



Links between research policy and national academic performance

A comparative study of Denmark, Sweden and the Netherlands

Main Report

Project partners:

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Technopolis Group: represented by Faugert & Co Utvärdering AB (Technopolis Sweden) and Technopolis BV (Technopolis Netherlands)

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Executive summary

Based on a study commissioned by The Danish Council for Research and Innovation Policy (DFiR) this report examines the relationship between research policy and research performance in a long term perspective. The study takes its departure from six hypotheses formulated by DFiR related to research funding balances, excellence schemes, PhD education, governance structures and collaboration (international as well as cross sectoral). A cross-country comparison between Denmark, The Netherlands and Sweden serves to examine the links between such policy changes and aggregated academic impact in different national settings. By providing an improved understanding of the foundation for sustained high systemic research performance across countries the study thus aims to strengthen the foundation for future research policy decisions.

Overall, the study finds support for several of DFiR's hypotheses: For Denmark it is showed how changes in the research funding system (including the establishment of the Danish National Research Foundation), the prioritization of PhD education and a general increased emphasis on academic quality and internationalization during the late 1980s and early 1990s contributed to reverse a negative development and subsequently laid the foundation for the constant increase in the aggregated Danish research performance during the following decades. Also with regard to Sweden and the Netherlands several factors associated with the hypotheses are highlighted as important elements in the explanations of the observed national developments. However, as soon as we move from a single-country perspective towards a comparative cross-country perspective, more generalizable patterns between specific types of research policy changes and developments in research performance become less obvious. Rather than universal relationships between specific policy measures and their effects, we find a number of highly context- specific explanations. Nevertheless, two central conclusions stand out at a more general level.

First, the highly positive development in performance observed for both Denmark and the Netherlands since the early 1990s can be partly attributed to the way in which strong national research cultures have been institutionalized at the system level in the two countries. Although the actual policy measures put to use differ, they have played the same overall role in creating long-term, stable points of orientation for institutions and individuals alike. As such they have underpinned a coherent, national research culture supporting excellence and internationalization. For Sweden, on the other hand, such long-lasting institutions with sustained system-effects have not been established. Rather, the Swedish science system has been the subject of more mixed political signals with strategic and utility-based considerations outweighing a clear focus on research quality as the most central pillar of the system.

Secondly, the developments in performance across the three countries are also related to the way in which the central balances of the national science systems have been calibrated over time. While a strong research culture (and several long-lasting institutions supporting such a culture) is an important condition for high academic performance at an aggregated level, it is not a sufficient factor. In order to provide conditions conducive to high research performance across a broad spectrum of disciplines, national research systems need to uphold a number of central balances for prolonged periods of time. This includes finding appropriate balances between opportunities for excellent groups on the one hand and securing a broad and strong growth-layer on the other. It also includes balances between steering and protected space, as well as balances between renewal and stability. Not least the funding system, the governance mechanisms and the organization and volume of the PhD education play important roles in maintaining such balances.

The cases illustrate how systemic imbalances rather quickly can lead to decreasing results, but also how ongoing well-executed calibrations of the central balances can create stable, long term foundations for high research performance. The case-studies also show, however, that multiple balance points between different policy measures may lead to sustained high national academic performance.

Finally, the study highlights a number of emerging imbalances in all three countries which may have long- term effects on the research performance of the science systems if they are not corrected. The study may thus spark a number of research policy discussions on whether current adjustments are needed to secure sustainable, coherent and well-functioning national science systems in the decades to come. This calls for informed policy considerations of the future calibration of the central systemic balances and underlines the importance and the timeliness of the agenda that DFiR has set with this study.

1. Introduction

This report presents the results of a study commissioned by The Danish Council for Research and Innovation Policy (DFiR) under the heading 'World Class Knowledge' (Viden i verdensklasse). The report consists of four chapters of which the first briefly outlines the objectives, methodology and data of the study. Chapter 2 presents the overall analytical approach which guides the analysis in the subsequent chapter 3 examining the relationships between research policy and research performance in Denmark, Sweden and the Netherlands. Finally, chapter 4 presents the overall conclusions of the study and discusses potential future lessons based on the analysis. The present report has been limited to 30 pages + an appendix, but further documentation and a rich list of references can be found in the background report of the study.

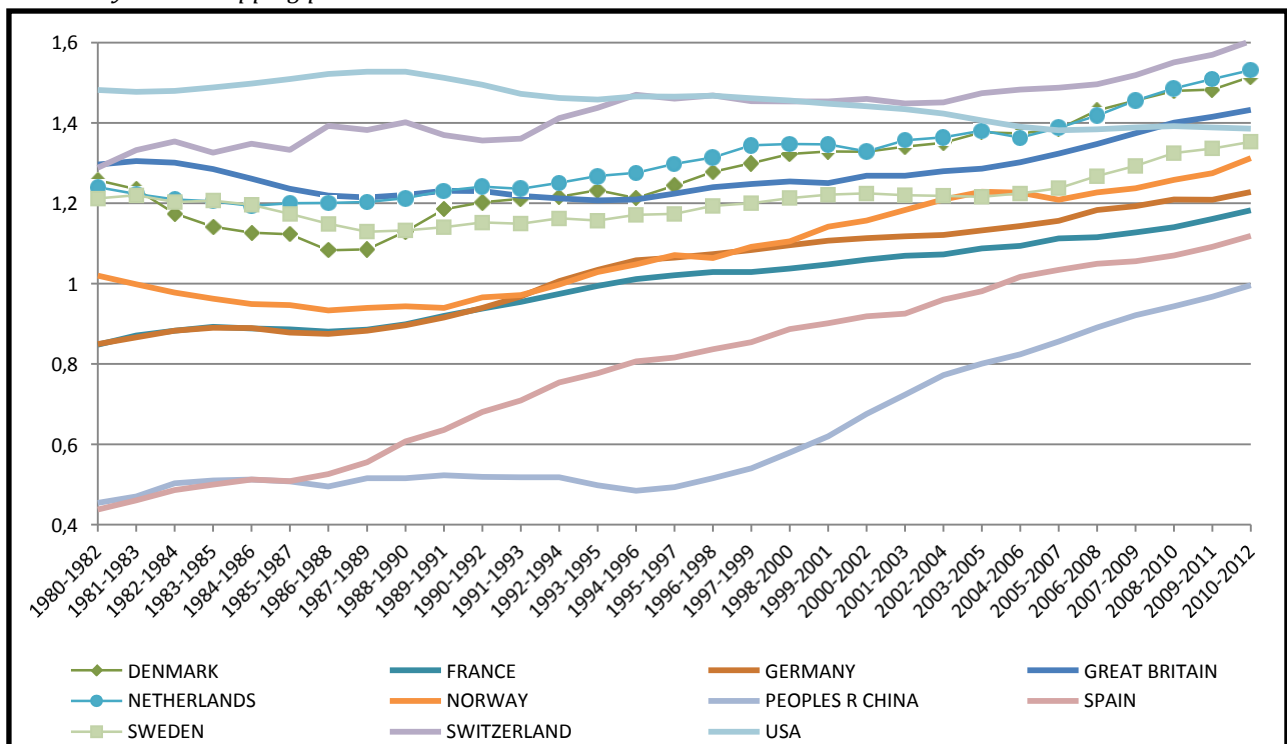
1.1. Research policy and academic performance: The study in context

The relationship between research policy and national research performance has high policy relevance and has been discussed extensively in academic, administrative and political circles in recent years. In particular the Danish case has attracted attention lately as Denmark currently stands out among the top performing countries of the world in terms of academic performance measured by bibliometric indicators. Not least a report by Öquist and Benner (2012) has highlighted the so called "Danish Miracle" and has raised the question: What factors may explain the long term increase in Danish research performance measured by mean normalized citation impact indicators?

Based on these discussions DFiR initiated a project aiming to improve our understanding of the development of Danish research performance. As a first step, a 'Scientometric mapping of developments in Danish research performance in the period 1980-2013 at macro- and meso-levels' was carried out (Schneider and Aagaard 2015). By examining a variety of indicators and comparing the current standing of Danish research to a selected group of comparable countries the report investigated the robustness of the performance claims and the consistency of the long term trends. Overall, the report showed a very robust and consistent picture with a strong Danish performance documented by a variety of indicators. The performance of Danish research did, however, display a remarkable drop during the 1980s. This trend was reversed by the end of the 1980s and since then few other countries have shown the same rate of improvement as Denmark.

Just like Denmark, the two benchmark countries of this study, Sweden and the Netherlands, also had high performing research systems by the early 1980s. The Dutch system has since then displayed a consistent high level of performance for more than three decades, while Sweden's strong position has faded somewhat. Figure 1 below shows the three selected countries for this study alongside some of the traditionally strongest research nations of the world (countries such as USA, UK and Switzerland). A number of more modest performing countries (such as France, Germany and Norway) as well as some upcoming nations (Spain and China) are also included to provide for the broader context. However, there are important database-effects that need to be taken into account when the long-term developments within and between countries are interpreted (see section 1.3 in the background report and Schneider and Aagaard 2015 for details). In particular, the strong increases in impact for most countries since 2006 should mainly be ascribed to a large intake of low impact regional journals in the Web of Science (WoS) database as well as to increased international collaboration which inflates full counts measures.

Figure 1. Development in mean normalized citation scores (MNCS) based on full counts for 11 countries; based on three year overlapping publication blocks.



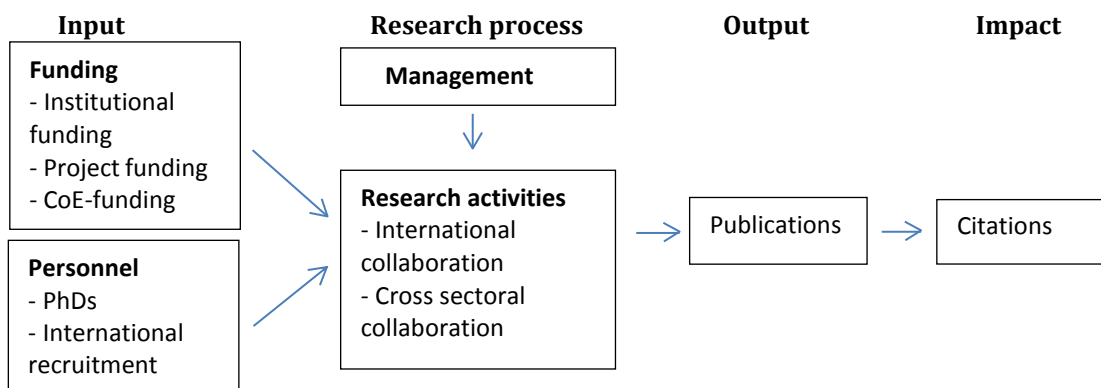
Source: Schneider & Aagaard 2015

1.2. Objectives and main questions

The present study examines the Danish relationship between research policy and research performance in a comparative perspective and aims to strengthen the foundation for future research policy decisions. The analysis has an explicit focus on academic performance measured by bibliometric indicators only. It does not accordingly address other types of impact directly. While it is generally assumed that there is a positive relationship between high academic research performance and both societal impact and high quality teaching, it is also acknowledged that this relationship may not exist under all circumstances. When the results of this study are discussed they must accordingly be placed in this wider context. It should also be noted that aggregated national academic performance measured by bibliometric indicators first and foremost reflects the performance of the medical and health sciences and the natural sciences due to both volume- and coverage issues in the WoS.

From this outset the report presents a quantitative and qualitative based historical analysis exploring the foundation for the development in Danish research performance from 1980 onwards in comparison with the corresponding developments in Sweden and the Netherlands. Based on six hypotheses formulated by DFIR a cross-country comparison serves to examine a number of proposed explanations in different national settings and at different points in time. The hypotheses suggest that the development in Danish research performance may be related to six selected policy factors (DFiR 2015). These factors are illustrated in Figure 2 and outlined in more detail below.

