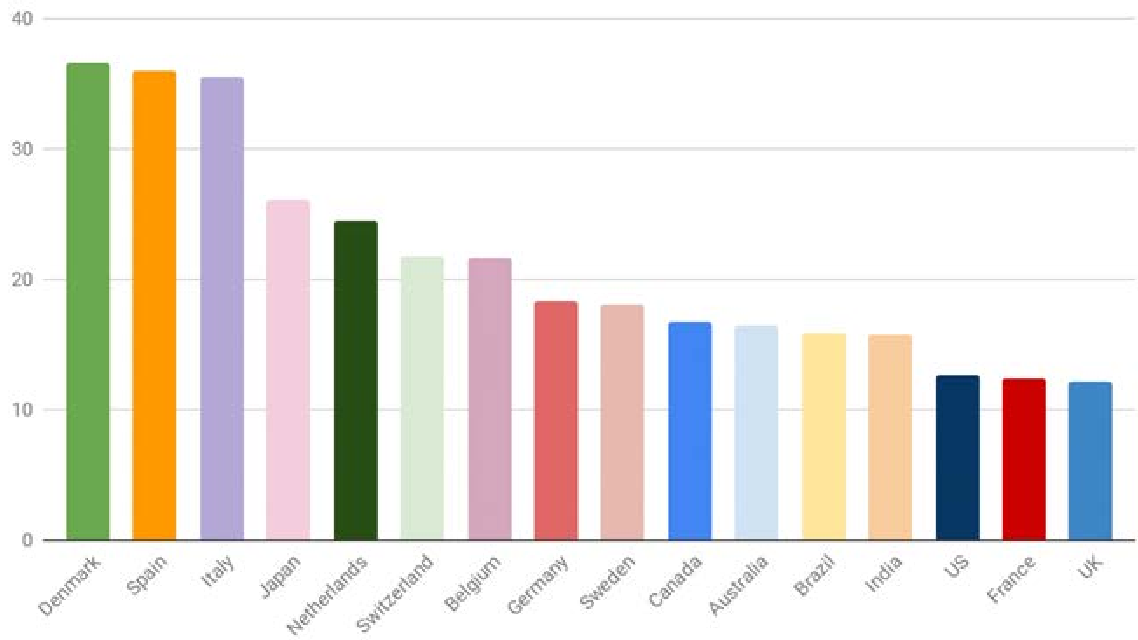


Fig. 55: Share of nonmobile natives that had temporary visits abroad for at least 6 months (data source: GlobSci 2015 study)

The share of French researchers who have had short-terms stays in foreign institutions is surprisingly low compared to other countries. Indeed, France stands alongside the UK and the US as the country's whose researchers spend least time abroad.

This will clearly be a problem for the UK and the US in the mid-term but it is less of an issue currently because they are the main destination countries for foreign scholars on short term mobility visits and thus gain connectivity thanks to this.

It is, on the other hand, an immediate issue for France, especially when you realise that scholars from both emerging European research systems and leading European research systems are up to three times more likely to spend time abroad (in the case of Spain and Denmark).

These examples highlight a couple of issues, which concern the way that the French research system is connected to the global research system. However, to address these issues it is necessary to change our perspective.

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[76] https://www.nber.org/globsci/

From national research systems to a global research system

As we underlined at the beginning of this chapter, the global network has a greater impact on the shape of the national one than vice-versa (Wagner, Park, and Leydesdorff 2015).

But what is even more important is that this global network is not shaped by national networks but by institutional ones. Researchers carry out their research, edit their journals and connect with their peers at an institutional level. The hubs of the global research network are thus not *countries* but *specific institutions within countries:*

> *[...] the fact that distance becomes irrelevant once collaboration is taken to the international scale suggests a globalized science system that is strongly influenced by the gravity of local science clusters* (Hennemann, Rybski, and Liefner 2012).

This matters because the connections we are describing are not country level connections, they are connections to hubs. As Wilsdon et al. (2011) put it:

> *gaining influence is through the quality of the nodes, which are not countries, but cities, and more precisely institutions within cities. Science is happening in more places but it remains concentrated. There continue to be major hubs of scientific production—flagship universities and institutes clustered in leading cities. What is changing is that the number of these hubs is increasing and they are becoming more interconnected (2011, 41)*

In terms of science policy, this is important in so far as it shows that what matters is not "internationalisation" as such but support to collaborate with the right institutions - whether they are international or not. The landscape of science is a landscape of universities and cities:

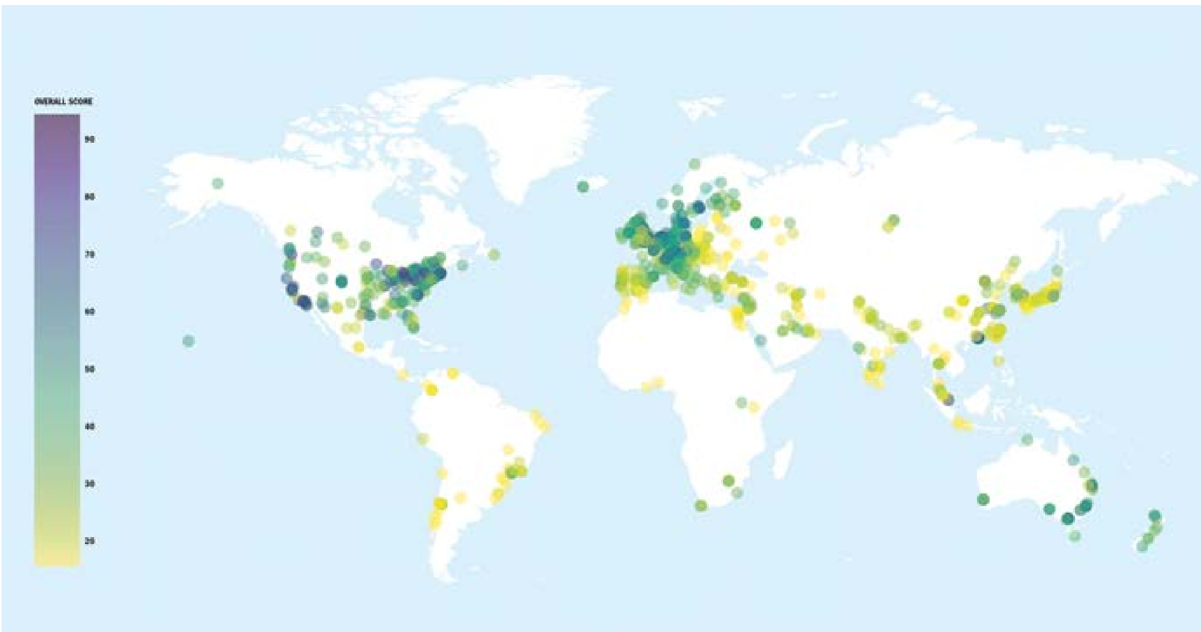

Fig. 56: Universities ranked by THE in 2018 (reproduced from THE)[77]

[77] Colour for score, the darker the better: https://www.timeshighereducation.com/news/world-university-rankings-2018-results-announced

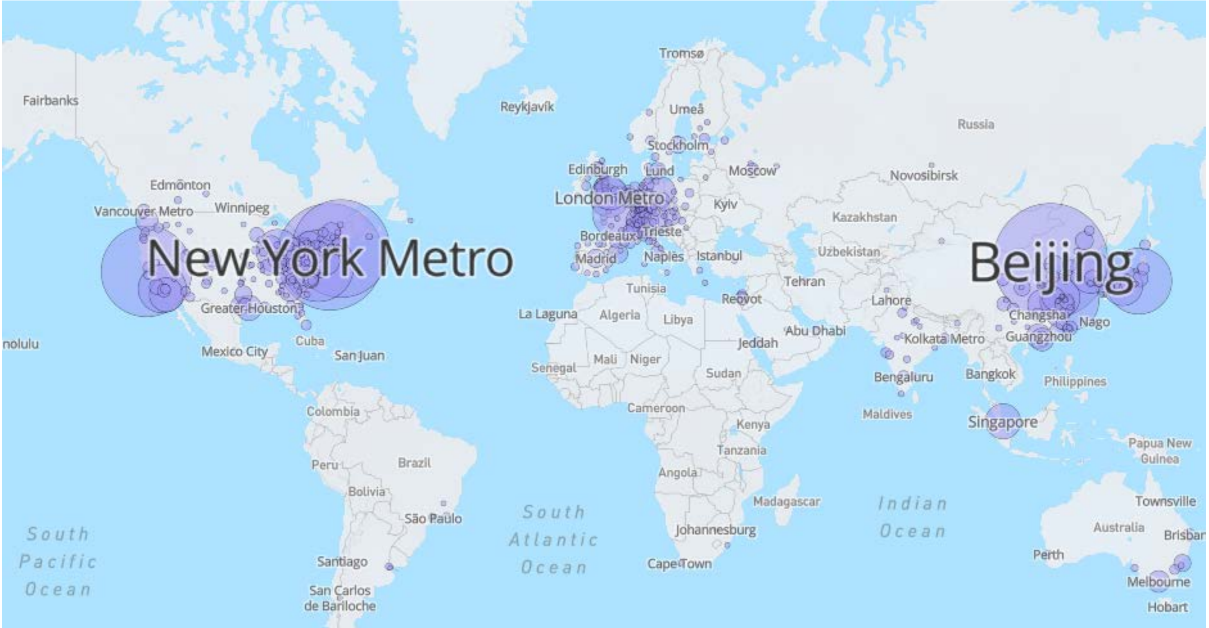

Fig. 57: Cities ranked by Nature Index according to research production (reproduced from Nature Index)[78]

Within this landscape, the hubs and clusters of this network are not immobile. The shape of the network evolves over time and new hubs appear on the basis of the quality of the research their produce. This has deep consequences:

> *When examined as interconnections across the globe over two decades, a global network has grown denser but not more clustered, meaning there are many more connections but they are not grouping into exclusive 'cliques'. This suggests that power relationships are not reproducing those of the political system. The network has features an open system, attracting productive scientists to participate in international projects. [...] The current growth of international collaborations puts into question the relationship between science and the state. [...] National governments could gain efficiencies and influence by developing policies and strategies designed to maximize network benefits—a model different from those designed for national systems. (Wagner, Park, and Leydesdorff 2015)*

National governments thus need to rethink the way they define research policy in two very important ways:

- First and foremost, the priority must shift from national visibility to boosting the visibility of individual hubs because these are the places where science is defined and where connections at a global level are forged;
- Secondly, science policy must ensure that the rest of the country remains well connected with these global hubs to enable global research results to be assimilated at a local level[79].

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[78] https://www.natureindex.com/supplements/nature-index-2018-science-cities/global-city-map

[79] Most research will remain at a local level: "The results of the analysis of six distinct scientific fields reveal that intra-country [i.e. local] collaboration is about 10-50 times more likely to occur than international collaboration". (Hennemann, Rybski, and Liefner 2012)

Factor 3: Structure of the French research system

To compare the structure of national research systems we distinguish three main features:

- the presence or absence of large national research organisations ;
- the degree of integration of universities and national research organisations;
- the degree of institutional differentiation among research intensive universities and institutions with a more local and/or educational focus.

The French national research system can be characterised as (a) weakly segmented with a low degree of institutional differentiation and (b) hybrid, with large national research organisations partly integrated within large research and teaching universities.

We then analyse the impact of this structure on the performance of the French research system in two steps:

1) The impact of vertical segmentation on performance

The first part of the discussion is closely linked to Factor 2 and shows that weakly segmented systems in which research in general and top research in particular is being performed by a greater fraction of institutions, tend to perform less well because they do not benefit from the knock-on effect of strong hubs.

2) The impact of strong national research organisations on performance

The second part of the discussion looks at the impact of strong national research organisations on the overall visibility and performance of a country when the global research system is structured around research intensive universities. It notably argues that:

- In a global system there is a premium for systems based on a “simpler” architecture. As a result, national research organisations have a measurable negative impact on:
  - rankings and visibility of universities
  - strategic decisions taken by potential international partners
  - student choices
- National research organisations perform well in purely quantitative terms but not as well in qualitative terms. They are behind the world’s leading universities in per researcher performance and, in some cases, behind research-intensive French universities on indicators such as citations per paper.
- The mixed research unit system is structurally costly because it implies large transaction costs and inhibits strong strategic profiling and planning.
- The two-track recruitment system differentiates the long-term mission and status of individual researchers for no good reason and on no strong basis.
- Finally, the size and geographic dispersion of large umbrella type national research organisations does not favour the emergence of cutting-edge fields.

We end with a short description of some recent evolutions of national research systems, which could be interesting to consider in a French context.

The structure of national research systems

Comparing the structure of a national research systems is complex because institutions do not perform the same role in different countries.

This is true of universities, which are categorised either formally or informally in different groups depending on the amount of research they perform. The Carnegie Classification of US institutions thus has over 20 categories including three for Doctoral Universities alone:

Doctoral Universities[80]

Includes institutions that awarded at least 20 research/scholarship doctoral degrees during the update year and also institutions with below 20 research/scholarship doctoral degrees that awarded at least 30 professional practice doctoral degrees in at least 2 programs.

Excludes Special Focus Institutions and Tribal Colleges.

The first two categories include only institutions that awarded at least 20 research/scholarship doctoral degrees and had at least $5 million in total research expenditures (as reported through the National Science Foundation (NSF) Higher Education Research and Development Survey (HERD)).

- R1: Doctoral Universities – Very high research activity
- R2: Doctoral Universities – High research activity
- D/PU: Doctoral/Professional Universities

But it is also true of national research organisations such as the CNRS or INSERM, for which there are numerous classifications.

The OECD thus distinguishes Mission Oriented Centres (MOC), Public Research Centres and Councils (PRC), Research Technology Organisations (RTO) and Independent Research Institution (IRI) (Sanz-Menendez et al. 2011), whereas the JRC (European Commission) distinguishes Public Research Organisations (PRO) and Umbrella Public Research Organisations (UPRO) (Reale, Lepori, and Scherngell 2017). According to the OECD classification, the CNRS is thus a PRC, whereas INSERM is a MOC, whilst according to the JRC, the CNRS is a UPRO and INSERM a PRO.

These distinctions are important and should be kept in mind, even if, in this report, we will limit our analysis of research systems in different countries to three main features:

- the presence or absence of large national research organisations following the OECD definition as “overarching institutions of considerable size”, which “perform [...] basic and applied research in several fields” (Sanz-Menendez et al. 2011);
- the degree of integration between universities and national research organisations;
- the degree of institutional differentiation among research intensive universities and institutions with a more local and/or educational focus.

[80] http://carnegieclassifications.iu.edu/

With these features in mind, three main models stand out:

- A "differentiated" model, with no large independent national research organisations, few research-intensive universities, more teaching universities, some independent research institutions;
- a "dual" model, with research universities, teaching universities, and relatively large national research organisations independent from universities;
- a "hybrid" model, with large national research organisations partly integrated within large research and teaching universities.

Differentiated model

This model is characterised by a differentiation between research-intensive universities, mostly teaching universities, and a relatively minor role played by national research organisations. Denmark, the Netherlands and Switzerland are classic examples.

In Denmark, research is carried out mostly within 3 research-intensive universities all ranked in the top 150 of ARWU (University of Copenhagen, Aarhus University, and TU Denmark). Alongside these research-intensive universities, 5 other universities focus equally on research and teaching focus equally on research and teaching, whilst other higher education institutions carry out mostly teaching activities (8 university colleges), or specialise in certain fields (9 institutions for architecture and the arts and 9 business academies). Research is also carried in a few independent "Sector Research Institutes"[81], but they are small and thematically focused institutions.

The structure is quite similar in the Netherlands, research being carried out mostly within universities, with the Netherlands Organisation for Scientific Research (NWO) as a funding agency for both the universities and research institutes[82]: there are 14 research universities in total, 8 of which rank within the top 150 ARWU (Utrecht University, University of Groningen, Leiden University, Erasmus University of Rotterdam, University of Amsterdam, Wageningen University and Research, Radboud University, VU University Amsterdam). Alongside these research universities, there are numerous universities of applied sciences (*hogeschool*). Finally the Royal Netherlands Academy of Arts and Sciences (KNAW) regroups 10 specialised research institutes.

Dual model

In this model national research institutes exist alongside research universities and teaching institutions, but research institutes are independent from universities. This model is typical of Germany and Japan.

Thus, in Germany, research is carried out both by research universities and large nation-wide research organisations, such as the Max-Planck Gesellschaft, the Leibniz Gesellschaft and the Helmholtz centres. Although such research organisations and universities collaborate locally, they retain independent strategies. Finally, like in Denmark and the Netherlands, research universities exist alongside universities of applied sciences whose main mission is teaching.

[81] https://en.wikipedia.org/wiki/Sector_research_institutes_of_Denmark
[82] https://www.euraxess.nl/netherlands/information-researchers/research-landscape

Hybrid model

Compared to these two systems, the French model is different in a number of important respects.

First the weight of national research organisations is similar or greater to that in Germany but, unlike in Germany, they are very closely integrated with universities thanks to joint research units (*Unités Mixtes de Recherche*), which include both researchers from the national research organisations and professors from the universities.

Secondly, although the university model is dual, like in most other countries, the equivalent of other countries' universities of applied sciences, the French *écoles d'ingénieurs*, are more selective than research universities. This deeply undermines the model of research intensive universities, which, in other countries, attract the best students.

In the remaining part of this chapter we will analyse the vertical segmentation of the different national research systems and explore the consequences of having a hybrid system.

Vertical segmentation of national research systems

Comparing the vertical segmentation of national research systems

As we saw in the first part of this report, France appears to be less vertically segmented than the US, the UK, the Netherlands, Switzerland and Denmark. This means that research in general and top research in particular is being performed by a greater fraction of institutions than in other countries: the landscape is less concentrated, and highly visible researchers are more evenly distributed among institutions.

This is linked to national scientific policy and notably the mid twentieth century decision to distribute CNRS research labs throughout the territory. With the development of mixed research labs, many universities found themselves both (i) playing an important role as reference higher education institution for a given territory; (ii) endowed with international-level research units in specific areas. The presence of UMRs in virtually all French universities helps explain why all universities see themselves as "research" universities. Whilst the prestige (and funding) of these units made it all the more difficult to adequately balance both missions within universities and often led to a "research drift".

An example of this is provided by the Lorenz curves below representing the distribution between institutions of the number of articles in the top 1% cited in their field (CWTS Leiden's Ptop1% indicator). The horizontal axis represents the cumulative share of institutions, and the vertical axis represents the cumulative share of top 1% articles. If such articles were homogeneously distributed among institutions, the resulting Lorenz curve would be a perfect diagonal, with a quarter of the articles in a quarter of the institutions, half of the articles in half of the institutions, and so on. The more skewed the curve, the higher the concentration of publications within a limited number of institutions.

The first chart depicts France with respect to China, Japan, the US and the UK. The second one shows France compared to its European peers.

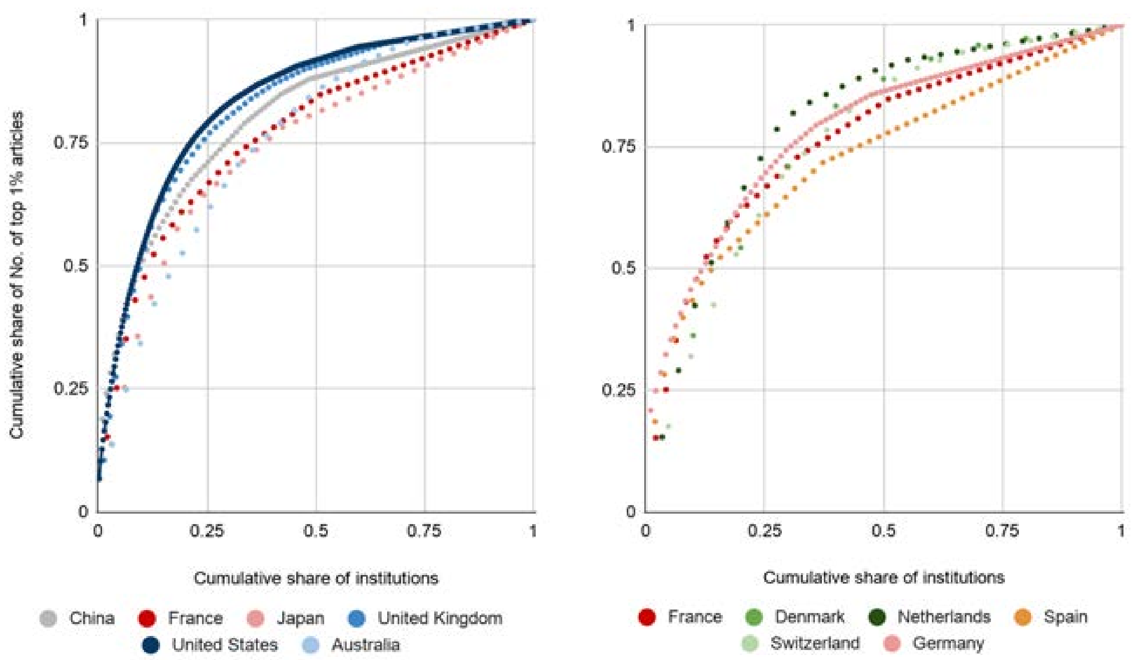

Fig. 58: Lorenz Curves - Top 1% articles in institutions by country with two sets (data source: CWTS Leiden)

The distribution of top 1% cited articles in France is less skewed than in the US, the UK or China, but also than in the Netherlands or Germany. Australia, Denmark and Switzerland are more skewed than France overall but less skewed at the very top of the curve (this is simply due to the fact that they are comparatively small countries with a handful of excellent universities at the top). Only Japan and Spain are clearly less skewed than France.

This distribution is confirmed by Lorenz curves for all other relevant indicators, such as the distribution of Highly Cited Researchers (HCR):

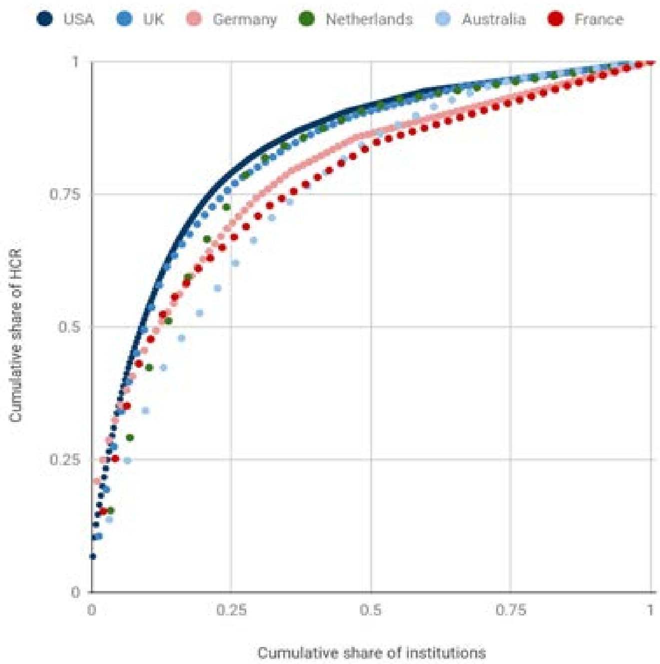

Fig. 59: Share of HCR per share of institutions (data source: Clarivate List of Highly Cited Researchers)

Here again Highly Cited Researchers are more widely spread throughout institutions in France than in the US, the UK, Germany or the Netherlands. Only Australia displays a less skewed curve.

Moving beyond Lorenz curves, Frederik Piro (2019) proposes a striking analysis of the profile of European countries by comparing the number and distribution of institutions that have submitted FP7 and H2020 proposals between 2007 and 2017 at a country level.

The following table lists the number of project-submitting "locomotive" Higher Education institutions (HEI) defined as institutions that have submitted more than 50 and more than 500 proposals (Piro 2019), along with the total number of R&D units in each country.

		50+ locomotives		500+ locomotives		500+/50+
Country	**R&D units**	**HEI**	**HEI/total units**	**HEI**	**HEI/total units**	**%**
Denmark	2,331	11	0.47%	5	0.21%	45.5%
France	8,485	96	1.13%	9	0.11%	9.4%
Germany	13,652	96	0.70%	34	0.25%	35.4%
Netherlands	5,702	24	0.42%	18	0.32%	75.0%
Spain	11,233	57	0.51%	18	0.16%	31.6%
Switzerland	2,495	22	0.88%	7	0.28%	31.8%
UK	12,400	108	0.87%	46	0.37%	42.6%

* This includes all institutions in a country that have applied for FP7 or H2020 funds.

Fig. 60: Number of project-submitting "locomotive" Higher Education Institutions (adapted from Piro 2019)

The distribution of institutions in the +50 and +500 categories for France is completely different to that of our other benchmark countries. With 96 institutions listed in the 50+ submission-institution category, France has exactly the same number as Germany and a very similar number to the UK. On the contrary, with only 9 of these 50+ HE institutions in the 500+ range, France has a ratio of only 9% between 50+ and 500+ institutions. All other benchmark countries retain at least ⅓ of their 50+ HE institutions as 500+ submitters.

France thus has very few top-producing institutions and a comparatively large number of medium-producing institutions, and this is true at all levels of analysis.

The following graph, adapted from a previous report (SIRIS Academic 2016a), shows the distribution of scientific production (measured in Web of Science) per institution in the cities of Boston, London and Paris.

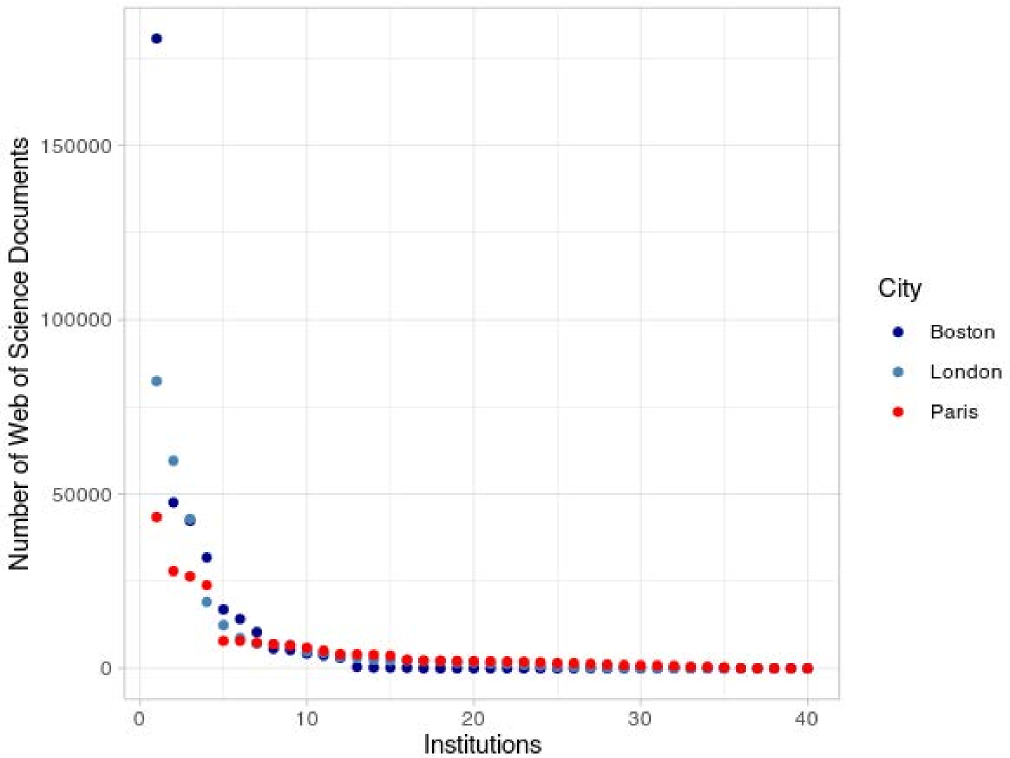

Fig. 61: Number of Web of Science Documents per university in Boston, London and Paris, 2016 (reproduced from Piro 2019)

Although the three cities are comparable in research potential, the distribution of this potential is very different:

- the hierarchy is clearest in Boston with only 16 institutions indexed in WoS, 11 with more than 3000 publications and 4 with more than 30,000;
- in London, 31 institutions have publications indexed in WoS (almost double), but there are only 12 with more than 3000 publications and 3 with more than 30,000.
- in Paris, 35 have indexed publications (similar to London), there are 15 with more than 3000 publications and only 1 with more than 30,000.

The link between vertical segmentation and performance

This relatively homogeneous distribution of research has an impact on the research performance of the French system (and not merely on its visibility), because, as we underlined in the introduction, science as a field is deeply skewed by definition. Skewed research systems benefit from a global “Matthew effect” that allows leading institutions to attract ever more resources and gain ever more visibility, thus favoring more vertically-segmented system.

In these skewed research systems, “the leading institutions are dense: they are leaders in all fields, their students are the best students and the percentage of highly cited publications of their researchers is extremely high. To be leaders, they have to ensure that the level of excellence is homogeneous. They cannot afford to retain laboratories that are not leaders in their field or deliver diplomas to students who are unlikely to be accepted by a Master programme at one of their peer institutions”. (SIRIS Academic 2016a)

Fredrik Piro thus shows that:

> *countries that can be characterized as well-performing on citation and innovation indicators seem to combine (a) high shares of Gross Domestic Expenditure on R&D as a percentage of GDP with (b) a highly skewed R&D system, where a small part of the R&D performing actors account for a very high share of the national R&D performance*. (Piro 2019, 116)

This diagnosis explains why countries worldwide have launched initiatives to create “lighthouses”, places where research funding, infrastructure and researchers are concentrated, in order to increase research performance. These “lighthouses” benefits the research ecosystem more generally - in the same way that Harvard and the MIT benefit all the higher education and research institutions in Boston.

The numerous Excellence Initiatives launched by countries worldwide to support world-class universities are the best known initiative of this type, however there are many others.

For example, the recent “Nobel pact” defined in the 2018 strategic plan of the Danish Ministry of Higher Education and Science plans aims to:

> *create the framework for a coordinated strategic effort to promote and recognise Danish research considered to be of a Nobel prize-winning quality i.e. excellent research at the ultimate international level with the potential to create fundamental and transformative scientific breakthroughs. As a central initiative to the pact, the Government will aim to establish a number of special Nobel prize centres with a sufficiently ambitious financial framework and long-term outlooks, in order to create research results that can compete with the absolute best international research. (Danish Ministry of Higher Education and Science 2018)*

It is too early to evaluate the impact of the French Excellence Initiatives[83], however the current target universities do not seem to have yet enabled a strong increase in the density of excellence as opposed to overall size.