Figure 2: Factors examined in the study



Hypothesis one concerns the funding system and in particular the balance between institutional funding and project funding. It states that the Danish system has benefitted from appropriate balances between these funding streams and highlights in particular how increased competition over time may have led to improved performance. It also states that the mix between different types of funding may have been more appropriate in Denmark than in other comparable countries.

Hypothesis two concerns the use of Excellence schemes. In particular, it states that the Danish system has benefitted from an early and well executed prioritization of a large scale excellence initiative related to the establishment of the Danish National Research Foundation (DNRF). It is argued that such excellence schemes in addition to their direct effects may have indirect positive spill-over effects on the research system as a whole.

The third hypothesis deals with the volume and the organization of the PhD education (and in broader terms with the recruitment and training of new researchers) and states that explicit and well timed prioritizations of the PhD system have secured a strong and talented growth layer in the Danish research system. The mechanisms mentioned include: increased competition for positions, improved and more formalized frame-conditions and more international recruitment.

The fourth hypothesis targets the governance of the universities and in particular the internal research management. It is argued that two reforms of the management system carried out in 1993 and 2003 respectively have strengthened the research management resulting in a strong quality culture and appropriate recruitment practices. It is in particular highlighted that the Danish 1993 act may have led to a stronger attention from the central management levels towards attracting the best international researchers.

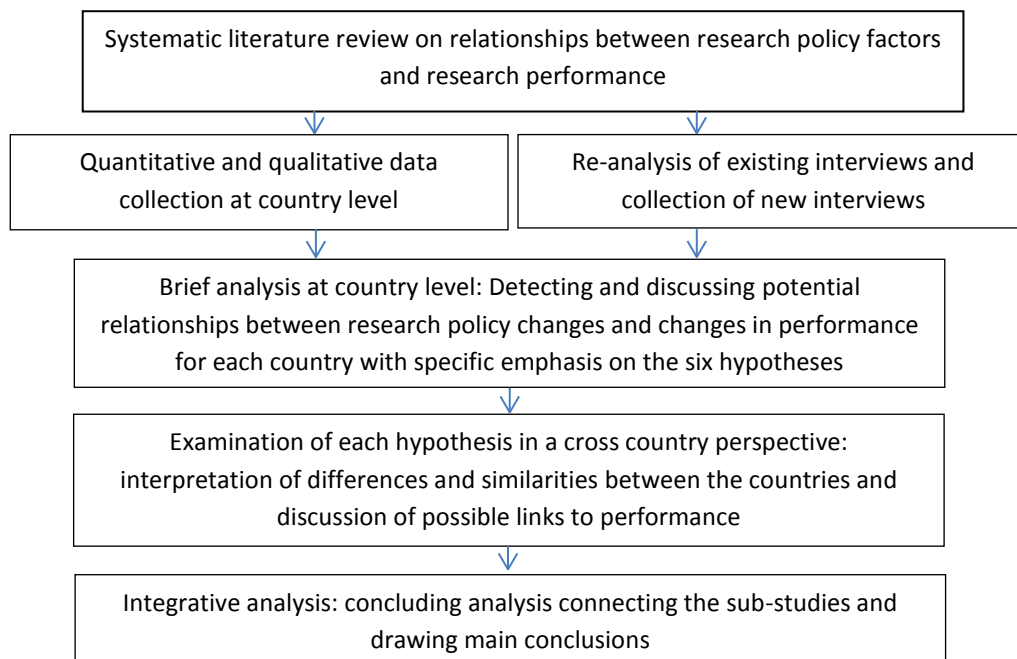
Hypothesis five concerns the internationalization of Danish research and states that the Danish system has benefitted from a high degree of international research collaboration.

The sixth and final hypothesis deals with cross sectoral collaboration and in particular public/private research collaboration. It is stated that a strong Danish tradition of this type of collaboration may be a contributing factor in explaining the high general impact of Danish research.

Although this study investigates the above mentioned hypotheses, it does not seek to confirm or disconfirm each individual hypothesis in a strict sense. While factors such as different types of funding, management, internationalization, collaboration, PhD training and recruitment obviously influence academic performance, they do so in indirect and interconnected ways and often with considerable time-lags.

Rather than a set of isolated tests of the individual hypotheses the study is thus an examination of the interconnectedness of these factors in different national settings at different points in time. The approach acknowledges that a policy that was successful in one context may not have the same effect in another and allow for the possibility that the same outcome can follow from different combinations of conditions. In examining these questions the study provides a discussion of how different balance-points between specific policy measures influence national research performance. To examine the relevant relationships the study applies a mixed methods approach using both quantitative and qualitative data-sources. Figure 3 below shows the work flow of the study.

Figure 3: Methodology and work flow of the study



As outlined above, the point of departure for the study was a comprehensive literature review carried out in order to establish a solid foundation for the subsequent analyses. Alongside this process the data- collection and interview-gathering was started within each of the three countries. As part of this process previously collected interview-material was re-analyzed. In the next phase brief country descriptions were developed for the three countries in order to outline important system characteristics and to highlight major policy changes related to the hypotheses for the period under examination. Policy timelines were constructed for each country and compared to the developments in performance. In continuation of this, specific analyses were carried out at hypothesis level. The majority of these were carried out in a cross- country perspective, but in a number of cases the comparative analyses have been supplemented with more detailed Danish analyses. Finally, all the analyses at hypothesis level were then examined in an integrative perspective in order to draw the overall conclusions of the study. The main conclusions are presented in this report, while the literature review, the country descriptions, the policy timelines, and the documentation of the detailed analyses at hypothesis level can be found in the background report. Further details on data and methods can also be found in chapter 1 in the background report.

2. Factors influencing national academic research performance

Based on a literature review (see chapter 2 in the background report) this chapter highlights a number of overall findings on the relationships between research policy and research performance and relates these to DFIR's hypotheses. Based on this, an analytical frame is presented which structures the country level case studies carried out in chapter 3.

Studies examining aggregated normalized citation impact indicators highlight a stable group of top performing countries (e.g. King 2004). This selection of countries has hardly changed the last three decades. Studies also show that competitiveness in research tends to be a package: some nations perform well at both a specific and a more general level, while others perform less well across the board. With very few exceptions, all leading scientific nations, both smaller ones such as Switzerland, Denmark and the Netherlands, and larger ones such as the U.S. and UK are thus world-leading not only overall, but also in many individual scientific disciplines. This indicates that excellence in individual disciplines or fields of research is hard to attain without a system that supports excellence at a more general level (Adams 1998). It is thus highly relevant to study systemic factors of importance for high impact research in a long term perspective. It also shows, however, that the group of high performing countries is very diverse in terms of how the national science systems are organized and funded. There is not one optimal national science policy model according to this literature, but rather a number of quite different models which all have shown high performance for several decades.

In correspondence with this observation the literature reveal a mixed and complex picture concerning the importance of individual policy factors. On the one hand it broadly supports the selection of factors included in DFIR's hypotheses: Funding mechanisms (including excellence schemes), PhD education, governance structures and internationalization are highlighted in the literature as important factors with regard to academic performance. The literature is, however, far from conclusive when it comes to characterizing these relationships in details. There are in other words no clear crosscutting conclusions on the mix of factors which together create the conditions for high performance in national research systems; except that we are dealing with highly complex questions and multiple possible answers (Geuna and Martin 2003; Auranen and Nieminen 2010). For all the examined factors positive aspects are highlighted, but it is at the same time underlined that there may be substantial negative side-effects associated with the same selection of factors. Most of the potential explanatory factors are likely only conducive to performance within a certain range and under certain contextual circumstances, meaning that both too much and too little of a factor may have negative effects. In addition, multiple balance points between these factors may lead to well-functioning systems.

Across all the examined factors a group of key concepts stand out as important preconditions for continuous high academic performance at both group levels and system levels. These factors include stability in funding and governance-conditions, flexibility to adjust and adapt research agendas along the way, long-term horizons, and diversity along a number of dimensions; not least in relation to funding mechanisms, funding sources and personnel composition (e.g. gender, age, nationality, disciplinary background) (Laudel 2006; Heinze 2008; Hollingsworth & Gear 2012). Together these factors create what is labelled 'protected space' (Whitley 2011) or 'room to maneuver' (Mintzberg 1983). Competition is also highlighted as an important factor, but it is underlined that competition for funding not necessarily is the only or even the most efficient type of competition. National science systems can be highly competitive in a variety of other ways; not least through competition for positions and as the result of strong reputational competition between individuals, groups and institutions. Furthermore, in high performing research systems these factors operate within strong

national ‘research cultures’ defined as sets of shared values, assumptions, beliefs, rituals and other forms of behavior which recognize, value and support academic research as a core activity at the national research institutions. Central characteristics of such cultures are meritocratic mechanisms based on notions of research excellence integrated in both funding schemes and hiring and promotion processes. Strong national research cultures also have internationalization as a key element and rewards and recognizes an explicit orientation towards the most prestigious, international journals as well as presence in leading international networks within each individual field of science (Altbach and Salmi 2011; Hollingsworth and Gear 2012).

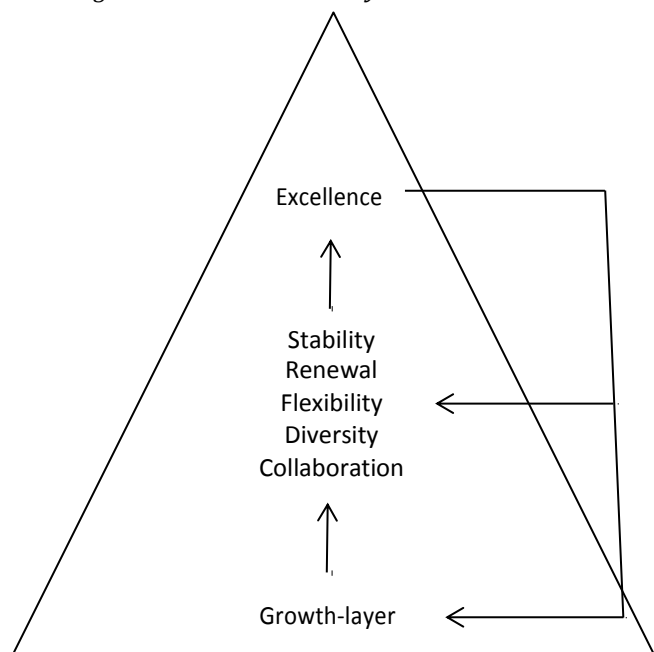
Based on these observations, a general model outlining the interplay of several important factors for high performing research systems has been developed. The starting point is the notion that science systems can be viewed as complex eco-systems where a number of vital balances must be maintained and continually calibrated in order to secure stable, long term high performance. In this perspective a national science system can thus be seen as a configuration of a large number of highly interdependent elements which reinforce each other positively or negatively depending on both internal and external dynamics. When the system is well balanced the interactions between the various elements are characterized by positive feedback mechanisms, while the opposite is the case if central imbalances are allowed to persist.

High performing national research systems succeed in balancing:

- A diverse growth layer and room for excellence
- Stability and change
- Diversity and concentration
- Steering and protected space
- Renewal and continuity
- Flexibility and a strong research culture

Continuous high performance reflects an ability to recalibrate these balances when changes in frame-conditions occur, or when single factors are changed – and an ability to operate with different balances within different areas and different scientific fields of the system.

Figure 4: The science eco-system



The factors selected by DFIR play important roles in securing these vital system-balances. The following section briefly outlines how each factor may influence the overall balances of a national research system and emphasizes why they must be carefully calibrated in order not to create unintended systemic effects:

Institutional funding: Is allocated to secure infra-structure, long-term stability, flexibility, diversity and a strong growth layer. In it-self institutional funding often lacks incentives for individuals and institutions to strive for excellence and this type of funding may thus lead to stagnation if the research culture is weak and/or if other types of competitive forces are absent from the system.

Project funding: Is allocated to draw out the best ideas and encourage research collaboration. The composition of the project funding is however important. Few, large grants support the top of the system and leads to concentration of resources, while many smaller grants draw the balance towards the growth layer and increased diversity of the system. Similarly, the academic orientation of the system may be affected by the balance between funding for curiosity-driven research vs. funding for more strategic or applied research¹. Also the time horizon of the grants plays a role: Long time-horizons increase flexibility, protected space and explorative research, while shorter horizons may lead to more 'safe' research. Finally, a high share of project funding creates large transaction costs and potential unintended effects.

Excellence funding: Builds on the assumption that stimulating a small number of excellent performers will have positive effects on the vitality, attractiveness, and productivity of the whole science system. These schemes have the potential to combine the benefits of both institutional funding and project funding, but may also have unintended effects if they become too dominant. In such instances they may lead to excessive concentration of funding, reduced diversity and a more vulnerable growth layer.

PhD education: Socializes students to research, reproduces faculty and is thus the primary source of renewal of any scientific community. PhD education therefore lies at the core of any nation's research capacity. The volume must however be calibrated carefully as it can displace investments at the expense of other parts of the science system and as it may skew the balance between continuity and renewal in the staff composition.

University Governance: The external university governance defines the autonomy of the research institutions and can limit/increase the room to maneuver at lower levels of the institutions. The internal university governance at the central level may secure healthy system balances within the institutions, but can at the same time create risks of increased bureaucratization, standardization and may influence the conditions allowing adaptive organizational forms to develop.

Internationalization: Plays an important role in explaining research performance, but is mainly driven by internal scientific dynamics. Internationalization lies at the core of strong research cultures (within the hard sciences in particular) and may lead to increased competition for positions, access to additional funding etc., but may also be a threat to the stability and continuity of science systems which serve other, more nationally oriented, functions than pure academic research (e.g. education and knowledge exchange).

Cross sectoral collaboration: Public-private research collaborations may lead to high citation impact for individual publications, but it is unlikely to be a main driver of aggregated national performance. Our examinations of this issue are documented in the background report and the appendix of this report, but the results are not explicitly integrated in this overall analysis.

As briefly outlined above, the factors selected by DFIR play central roles in securing appropriate balances in high performing science systems. The factors are, however, highly interdependent and

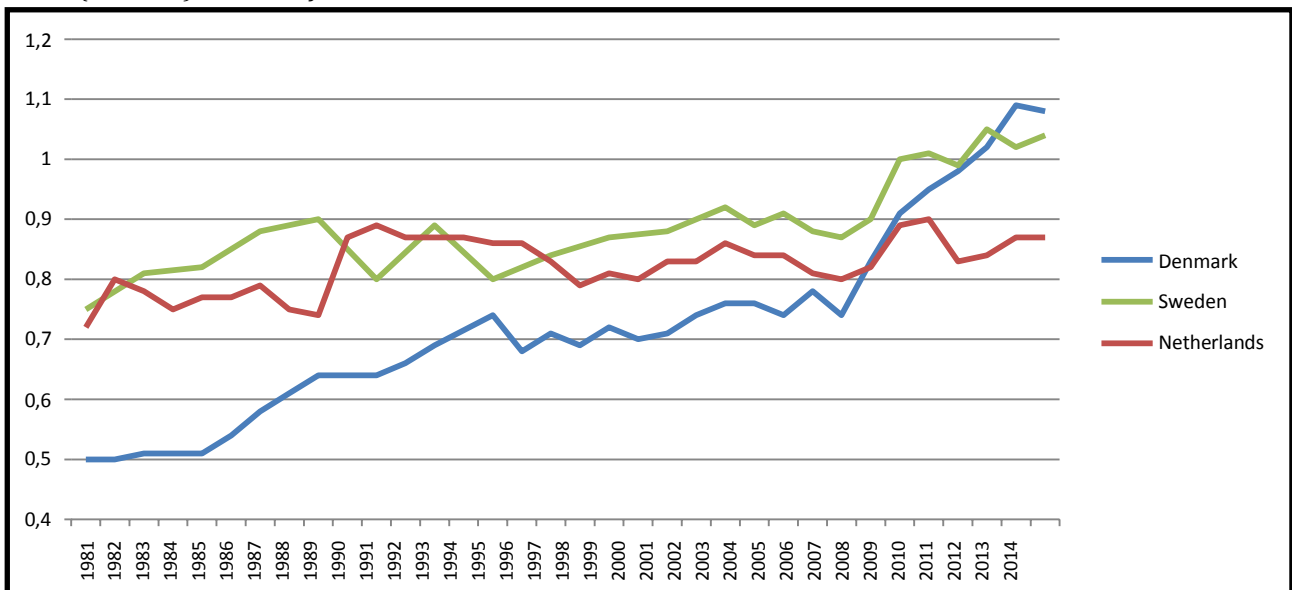
fairly similar factors may lead to different effects in different contexts. A meaningful assessment of the importance of each factor can thus only be conducted in a system perspective. This is done for all three countries in chapter 3.

¹The distinction between these categories is often blurred in reality and also here careful interpretations are needed.

3. Research policy and academic performance: Case studies

The present study deals with three very similar countries. They are all relatively small, fairly wealthy and very open western countries with highly developed welfare systems including strong education and health care systems. All three countries have also been characterized by longstanding and very strong research traditions with internationally highly renowned research environments established long before research became a theme on the political agenda. Furthermore, they are all both EU- and OECD members and have accordingly been subjects of the same international forces shaping the governance of the national research systems. Also with regard to the basic structures of the public research systems there are clear similarities between the three countries. The university systems all share a distinct Humboldtian legacy and thus a strong emphasis on the research-teaching nexus. Similarly, these countries have research funding systems which have developed from traditional dual funding systems with a relatively high share of institutional funding towards more mixed funding configurations with large shares of project funding. In terms of funding volume all three countries today spend close to the Barcelona goal of investing 1 percent of GDP in public research. In 2013 Denmark held the highest share, but it is noticeable that Denmark started out from a significantly lower level than Sweden and the Netherlands during the 1980s as Figure 5 shows.

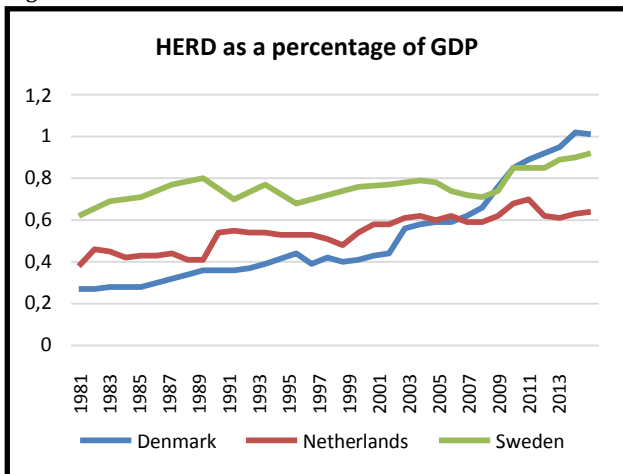
Figure 5. Higher Education Expenditure on R&D (HERD) + Expenditures to R&D performed in the Government sector (GOVERD) as share of GDP, 1981-2013



Source: OECD MSTI

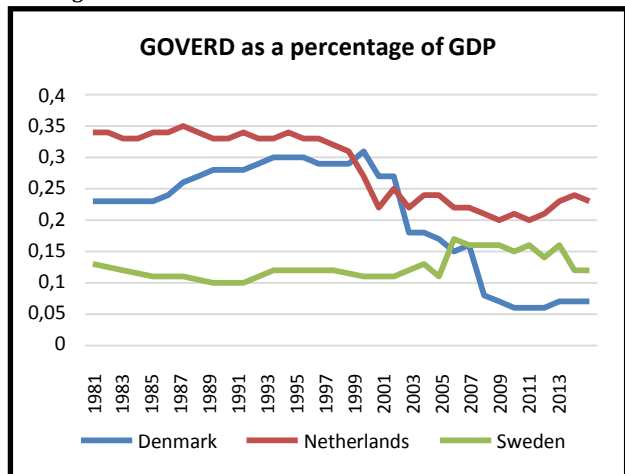
Another interesting difference between the three countries can be observed with regard to the division between Higher Education Expenditure on R&D (HERD) and expenditures to R&D performed in the government sector (GOVERD). As Figure 6 and Figure 7 show: up until around 2000 both Denmark and the Netherlands had substantial government research institute sectors, while Sweden throughout the period has had a public research sector almost fully dominated by Higher Education (HE) institutions. However since 2000 the three countries have become more similar in this respect.

Figure 6. HERD



Source: OECD MSTI

Figure 7. GOVERD

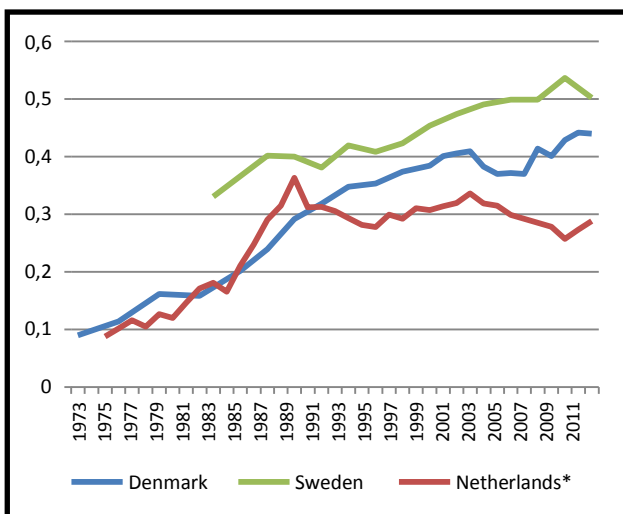


Source: OECD MSTI

Also in contrast to Denmark and the Netherlands, Sweden has had a unified HE sector for most of the period under examination, while the two other countries have had binary systems with a clear division between research universities on the side and non-research HE-institutions on the other. The result has been a concentration of research resources in a smaller number of HE-institutions in these two countries.

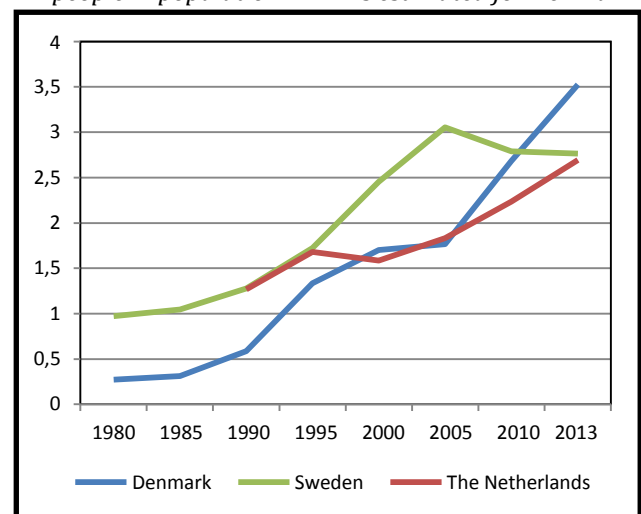
Finally, Figure 8 and Figure 9 show the developments in the three countries with regard to their share of project funding and their PhD graduation volume. It is noticeable that the Swedish system has a larger share of project funding than Denmark and the Netherlands throughout the period, and also that the two latter countries have very similar developments up until 1990. Since then the Dutch system has operated with a lower share of project funding than the two other countries, but a less developed overhead system in the Netherlands means that the differences between the countries may appear larger than they are in reality. With regard to the PhD graduation volume, it is in particular noticeable that the Danish system was characterized by a very low degree of PhD education throughout the 1980s.