The impact of National Research Organisations

To look at the impact of national research organisations on research performance, we will return to the data compiled by Fredrik Piro, which systematically includes Public Research Institutions (PRI) and notably NROs. He concludes on the respective weights of (1) higher education institutions (HES), (2) government-sector research institutions (REC) and (3) private company research in Europe’s research systems:

> *The highest share of contribution is found in the UK (64%) where the REC sector’s share is very low. In many countries there is a trade-off between these two sectors. Large shares in the REC sector is at the expense of the HE sector, foremost in countries with a dominating research performing national research council (e.g. France and Spain) or with a national academy of science (e.g. Moldova and Bulgaria). A third option is to have a strong governmental research institute sector such as Norway (REC accounts for 31%), unlike Denmark where most research institutes are now integrated in the universities, so that the REC sector here only accounts for 8%. (Piro 2019)*

[83] “[…] upgrading a university takes many years, eight to ten at the very minimum” (Salmi 2016).

This point is even clearer if we return to the "locomotives" of EU project submissions.

	50+ locomotives			500+ locomotives			500+/50+ locomotives		
Country	HEI	PRI	Share HEI	HEI	PRI	Share HEI	HEI	PRI	Share HEI
Denmark	11	10	52.4%	5	0	100.0%	45.5%	0.0%	100.0%
France	96	49	66.2%	9	9	50.0%	9.4%	18.4%	33.8%
Germany	96	98	49.5%	34	8	81.0%	35.4%	8.2%	81.3%
Netherlands	24	30	44.4%	18	5	78.3%	75.0%	16.7%	81.8%
Spain	57	128	30.8%	18	6	75.0%	31.6%	4.7%	87.1%
Switzerland	22	12	64.7%	7	4	63.6%	31.8%	33.3%	48.8%
UK	108	39	73.5%	46	3	93.9%	42.6%	7.7%	84.7%

Fig. 62: project-submitting "locomotive" Higher Education Institutions (HEI) and Public Research Institutions (PRI) (adapted from Piro (2019))

The weight of NROs in France in terms of EU project submission is remarkable. Whilst the share of PRI in the 50+ range is not particularly high (most countries have a stronger presence of PRI in the 50+ range), this ratio is totally reversed in the 500+ range of institutions. Here, PRI make up half of the institutions, the highest ratio among the benchmark countries, who (with the exception of Switzerland) have at least a 3/1 ratio. This confirms the exceptionally strong weight of PRI (and thus of NROs) in France even with respect to Germany or Spain.

The composition of national research funding, as analysed by the JRC (Reale, Lepori, and Scherngell 2017), confirms the weight of National Research Organisations:

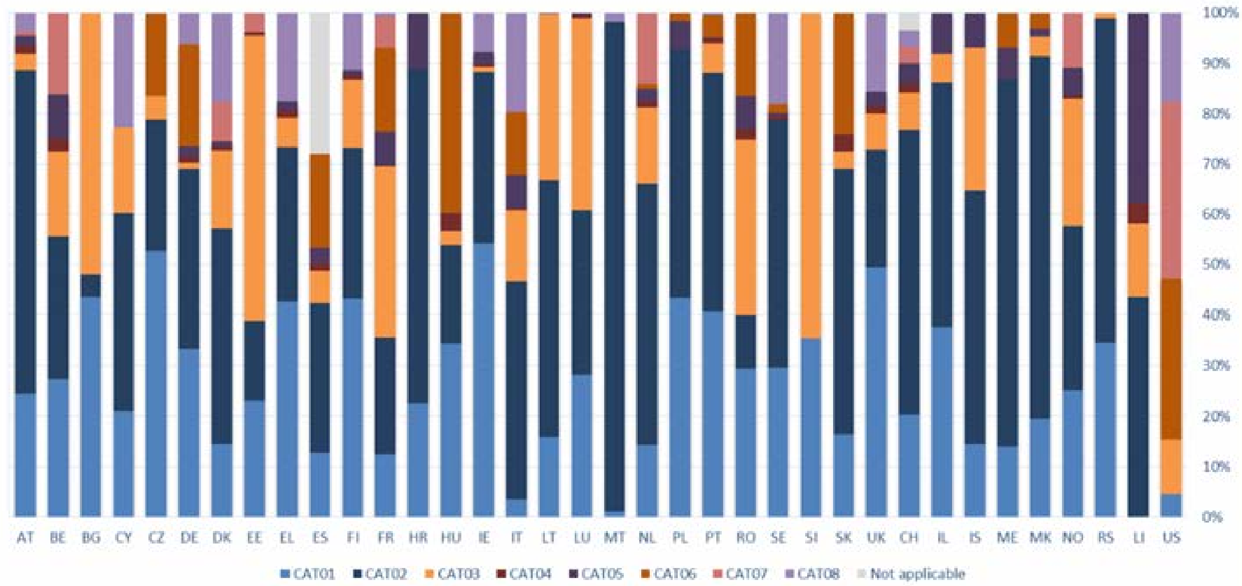

Fig. 63: GBARD (Public research funding) by stream category, %, 2014 - NROs are in categories 03 - PROs (Public Research Organisms) - and 06 - UPROs (Umbrella Public Research Organisms). (reproduced from (Reale, Lepori, and Scherngell 2017, 39))[84]

[84] "Note: CAT01 = Funding to RFO; CAT02 = Funding to HEIs; CAT03 = Funding to PROs; CAT04 = Funding to international performers; CAT05 = Funding to international funding agencies; CAT06 = Funding to UPROs; CAT07 = Exchange funds; CAT08 = Intramural R&D of the government. Reference year for AT, ES, LT, UK is 2013, and 2015 for FR."

Unlike our benchmark countries, the weight of PROs and UPROs within the French research system is clearly superior to that of Higher Education institutions (category 02) or even research funding organisation (category 01).

The correlation between the weight of NROs and the poor overall performance of the French research system could be a pure coincidence, however the following five arguments seem to show quite conclusively that the current weight of NROs and their existing missions (as defined in their contracts with the state) has a negative impact on the overall research performance of France.

Argument 1. Visibility

In a global system based on international comparison, visibility matters and there is a premium for systems based on a "simpler" architecture. In this context, the specificity of national organisations with NROs and universities becomes a problem because it hinders visibility. This can be illustrated by multiple examples:

Affiliation errors and impact on rankings

One of the main problems is one of affiliations. When researchers include multiple affiliations (to a university and to a national research organisation) in their scientific articles, this causes confusion:

> *The retrieval of affiliation information from databases is subject to errors of various kinds. This is particularly true in some European countries such as France, in which researchers affiliated to universities are also often members of joint laboratories with national PROs, such as CNRS or INSERM. According to several experts in the field, it may happen frequently that authors only mention the name of the laboratory, assuming that readers know the names of affiliated universities. There are estimates that Scopus data underestimates French universities by a wide margin (between 10 and 50% depending on the university) (Bonaccorsi, Cicero, et al. 2017)*

In some cases, such as Clarivate Analytics list of Highly Cited Researchers, the impact can be easily calculated and simply changing the affiliation of a few national research organisation researchers to the university where they are based can result in a jump of dozens of positions within a ranking such as ARWU (SIRIS Academic 2019).[85]

The impact on bibliometric databases is both more complex and potentially even more serious. When a scholar correctly identifies all institutions to which she is affiliated, many agencies will automatically attribute a portion of total points to each of these institutions. This means that including both the university and national research organisation as affiliations can result in a loss of both visibility and impact for the university and therefore the national research system as a whole.

[85] E.g. by changing the main affiliation of 2 researchers (Francis Bach and Laurent Bopp) École Normale Supérieure would gain 2.7 points and would move up from the 64th to the 54th position in ARWU; by changing the main affiliation of 5 researchers (Sandra Lavorel, Dominique Raynaud, Cordelia Schmid, Wolfgang Wernsdorfer and Wilfried Thuiller) Université Grenoble Alpes would gain 3.84 points and would move up from the 151-200 range to to the 101-150 range and only 1.8 points would separate it from the top 100 (all other factors remaining equal). See also the work of Daniel Egret.

Affiliation and impact on visibility

As mentioned previously, research intensive universities are the key hubs in the global research system: they ensure the visibility of each national research system.

The question of visibility is nicely illustrated by the results of the Times Higher Education ranking. One of the key sources of data for this ranking is a global reputational survey sent to tens of thousands of researchers around the world (it counts for 33% of the total overall score). The decision of THE to use a reputational survey is problematic from a methodological point of view[86]. But the global impact of the ranking is unquestionable and therefore needs to be taken into account. The results are surprising:

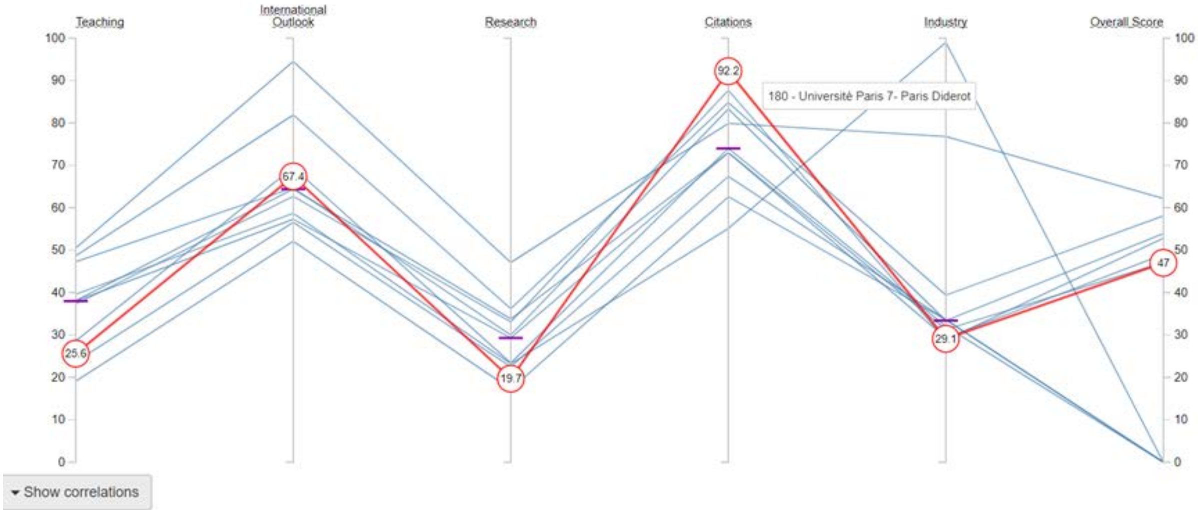

Fig. 64: Score of Paris Diderot - Paris 7 according to Times Higher Education 2015 ranking on five composite indicators (lines in blue represent other French institutions) (data source: THE)

The fact that, according to THE, Paris Diderot is one of the best universities in the world in terms of Citations with a score of 92,2 and very weak in Research with a score of 19,7 is really strange. It is a direct result of the very poor scores of the university in the reputational survey. The explanation is simple: Paris Diderot should have had a high score in research but international scholars were not aware that some of their colleagues worked in this university, either because they could not remember the name, did not understand the French system and/or because these colleagues did not mention the university as their key affiliation. The first step to improving the situation has been finalised with the merger of Paris Descartes and Paris Diderot and the creation of the University of Paris. However, results on indicators such as this will only really improve when all scholars, including employees of National Research Organisations, underline in all their communications both formal and informal, that their primary affiliation is with the university .

[86] Although it makes sense from a purely commercial point of view, because survey data are proprietary non-reproducible data.

Visibility and impact on partnerships

The following screenshot from a strategic dashboard[87] shows the main Horizon 2020 partners of Italian universities in Tuscany. It is used by these universities to help define priorities in terms of international partnerships.

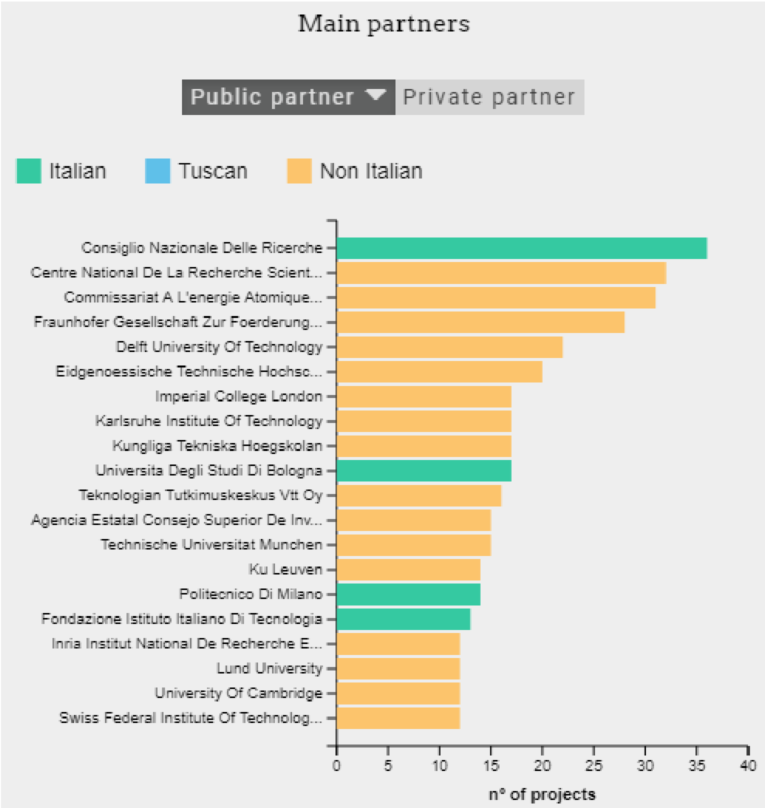

Fig. 65: H2020 partners of Italian universities (data source: CORDIS)

In the case presented in the figure above, the two main foreign partners are both French: CNRS and CEA. However, this information is useless to define partnership strategies with France.

Indeed, when a Tuscan university discusses key strategic partnerships, this tool helps them visualise the importance of their research partnership with universities such as Delft, ETH Zurich, Imperial or Karlsruhe. They do not take into account the fact that two French national research organisations should top the list because Tuscan universities' homologues are universities, not national research organisations. As a result, such a dashboard risks encouraging them to downgrade partnerships with French universities because none appear in their list of key research partners - the strong existing research links between Tuscan and French universities are completely masked by the affiliation of H2020 projects to national research organisations[88].

Tools such as this one are becoming more and more common across Europe and will have a major negative impact on the French national research system, unless all European projects are systematically affiliated to universities.

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[87] http://toscanaopenresearch.it/en/

[88] The authors of this report observed this process underway. Explaining that some of the research projects affiliated to a French national research organisation were, in fact, carried out within a university in a mixed research lab proved to be particularly difficult to explain.

Visibility and impact on student choice

The following graph comes from an article aimed in particular at potential US students in computer science. It lists the top 25 graduate schools for those who want to specialise in artificial intelligence, stating: "If you are open to going to grad school anywhere in the world, here is the top 25 chart".

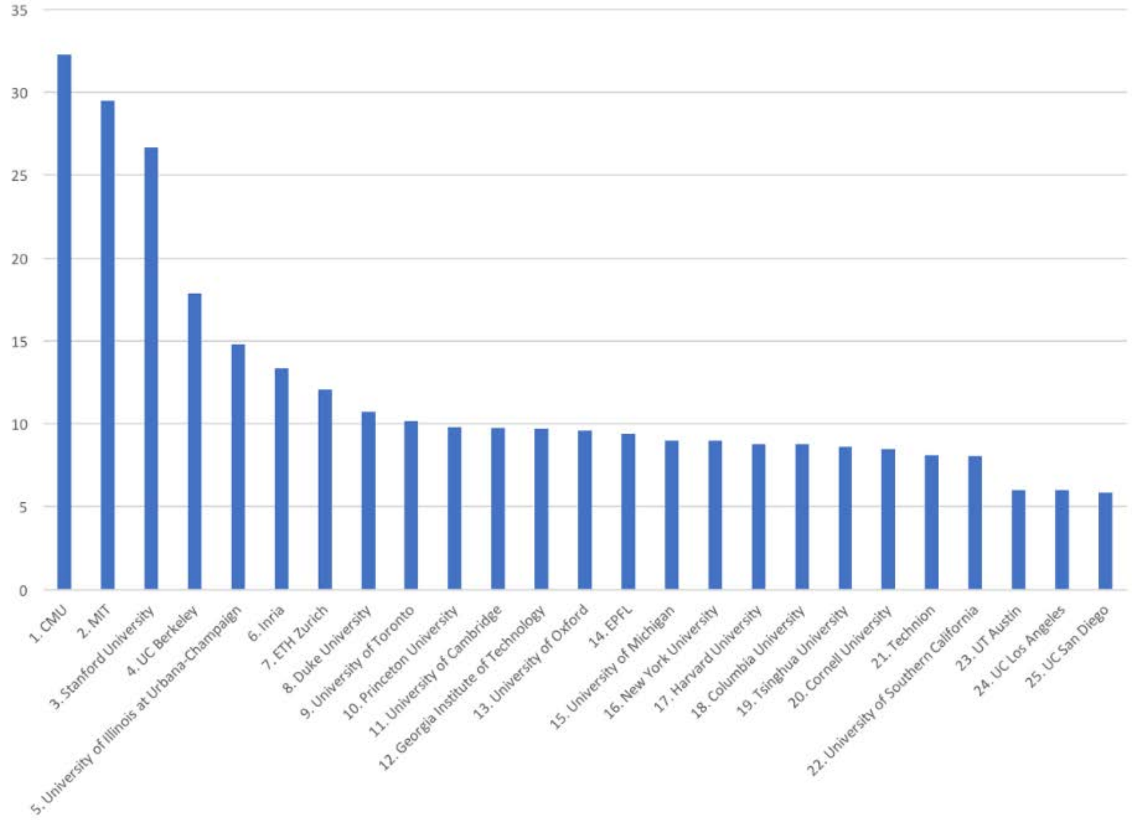

Fig. 66: World-top 25 universities in AI research at NIPS 2017 publication index (reproduced from Chuvpilo (2018))

It is remarkable that INRIA should be listed as 6th best institution worldwide and first outside the US. The problem is that INRIA is the only national research organisation listed amongst the 25 institutions and that, seeing that INRIA does not deliver diploma, a US student will have the choice between applying to a university in Switzerland, Canada, the UK, China or Israel, and is likely to eliminate France from his list of potential destinations, because no pertinent institution is included.

Argument 2. National research organisations are not elite performers

Throughout this report, we have shown how highly performant national research systems concentrate excellence in a few leading research intensive institutions. In theory, national research organisations concentrate excellence and should therefore perform far better than universities, especially since their researchers are fully dedicated to research and do not spend half their time teaching. This is however not the case.

The CNRS highlights excellent results in international rankings[89], listing notably the Nature Index Ranking and the Scimago Institutions Rankings. The problem is that all the rankings listed by the CNRS are size-dependent: they measure the total number of publications. It is therefore logical that the leading institutions should be the biggest in number of researchers employed: in both cases, the CNRS is second, just after the Chinese Academy of Sciences. In Nature Index the third is the Max Planck, whereas in Scimago it is the Ministry of Education of the People's Republic of China. Unsurprisingly, the impact of these rankings is limited.

To the best of our knowledge, the best tool comparing research performance of national research organisations and universities on a global level, in a qualitative way is Mapping Scientific Excellence (Bornmann et al. 2014)[90]. The tool compares the number of papers produced by an institution in a given discipline with the number of those that are among the top 10 percent of most highly cited papers in their field. As such it is similar to CWTS Leiden's PP Top10% indicator.

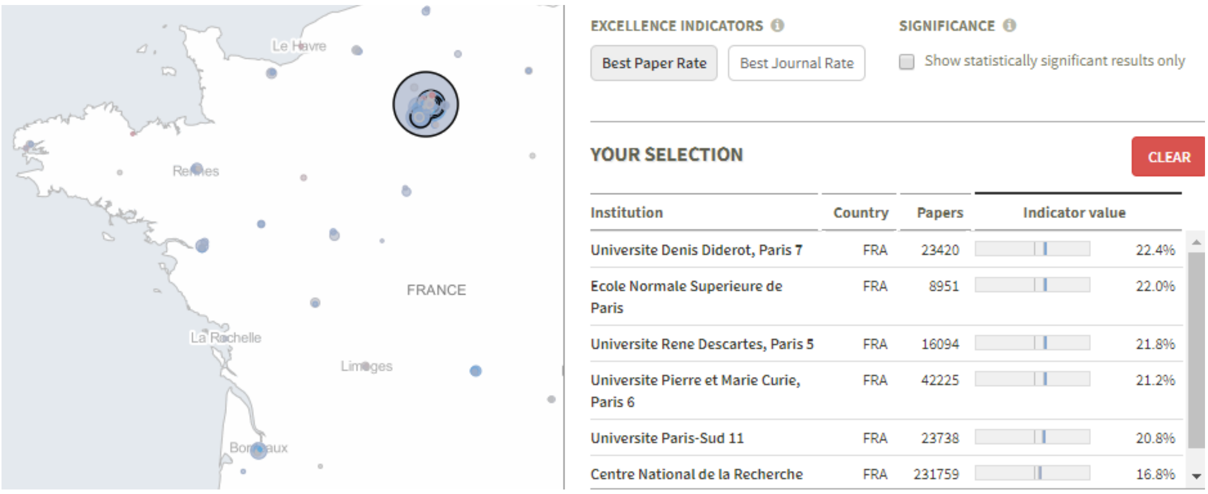

Fig. 67: Screenshot of the Mapping Scientific Excellence tool, showing six selected institutions and their score on the percent of papers in the top 10%

Research intensive French Universities thus score better than the CNRS in terms of research excellence with Paris Diderot (22,4%), ENS (22,0%), Paris Descartes (21,8%), Pierre et Marie Curie (21,2%) and Paris Sud (20,8%) all scoring well above the CNRS (16,8%). This means that the average paper published by a researcher affiliated with one of these institutions has more impact than the average paper published by a researcher affiliated to the CNRS[91].

Argument 3. Transaction costs and strategic paralysis

The fact that national research organisations do not seem to concentrate excellence more efficiently than leading research-intensive universities is an important argument. But the main argument against the *unités mixtes de recherche* (UMR) model is one of strategy.

When UMR were first created, universities had no autonomy or strategic decision-making capacity and limited research potential. Thanks to the UMR, national research organisations

[89] See the list of Achievements at http://www.cnrs.fr/en/cnrs

[90] See http://www.excellencemapping.net

[91] This is a truly surprising result and would deserve an in-depth study using robust bibliometric approaches such as those applied by CWTS Leiden.

were able to introduce control-mechanisms, which supported emulation and encouraged accountability: having two “tutelles” made it more difficult for a lab to slip into complacent practices (lowering standards, questionable recruitments, etc.). Indeed, in certain fields such as mathematical research the dynamic between universities and national research organisations is viewed as an extremely positive factor.

However, such a system also created higher coordination costs. By definition, it implies systematically splitting leadership and decision-making power over the main resources of a lab - infrastructure, funding and HR decisions. In other words, the mixed units systems means that, for a lab, a coherent strategy requires a perfect alignment between university and NRO leaderships[92].

In the best case scenario, this alignment of strategy between the various “tutelles” simply requires a cost in time. In the worst case scenario, the alignment does not happen and results in loss of efficiency. At the end of the day, organisational theory clearly shows that the usual outcome will be weak, low-ambition strategic plans, and thus, as Richard Rumelt would say, “bad strategy”.[93]

Instead of having a clear-cut situation where one actor formulates and implements strategy and is accountable for it, whereas another actor controls and allocates resources (the French term for this would be “agence de moyens”), the current system dilutes both means and responsibility.[94]

A perfect example of the existing lack of strategic planning capacity is the fact that it is remarkably difficult to obtain consolidated data about the resources of a lab[95]. The lab director theoretically has access to this information, even if he needs to juggle with several, mutually non-compatible, information systems. But for both the administration of the university and that of the national research organisation, the default position is that they have access to only that part of the resources of the lab which depend directly on them. This creates the bizarre situation whereby universities are supposed to define an ambitious research strategy whilst not even having full information over their labs.

Research in economics and political science has long since established that such an information asymmetry necessarily results in a loss of strategic effectiveness and efficiency (Stigler 1961; Komai, Stegeman, and Hermalin 2007; Poth and Selck 2009).

The problem is sometimes dismissed as being purely technical but the fact that no solution has been implemented despite the problem having been identified 50 years ago would seem to argue for another interpretation: it is an inbuilt consequence of an inefficient model.

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[92] The case of *multi-tutelles* laboratories with various universities and grandes écoles is, of course, even more problematic.

[93] Multiple-leadership setups typically have difficulties in defining challenges (which may not be the same from each perspective), and thus formulating clear objectives and act to achieve them (Rumelt 2012).

[94] In a classic article, Douglass C. North (1990) insists on the fact that an institutional framework must provide actors with clear signals and incentives to the relevant actors to avoid increased transaction cost.

[95] A report of the *Inspection générale de l'administration de l'éducation nationale et de la recherche* of 2014 describes the problem and highlights the lack of common Information systems enabling access to very basic data regarding HR and funding of the labs. (Toussain et al. 2014)

Argument 4. Human Resources

We will look at human resources in more detail in the next chapter, however, it is obvious that any organisation that wishes to implement a strong strategy needs to have authority over human resources. Simply put, a university has no authority over national research organisation researchers, which it does not employ, even if they work within the university.

The dual hiring process between national research organisations and universities provides a good illustration of the problem. Currently most young researchers apply to a position at both a national research organisation and a university. Whether they end up being recruited by the national research organisation or by the university, they may well end up working in the same lab. Yet, in one case they will be expected to spend half their time in research and half teaching and in the other case, their contract will enable them to spend 100% of their time in research for life.

Attempts are being made to correct this by encouraging NRO researchers to teach and providing more opportunities to *maîtres de conférence* to spend long periods exclusively dedicated to research.

But even with improvements such as these, the dual hiring process remains very hard to defend. Surely it would make more sense to recruit all starting researchers and professors with the same status and enable the university that employs them to modulate the time spent teaching and researching on a yearly or pluriannual basis?

Argument 5. Developing new cutting-edge fields of research

One of the most important conclusions of Part I of this report was that French research is weaker in cutting-edge fields than in more classical ones. Addressing this issue should be a national priority because such fields are likely to produce breakthroughs in fundamental research and because they often enable innovation[96].

Theoretically, this is precisely one of the issues that a large scale national research organisation is supposed to tackle. However, in a world in which the global system is dominated by research intensive universities competing and collaborating with each other, it is not clear that national research organisations are the most suited institutions to do this.

Choosing new priorities in terms of disciplinary fields necessarily involves diminishing the funding available for other existing fields. This is increasingly what research intensive universities do, because they are competing with other similar universities to attract leading scholars and students. Ludwig Maximilian University has thus identified priorities in fields such as Quantum Science and Technology or Systems Neurology after an extensive strategic analysis of their strengths and weaknesses and a global benchmark. Since 2004, they have implemented the 50/40/10 process, which enables them to reassign human resources to new fields (only 50% of positions are renewed in any given field)[97] and are reinforcing their position as a key hub in the global research system. They can do this because they are constantly comparing themselves to dozens of other universities at a global level.

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[96] This question is not about fundamental versus applied research but about the capacity of a research system to develop new fields of research and rebalance financing between fields. High performing systems tend to be able to shift focus faster (current examples include boosting the weight of life sciences, focusing new resources in neuroscience, encouraging the study of ethics or developing labs specialised on graphene - there are countless others).

[97] http://www.en.uni-muenchen.de/about_lmu/research/research_profile/strategy/index.html

In a country such as France, an umbrella public research organisation will necessarily need to balance priorities both in terms of geography and in terms of disciplinary fields. The tendency to compromise will naturally increase with time, because each region and each institution will defend its laboratories and each disciplinary field will defend its prerogatives. This tendency will be reinforced by the fact that an umbrella public research organisation is, by definition, not comparable to any other institution and therefore does not compete directly with other institutions and cannot compare itself to other institutions. It will logically promote indicators such as total number of publications or grants and avoid those which look at true research performance.

For structural reasons, the strategy of such an institution will thus be to promote a conservative outlook and to limit risk-taking. From a national perspective the result is visible in the French research performance in cutting-edge fields.

Lessons from abroad

Over the last 20 years, many national research organisations have re-thought their role within the national research systems. This is a direct result of the growing importance of universities as key hubs that increase the visibility and attractiveness of national research systems. To illustrate this, we have chosen three examples.

University of Chinese Academy of Sciences

Our first example is that of an institution with the role of a national research organisation choosing to compete with universities, by *creating* a university.

The launch of the 985 and 211 excellence initiatives in China led to a series of mergers of both universities and national research institutes. They also questioned the role of the Chinese Academy of Sciences.

Unlike in other countries, where national research organisations reinforced their link with universities, the Chinese Academy of Sciences chose to go it alone by boosting a small existing Graduate School, renaming it Graduate School of Chinese Academy of Sciences (GSCAS) in 2000, Graduate University of Chinese Academy of Sciences (GUCAS) in 2005, University of Chinese Academy of Sciences (UCAS) in 2012 and enlarging its recruitment to undergraduates from 2014.

UCAS is in direct competition with the Chinese C9 universities and its president feels confident advertising in Nature with an interview outlining what makes UCAS stand out among the 2,300-plus Chinese universities[98].

However, although the total production of the university makes it a global player, it does not perform as well as the C9 on size-independent indicators. More importantly, UCAS has not been selected by the latest Chinese excellence initiative launched in 2017 that includes 36 “double first class” universities that will concentrate most of the research investment in the coming years[99].

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98 https://www.natureindex.com/supplements/nature-index-2017-china/university-of-chinese-academy-of-sciences-ucas

99 https://internationaleducation.gov.au/News/Latest-News/Pages/Implementation-measures-released-for-China%E2%80%99s-new-world-class-university-policy.aspx

Wageningen University

Wageningen University is a classic recent example of a merger between a university and a national research organisation, which used to be placed under the Ministry of Agriculture, the Agricultural Research Service (DLO).

The process started in 1997 with the creation of Wageningen University and Research, a holding regrouping the University and the National Research Organisation. All staff was then transferred to the new university, which progressively integrated, rebranded and transformed the national research institutes over a period of 10 years[100].

Many similar cases of mergers between national research organisations and universities exist, such as the recent one, which merged a Helmholtz Research Centre with University of Karlsruhe to create the Karlsruhe Institute of Technology in 2009.

In France, a comparable project involves the merger of six institutions including IFSTTAR, a national research organisation, in order to create the University Gustave Eiffel[101].

Mergers of NROs in Denmark

The Danish case is perhaps the best example of a large scale systematic merger of universities and national research organisations in order to be more competitive at a global level.