Figure 8: Share of project funding, 1973-2010



Source: National statistics

Figure 9: Number of graduated PHDs per 10.000 people in population: 1985 is estimated for Denmark.

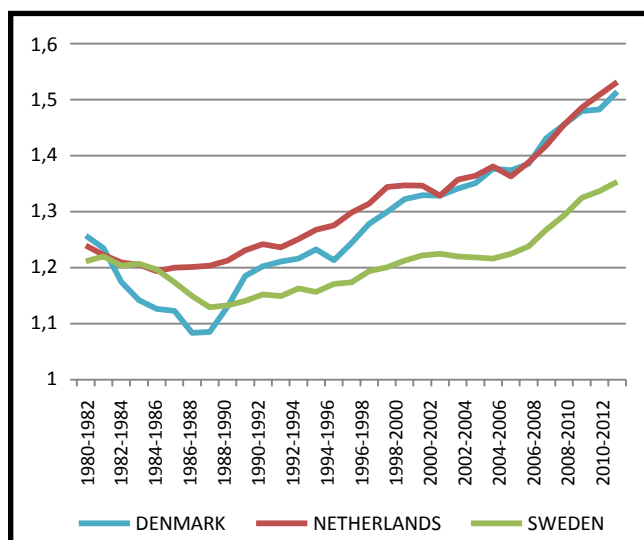


Source: National statistics

As mentioned in the introduction, Denmark, Sweden and the Netherlands can be labelled as high performing research nations in terms of mean normalized citation scores at an aggregated level. There are, however, interesting differences in the trajectories of the three countries as can be seen from Figure 10 below.

All three countries performed at a high international level in the early 1980s where the time-series start, but from there on the developments differ: The Netherlands remains at a high and relatively stable level throughout the period. Denmark experiences a significant decline during the 1980s, but shows a strong catch-up during the 1990s bringing the performance back on par with the Netherlands for the remaining part of the period. Also Sweden experiences a drop during the 1980s, but unlike Denmark, Sweden is unable to fully reverse this trend. A main question in the following analysis is to what extent relationships between policy changes (or non-changes) and developments in academic performance can be detected across the three countries.

Figure 10. Developments in MNCS for Denmark and the two benchmark countries. Based on full counts and calculated for three year overlapping blocks.



Source: Schneider and Aagaard 2015

3.1. Denmark

The Danish science system was performing remarkably well during the 1970s and up until the early 1980s in spite of a low level of public funding. The overall high performance was not least the result of a number of very strong research groups within the technical and natural sciences (Schneider and Aagaard 2015). However, during the 1980s the aggregated Danish mean citation impact dropped dramatically and reached a low point by the end of the decade. It is however interesting to notice (as shown in chapter 8 in the background report) that the decline in impact first and foremost was seen for national publications, while internationally co-authored publications continued to show a remarkably high citation impact. Several explanations for this decline are presented in the following – most of them closely related to the hypotheses formulated by DFIR.

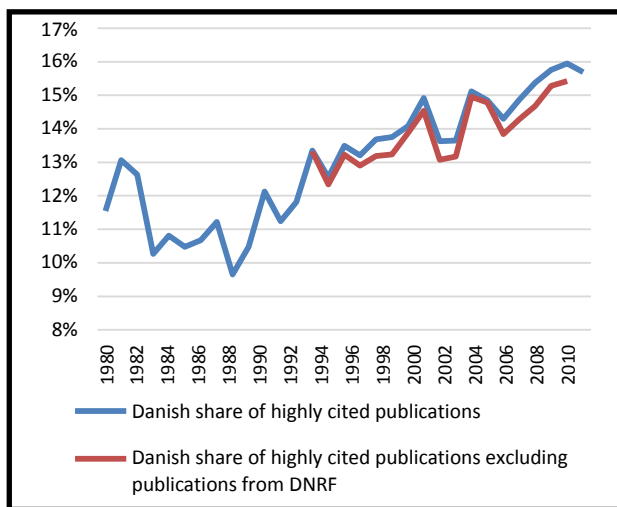
From the 1970s onwards the Danish science system began to show signs of a number of growing imbalances. First of all the system was suffering from a very low degree of renewal. As a result of a rapid expansion during the 1960s and early 1970 a large number of researchers of roughly the same age were hired at Danish universities within a short period. As the growth of the system slowed down during the 1970s and 1980s almost no new positions became available. At the same time and partly for the same reasons the number of graduated PhDs was very low: between 140 and 167 per year from 1980-1987 (Forskningsstyrelsen 2003). The result was a system with a weak growth layer, very little renewal and dynamic, and lack of competition for positions. According to critics a contributing factor to the lack of renewal and dynamic within the universities was a weak and consensus-oriented leadership model.

While the situation at the personnel side was characterized by stagnation and lack of renewal, the funding system went through rapid changes. In the early 1970s, less than 10 percent of all public research funding was allocated as project-funding. By the end of the 1980s this figure had increased to close to 30 percent. The increase was first and foremost the result of a number of large-scale, strategic programs implemented from the mid-1980s onwards. In addition to the lack of stability in the funding system there were limited possibilities for excellent research groups to expand. The situation was thus characterized by challenges at all important levels of the research system: at the bottom of the system (a weak growth layer); in the middle (lack of competition and dynamic); and at the top (limited possibilities for excellent groups). These imbalances were however addressed through a number of steps in the years around 1990.

As a first step the so called Researcher Academy (Forskerakademiet) was established in 1987 with the aim to support and stimulate the education of highly qualified young researchers. The establishment did not only lead to a strong growth in the volume of graduated PhDs during the following 10 years (as shown in Figure 9 above), but resulted also in a much more formalized and quality-oriented PhD education structure. The aim to increase the internationalization of Danish research was an integrated part of this development right from the beginning. This process, driven by the Researcher Academy, was eventually formalized in 1993 when a new PhD reform was passed. As documented in chapter 6 in the background report, the increased volume of graduated PhDs started to level out the highly skewed age distribution within the universities from the middle of the 1990s and onwards as the public research system entered a period of stable growth. During the following decade the age distribution within the universities thus became much more balanced as the increased number PhDs progressed to the next levels of the careerladder.

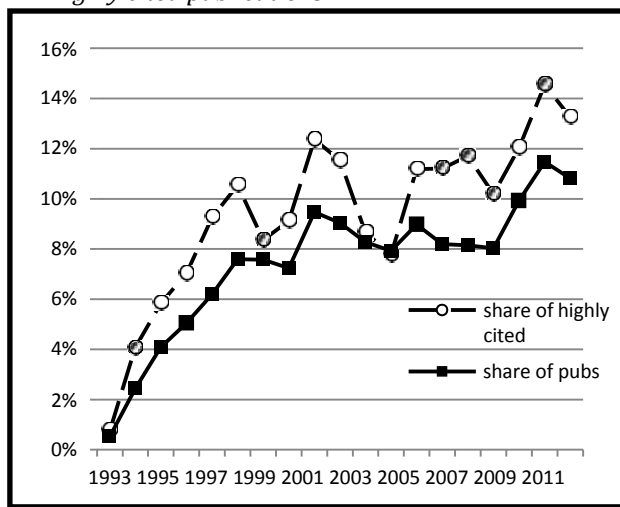
As the background report also documents it is however difficult to establish direct, quantifiable links between most of the policy changes of the early 1990s and the subsequent changes in performance. The most direct relationship can be found in relation to DNRF where the funding of the Centres of Excellence (CoEs) can be linked directly to our performance indicators (as shown in Figure 11 and Figure 12), but even in this case the results need to be interpreted cautiously. First of all, the publications attributed to DNRF can also be attributed to a number of other funding sources. There is thus a risk of overestimating the impact of DNRF. Secondly, a counterfactual analysis cannot be established: What would for instance have happened if the same amount of money had been allocated through the traditional research councils rather than through DNRF? Nevertheless, both our quantitative and qualitative data support the view that DNRF plays an important role in the Danish science system and that it has been a driver of a strengthened research culture not only within the CoEs, but in the system as a whole. The timing of the establishment of DNRF was thus important as it contributed to the general academic reorientation of the system taking place during these years.

Figure 11: Developments in Danish impact



Source: CFA

Figure 12: DNRF share of publications and share of highly cited publications



Source: CFA

For the other relevant factors the difficulties in establishing direct links are even greater. Here we have to rely on a careful interpretation including both quantitative and qualitative data. With regard to the balance between institutional funding and project funding the positive development in research performance gained momentum as the balance stabilized after more than a decade of rapid change. In addition, the overhead reform implemented in 1995 further contributed to improve the calibration of the system. However, also the composition of the project funding changed during these years. Most importantly, the responsibility for the allocation of the majority of the project funding was gradually returned to the disciplinary and more academically oriented research councils after a decade dominated by strategic funding allocated by independent committees outside of the traditional research council system. The importance of the funding changes can thus not only be attributed to the simple balance between institutional funding and project funding, but rather to the fact that a long term stability was found, where the institutional funding, the overhead system, the composition of the project funding and the contributions from DNRF together created a dynamic and diverse funding landscape with a strong academic orientation and support for a diverse growth layer as well as excellent groups.

The changes in the late 1980s/early 1990s thus restored a number of central systemic balances: The growth layer and the recruitment was strengthened through the Researcher Academy and the subsequent PhD reform; the system as a whole was improved by providing stability, flexibility and competition through the changes in the funding mechanisms and the increased number of young researchers; and the top of the system was supported by creating better opportunities to establish world leading research environments – which in turn had positive spill-over effects for the system as a whole. Integrated in the majority of these changes was an increased emphasis on internationalization and a general strengthening of an academically oriented, national research culture. The following period up until the mid-2000s was subsequently characterized by relative stability in both funding and governance; appropriate balances between diversity and concentration; long term stability and flexibility, a strong growth layer and support for excellent groups.

Uncertain effects of recent research policy reforms

However, the Danish system has undergone a number of major changes during the last decade. Once again the majority of the factors associated with DFIR's hypotheses have been affected. While some of the reforms were presented already in 2002 and 2003, most of the reforms did not take real effect before the latter half of the decade. To increase the competition in the system and to avoid spreading the funding too thinly the Government aimed for a turn towards a 50/50 balance between institutional funding and project funding. In addition, the research council structure has been reformed rather fundamentally. The existing councils of the 1990s were all restructured and renamed and a few new ones were established. The changes were most visible in relation to the strategic or innovation-oriented research funding channels while only DNRFF was allowed to continue unchanged. Although the ambition to reach a 50/50 balance was never fully reached the result was a gradual shift from institutional funding towards project funding. The composition of the project funding has however also changed in this process as a shift from curiosity-driven research towards applied or strategic research has been observed alongside a shift from the allocation of many small grants towards fewer and larger projects (Aagaard 2011). In particular from 2006 and onwards these changes have been accompanied by a significant increase in total public R&D investments as figure 5 shows.

Alongside the changes in the funding system a new University Act from 2003 has introduced boards with a majority of external members and prescribed employed leaders instead of elected leaders at all levels of the institutions. The objective was to sharpen up the profiles of individual institutions, to professionalize and empower managerial structures, and to increase collaboration between the actors of the research and innovation system. The new boards were in place in late 2005 and most universities had the appointed leaders installed by 2006. Shortly after this the Government implemented a far-reaching merger process which reduced the number of universities from twelve to eight and transferred 12 out of 15 Government Research Institutes (GRIs) to one of the remaining universities - in reality closing down the majority of the GRI sector.² The result was a large concentration of resources within a few select institutions, and also a clear break with the former division of labor between academic research and the more applied GRI research (Aagaard 2011). Finally, PhD education has once again been highly prioritized with a 100 percent increase in uptake in the period 2004-2010. This increase has been quite selective as almost 90 percent of the increase has taken place within the natural, medical and technical sciences.