The main aim was to strengthen the research potential of research-intensive universities, by creating institutions with both more resources and a unified strategic leadership. The long quote below, explains those motivations in more detail:

> *The university merger processes consisted of integration of government research institutions (GRIs) into the university sector, which were a target directly embedded in the Globalisation Strategy; and mergers between universities, which were initiated by the government subsequent to the decision on the Globalisation Strategy. The integration of GRIs had as its main aims: to stimulate research synergies between until now institutionally separated sectors, to fertilise the university sector with practice oriented research leading to close contacts with societal, i.e. private and public sector agencies, and to make additional research resources available for educational processes, leading to a strengthening of the link between higher education and research. The mergers were voluntary as regards the universities; forced mergers would only have been possible through a change in the existing University Act - a change for which there was no majority in Parliament. As regards the GRIs the merging decision should preferably be supported by the boards of the GRIs. While the Ministry of Science, Technology and Innovation hinted at a preferred overall result of 6 universities, the actual result of the merger processes was a new university sector consisting of 8 universities, while also some of the government research institutions remained independent. (The Danish University and Property Agency 2009)*

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[100] As part of the process, the university also merged with Van Hall Larenstein, a university of Applied Sciences in 2006. This merger was however unsuccessful because the two structures had different missions (research intensive university versus mostly undergraduate university). As a result, in 2015, the merger was reversed and Van Hall Larenstein became independent once again.

[101] http://www.univ-gustave-eiffel.fr/faq/

The Danish mergers took place in the mid 2000s. They are one of the key factors that explain the remarkable performance of the Danish national research system, when compared to the French national research system.

French National research organisations as funding agencies

Seen from abroad, it is interesting that French national research organisations are regularly classified as research funding agency, rather than national research organisations *stricto-sensu*. For example:

> *[...] the most important group of funding agencies for example the various Research Councils in the United Kingdom; the most part of the 'grands organismes de la recherche' in France and the overwhelming part of research institutes situated at American federal departments like the National Institutes of Health* (Braun 1998).

In this sense, it is worth reading Theves et al. (2004). In their article, the authors analyse the CNRS as an agency for project-based allocation of human resources:

> *Our proposal is thus to consider CNRS (and its 26 000 employees!) not as a classical public research organisation (PRO), but, following Guston ([2000] 2007) as a boundary organisation, being a stabilizing organisation within the national R&D system and serving both scientific and political interests, as the agent of the State and the principal of academic labs. We argue that the mechanisms put in place by CNRS for labelling "joint research units" typically correspond to "project-based" processes: a periodic open call, a strong selection process, a support limited in time and scope, with clearly defined direct and indirect benefits. Through this mechanism, CNRS allocates different resources: funds, access to large facilities and, first and foremost, human resources. This is this latter dimension that has driven us to speak of an agency for "project-based allocation of human resources". (Theves et al. 2004, 15)*

Classifying French national research organisations as funding agencies might make sense from an organisational perspective. But it will only help increase the performance of the French research system if the French state rethinks the mission that national research organisations are supposed to fulfill: today a national research organisation is evaluated according to indicators such as "Number of European projects". Things would be very different if the indicator was "Number of European projects won by French universities, thanks to a contribution by the national research organisation". Until this is the case, the role of national research organisations can be questioned but they cannot be expected to change.

Factor 4: Human Resource model

At the end of the day, research performance depends on individuals: researchers publish articles, which are cited, they are awarded ERCs and become Highly Cited Researchers. Attracting talented researchers is thus key, which is why our fourth factor explores the main features that makes a research system attractive.

France currently experiences a brain drain towards high performing countries, a balanced brain circulation with Germany, and a brain inflow from lower performing countries. This brain circulation is not only linked to working conditions but also to research performance: studies show that a researcher with an ERC will obtain better results if she chooses to move to a high performing country.

Brain circulation has a major impact because research performance depends primarily on talent: fomenting excellence is far harder and less efficient. This is why attracting talent is so important for national research systems.

Studies show that researchers are attracted first and foremost to:

- “outstanding faculty, colleagues or research team”;
- and “excellence/prestige of the institution”.

Better research infrastructure and access to research funds are important, but less so. The same is true of better salaries, quality of life and working conditions.

In other words, leading researchers are attracted to vertically segmented research systems and perform better within them, thus reinforcing the impact of structure described previously in Factor 3.

To attract the best researchers, high performing countries have launched specific funding programmes, or “talent schemes”. These aim to support the emergence of national lighthouses by providing long term research autonomy to successful applicants.

However, the French research system is unable to compete with these countries because universities do not have the necessary autonomy and power to define their Human Resource policy.

Close to half of the academic staff working in research intensive universities are still employed by national research organisations who define their own Human Resource rules. The university has no power to define their workload (balance between teaching and research) or incentives.

Within the university itself, staff promotion and hiring decisions depend on national agencies such as the CNU, that have strict national rules, which dramatically limit each university’s autonomy. Universities cannot even freely modulate the time an employee spends on research, academic and administrative duties.

At the end of the day, the key issue, which underlays each of the three factors we have explored so far, is that of Human Resources: researchers publish articles, which are cited, they are awarded ERCs and become HCR. Our fourth factor therefore concerns the attractiveness of the French research system for individual researchers.

International researcher mobility

Direct data about the international mobility of researchers are surprisingly scarce[102], however recent data and survey-based studies make it possible to outline key trends[103].

Studies of the bilateral flows of researchers unsurprisingly show that these tend to favour better performing research systems[104]. Thus, a recent study by S. Appelt et al. underlines that France suffers from a high negative brain drain towards Canada, Switzerland, the US and the UK, it has a neutral brain circulation with Germany, and a fairly high positive inflow from Italy.

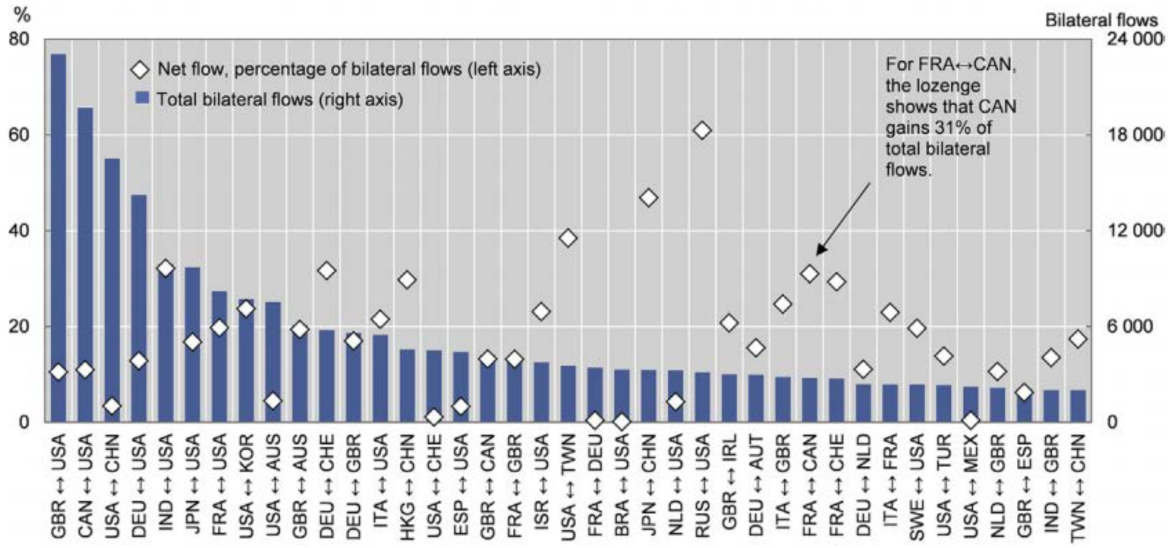

Fig. 68: "International flows of scientific authors, 1996-2011. Largest bilateral flows, by first and last affiliation. Source: OECD (2013), OECD Science, Technology and Industry Scoreboard 2013, based on OECD calculations applied to Scopus Custom Data, Elsevier, version 5.2012. http://dx.doi.org/10.1787/888932891511." (Appelt et al. 2015)

[102] For example, whereas OECD data shows a five-fold increase in foreign students worldwide between 1975 and 2012, global data does not exist for foreign researchers (a similar increase seems to have occurred - see for example Moguérou and Di Pietrogiacomo (2008).

[103] The reference book on the topic is: Global Mobility of Research Scientists: The Economics of Who Goes Where and Why (Geuna 2015).

[104] Some reports include tables, which indicate a massive negative outflow from countries like the UK and a massive positive influx to countries like China (see for example table 3.1 in Elsevier (2016)). The explanations given for this are not always clear. Our interpretation is that studies of mobility typically track changes in researcher affiliation automatically extracted from publications. As a result, researchers are first taken into account when they publish their first article and automatically assigned to the country where they were affiliated when they published this first article, not to their country of origin. Chinese PhD students and/or PostDocs in British universities thus become "British researchers" in the database. The negative flow between the UK and China thus records not an outflow of senior British researchers, but simply Chinese PhD's and/or PostDocs returning to China to take up a permanent position.

The most interesting dataset is the GlobSci initiative[105], which gathered detailed cross-country data on nearly 50 000 active researchers in four fields (biology, chemistry, earth and environmental sciences) who were working in 16 countries and includes individual feedback.

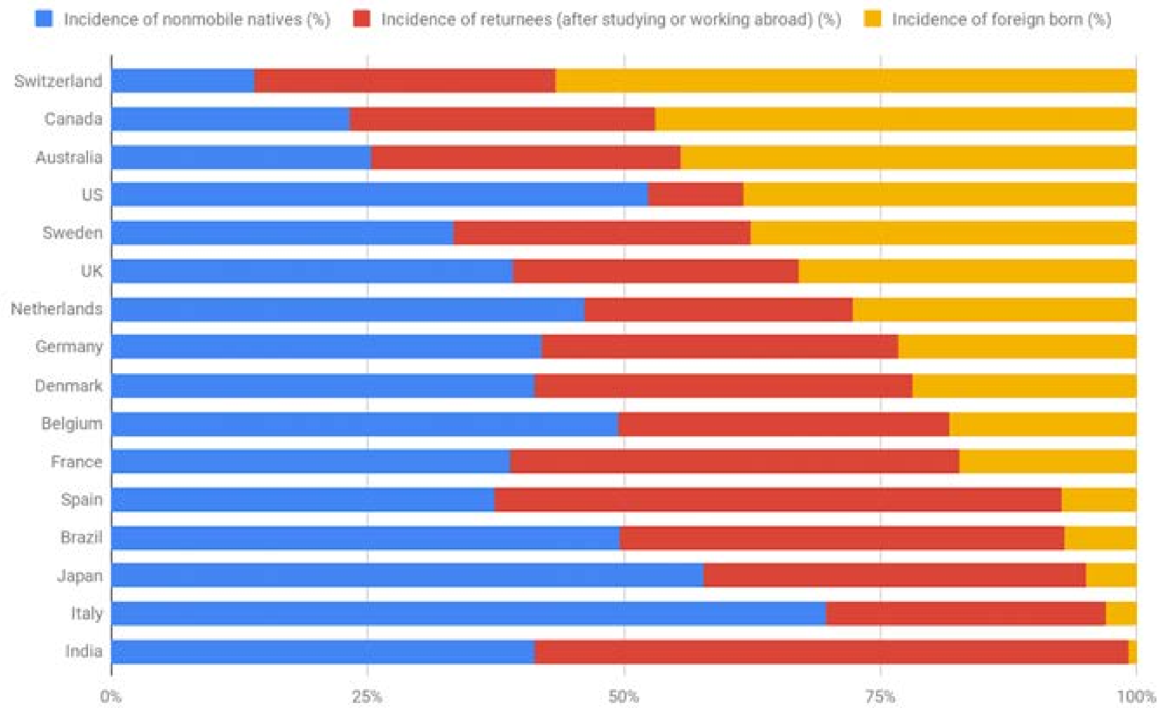

Fig. 69: Incidence of foreign born, returnees and native non mobile across 16 countries (data source: GlobSci study)

The results confirm that France has a problem attracting international scholars (yellow bar in the figure above) with only Spain and Japan (amongst our benchmark countries) having lower percentages of foreign born scholars.

Of course, the size of the country should be factored in: all things being equal, smaller countries tend to have higher rates of international mobility indicators. But size alone is not enough to account for the fact that a lower proportion of foreign born researchers are active in France. And this is all the more true when you factor in the fact that citation scores are systematically lower for scholars working in France than in the above mentioned countries[106].

Comparing individual performance

Cross country comparison of ERC performance

Measuring the impact of the research environment on the performance of individual researchers across different countries is complex because each country (and in most cases, each institution) has its own selection processes. Differences in performance can just as easily be due to initial differences in potential than to actual differences in working environment.

[105] See Franzoni et al. (2012). Data downloadable from http://www.nber.org/globsci/

[106] 0.91 for France, versus 0,74 for Spain but 0,97 for Belgium, 1.01 for Sweden, 1.08 for Denmark, 1.11 for the Netherlands, 1.17 for Germany, 1.23 for the UK and 1.55 for Switzerland.

A recent study (Rodríguez-Navarro and Brito 2019) has found an elegant way around the problem by (1) calculating the expected impact of publications in cutting-edge fields, (2) calculating the expected impact of publications in cutting-edge fields by ERC laureates.

Because the selection process is undertaken at a European level and cutting-edge fields are global by definition, all selected ERC researchers can be expected to produce excellent research. This means that differences in performance between them should be random both across institutions and across countries.

The results are startling: not only do ERC projects hosted by Germany, France, Italy or Spain (GFIS) produce less visible publications than projects hosted by the UK, the Netherlands or Switzerland (UKNCH), but these publications are less susceptible to report a breakthrough. Furthermore, in these specific fields, GFIS show lower capacity than UKNCH at obtaining ERC grants, and, unlike in more mainstream fields, this lower success is not due to a lower application rate, but to a higher number of rejections.

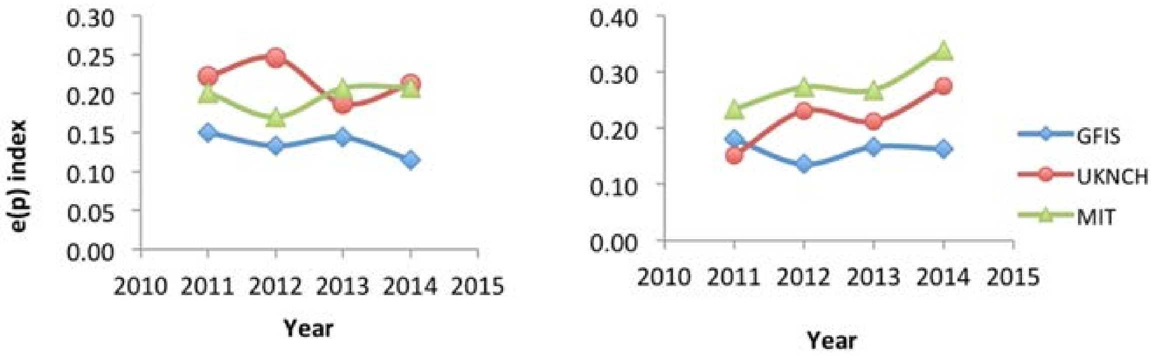

Fig. 70: "ERC publications in GFIS and UKNCH countries (TECH on the left and BIO-MED on the right). The e_p index is a coefficient based on impact percentiles (top 1%, 10% etc.). MIT publications are used as an external standard"
(reproduced from (Rodríguez-Navarro and Brito 2019))

Talent versus working conditions

The fact that, all things being equal, the production of an ERC laureate will have less impact if she chooses to work in France than if she chooses to work in the Netherlands seems to be a clear indictment of the Research System as a whole. However, the study does not explore the causes between this difference in performance: do ERC laureates perform better in the Netherlands because they are concentrated in research intensive universities that offer better work conditions, whereas they are dispersed throughout the system in France? Or do they perform better because the national research system as a whole, and the HR conditions specifically, are more suited?

To address this question, we will start by comparing the impact of the working environment versus individual potential on the research output of individuals in both widely distributed systems (Poland) and hierarchical systems (UK and US). The first study is survey based and looks at the predictors of performance, whereas the second and third use changes in affiliation to track changes in productivity.

Marek Kwiek undertook an in-depth study of Polish top-10% scientists, to define their characteristics and determine predictors for joining this top-group (Kwiek 2018). The main predictors among those that could be tested were: (1) the number of working hours spent on research[107]; (2) international collaboration and publishing abroad: this specifically refers to publishing networks, not to content[108].

The main conclusion which interests us is a negative one:

> *"The determinative power of institutional-level predictors emerged as marginal [...]. This might mean that, generally, neither institutional policies nor institutional support matters substantially in becoming a top performer in Poland, possibly because top performers and low performers are scattered across the whole system." (Kwiek 2018, 448)*

In other words, policies defined at an institutional level to support individuals in becoming top-performers seem to have a marginal impact in horizontally distributed systems such as the Polish one[109]: you can attract strong performers but fostering them is much harder.

In another study, Pierre Deville et al. (2014) extracted author information from all articles published in Physical Review between 1893 and 2010 in order to measure mobility patterns and their impact on the career of Physicists. The results, based on a total of almost 6000 career movements confirm the limited impact of institutions on research performance.

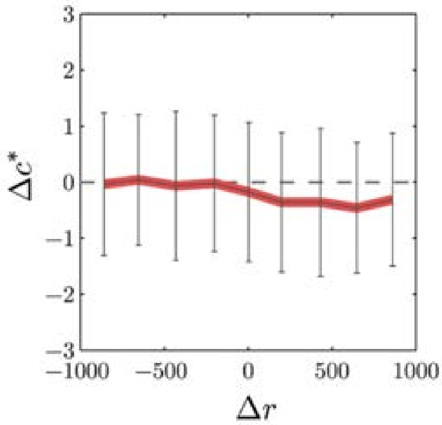

Fig. 71: Impact of movements on career performance[110] (reproduced from (Deville et al. 2014))

The researchers conclude that

> *career movements are not only temporally and spatially localized, but also characterized by a high degree of stratification in institutional ranking [i.e. most researchers move between institutions of similar prestige]. When cross-group movement occurs, we find that while going from elite to lower-rank institutions on*

[107] With varying levels of impact: in the Physical Sciences and Mathematics, top performers typically worked 13 hours more per week than the average, while in less competitive disciplines, notably with respect to funding, like the SHS, this divide tends to be less important

[108] Kwiek (2018) shows that an international outlook as an academic attitude (rather than in practice) actually decreases the odds of becoming a top performer! This is coherent with our analysis of the importance of the connection to hubs. Having an international perspective on contents as such might be fundamental for teaching purposes but has no impact on research performance.

[109] According to Kwiek (2018), these conclusions are validated by other studies in other countries.

[110] "The relation between the statistical difference of citations (**Δ**c*) and the ranking difference (**Δ**r) associated to a transition shows that, when people move to institutions with a lower rank (**Δ**r>0), their average change in performance is negative, corresponding to a decline in the impact of their work. Yet, what is particularly interesting lies in the **Δ**r<0 regime. Indeed, when people move from lower rank location to elite institutions, we observe no performance change on average." (Deville et al. 2014)

average associates with modest decrease in scientific performance, transitioning into elite institutions does not result in subsequent performance gain. (Deville et al. 2014)

Although the study is global, most career movements occur between US institutions, making it difficult to evaluate the impact of a move between research systems on performance.

Another recent study looked at the impact of mobility on the productivity of research scientists in the UK context (Fernández-Zubieta, Geuna, and Lawson 2015), using WoS publication data in two main subject categories (natural sciences and engineering sciences) between 1982 and 2005 and classifying UK universities according to percentile using bibliometric data.

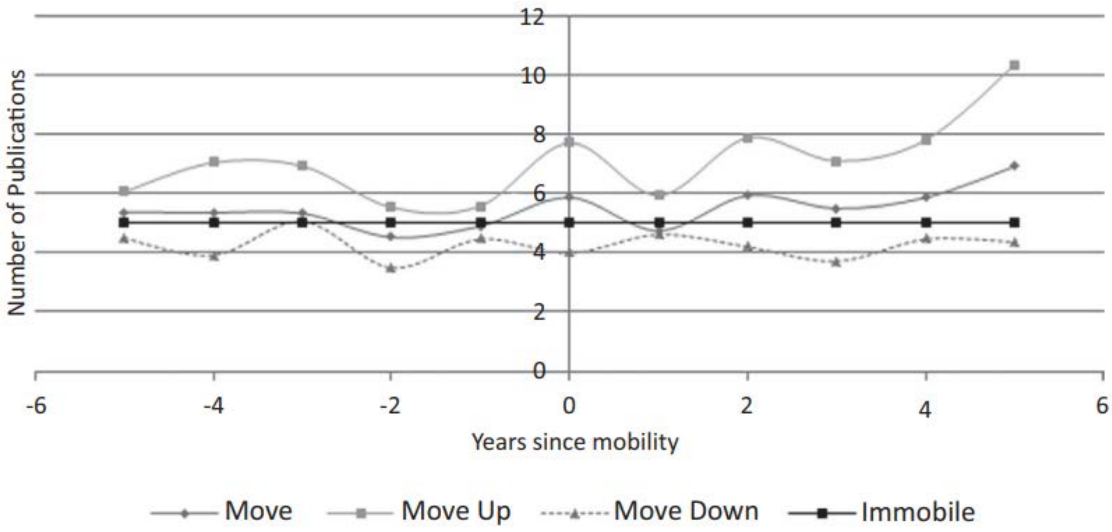

Fig. 72: Publication numbers in years since move for academics working at UK universities (Fernández-Zubieta, Geuna, and Lawson 2015)

The study shows that:

mobility to a higher-ranked university has a weakly positive impact on publication output but not citations, while downward mobility tends to decrease the researcher's overall research performance [especially over the long-term].

Taken together, these three studies clearly show that within a national research system talent comes first. Great work conditions don't necessarily produce good research - good researchers produce good research. This does not mean that institutions should not strive to provide outstanding working conditions, of course: but that they should do so because this is what attracts talented staff.

Interestingly, these results are not aligned with those showing that an ERC researcher will perform better in the Netherlands than in France. We suspect that this is because the three studies measure performance within a country and that there is therefore little difference in terms of HR conditions between institutions whereas the previous study measured differences in performance between countries in which HR conditions are very different.

What makes a research system attractive?

A number of European-wide research studies and surveys have recently been undertaken to analyse the main factors, which influence the attractiveness of competing national research systems and institutions. Two are particularly important: GlobSci[111], which we mentioned previously and a working paper by Janger and Nowotny (2013)[112].

GlobSci study

The GlobSci study includes an analysis on the determinant of career mobility, which underline where the French research system and French institutions should concentrate their efforts (Franzoni, Scellato, and Stephan 2012, 2015; Geuna 2015). The authors underline that there is virtually no variation from country to country in response, suggesting that reasons for emigrating are consistent across countries.

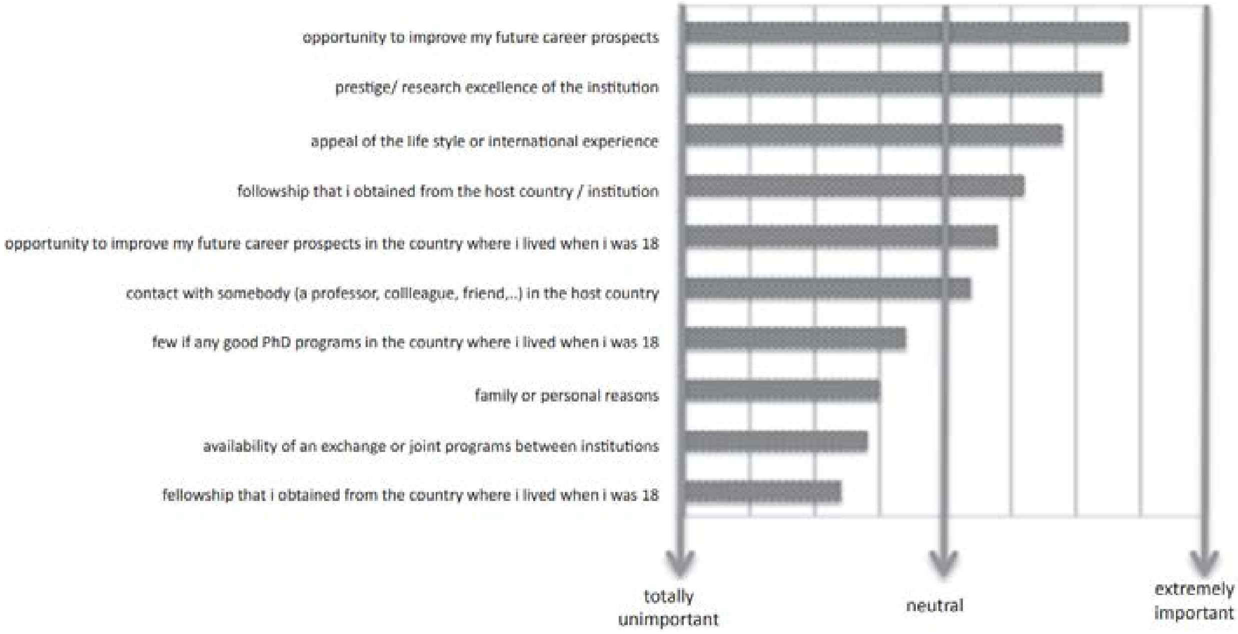

Fig. 73: Description of factors in decision to study abroad (reproduced from Franzoni, Scellato, and Stephan 2015)

The study proposes an analysis both at PhD level and researcher level. At the PhD level, the questions were designed to test a set of variables, including research policy, labour market, level of resources, prestige, immigration policy as well as personal factors.

Answers clearly underline the importance of prestige and career prospects (which are directly linked to prestige) as the driving forces behind decision making. Maybe more interestingly,

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[111] http://www.nber.org/globsci/

[112] Other examples include a study by the Dutch Academy of Sciences, KNAW, which is centered on top researchers awarded a VIDI or VICI grant (The most prestigious Dutch Research grants, partly modelled on the ERC and equivalent in prestige to the French IUF). The study outlines the attractiveness of the Dutch system (a third of the VIDI laureates and a quarter of the VICI laureates are not Dutch nationals) and the success of the NWO's Talent Scheme a ensuring brain circulation. The report concludes that "There are many different push and pull factors that play a role in researchers' international mobility, but what they appear to find most important is the available research budget and the intellectual freedom to spend it as they see fit". See KNAW (2018).

the answers also show that institutional incentives such as "availability of an exchange or joint programme between institutions", "offer fellowships to study abroad" (by opposition to fellowships from the home country) or even personal connections "contact with somebody (a professor, colleague, friend, ...)" are relatively minor factors.

These conclusions are further supported by additional work by the authors showing that the number of institutions ranked in the top 400 by World University Rankings, the percentage of GDP spent on higher education, research and development (HERD), and the H-index are directly correlated with a host's country's science policy.

Item	Score
Opportunity to improve my future career prospects	4.30
Outstanding faculty, colleagues, or research team	4.25
Excellence/prestige of the foreign institution in my area of research	4.15
Opportunity to extend my network of international relationships	3.90
Better research infrastructures and facilities	3.80
Appeal of the life style or international experience	3.75
Opportunity to improve my future job prospects in the country where I lived when I was 18	3.65
Greater availability of research funds	3.60
Better quality of life	3.05
Better wage/monetary compensation	2.95
Few or poor job opportunities in the country where I lived when I was 18	2.60
Better working conditions (vacations, hours of work, ...)	2.45
Family or personal reasons	2.40
Better fringe benefits (parental leaves, pension, insurance, ...)	2.35

Fig. 74: Description of factors in decision to work abroad
Scale 1: Totally unimportant, 5, Extremely important (reproduced from Franzoni, Scellato, and Stephan 2015))

For researchers, the same conclusions are true, but in an even more marked fashion: what counts is the career prospects and these are correlated first and foremost to "outstanding faculty, colleagues or research team", "excellence/prestige of the institution". Better research infrastructure and access to research funds are important, but less so. Better salaries, quality of life and working conditions are almost an afterthought.

Career Choices in Academia

The study by Jürgen Janger and Klaus Nowotny (Jürgen Janger and Nowotny 2013) is based on a survey to examine the determinants of career choice in academia. The respondents were asked: "Assuming all job attributes not mentioned in the job offers are equal, which job do you consider to be the most attractive, irrespective of your current job?" - this question being asked respectively to early stage and late stage researchers.

The results confirm those of the GlobSci report but enable a much finer understanding of what "prestige" actually means. They are key to understanding the problems of attractiveness that the French research system is facing:

	Early stage	Later stage
Net salary p.a. (10 000 €)	36	40
Quality of life worse	-51	-60
Quality of life better	13	12
Peers among top-50 worldwide	30	40
Peers among top-20 worldwide	45	45
Peers among top-5 worldwide	82	62
Availability of short-term grants good, of long-term grants poor	14	20
Availability of short- and long-term grants good	32	37
Balance between teaching and research (+20 percentage points teaching)	-14	-12
Career prospects I: length of initial contracts (+2 additional years)	17	
Career prospects II: 3 years contract extension after positive evaluation	72	
Career prospects II: tenure based on resesarch performance and on availability of position	97	
Career prospects II: tenure based on research performance only	115	
Research autonomy (+50 percentage points)	38	
Research autonomy (+100 percentage points)	76	
Financial autonomy (funding by university relative to negotiation with chair-holder)	-12	
Ease of setting up new lines of research (from 25 to 75% research continuity necessary)	-18	-17
Share of research which can be funded from university-internal sources (+25 percentage points)		15
Share of administrative tasks in total working time (+5 percentage points)		-9

Fig. 75: Factors of attractiveness for career choices (Jürgen Janger and Nowotny 2013)

Money is important but not as important as expected with quality of life clearly outscoring an increase of 10 000€ in annual salary. What is most striking is the pair formed by elitism and research intensiveness: the best researchers will join a university only if it is focused on research and if they feel that researchers in this university are amongst the best in the world.

In other words, it appears that:

1. money is part of the equation, but only so much: universities who have been trying to attract faculty with high salaries alone have had limited success;
2. the quality of peers and prestige of the host institution is a massive determinant: there is a very strong cumulative effect at play and not lagging behind is key;
3. two others important factors are at play, which are directly actionable in terms of policy: (a) flexibility of the distribution of teaching, research and administrative duties; (b) autonomy and research freedom.

This has massive implications for the French Research System because it implies giving a limited number of hub institutions full autonomy in terms of HR and concentrating available public research funding on these institutions.

It is only in these conditions that the French system will be able to compete on equal terms with the Dutch, Danish or UK system in order to attract leading scholars.

Attracting leading researchers

The robustness of our conclusions is supported by looking at how different countries have been adapting their HR policy in order to attract and retain leading scholars. The approach can be fairly crude such as the initiatives launched by King Abdulaziz University to recruit Highly Cited Researchers (see supra), however their aim is identical: ensure that the *best* researchers come to your country and ensure that they are hosted by a world-class university.

The importance of talent schemes

To help institutions attract the best researchers, many countries have launched specific funding programmes, or "talent schemes". These aim to support the emergence of national lighthouses by providing long term research autonomy to successful applicants. Such nation-wide programmes have been successful in attracting international researchers in many countries. For example:

- The Dutch Research Council (NWO), launched a Talent Scheme in 2000, offering individual grants "to talented, creative researchers. The funding enables applicants to do their own line of research. This boosts innovative research and promotes mobility within scientific research institutes."[113] The initiative is the result of joint efforts of the Minister of Education, Culture and Science, the Royal Netherlands Academy of Arts and Sciences (KNAW), the Association of Universities in the Netherlands, and NWO and has three funding instruments (Veni, Vidi, Vici) for different phases in the careers of researchers (recently graduated, experienced, and senior / advanced).