Most of the recent reforms have thus targeted the same areas as the reforms of the early 1990s, but this time in a quite different context. Where the prioritization of PhD education during the late 1980s and the early 1990s mainly was driven by an internal demand for renewal within the universities, the expansion observed from 2004 onwards was driven by perceived external demands for more PhDs outside of the public research sector. Similarly, the new funding instruments were not mainly introduced to improve academic performance but rather to strengthen the societal and (in particular) the economic impact of the public R&D investments. The impact of these policy changes on performance is however difficult to assess at this point. First of all, they have been implemented alongside a substantial increase in overall funding as shown in Figure 5. Potential negative effects of the reforms in isolation may thus have been outweighed by the benefits of the increased funding.

² A more limited number of mergers involving GRIs and universities were already implemented in 2004 as a prelude to the subsequent large scale merger process in 2007.

Secondly, the changes have coincided with a period characterized by large changes in the WoS database as well, which for almost all developed western countries have resulted in a perceived improvement of their performance.

The three countries in this study thus all have very steep, almost identical improvements in performance in the period from 2006 and onwards. However, most recently the Danish public R&D sector has experienced stagnation and even cuts in the funding which will test the current balances of the system. While clear links between these policy changes and the effects on performance cannot be established, the changes can be analyzed in a systemic perspective in order to discuss to what extent the reforms have altered the balances of the public Danish research system. We return to these discussions in the final part of chapter 4.

3.2. The Netherlands

The Dutch science system has been performing rather well internationally for more than three decades. According to many of the interviews conducted for this study, a longstanding, strong academic culture has been a decisive factor for this success. In contrast to many other continental European countries the Netherlands was an early adopter of its own version of a competitive (Anglo-American) output-oriented research culture. Although the output-oriented model was met with some concern and discussion it quickly gained broad support. Researchers, university boards and policymakers thus internalized this new research culture which soon became undisputed.

In particular, the introduction of a research assessment system in 1986, which entailed the establishment of a model of assessing research areas and research units, must be seen as a key reform in Dutch research governance. The system fast became a mechanism of regulating academic behavior, in particular publication practices. The initial ambition behind the system was to link the research assessment to resource allocation but this proved to be a controversial issue. Instead, universities committed themselves to adapting to the outcomes of the assessments and demote areas that were not of international significance. This entailed gearing resources towards more promising and viable activities and transferring staff and activities not active in these fields to other universities where these fields were more prominent (which in turn entailed coordination between universities, which had hitherto been unusual). Even 30 years on, the voluntary system has remained intact and has become an institutionalized component of Dutch research governance, where universities self-select areas to be assessed and use the assessment for their own purposes without government interference. Various sources indicate that the assessment system has given a major boost to the scientific impact of Dutch research, primarily by demoting research which resulted “only” in domestic publications and by reducing research activities of limited international significance. Since its inception, the protocol for these assessments has been renewed every five years. In the latest protocol the emphasis on outputs (publications) decreased, while more attention is given to the societal relevance of the research.

The introduction of the assessment system was part of a broader set up of policy measures to support excellence. One such was introduced in 1991 by the Ministry of Education, Culture and Science when the national research schools were established as a new policy instrument. The aim of this instrument was to stimulate focus and mass by concentrating the best researchers at a national level and combine it with PhD training. The Research schools have to be accredited by the Royal Academy of Sciences. In the late 1990s the Ministry also introduced the Bonus Incentive Scheme. Its purpose was to identify and encourage national concentrations of outstanding scientific research in top research schools. The effect of the (top) research schools was more national collaboration, a more interdisciplinary approach

and better PhD- training. Both instruments were replaced by the Gravitation program of the Netherlands Organisation for Scientific Research (NOW) in 2009. Besides the research schools and the Bonus Incentive Scheme many other excellence initiatives have been introduced. Some have targeted specific scientific areas (in which the Netherlands could excel), while others have been concerned promising economic areas or societal challenges. These initiatives did not exist in isolation, but often strengthened each other. Although the Dutch policy for excellence initiatives has been somewhat fragmented, the total amount of additional funding generated by these initiatives has been substantial. All these policy measures secured sufficient support for excellence and in addition allowed room for a tailor-made approach for different domains and different aims.

The voluntary assessment system and the different excellence initiatives were all part of a more general realignment of the relations between the state and the universities. The state receded from its relatively fine-grained model of steering into a model of 'steering at a distance'. Increased university autonomy was therefore coupled to performance expectations and evaluations (De Boer et al 2006). The new governance arrangements also changed the management of universities and research institutes. The institutional autonomy was used for more pro-active research management where the boards of the universities put more emphasis on quality and excellence and promoted an output-oriented research culture. In terms of policy the management of universities and institutes created local focal points and changed the Human Resource policy: e.g. by use of performance indicators for appraisals, increased demands for hiring new staff and the introduction of tenure track positions. For individual staff members the prerogative of 'total academic freedom' disappeared and was replaced by a much more competitive system with performance indicators and increased demands in general.

Finally, the academic research culture has also been supported by a strong and long standing international orientation. Dutch researchers have always been open to international collaboration and have historically been well embedded in the international research community. The open mindset (as part of a long cultural tradition), the relatively central location in Europe and good infrastructure, a research infrastructure and environment that is attractive to foreign researchers and good language skills (often one or more other languages besides English) have all contributed to the international orientation of Dutch research. These international contacts have been beneficial for the visibility and impact of the research as it encourages informal peer review, mutual exchange of ideas and stimulates a multidisciplinary approach.

A second important, overall factor for the strong research performance in the Netherlands is the long term funding stability. The data collected for this study show an increase in both basic and project funding over the years (from 1975 on). The Ministry of Education, Culture and Science primarily provides the institutional funding to universities and other public research institutes. The data show how both types of funding increased at the same pace until 1990 and how university institutional funding has increased at a faster pace afterwards. Only in recent years has the institutional funding shown a slight relative decrease.

The lump sum size of the institutional funding for universities is formula based, and made operational in a funding model that includes several parameters. In addition to that, universities can receive extra funding for meeting certain additional indicators that are referred to as 'performance agreements'. The budget for this can make the overall lump-size increase by 6 percent. The formula contains indicators like the number of PhDs, the number of MA diplomas, a contribution for research schools and specific tasks. A larger part (almost 60 percent) of the funding is based on 'strategic considerations'. However,

the distribution of this 'strategic part' amongst the universities has remained stable for a long time and is mostly based on historical grounds. Overall the distribution of the institutional funding shows a rather stable pattern. The increased emphasis on output funding has not influenced the distribution of institutional funding among universities. This is done within universities and by the increase of competitive project funding.

In addition to the institutional funding there is also project based funding. This encompasses the project funding from research councils, contract research, governmental programs, etc. The project funding shows a clear upward trend from 1975 to 1990. The share of the project based funding almost tripled (from 10 to 30 percent of the total amount). Afterwards the share of project funding remained stable at about 25 percent. The growth in project financing is mainly due to the availability of increased project financing by the Ministry of Economic Affairs. In 1975 the ministry introduced a temporary large new innovation instrument (the INSTIR), which explains a peak of funding in 1990. As this instrument ceased to exist, other instruments continued to supply project funding (but they were relatively smaller in size). Another reason for the increase of project funding has been the expansion of the budget of the NWO. Most of the NWO budget is aimed at supporting excellent research.

An important characteristic of the Dutch funding system is an equal distribution of resources for basic research. Unlike the REF system in the UK, research assessments in the Netherlands are not linked to resource allocation. And as mentioned, in the allocation of research funding at the level of universities and research institutes output indicators are not a decisive factor. Although there are clear differences in the level of funding (mostly based on historical grounds), all universities and research institutes can build on a sufficient level of institutional funding. This enables them to develop and maintain a state-of-the-art local research infrastructure and attract good researchers. This is, according to the interviewees, one of the explanations why all of the 12 universities are in the top-100 of most university rankings. At the same time, it might also explain why none of the Dutch universities are in the top-20 of rankings. The metaphor of an elevated plain field without peaks is often used to describe this phenomenon. One of the benefits of the egalitarian system might be that it offers a good base for national collaboration. The institutions can not only profit from complementary expertise and infrastructures but may also benefit from high-level research quality of their counterparts. The whole research system thus offers a high level platform for collaboration, multidisciplinary approaches and mutual learning. The fact that the Netherlands is a small country in a geographical sense also contributes to close interactions within the system.

A third and final important factor for the sustained Dutch research excellence is a well-balanced policy mix at the national level. The expansion of research funding in the 1990s and 2000s has been operationalized in a series of loosely coordinated, but mutually reinforcing steps to propel funding, and create a more coherent, yet diverse, funding system – all under the auspices of a national model of policy coordination and policy advice. The national policy mix contains a number of initiatives supporting focus and mass in research. The different kind of excellent schemes stimulate national collaboration and offers sufficient funding for excellent research. In addition the major players in the research landscape (the Ministry, NWO, universities, the Academy) instigated a scheme for talented researchers. In 2000, the so-called Innovation Renewal Research Incentives Scheme (Vernieuwingsimpuls) was established. The scheme offers personal grants to talented, creative researchers and enables applicants to conduct their own line of research. The scheme is expected to boost innovative research and promotes mobility within scientific research institutes. The Scheme comprises three grants geared to different stages in a researcher's scientific career: *Veni* - for

researchers who have recently obtained their PhD; *Vidi* - for researchers who have gained several years of research experience after their PhD; and *Vici* -for senior researchers who have demonstrated an ability to develop their own line of research. Evaluations of the scheme have been positive and functioned as a blueprint for the ERC grants and the Danish 'Sapere Aude' program. It thus not only supports the established top researchers but also facilitate career paths for young (innovative) talents.

In addition, as a more recent feature, there is increased attention for the importance of (large) research infrastructures. This kind of research infrastructures are today considered to be of paramount importance for scientific excellence as they push the limits of possible data collection, support pioneering experiments and offer access to comprehensive databases. NWO provides access to such research facilities for many dedicated schemes. The Netherlands was an early adopter of an explicit national policy for large research infrastructures. In 2007 – as a follow up to the European Strategy Forum on Research Infrastructures – the Dutch Minister of Education, Culture and Science set up the National Roadmap Committee for Large-Scale Research Facilities. In order to implement the national roadmap the Ministry provides funding for research infrastructures: Initially, mostly as ad hoc funding, but lately as a recurrent annual budget. NWO organized a biannual call for proposals for large research infrastructures with a budget between € 75–100 million.

Concerns about the sustainability of the Dutch research performance

Although the Dutch research system has undergone extensive reforms positively affecting international performance, the interviewees also expressed some concerns regarding the sustainability of the research performance. The main concerns are related to the following issues:

The emphasis on output indicators in the university system has created unprecedented competition throughout the whole system. In order to be successful researchers are aiming for the production of articles in (top) journals, and attracting competitive funds for their research, while the institutions also aim for high numbers of PhDs awarded. The increased significance of output indicators could lead to perverse behavior: indicators can be misused or gamed ('sharing' or 'slicing' publications) and there are many examples of fraudulent scientists. More important is however, that the personal interest of the researcher does not automatically (any longer) correspond with the higher goal of science.

In addition the interviewees state that the system has become too much of an 'aggregation machine'. The system has very well developed processes in place to produce a high number of articles, conference papers and make sure that they are well-cited. The outputs of the system reflect the inherent demands of the same system. But there is a concern that the system as a whole lacks 'change agents'. The capacity for or focus on real ground-breaking research has been diminished. Likewise, the system doesn't seem to be very successful in adopting new disciplines (like nanotechnology, ICT, etc.). In these domains there are excellent groups, but they are on average rather small and dependent upon a limited number of top researchers. The main part of the most excellent research still comes from traditional disciplines like astronomy, physics and medical research.