- The Catalan government supports a foundation called the Catalan Institution for Research and Advanced Studies (ICREA). It "was created in response to the need to seek new hiring formulas that would make it possible to compete with other research systems on a similar footing by focusing on hiring only the most talented and extraordinary scientists and academics."[114] Since 2001, the foundation works with Catalan Universities and research centers, offering permanent positions to international researchers. It currently employs 264 researchers in all fields, in 48 institutions, and offers new research positions every year. In 2018, 10 ICREA researchers were ranked in the top 1% most cited academics in the world[115]. ICREA researchers negotiate their salaries and are hired on renewable contracts rather than permanent positions.

- In the UK, the Royal Society will launch a research award in 2020 with the aim of "provid[ing] long term support for world-class researchers of outstanding achievement and promise."[116] The scheme will provide funding in salary, research assistance, PhD studentship etc. This follows a Talent Scheme launched in 2018 by the different institutional actors (such as the British Academy, UK's Government's Investment in Research Talent etc.), which have secured 108 million pounds "to support, attract and retain the best research talent to the UK"[117], for the 2018-2021 period alone.

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[113] https://www.nwo.nl/en/research-and-results/programmes/Talent+Scheme/awards
[114] https://www.icrea.cat/en
[115] http://memoir.icrea.cat/
[116] https://royalsociety.org/grants-schemes-awards/grants/research-professorship/
[117] https://royalsociety.org/news/2018/06/academies-announce-additional-108-million-pounds-for-investing-in-talented-researchers/

- Canada put in place the Banting Postdoctoral Fellowships programme in 2013. It is explicitly aimed at attracting and retaining "top-tier postdoctoral talent, both nationally and internationally, to develop their leadership potential and to position them for success as research leaders of tomorrow, positively contributing to Canada's economic, social and research-based growth through a research-intensive career."[118] The programme awards around 70 fellowships annually for a duration of 2 years.

- In China, the Thousand Talents Plan[119] is attracting foreign researchers and providing incentives for Chinese scientists living abroad to return to the country. Launched by the Chinese government in 2008 (and replaced in 2019 by the "High-end Foreign Experts Recruitment Plan"), it has attracted more than 7,000 researchers in total. Funded applicants receive a consequent starting bonus (around $150,000). The programme includes a plan targeting specifically scientists under the age of 40, or a plan focusing on entrepreneurs.

Nation-wide Talent Schemes can thus be very different (supporting specific career stages or open to all, targeting certain fields or open, operating as a supporting fund, or as a hiring institution without walls, tailored or not to the country's strategic priorities). But behind this variety, they all share the same long term aim of attracting and retaining high quality staff.

Over the last few years, France has launched a number of initiatives to attract leading researchers. However, France does not have any comparable long-term talent schemes and existing initiatives have difficulties reaching their goal[120].

The "Make Our Planet Great Again" (MOPGA) programme, launched in June 2017 was explicitly meant to attract top-notch international researchers in France. In March 2019, it had attracted a total of 42 researchers[121], each granted 1 to 1.5 million euros. These good results notwithstanding, the initiative has not been as successful as expected and has attracted mostly researchers who already had strong links with French research labs[122].

The results closely echo attempts by IDEX universities to attract senior researchers. Although, there is no consolidated study of this, feedback from the IDEX initiatives and interviews with senior researchers who accepted a position clearly demonstrate how difficult it is to attract leading scholars to France. To the best of our knowledge, senior talent attraction schemes (often called "senior chairs") are the only initiative which have been launched by all selected IDEX proposals and systematically failed to reach the announced goals in terms of number of recruitment and profile of the researchers finally recruited[123].

This failure is indicative of the systemic human resource issue that France is facing.

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[118] http://www.sshrc-crsh.gc.ca/funding-financement/programs-programmes/fellowships/banting-eng.aspx?pedisable=true
[119] http://chinainnovationfunding.eu/thousand-talents-plan/
[120] Initiatives such as the Labex have successfully attracted international researchers, but they are not "talent-schemes" *stricto senso* and are not targeted exclusively at international scholars.
[121] Source ANR: https://anr.fr/fileadmin/documents/2019/MOPGA-CP-3e-vague-14-03-2019.pdf
[122] No evaluation of the programme has yet been made. For a critical perspective, see: https://www.franceinter.fr/sciences/make-our-planet-great-again-la-ruee-de-chercheurs-americains-n-a-pas-eu-lieu
[123] We were able to hold a number of confidential interviews with researchers who were recruited using such talent schemes and were struck by the largely negative feedback, when speaking off the record. In some cases, this feedback was almost aggressive: "after 6 months in France, my main aim is to leave the country as soon as possible: work conditions and bureaucracy are unacceptable" (senior researcher recruited from the US on a long-term position).

Competitive career management

In parallel with talent-schemes, research systems in Europe either already have or are taking steps towards allowing research-intensive university more flexibility in terms of recruitment, career management and distribution of work conditions.

As a counterpoint to the French situation, the 2013 Danish reform regarding job structure within universities is particularly eloquent (Danish Ministry of Higher Education and Science 2013).

The legislation makes it clear that it is the responsibility of the university to be able to cover both its research and teaching duty, but leaves autonomy to the university to fix the exact ratio of the activities of the researcher. For example, the legal formula with respect to the research vs. teaching ratio is: “The university determines the exact ratio between the various responsibilities. The ratio may vary over time.”

Similarly, the position of assistant professor / researcher obeys the general principle of a tenure track making it far easier to attract and retain top research performers.

Another strong signal is the 2018 plan from the Danish Ministry of higher education, which includes amongst its central initiatives an evaluation of the career paths within Danish universities. The government does not define the rules, it helps the universities establish a framework and provides support structures:

> *Good career paths in Danish research: The Ministry of Higher Education and Science, in cooperation with the universities, will initiate an inspection of career paths at Danish universities. The aim is to establish the necessary framework for universities’ ability to support healthy career development, effective use of talent and a high level of mobility. The Government will also earmark funds for future top researchers. For example, the Government will establish a national support programme with the aim of improving talented young researchers’ opportunities to receive grants from the European Research Council for excellent research. (Danish Ministry of Higher Education and Science 2018)*

In a 2010 note recommending to the Dutch Royal Academy of Arts and Science (KNAW) to put in place a Talent Scheme, the necessity of long-term funding for researchers is discussed with great emphasis. But more importantly, the role of universities and research centers, in complement to such national funding schemes, is pointed out:

> *It is also important for universities and research institutes to keep a close eye on talent development. Crucial in this regard are clear-cut agreements with researchers about career prospects and performance appraisals covering research, teaching and valorisation.* (Koninklijke Nederlandse Akademie van Wetenschappen 2018)

Similar examples exist in all the better performing countries that we have discussed in this report.

Key consequences

To attract and retain leading researchers, you need excellent all round conditions. The French research system has a few competitive advantages (good social security conditions, excellent living conditions, access to permanent positions at an early career stage…), however these are clearly not enough.

Janger and Nowotny thus conclude, at the end of their study:

> *Our results indicate that overall, the US research universities offer the most attractive jobs for early stage researchers, consistent with the asymmetric flow of talented scientists to the US. Behind the US is a group of well performing European countries, the Netherlands, Sweden, Switzerland and the UK. Austria and Germany are next, closely followed by France, which in turn is followed by Italy. Spain and Poland are, according to our results, least able to offer attractive entry positions to an academic career*. (Jurgen Janger, Strauss, and Campbell 2013)

And Rodríguez-Navarro and Brito add, even more brutally:

> *MIT and all other elite research institutions attract the brightest researchers because these institutions offer a superb research environment. Once in the institution, these researchers can freely apply for competitive research funding without any specific internal requirements. […] No [German, French, Italian or Spanish] university is among the top 25 in the CWTS Leiden ranking and there are few among the top 100 […], which implies that a certain number of ERC grantees can be in universities that do not provide a research environment that is at the expected ERC level. (Rodríguez-Navarro and Brito 2019)*

The French research system is unable to compete with other countries because universities do not have the necessary autonomy and power to define their Human Resource policy.

Close to half of the academic staff working in research intensive universities are still employed by national research organisations who define their own Human Resource rules. The university has no power to define their workload (balance between teaching and research) or incentives.

Within the university itself, staff promotion and hiring decisions depend on national agencies such as the CNU, that have strict national rules, which dramatically limit each university's autonomy. Universities cannot even freely modulate the time an employee spends on research, academic and administrative duties[124].

If the French government expects its universities to compete with those from leading countries around the world, then it must let them play by the same rules.

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[124] As Jamil Salmi writes: "In [France and Germany], universities are government entities constrained by civil service employment rules and rigid management controls" (2009, 29).

Factor 5: Autonomy, accountability and governance

All four previous factors underline how high performing countries have segmented research systems in which a relatively low number of research intensive universities play a key strategic role.

This implies that the leadership of these research universities must be able to define and implement an ambitious global strategy. And this, in turn, requires autonomy, accountability and good governance.

Today, despite the important reforms of the last decades, French institutions are in the paradoxical situation of being *accountable* without having real *autonomy*.

The 2017 EUA scoreboard on university autonomy shows that France still lags behind the rest of Europe on all indicators: financial autonomy, organisational autonomy, staffing autonomy and academic autonomy. Indeed, globally, France ranks last of all 29 research systems analysed.

This said, the solution is not simply to increase autonomy on each indicator: autonomy cannot be isolated from accountability or governance as a whole. Indeed, for autonomy to be meaningful entails *a minima* 3 requirements:

- autonomy must not be merely legalistic, but effective: it is not (only) about statutes, but about the factual political system of university governance;
- governance must have true authority over all domains of activities;
- accountability must ensure alignment with general sectoral policy objectives and foster professionalisation.

There is no magic formula which demonstrates that the election or nomination of leaders is necessarily better, nor is there one, which defines the ideal proportion of external members in the governing bodies. However, there is a logical relation between (a) how resources come to an institution, (b) how much power the leadership has in terms of decision-making, and (c) how this leadership is appointed.

> *For the sake of argument, let us consider the following: how would Barcelona's professional football team (FC Barcelona) perform if it were constrained by all the rules that burden our universities? What would happen if all the players were civil servants with salaries determined by a government ministry and if they were allowed to continue playing every day regardless of their performance during official games and behavior during practice sessions? What would happen if the club's income were not linked to its game results, if it could not pay higher salaries to attract the best players in the world or if it could not rapidly get rid of the under-performing players? What would happen if team strategy and tactics were decided by the government rather than by the coach? Wouldn't such an approach risk relegating the Barcelona team to the sidelines of mediocrity?*" (Sala I Martín 2006)

The first four factors all illustrate the growing role of research intensive universities as the key hubs of the global research system.

To increase national competitiveness, high performing countries have acted in consequence: they have enabled greater differentiation in terms of mission, concentrated funding, delegated strategic decision making, transformed national entities and encouraged competition. This has enabled them to foster the emergence of a limited number of world-class universities with strong strategic capacity.

The French research system has been progressively adapting to this global reality but, as we have seen, a number of key reforms still need to be made: performance will only increase if the state further delegates both decision-making and implementation capacity to research intensive universities.

Such an evolution has important consequences. As Sala i Martín's comparison with football underlines, universities cannot be expected to compete at a global level if they lack autonomy and are required to follow strict rules that do not apply to universities in high performing countries.

But increasing autonomy necessarily also involves an increase in terms of accountability and a move from a model dominated by internal accountability to one where public accountability comes to the fore. And this questions existing governance models.

This is why, in this final chapter, we will turn to questions of autonomy, accountability and governance.

Autonomy in perspective

Key factors

In the UK and the US, unlike in France or Germany, the state rarely attempted to "control" universities. In both countries, research intensive universities remained largely free to define their strategy. This was true whatever their legal status: either public or private not-for-profit organisations in the US (or in some cases, such as Cornell public *and* private), or, in the UK, private, not-for-profit corporations that receive public funding and are treated as public bodies for a number of legal purposes.

Both the state and the universities constantly test the border between public and private. For example, in the UK, richer, more prestigious, universities regularly claim that they could refuse state funding and thus become fully private, whereas in the US, the state mulls ending the tax-free status of private university endowments. But neither actor questions the idea that universities should be largely autonomous from the state and that they are best placed to define their research strategy.

Anglo-Saxon universities have thus historically been amongst the most autonomous at a global level (1998). This gave them a competitive edge, which reinforced the massive advantage they had from being localised within the national research systems that drove the globalisation of higher education and research.

To compete with them and in order to ensure visibility and performance within a global system, countries worldwide have progressively shifted their own model from one in which universities were state controlled to one which they are state supervised. A World Bank report on the topic (Fielden 2008), thus concludes that:

> *The reforms in higher education governance in recent years are driven by the same external and internal pressures and are largely following the same pattern. They tend to have the following elements:*
>
> - *Legislation that establishes universities as autonomous independent entities*
> - *Withdrawal of the state from certain detailed control and management functions and the devolution of responsibility to universities themselves*
> - *The creation of buffer bodies or agencies to carry out some of the detailed financial control and supervision functions in the sector or to provide sectorwide services*
> - *Adoption of funding models that give institutions greater freedoms and that encourage them to develop new sources of income*
> - *Creation of external agencies that monitor the quality of all courses delivered by institutions*
> - *The development of new forms of accountability through reporting on performance and outcomes in achieving nationally set goals for the sector, as well as institutionally set targets*
> - *Confirmation of the role of a university board as having overall responsibility to the minister or the buffer body*
> - *Gradual withdrawal of the state from decisions on the appointment of the chair of the board or president and members of the board*
> - *Expectations of managerial competence by the board and the president*

Impact on performance

Autonomy has been listed amongst the determinants of “world-class” universities. Salmi (2009) thus identifies three major conditions for the emergence of such universities: autonomy of governance, concentration of talent and abundant resources. He argues that:

> *[…] institutions that have complete autonomy are also more flexible because they are not bound by cumbersome bureaucracies and externally imposed standards, even in light of the legitimate accountability mechanisms that do bind them. As a result, they can manage their resources with agility and quickly respond to the demands of a rapidly changing global market*. (Salmi 2009, 28)

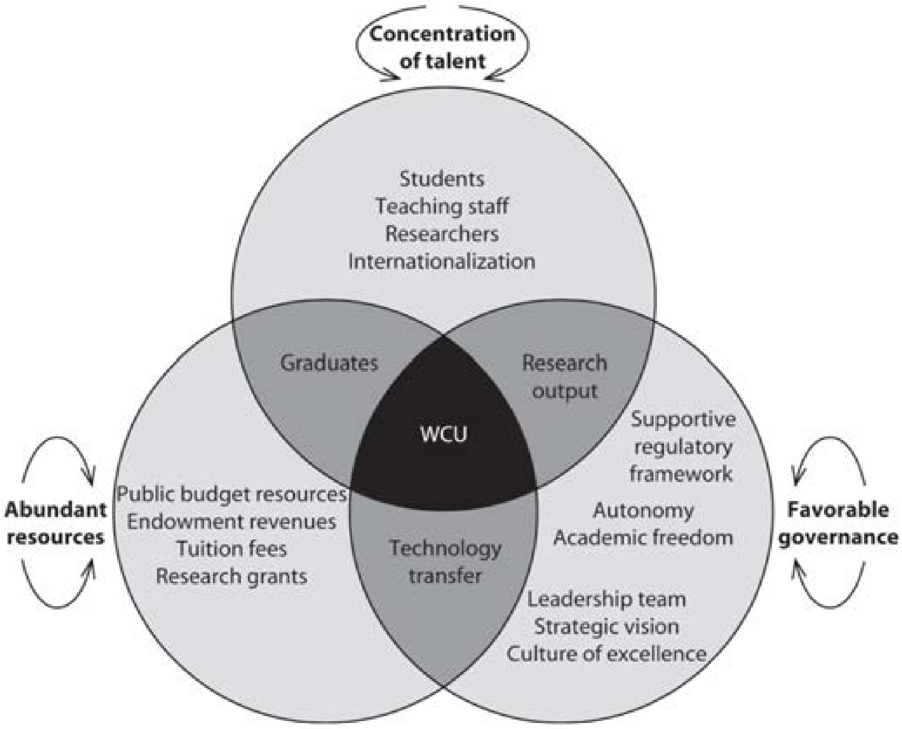

Fig. 76: Characteristics of a World-Class University (WCU) Alignment of Key Factors (reproduced from Salmi (2009))

Aghion et al. (2008) underline that the main result of their work

> *is not simply that more money or more autonomy is good for research performance, [but] that more money has much more impact when it is combined with budget autonomy. To be more precise: [they] find that having budget autonomy doubles the effect of additional money on university research performance.*

In a later study, they further emphasise the importance of a competitive environment and institutional autonomy for research performance, arguing that "university autonomy and competition are positively correlated with university output" (Aghion et al. 2010, 28).