There also seems to be an emerging imbalance between institutional funding and project funding. For their personal careers, and for attracting PhDs and postdocs, researchers are heavily dependent upon competitive funding. This has led to an increased number of applications for funding from research councils and as a result to decreasing success rates. In some (prestigious) schemes the success rate is now below 10 percent. The whole system of competitive funding thus requires substantial efforts of the research community. Designing a research proposal is time consuming and this also applies – as

the system is based on peer review – for the assessment of individual proposals by multiple peers and the participation in panels and juries. The interviewees question whether there is still a right balance between the cost and the benefits of this system. In addition, they indicated a worry that research councils fund sound but not ground-breaking (and therefore often less feasible) research. Studies show that it is very difficult to select the best proposals from the middle group (among the category very good). The existing criteria are not useful to define a clear cut off in this middle group, making it a kind of 'lottery'.

A final remark concerns the increasing top down steering of university research. There is an increasing emphasis on the societal relevance of university research. In recent years a larger part (50%) of the competitive funding of NWO has been aligned to the innovation agenda (the top sectors) of the Ministry of Economic Affairs. Currently, a National Science Agenda is being developed and this agenda is considered to be an important tool for research programming in the future. Although many researchers are convinced that university research can contribute significantly to economic and societal challenges, there is a dispute about the way this should be organized. In addition there are some concerns about the funding possibilities for more fundamental ground-breaking research.

3.3. Sweden

The impact of research carried out by the Swedish academic system was generally very high throughout the 1970s and early 1980s. In part, this can be explained by a comparatively generous state support; Sweden has for many years had a high level of investment in R&D in the Higher Education sector, which was shown in Figure 6. However, during the latter half of the 1980s the Swedish mean citation impact dropped, and for around two decades until around 2005, Sweden continued to lose ground to most other comparable countries, not least to Denmark and the Netherlands, which had a more positive development than many other high-performing countries. Only during the last ten years has Swedish research managed to improve its performance on par with that of Denmark and the Netherlands, but it has not been able to close the gap opened up in the two preceding decades.

There are multiple reasons to why Sweden kept falling behind during this period. Some of these are closely related to the hypotheses that DFIR has formulated, while others depend on other factors. Due to the exceptionally complex nature of research systems, it is not possible to clearly separate single explanations from each other or to provide precise estimates of the importance that single factors have played. Underpinned by the quantitative and qualitative empirical material put together for this study, our assessment is therefore provided in a chronological structured discussion. Our main argument is that Sweden during this period has provided less favourable conditions for elite research than Denmark and the Netherlands.

The overall level of research funding has certainly not been a problem; Sweden has during practically the whole period allocated more government expenditures to research than the two other countries. We also cannot see that Swedish research has been less internationalized than its Danish and Dutch counterparts. The explanations are instead found in a number of imbalances and structural problems in the Swedish academic system. Starting from the 1960s, Sweden focused its HE-system on supporting society in other ways than through elite research. Throughout the 1960s, 1970s and 1980s, more emphasis was put on the education activities than research, reflected not only in a strong growth in the number of students, but also in an increased focus of university staff on education. In addition, a large number of regional university colleges were established in 1977 and were integrated into the

university system, although until the late 1990s without institutional funding for research. Already in the 1960s, efforts were made to increase the output of PhDs in the Swedish system, including making the PhD education more structured and efficient. Still it took around 30 years before strong measures were taken to make the reform fully effective. Throughout the 1980s, Sweden nevertheless trained far more PhDs per capita than Denmark did, and from the early 1990s and onwards Sweden has had a considerably higher production of PhDs than the Netherlands has. Consequently, there has not been any lack of research trained individuals in Sweden.

Around 1980, Sweden once and for all decided to focus the vast majority of its government R&D spending on the university system. Already in the 1960s, Sweden pioneered the customer-contractor model of research governance in Europe under the banner of 'sectoral research' (Stevrin 1978). The state expanded research funding dramatically in areas with hitherto very limited research funding or activities – environment, housing, work environment, social affairs, etc. A notable share of these mission-oriented activities took place in a university setting. Unlike the other countries, Sweden thus abstained from a full-blown research institute sector and primarily channelled the sectoral funding via the university system.³ Sweden thereby established one of the very first non-binary academic systems in the world. The traditional academic order with research councils and faculty structures existed alongside this widening of both research and the HE system more generally, but it was not as dominant as in Denmark and the Netherlands.

Sweden's relative focus on sectoral research in the 1970s and 1980s has however only had a limited, direct negative impact on Sweden's research performance measured by mean citation impact indicators, essentially because the sectoral research mainly was concentrated in areas that are marginal in WoS. However, it may have had an impact by providing opportunities for application-oriented researchers to make university careers.

In comparison, the large increase in student numbers probably had greater impact on the research performance, mainly because it led to university staff spending more time on education and less on research. Besides professor, university lecturer was the only academic employment that was permanent – and professors were until the early 1990s holders of chairs, which could only be applied for when the previous holder resigned. Unlike in many other countries, the Swedish university lecturers had practically

no time for research in their employment contracts; they more or less entirely had to rely on attracting external research funding. While temporary positions as full-time researchers existed (primarily aimed for young researchers), highly qualified researchers could be stuck in positions as university lecturers with prolonged periods offering very limited opportunities to conduct research.

In the 1980s the very strong expansion of funding via sectoral agencies came to a halt and resources were partially redeployed to the research councils, which included the establishment of two new councils. Major changes were also made in the constitution of funding in other areas, such as housing and agriculture (Premfors 1986). In 1989, the funding of PhD education was reformed, with the introduction of fully funded PhD positions instead of the earlier system of stipends. Hence, the 1980s represented a modest retreat of research policy and of university governance into more 'orderly forms'.

³ A significant share of the sectoral research was however performed by the sectoral agencies themselves, primarily because they did not believe in the universities' capacities to produce results that were relevant

enough for policy.

The 1990s, which most markedly is the period where Swedish research was losing ground, was a hectic period for reforms of Swedish research funding and governance (Benner 2001). A wide-ranging series of changes were incepted in 1992–1994 when a string of independent research foundations were established, mostly oriented towards strategic research. The allocation of resources for research to universities was altered at the same time, and the fine-grained allocation to individual faculties among Sweden's universities was replaced with a lump-sum allocation to universities. Universities were also given the right to appoint professors on their own. In 1995 this transformation was to some extent reversed, as a consequence of an economic crisis. Institutional funding to universities and research council budgets were cut with up to ten percent, but the new government failed to dismantle the strategic research foundations. In parallel important changes took place within the university college sector. Institutional research funding was appropriated for university colleges; the university colleges were given the right to establish professorships independently in 1997, and in 1999 three university colleges were elevated to universities, including the right to confer PhD degrees and to receive higher levels of institutional funding from the government.

It is also noticeable, that the Swedish system for all of the investigated period has had a higher share of external funding than Denmark and the Netherlands, between 40 and 50 percent during most of the period. Funding from the research councils and the new research foundations, originally intended to provide better opportunities for gifted researchers, in effect became a replacement for institutional funding. In many fields it became practically impossible to pursue a research career without a constant inflow of external funding. Besides spending much time writing research proposals, many researchers had to rely on relatively short-term funding, which increased the incentives to conduct less risky projects and to publish continuously. As competition for research council funding grew, projects tended to receive less generous support. Young researchers, recognised as a group with particular potential for conducting high- impact research, have had a particularly challenging situation throughout the investigated period. One reason is that they have often been dependent on a professor and thereby less able to develop their own lines of research. Another consequence of the reliance of external funding is that university managements and faculty boards have lost power. Strategic decisions on, for instance, to which research areas additional resources should be channelled were in practice often taken by the research council committees in their decision on whom to fund. Such committees are often rather conservative; they tend to be defenders of their subfields, universities etc. rather than organs that take an overall long-term strategic responsibility. In the 2000s many funders also requested co-funding from the HEIs, which has tied parts of the institutional funding.

A couple of unfunded reforms in the late 1990s further challenged the universities. The most profound of these was the reform in 1999 that reformed the chair-system for appointing professors, whereby university lecturers were given the right to apply for promotion to professor. If they had enough merits to qualify as a professor, they had to be appointed, regardless of the need or the availability of resources. Most universities felt a pressure to support the newly promoted professors with more time for research in their positions, besides a higher wage. This, since the reform was unfunded, increased the internal competition for institutional funding. Also the PhD reform in 1998, which in essence prevented non-funded recruitment of PhD students, put pressure on the institutional funding. The PhD students had to be supported by external funding, scholarships, or plain salary from the host institution. Step by step during the 2000s practically all universities have also been pressured to guarantee their PhD students four years of regular employment, instead of scholarships with significantly lower wage (and no social security) during the first one or two years of studies.

To remedy the problem of inadequate opportunities for elite research, many external funders started to initiate their own excellence schemes. Such schemes have existed since the mid-1990s, but around 2003– 2004 there was a significant growth as several funders established more long-term excellence schemes which targeted larger constellations of researchers. In 2008 the government established a number of generously funded Strategic Research Areas to support elite research in certain fields. It is however unclear whether the schemes have led to higher performance; studies of smaller samples of centres and mid-term evaluations have indicated marginal improvements at best and often pointed at insufficient leadership.

While the overall funding for research has been high, the system has been characterised by a high degree of competition for resources. One may argue that Sweden has spread the resources too thinly, employing too many researchers, and awarding too small research grants. On the other hand, the HEIs have been under pressure to employ more staff for teaching, to maintain the link between research and education, and not close the doors for new generations of researchers. Similarly, the research funders have felt a need to grant a certain degree of applications and to be reasonably “fair” with regard to specific disciplines and universities. The situation is also a consequence of the expanded PhD training – while the political intention has been to provide PhDs to society outside of academia, PhDs have often tried to remain in academia, even if the conditions have been harsh.

Unsolved problems in the Swedish system

As outlined, there have accordingly been many features and circumstances in Swedish research policy from the 1980s onwards that did not play in favour of exercising a rigorous internal quality control and maintaining a high research quality across the institutions. While it is not possible to assess the exact impact of those changes, it seems reasonable to assume that a weakened quality culture and, over time, insipid internal quality control, has been the key explanation to why Sweden has fallen behind Denmark and the Netherlands. The high dependence on external funding has made it difficult for universities to steer their research environments, including which recruitments to make. The increasing reliance of external funding may also have affected researchers’ interests in maintaining a collegial structure.

The high dependence on external funding has also resulted in research priorities that have been short-term and safe, in order to secure funds the coming years, rather than long-term and novel. A rather constant output of decent publications has typically paid off better than one top publication after five years of uncertain research. In addition, collegial steering at faculty level was largely abolished already in the late 1960s. Since then the main role of the faculty collegiate has been to elect their representatives to faculty boards etc. The elimination of faculty meetings and the consequential weakening of the cross-faculty networks that came with such a structure, has without a doubt resulted in less quality control of single departments and research environments.

Also the quality control of PhD examinations has been partly eroded. Opponents and PhD committee members are in practice appointed by the department in question and not the faculty, which they used to be. As the opponent thus came to represent a field rather than a collegial structure, this change of procedure lowered the internal quality control. In addition, Sweden abolished a grade system for PhD dissertations already in the 1960s; since then the PhD committee have not even been allowed to provide written or oral assessment or comment of the quality of the dissertation.

Furthermore, when research peers from abroad evaluate Swedish research environments or funding programmes, they often point at an insufficient academic leadership. One may ask to what extent that situation is an effect of the quite powerful external funders and the relative absence of collegial systems for internal quality control.

Finally, the structure of the Swedish research system implicates that HEIs must take on roles that in many other countries are played by research institutes. While that structure perhaps benefits Swedish industry and other parts of society, it also provides career opportunities for less academically oriented researchers and in general introduces other goals than performing research that gives high impact in academic journals.

4. Conclusion and future perspectives

This final, concluding chapter follows up on the case studies of chapter 3 and highlights a few cross-cutting conclusions. In continuation of this a number of current challenges facing the three national systems are outlined and it is discussed to what extent the results of the analysis can inform future research policy decisions in order to support continuous high academic performance. Finally, Appendix A presents the main findings of the analyses at hypothesis-level with a brief discussion of how changes in the selected factors influence research performance in the different national contexts.