Some scholars argue that the evidence is not conclusive. Enders et al. thus accept that: "our review of the empirical literature provides some support for the institutionalist economic logic, namely that more autonomous universities with managerial discretion that need to compete for resources are more productive." (Enders, de Boer, and Weyer 2012, 21). But they also underline that autonomy is more important in certain areas (primarily human resources) than in others and conclude that the link between organizational autonomy and performance is not clear and requires further study.[125]

[125] "While the attention for and use of performance measures in higher education has grown, little political action has so far been taken to evaluate the impact of changes in systems' governance and organizational autonomy on the performance of universities and higher education systems. Research in organizational studies has focused on regulatory public agencies and shown a mixed picture of positive and negative correlations between organizational autonomy and performance (see Verhoest et al. (2010)). Empirical investigations into university autonomy and performance are a quite recent phenomenon." (Enders, de Boer, and Weyer 2012, 13). Indeed, Aghion et al. concede that the correlations "are merely suggestive. They do not necessarily indicate that university autonomy and competition cause higher output. Reverse causality is quite plausible: Perhaps governments allow very

This said, evidence from other contexts reinforces the argument that autonomy and performance are correlated. The OECD's PISA report thus shows how the autonomy of primary and secondary education institutions is directly correlated to the scientific performance of young students: an increased autonomy for school principals and teachers was shown to increase the results of 15 years old students, whereas increased decision-making power at a national level is very strongly correlated with weaker science performance:

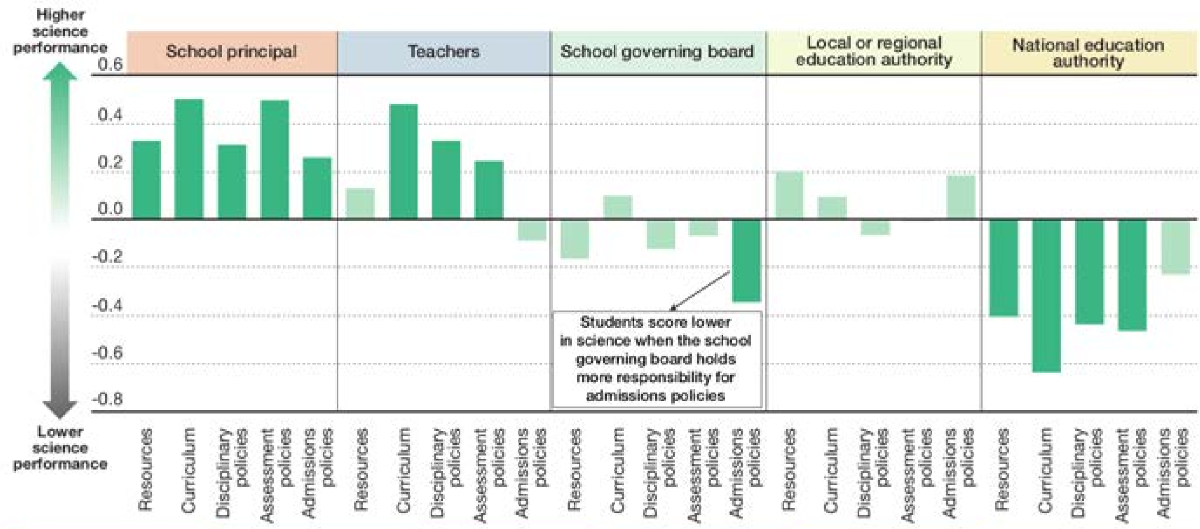

Fig. 77: Correlations between the responsibilities for school governance and science performance (Reproduced from Pisa (OECD 2015b))

Although we do not have similar data for universities, there is no reason for which the results should be radically different[126].

The French context

Despite the important reforms of the last decades, French institutions are still in the paradoxical situation of being accountable without having real autonomy. Thus, in 2009, Jamil Salmi underlined that mergers (and IDEXes) by themselves would not be sufficient to create "world-class" universities, because they did not tackle the governance issue:

> *In the case of France, for example, mergers would augment the critical mass of researchers and bring about a higher place in the [ARWU] ranking that favours research output, but they would not address the fundamental limitations of French universities, including inflexible admission policies, a weak financial basis, rigid governance arrangements, and outdated management practices* (Salmi 2009, 44)

The 2017 EUA report on university autonomy proves that little has changed: despite recent legislative changes, France still lags behind the rest of Europe in terms of autonomy (Pruvot and Estermann 2017), with very low scores on all of the dimensions analysed (when

productive universities to be more autonomous and such universities campaign for resources to be allocated by competition, rather than rules." (Aghion et al. 2008, 3)

[126] The main difference is that university professors have a very high degree of autonomy in terms of what they teach, compared to primary and secondary school teachers.

combining the average position across the four dimensions analysed by the EUA, France ranks last of all 29 systems analysed)[127].

EUA Autonomy Scorecard[128]

Organisational autonomy (*Indicators: Selection procedure, criteria, term of office and dismissal of the executive head; External members in university governing bodies; Capacity to decide on academic structures; Capacity to create legal entities*) – Overall, France is ranked 20th out of 29. Among our benchmarks, France is ranked below the UK, Denmark and the Netherlands, but ahead of Spain and Switzerland. The autonomy in Germany varies greatly between *Länder*.

Financial Autonomy (*Indicators: Length of public funding cycle; Type of public funding; Ability to borrow money, to keep surplus and to own buildings; Tuition fees for national/EU and international students*) – France is second to last of our benchmarks countries, with only German universities being less autonomous.

Staffing (*Indicators: Recruitment procedures for senior academic and administrative staff; Salaries for senior academic and administrative staff; Dismissal of senior academic and administrative staff; Promotion procedures for senior academic and administrative staff*) – France is last in our list of benchmark countries. Among the 29 ranked entities, only Ireland and Hungary are ranked below.

Academic (*Indicators: Overall student numbers; Admissions procedures; Introduction of programmes; Termination of degree programmes; Language of instruction; Selection of quality assurance mechanisms and providers; Capacity to design content of degree programmes*) – France is ranked second to last of the 29 systems.

Autonomy, accountability and governance

Autonomy is not only an abstract legal concept but a practice which can vary widely, even within the same legal framework. This is why it is important to measure factual autonomy or "autonomy in use" (Enders, de Boer, and Weyer 2012, 21) or "effective autonomy" (Raza 2009):

> *Opening the 'black box' of universities as organizations would also greatly enhance our insight into the interaction between the external and internal control of universities.* (Enders, de Boer, and Weyer 2012, 21)

Building on Raza (2009), "Meaningful autonomy" for universities entails *a minima* 3 requirements:

1. Autonomy must not be merely legalistic, but effective: this is not (only) about statutes, but it is about the factual political system of university governance.
2. Governance must have authority over its domains of activities. It must be able to make a difference in these domains.

[127] These include as separate entities 5 German *Länder* and the 2 Belgian regions Wallonia and Flanders.
[128] https://www.university-autonomy.eu/

3. Accountability ensures alignment with general sectoral policy objectives and fosters professionalisation.

Autonomy only makes sense if institutions are directly impacted by the consequences of their own choices. And for this principle to be effective, they need to be held accountable for such consequences:

> *The basic principle behind institutional autonomy is that institutions operate better if they are in control of their own destiny. They have an incentive to change if they can directly benefit from their actions; they can be entrepreneurial and reap the rewards. Or they can be timid and see their competitor institutions overtake them (Fielden 2008, 9:18).*

Institutions thus tend to be more performant if their leadership is both autonomous (in the sense that it can indeed take decisions that matter for the institution) and accountable (in the sense that it has to justify such decisions to stakeholders and bear the consequences of bad choices).

Different governance models can be equally efficient, so long as the conditions of autonomy and accountability are met simultaneously. Indeed, the best governance structure is useless if autonomy is nonexistent because, in this case, it cannot act. Vice-versa, effective autonomy gives a strong incentive to governing bodies to take good decisions, *only* provided that they are also accountable to the right constituents.

An effective governance board must (a) enable leadership teams with the capacity and legitimacy to take the difficult decisions required to support long-term research performance in a context of increasing competition, and (b) ensure that they are held accountable to society as a whole.

The classic way of approaching this question is by comparing the composition of university governing bodies to see whether they are elected, which tends to make them mostly accountable to their constituents; or whether they are appointed, which tends to make them more accountable to the authorities in charge of the nomination. This question is for instance the starting point of the 2010 Aghion report on academic excellence, which looked at the composition of Boards as a symptom of strong strategic capacity.

This debate has led a number of countries to replace internal elections by nomination processes: the 2003 Danish reform of the university governance system is a case in point:

> *The reform replaced a form of institutional democracy, which was introduced in 1970 in the wake of the 1968 student revolt, with a corporate management system. Boards with a majority of external members have replaced the university senates, and elected leaders have been replaced by appointed leaders. In the present system, the vice-chancellor is appointed by the board, the pro-vice chancellors and the deans are appointed by the vice-chancellor, and the heads of department are appointed by the deans. The earlier bottom-up-based system has been replaced by a strict, hierarchical, top-down system.* (Hansen 2011, 236)

However, the debate around election or nomination of board members is complex: the aim is to empower the governing body to make difficult choices by ensuring that it is accountable to the right constituents. And, if it is true that elected board members often defend the interests of their electors, it is also true that nominated board members can just as easily serve vested interests, which can be just as conservative if not more (this is often the case of alumni).

The challenge is to find the right balance between two elements:

(a) because universities and research organisations are expert-type organisations, top-down management can only go so far, because expertise lays with individual actors. Within universities, expertise is at the individual level and more responsibility does not equate with more competence in the field. Hence the case for systems which are based on a strong representation of the academic community;

(b) on the other hand, weak external accountability creates endogamy, encourages vested interests and leads to overall weaker performance - hence the choice of some countries to move away from elections and make the leadership team directly accountable to the government.

Today, French research performing institutions are in competition with international universities whose leadership has more room for manoeuvre as well as stronger incentives to obtain results. In other words, they are competing with institutions where it pays to take the tough decisions needed to lead an institution at a time of change. In this context, pleading for more autonomy is clearly necessary.

However, as French universities make their case for stronger, more effective autonomy, they must also show that they are primarily accountable to the general public, not to the interests of the university community.

Reforms about governance and accountability are necessarily interrelated. There is no magic formula, which demonstrates that the election or nomination of leaders is necessarily better, nor is there one, which defines the ideal proportion of external members in the governing bodies. However, there is a logical relation between how resources come to an institution, how much power the leadership has in terms of decision-making, and how this leadership is appointed.

Epilogue: "Getting to Denmark"

When we started working on this report, we expected to show that French research performance was within the average at a European and OECD level and that the clear leaders were the UK and the US. We expected that our recommendations would have a strong neo-liberal component.

The results are surprising, both because the performance of the French research system was weaker than expected and because the most meaningful divergence proved to be within continental Europe.

These results echo Alex Usher's comment that the Malthusian model of excellence promoted by Ivy League US universities or Oxbridge is not the only model. His citation deserves repeating:

> *One of the most striking conclusions [...] is how many parents believe "all Canadian universities are reasonably good". It's not that they don't see variations in quality, or believe that some institutions might better than others for their kids: it's just they don't see the gaps in quality as being very large. There are very few other countries where this is true. New Zealand, maybe. The Netherlands. Germany. After that, forget it: high stratification of prestige is the norm in the world. But not here. Broad access, strong community colleges and polytechnics, and a university system where excellence is not confined to a tiny elite. It's not a complete recipe for success, but it's a good start, and one we should acknowledge more publicly. (Usher 2018)*

We think that our study has clearly shown that this "other way" is valid not only for the higher education landscape but also for the research landscape. Clearly there are differences between A. Usher's list and ours: Germany may have a performing higher education landscape but its research system is far from being as successful, New Zealand is not a major research player. But Canada and the Netherlands clearly qualify, as do Denmark and Switzerland.

Today, France has the worst of both worlds. On the one hand, the higher education system is highly stratified and the most prestigious institutions are not the main research centres. On the other hand, the research system is weakly stratified and underperforms and the key research actors are not universities. This leads to a paradoxical result: France ends up with both the social stratification of elitist education systems, and the modest research performance of more socially oriented education systems. As an old maxim puts it, "he who follows two hares is sure to catch neither."

In a famous paper, Land Pritchett and Michael Woolcock quipped that the problem of getting to strong, reliable, transparent public institutions could be summed up as the problem of "getting to Denmark" (2004)[129]. We feel that such a conclusion applies quite nicely to the topic

[129] They write: "By 'Denmark' we do not, of course, mean Denmark. Rather, we mean the relatively homogenous, common core of the structure of the workings of the public sector in countries usually called 'developed' [...]. To be sure, there are numerous variations on the core 'Denmark' ideal; indeed, remarkably similar performance outcomes are delivered by different, and culturally distinctive, institutional forms—e.g. Denmark, New Zealand , Germany, and Japan. The historical evidence is surely that while development is likely to entail a "convergence" in terms of institutional performance outcomes, the precise form those institutional arrangements actually come to take in each country will continue to be as varied as the countries themselves. Indeed, as we argue in detail below, the strategy

that we are discussing. The model is not necessarily “Anglo-Saxon”. Danish and Dutch systems of higher education in the recent years are good examples of how to balance the competitive, and intrinsically elitist game of “world-class” research, and the demand to provide a higher education and research system which promotes openness, inclusiveness and comprehensive social well-being. The fact that they increasingly outperform the UK and US on size-independent research criteria show that another world is possible.

It is time for France to accept that the model already exists, time to reinforce research intensive universities, to create excellent university colleges and polytechnics, to rethink the role of national research organisations and to end the distinction between *grandes écoles* and universities. It is time, in other words, to look at what other European countries are doing right[130].

of “skipping straight to Weber”—i.e., of seeking to quickly reach service delivery performance goals in developing countries by simply mimicking (and/or adopting through colonial inheritance) the organizational forms of a particular ‘Denmark’ — has in fact been a root cause of the deep problems encountered by developing countries seeking to deliver key public services.” see also Fukuyama (2011).

[130] Readers from Denmark, the Netherlands or Switzerland will no doubt quip that their National Research Systems are far from perfect, that their governments are too meadlessome, that the way research funding is distributed is suboptimal … We would agree, but for a French research university, these are a rich man's problem.

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