4.1. Cross-cutting conclusion from the case studies

The previous chapter presented three individual accounts of relationships between research policy and research performance. Overall, empirical support was found for several of DFIR's hypotheses for Denmark and it was shown how changes in the funding system (including the establishment of DNRFF), the prioritization of PhD education and a general increased emphasis on internationalization during the late 1980s and early 1990s contributed to reverse a negative development and subsequently laid the foundation for the constant increase in the aggregated Danish research performance during the following decades. Also in Sweden and the Netherlands several factors associated with the hypotheses were highlighted as important elements in the explanations of the observed national developments. However, as soon as we move from a single-country perspective towards a comparative cross-country perspective, more generalizable patterns between specific types of research policy changes and research performance become a lot less obvious. Rather than universal relationships between specific policy measures and their effects, we find a number of highly context-specific explanations – often involving a complex interplay between several factors. Nevertheless, two central conclusions stand out at a more general level; the first is related to whether and how strong national research cultures have been institutionalized at the system level within the three countries; the second concerns the importance of continuous calibrations of the central balances of national science systems.

Institutionalization of a strong national research culture: The 1970s and 1980s can be perceived as an important transition period from a traditional 'republic of science' model towards systems based on 'New Public Management'-inspired funding and governance mechanisms and increased societal demands towards public research. While this transition period for all three countries resulted in stagnating or decreasing national academic performance at first, the subsequent national policy responses differed in important respects. The period during the late 1980s and early 1990s, where new balance-points between classical academic values on the one hand and demands for

accountability, utility and competition on the other were to be found, can in other words be seen as a critical juncture which contributes to the understanding of the subsequent developments in performance up until today.

The following section outlines the main point in this explanation:

During the post-war period and up until the 1980s Denmark, Sweden and the Netherlands all had high performing, internationally oriented, research groups. The strong research culture of these groups was, however, in most cases locally anchored at group- or institution-level rather than the result of policy- induced initiatives at the systemic level. But beginning from the late 1980s both Denmark and the Netherlands established independent institutions with a clear responsibility of upholding academic quality and with a high degree of both internal and external legitimacy. In Denmark, the Researcher Academy, DNRF and increasingly also the traditional research councils became such institutions with system-level effects. In the Netherlands it was in particular the research assessment system established in the late 1980s which played this role, but also the strong tradition of coordination between the most important actors of the academic system must be highlighted as an important element in this explanation. Although we are dealing with quite different policy measures put to use in different national contexts, they have played the same role: In both Denmark and the Netherlands the initiatives implemented in this period have created long-term and stable points of orientation for institutions and individuals alike and thus contributed to a general strengthening of a coherent, national research culture supporting excellence and internationalization. While there have been an ongoing tension between excellence and utility in both countries throughout the period, the measures and actors supporting the first have been long-lasting, deeply institutionalized elements of the systems, while the latter have been of shorter duration and often characterized by shifting orientations. For Sweden, on the other hand, such long-lasting institutions with strong system-effects were not to the same extent established during the crucial years around 1990. Rather, the Swedish system in this period became the subject of more mixed political signals with strategic and utility-based considerations outweighing a clear focus on research quality as the most central pillar of the system. This trend was further strengthened as the result of the economic crisis in the mid-1990s which in particular led to cuts in the funding of the most academically oriented parts of the Swedish system. For individuals as well as institutions the Swedish system has thus lacked the permanent, strong, quality- oriented and highly institutionalized points of orientation that we have seen in Denmark and the Netherlands throughout the period.

Continuous calibration of system-balances: A strong research culture (and several long-lasting institutions supporting such a culture) is an important condition for high academic performance at an aggregated level, but it is by no means a sufficient factor. In order to provide conditions conducive to high research performance, the research system as a whole needs to uphold a number of central balances for prolonged periods of time. As outlined in chapter 2 this includes finding appropriate balances between opportunities for excellent groups on the one hand and securing a strong growth-layer on the other (balance between concentration of funding and diversity). It also includes balances between steering and protected space, as well as balances between renewal and stability. Not least the funding system, the governance mechanisms and the organization and volume of the PhD education play important roles in maintaining such balances.

In particular the dramatic drop in the performance of the Danish science system during most of the 1980s illustrates how a number of systemic imbalances rather quickly can lead to negative effects. In

the Danish case it was not least lack of renewal in the science system and the absence of a strong and diverse growth-layer that resulted in almost a decade of decreasing performance. A number of funding imbalances most likely also contributed to this development. However, the Danish case shows how the imbalances were corrected during the 1990s by focusing on a strengthened PhD-education, the establishment of a new funding mechanism targeting the top of the system through DNRF, and a recalibration of the remaining part of the funding system in order to support the base-layer of the system. In fact, these policy changes can be seen as the culmination of a general academic reorientation of the system which already was gaining momentum within the academic system towards the end of the 1980s. In the Dutch case the overall development has been much more stable and the need for large corrections has thus been more modest. But also in this case we observe how a series of smaller calibrations over time have secured long-term stable balances in the system as a whole. Finally, also the Swedish case shows how, in particular, funding imbalances can create long-term effects by diminishing flexibility and protected space. It furthermore shows how lack of long-term stability in the orientation of the system may have negative effects at both the individual and the institutional level.

The case studies underline, that to get a proper understanding of the factors conducive to high system performance we need to move from the single-factor perspective to a broad system-perspective. The crucial question is not whether a given policy factor differs from a similar policy factor in a comparable system, but rather how well it is calibrated to other important elements within the system in order to secure the vital balances in the national science systems as a whole. Both the Danish and the Dutch cases illustrate that multiple balance points between different policy measures may lead to sustained high national academic performance.

4.2. Current balances and future challenges

As highlighted in the country analyses in chapter 3, causes for concern are voiced today in all three countries related to the current balances of the systems. The interviews as well as the rest of the empirical material indicate that the science systems of the three countries are starting to suffer from a number of growing imbalances, and that these imbalances may have long-term negative effects on the aggregated research performance of the systems if they are not corrected. In the following we will briefly outline the concerns related to the Swedish and the Dutch systems, before the current Danish imbalances are addressed in a little more detail.

The current challenges of the three national systems are not identical, although there are clear overlaps. Also here we observe very context-specific problems related to the overall national policy mix. In the Swedish case it is highlighted that a weakly developed tradition of academic leadership in turn leads to a weaker academic research culture and a less developed internal quality control system. A problem of blurred university missions where the academic orientation is outweighed by prioritizations of societal utility and mass-education is also identified as a problem. These challenges appear to be amplified by a funding- and career system which favors short-term horizons and 'safe' research.

In the Netherlands the major concerns are related to a perceived over-emphasis on output indicators which may lead to unintended behavior at both individual and institutional levels. In addition, there is a concern that the capacity for creating real ground-breaking research in emerging areas has been diminished in the Dutch system. The majority of the most excellent research still comes from traditional well established disciplines. As in Sweden this is linked to an emerging imbalance in the

funding system which not only is related to the balance between institutional funding and project funding, but also to the more general composition of the funding and to the conditions related to the allocation of the research resources. It is questioned whether there is still a right balance between the cost and the benefits of this system and it is discussed whether the balance between funding of strategic or applied research on the one hand and the funding possibilities for more fundamental, ground-breaking research on the other still is appropriate.

Also the Danish system appears to be facing a number of growing imbalances which to some extent resemble the ones found in Sweden and the Netherlands. Some of the potential Danish problems are however amplified as a decade of strong funding growth has been replaced by current cuts in the funding of the universities. There is accordingly a need to consider whether the systemic balances which have worked reasonably well in a period of sustained growth will be appropriate in a situation characterized by contraction. The emerging Danish imbalances are in particular related to the following points:

- **Growing imbalances in the funding system:** As the Danish country analysis showed, a number of major reforms have changed several important systemic balances during the latest decade. The changes have not least affected the funding system. The picture is however rather complex as it not only concerns the balance between institutional funding and project funding, but also the balance between smaller and larger grants as well as the balance between strategic or applied funding on the one hand and funding targeting curiosity-driven research on the other. In spite of the complexity, the changes may all contribute to a potential diminishing of the diversity of the system and to a reduced room to maneuver at local levels. Reduced levels of institutional funding available for actual curiosity-driven research at the 'shop floor' of the institutions and a diminishing number of smaller grants may lead to a decreased breadth and depth of the Danish growth-layer. This tendency may be amplified by two additional factors: 1) A negative spiral of a steadily increasing pressure on the available project funding which in turn reduces the success rates of the applications; 2) The combination of internal and external mechanisms leading to concentration of funding in already established strongholds.

While it is uncertain how the optimal balance between diversity and concentration should be set, it is important to underline that both the Danish and the Dutch systems have performed extremely well across many different fields in periods with very diverse funding landscapes, a rather strong egalitarian culture and a quite limited concentration of resources. This supports the view that even relatively small science systems can perform well across the board – and contradicts the often voiced notion that lack of concentration of funding to existing strongholds leads to an undesirable thinning of the resources detrimental to quality. From an eco-system perspective the argument would be that diverse eco-systems are more resilient, more productive, and more innovative than simpler ecologies in the long run. While strong concentration of research funding within the highest performing environments may lead to good results in the short run, there is a risk that it may have negative long term effects for the diversity, dynamic and renewal of the system.

- **Growing imbalances in the career system:** Another, closely related, potential imbalance concerns the career system and thus the balance between the numbers of available positions at different levels within the Danish science system. Unlike the situation during the 1980s the problem today is not a lack of highly qualified PhD students, rather the opposite. There is still a

risk however, that the problem of the 1980s where the system suffered from lack of renewal due to very few open positions at senior levels at the universities may be repeated. The strong general growth during the latest decade and the high prioritization of PhD education has created a situation with a substantial number of short-term employed young researchers within the system. As the general growth has stopped, a likely scenario is that very few positions will be available at the associate professor and professor level during the coming years. This may in effect close the door for most of the current generation of talented young researchers and once again lead to a situation with lack of renewal and an undesirable age-distribution in the system as a whole. As part of a future discussion of balances it could be considered whether the large amount of resources currently invested in PhD education should be redistributed in order to create a more balanced system offering more opportunities at the next steps of the career ladder within the research system. While the strong prioritization of PhD education may have been an asset of the system in a period of strong overall growth at all levels, it may not be appropriate in a situation characterized by cuts in the overall level of funding.

- **Growing goal-complexity at the institutional level:** Finally, concerns have also been voiced with regard to the internal dynamics at the Danish universities as the result of the large scale mergers and the latest management reforms. It is argued that the Danish system may be in the process of imitating the Swedish situation with (too) many, partly conflicting, demands to the universities, and that this process may affect the research culture and the previous strong academic orientation of the institutions. Furthermore, one may argue that while the societal demands to the universities have become more diverse and complex, the internal and external steering has in many cases become more centralized, hierarchical and standardized which may lead to diminished flexibility and adaptability related to the research activities and consequently may reduce the protected space at the research level.

Is there a need for recalibrations of the Danish system in a new funding situation? As outlined above the current shift in the Danish system, from a decade of strong resource growth to the recent cuts in the overall funding, may challenge a number of central balances of the system. While the policy mix of the past obviously would not fit the more internationalized and more competitive, global research system of today, there is still a need to carefully consider whether the current balances are optimal in the present situation. The study may thus spark a number of research policy discussions on whether current adjustments are needed to secure sustainable, coherent and well-functioning national science systems in the decades to come. This calls for informed policy considerations of the future calibration of the central systemic balances and underlines the importance and the timeliness of the agenda that DFiR has set with this study.

Appendix A: Main conclusions concerning DFIR's six hypotheses

Although few cross-cutting conclusions could be drawn from the comparative analysis with regard to the relationship between individual hypotheses and developments in performance, the analyses clearly showed that the associated factors play central roles in the calibration of high performing research systems. In the following we outline the analyses carried out in the background report and briefly present our main findings with regard to each individual hypothesis. In addition to the analyses outlined here, a comprehensive interview material has contributed to the interpretation of the results for each of the hypotheses. Further details on the analyses and the results linked to each individual hypothesis can be found in the background report.

A.1. Balance between institutional funding and project funding

Two main questions have been analyzed in relation to the developments in funding of public research: First, to what extent does the development in the overall level of funds available for the public research institutions play a role for the development in citation impact? Secondly, to what can we detect any links between developments in the balance between institutional funding and project funding on the one hand and developments in publication volume and citation impact on the other? Following up on this a number of additional analyses were carried out based on Danish data alone. These analyses address the same questions but include more contextual material and longer time series and they were also carried out at the level of the main scientific fields.

As indicated in the present report, no generalizable relationships between levels of institutional funding and performance were found in our analysis. This is evident within the selected countries where both Denmark and the Netherlands have performed at a very high level in different periods under very different funding conditions. Danish research was performing well in 1980 in a situation almost fully dominated by institutional funding, but the Danish science system performed at least equally well around 2000 when the share of project funding had stabilized around 40 percent. The same picture can be found for the Netherlands. The Swedish case on the other hand indicates that lack of institutional funding in this particular context has been at least part of the explanation for the development observed. Across all three countries we do however see indications of negative effects of drastic shifts from one stable balance to another. All three countries thus show a decreasing or stagnating performance trend in the 1980s where the increase in project funding was most rapid. Finally, also at a disaggregated level for Denmark we find no clear patterns, when we look for relationships within individual fields as shown in chapter 4 in the background report.

The lack of a clear pattern between the share of institutional funding and performance is also evident across a wider set of countries. Switzerland and the US for instance, are at opposite sides of the continuum with regard to the balance between institutional funding and project funding, but both systems have displayed academic performances at an absolute world class level for more than four decades. These examples show that if the rest of the system is calibrated well, both a very high and a very low level of institutional funding may contribute to high performance. The simple distinction between institutional funding and project funding does not accordingly fully capture the importance of the research funding when we look at this balance in isolation – and such a figure does not tell us much about the performance of a given national science system. It does, however, in many cases work well as a proxy for the balance between the stability, diversity and flexibility of the system on the one hand and the competition and dynamic on the other. But, as outlined in the background report, a scientific system can be very competitive even if the share of project funding is low. Similarly, a scientific system can offer a high degree of protective space and long term stability to (some) individual researchers and research groups even in situations with very high shares of project funding. We thus need to look at both the composition of the project funding (small vs. large grants and applied or strategic vs. curiosity driven grants) and the time horizons of the grants to get a clearer picture of the systemic conditions for conducting high impact research. This fits well with our overall conclusions from the national case studies: the balance between different funding streams is of very high importance, but we need to include more than just a simple distinction between institutional funding and project funding.

A.2. Excellence initiatives

The analysis of the excellence hypothesis in the background report includes an overview of existing schemes in the three countries and a brief discussion of relevant evaluations. In addition a comparison of the ability to produce highly cited/breakthrough articles in the three countries has been carried out. For the Danish case a more detailed examination of D NRF was conducted based on data which enabled us to link the CoE-funding directly to a number of performance measures.

Overall, the analyses underline that D NRF's CoE-scheme has played an important role in the positive Danish development since the mid-1990s, but also that the Dutch system has performed equally well without a comparable scheme. In the Netherlands, individual excellence incentives as well as a long running research assessment system seem to be the most important explanations for the continued high performance of this system as a whole. Also in this case we do accordingly find more than one way to high performance at the system level. Finally, with regard to Sweden: Academically oriented CoE-schemes have been introduced in the Swedish system since 2005 and this development correlates with a quite steep increase in impact in the same years. However, the Swedish development in performance is not different from the developments in Denmark and the Netherlands in the same years and it cannot (based on the available data) be concluded whether the CoE-schemes have made a measurable difference. The available Swedish evaluations do however indicate that the schemes have had limited effects so far.

But even in the Danish case D NRF's CoE-scheme does not by any means stand alone in explaining the high performance of the system. As shown in the background report the positive Danish development was well established before the CoEs started to play a role. Even after the CoEs have become an established and integrated part of the Danish system they are only one piece in the larger puzzle of explaining the strong Danish overall performance. Both the Danish and the Dutch cases thus seem to suggest that the most important factor in explaining strong system performance cannot be found in isolated excellence schemes. Rather, it can be found when the overall system is well calibrated and offer good opportunities across a broad spectrum of disciplines and sub-disciplines where both upcoming and established researchers find chances to develop their ideas – and when these mechanisms are underpinned by strong national research cultures. CoE-schemes may be one element in such systems, but they rely on a strong growth layer. A diversified funding landscape with a strong academic orientation and long time-horizons thus appear to offer the best conditions for breakthrough research by securing flexibility and protected space for more than a small part of the system. In the countries studied in this report this has been secured with a fairly large share of institutional funding as well as many small and medium-sized grants and fewer large grants.

A.3. PhD education

With regard to the PhD education hypothesis the background study examined to what extent the Danish case differs from the developments in Sweden and the Netherlands and whether developments in the scope and content of PhD education quantitatively or qualitatively can be linked to the aggregated development in research performance. A broad quantitative overview of the development in the volume of PhD education in the three countries is presented in combination with a more qualitative account of the development in the organization and formal regulatory framework of PhD education in the three countries. In addition, an indicative bibliometric analysis examining the relationship between the growth in the number of PhDs and the growth in the number of 'visible' researchers in WoS has been carried out.

In the Danish case the hypothesis concerning PhD education stands out as one of the most important explanations for the reversal of the negative trend during the early 1990s. The power of the explanation has however more to do with the character of the imbalances in the Danish system during the 1980s and thus with the timing of the initiatives, than with the actual content of the changes. As shown in the analysis and in the background report the Danish system suffered from a very low volume of graduated PhDs and limited renewal in the composition of the staff at the universities throughout the 1980s. The Researcher Academy and the

subsequent PhD reform addressed this imbalance and in turn created a solid foundation for the growth that characterized the Danish system throughout the following decades. Neither the Netherlands nor Sweden were suffering from the same problem during the 1980s as they already had a fairly large PhD-production during the 1980s.

While the PhD education hypothesis thus stands out as an important factor in explaining both the Danish drop in performance and the subsequent reversal of the trend, we find no indications that the Danish PhD education system today should be seen as fundamentally different from the systems in Sweden and the Netherlands. Seen in a comparative perspective the Danish PhD reform of the early 1990s and the following changes throughout the period have shared a great deal of similarities with the PhD reforms carried out in other countries during the same period. PhD education do however lie at the core of the research capacity of all nations, and as such form a central part of the foundation for high academic performance. The volume must however be calibrated carefully as it can displace investments at the expense of other parts of the science system and as it may skew the balance between continuity and renewal in the staff composition.

A.4. University governance

To examine the university governance hypothesis a structured comparison of the developments in both external and internal governance models in Denmark, Sweden and the Netherlands between 1980 and 2015 was carried out as part of the background study. Based on this comparison it cannot be substantiated that differences in university governance play an important role in explaining developments in performance. It is evident that all three countries underwent rather similar changes towards more autonomy, notably in the 1990s, albeit at slightly different moments in time. There certainly are some differences between the three models, whereby Sweden has chosen a slightly different path than the Netherlands and Denmark, with a little less autonomy in terms of strategy, finances and cooperation (until 2008) and notably more autonomy when it comes to human resource management and quality assurance. However, these distinguishing factors alone do not appear to contribute directly to the over- or under- performance of the three countries. As these countries are rather similar in their approach to governance, it would be of interest to further test this hypothesis with models that contain substantially less autonomy.

This interpretation of the hypothesis was also dominant in the interviews conducted in relation to the Danish case. The management reforms were in general not seen as highly important factors in explaining the Danish development. One, more indirect, effect should however be mentioned. The two major governance reforms in Denmark in 1993 and 2003 may not have had a direct effect in improving the conditions for high impact research within the institutions, but they both played an important role in restoring the confidence and trust in the university sector from the political system. This in turn led to increased resources – and in particular in relation to the 1993 reform to more protected space for the academic system as a whole.

A.5. Internationalization

In order to examine the internationalization hypothesis empirically the bibliometric findings presented in Schneider and Aagaard (2015) have been utilized and extended in our background study. The developments in volume and impact of different collaboration types, i.e. publications with respectively no institutional collaboration, national institutional collaboration or international collaboration were examined. In addition, a number of analyses also investigated the relationship between country size, impact and degree of international collaboration, as well as the collaboration networks between high-performing countries and the potential impact benefits coming out of this. Finally, mobility was examined through desk research with a main emphasis on mobility rates and potential associations between higher-impact levels and mobility rates.

Overall, it can be concluded that internationalization plays an important role in explaining academic performance. It is, however, only weakly and often indirectly linked to specific policy initiatives. If we look at a wider set of comparable countries we find almost identical patterns in the developments of the share of internationally co-authored publications over time. This underlines the fact that increased internationalization mainly is driven by forces internal to the scientific system and most likely also to the increased importance of EU-funding etc.

If we look at the three countries included in the present study we thus find more or less the same patterns. Although a few minor differences can be observed they are unlikely to hold major explanatory power. Denmark's high performance cannot be explained as a result of a higher degree of internationalization than Sweden. Rather as shown in chapter 8 in the background report, the Danish drop in performance during the 1980s was mainly the result of a decreasing impact of the national publications. It is important to notice that in 1980s and 1990s the proportion of internationally co-authored papers only constituted between 20 and 50 percent of the total Danish output. The decline in Danish impact in 1980s was thus mainly attributable to substantial drops in the impact levels of the nationally authored papers at a time when they constituted 70-80 percent of the total output. The subsequent increase in the Danish impact during the 1990s was also mainly attributable to an improvement of the nationally authored papers. Although this happened in a period when their relative shares were decreasing. At the same time, the relative share of internationally co-authored papers was increasing, and this obviously had a stabilizing effect on the total impact level for Denmark.

A.6. Cross sectoral collaboration

Finally, the sixth hypothesis deals with the impact of public-private research collaboration. In order to examine this hypothesis empirically, we have carried out a number of bibliometric analyses utilizing the special coding of publications linked to "industry" in the CWTS' version of the WoS database. We have examined developments in volume and impact for Danish, Swedish and Dutch publications coded as "university-industry collaboration" (UIC); and we have mapped Danish UIC-clusters for three time periods. This hypothesis has however not been integrated explicitly in the overall analysis of this main report as it has a distinctively different character than the other hypotheses, but it has been examined and documented in the background report.

The main conclusions of these analyses are summarized in the following: The hypothesis states that a strong Danish tradition for public-private research collaboration has been a contributing factor in explaining the general high national impact. Based on our bibliometric analyses, we find limited support for this claim when we look at the three selected countries only. It may however be of importance if we look at a wider set of countries. The overall developments in volume for the three countries included here are very similar, and while the share of public-private collaboration is highest for Denmark in periods, it is never more than 1 to 2 percentage points above the corresponding figures for Sweden or the Netherlands. But more importantly, the overall developments in citation impact for public-private collaboration papers between the three countries are even more similar, disregarding annual fluctuations. There is thus no indication that Danish public-private collaboration papers have played a major role in the continuous impact increase from the early 1990s onwards. While removing these papers from the total Danish publication set does reduce the overall impact level somewhat on the second decimal, it does not influence the general development. Similar observations are found for the Netherlands and Sweden. Furthermore, interpretations of these relationships should be carried out with utmost caution as we know very little about the assumed 'collaborative' activities implied by the co-authorships counted between public research institutions and private profit organizations.

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