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Christensen, Jesper Lindgaard; Knudsen, Mette Præst

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Chapter 2.

The Performance, Challenges, and related Policies of the Danish Research and Innovation System.

Jesper Lindgaard Christensen

Dept. of Business and Management,

Aalborg University, Denmark

jlc@business.aau.dk

ORCID 0000-0002-8779-5170

Mette Præst Knudsen

Center for Integrated Innovation Management

Dept. of Marketing & Management

University of Southern Denmark

Mpk@sam.sdu.dk

ORCID: 0000-0002-2055-5308

ABSTRACT

We investigate the performance of the Danish research and innovation system, while linking with related policies. In an international comparison, Denmark fares extremely well regarding the research performance. Likewise, Denmark is positioned as an innovative leader in Europe, and has been for several years. Even if the overall innovation performance appears superior by European standards, the numbers for firm innovation performance call for attention as negative development trends are observed. Based on the diagnosis of the system, we identify a challenge and four steppingstones for continued Danish innovation performance. These support our discussion of the effectiveness of the research system in transforming research to innovation output, and how future policies should become more systemic to further Danish innovation.

1. Introduction

Danish research and generally the innovation system has for years performed tremendously well by any of the standard indicators and the research performance is in the European top (European Commission, 2020). Likewise, Denmark has persistently, since the early 2000's when systematic comparative measurements begun, been in the top at the EU Innovation Scoreboard (European Commission, 2001). Despite this position as an innovative leader in Europe, some warning signs are noticeable. The main (relative) weakness lies in the problems in transferring and transforming R&D-based knowledge to commercial use, particularly in the main segment of companies, the SMEs. Thus, even when aggregate system indicators remain high in international comparisons, some disaggregated areas and development trends point to potential challenges for the system.

This is the focal story in this chapter, which we unfold through a presentation of the innovation system and identify these challenges. An international evaluation panel recently (March 2019 – October 2019) looked into the Danish research and innovation system (European Commission, 2019). The Panel pointed to several challenges for the system and came up with a number of recommendations. Specifically, the panel recognizes the strong research system and sectoral strongholds (e.g. life sciences and energy), but also point to weaknesses and challenges in (among others) a limited number of large, R&D-intensive firms, and a decreasing number of R&D-performing firms. Moreover, the links between large and small firms in innovation activities remain limited. Their primary concern is that Denmark is not making the most out of its superior research system in terms of business innovation (European Commission, 2019). The latter complies with our main focus area in this chapter.

The conclusions from the panel are particularly interesting in the context of the present book. The panel points to specific adjustments that can be made to fine-tune the individual institutions in the system and the links between these to promote innovation. This is in accordance with innovation system thinking where core focal points are links between actors in the system. However, the overall conclusion of the panel is that Denmark has hitherto been relatively vague in specifying where the innovation should go. There has been attempts to provide innovation action plans (2012 and 2017), but not really a holistic strategy that would also explicate value propositions that would form the basis for directionality and prioritization.

Much in accordance with the points made by the evaluation panel, we particularly envisage a main challenge that are likely to hamper the future performance of the innovation system, and we discuss at the end of the chapter innovation policies that are more geared towards providing direction than the innovation policies pursued thus far. Hence, we give special attention to the research system and how it links with innovation, while recognising that innovation is dependent upon a much wider range of factors.

We consider the Danish case to be both interesting and relevant for other countries for at least two reasons. First, the high rankings on leading indicators of especially research but also several

innovation indicators have attracted international interest, and in this way, the Danish research system could be considered a role model for other countries. Second, in the 1990s, a discussion evolved around what was termed the 'Swedish paradox', i.e., that Sweden led world rankings of R&D-intensity but showed mediocre performance on innovation. This paradox was, though, soon broadened to a small country paradox and further to a European paradox as other countries showed similar patterns (Dosi, Llerena, & Labini, 2006). Thus, the observations in Denmark are paralleled in other countries and the possible solutions transferable under the right circumstances. Whereas there are numerous studies of research and innovation in Denmark (see a detailed account of these studies in chapter 1 of this book), there are fewer studies on the link between research and innovation, hence system performance and the associated implications for policy learning. This chapter contributes to filling this gap, as well as providing an overview of current policies and selected, relevant innovation system features.

We pursue the analysis in the following steps. We first provide a short note on the fundamental issue of relating innovation input and output indicators and interpret this as system performance, the core problem area in this chapter. In section 3, we list some of the key indicators for R&D and innovation in Denmark compared to Europe in order to provide an overall picture of the performance and problems for the Danish innovation system. Section 4 elaborates on the overall challenge of transforming research to innovation and what has been the most recent policies pertaining to the challenge and improvement of innovation performance. In section 5, we briefly pose hypotheses as to why there might be problems in transferring research to innovation. Before concluding, section 6 points to four steppingstones that contribute to explaining why Denmark is still faring well in innovation despite the challenges described in this chapter. Section 7 rounds up the chapter by summarizing and discussing the research and innovation system and policies in relation to broader societal objectives. Moreover, we point to the observation that innovation policies are now extensively discussed in relation to societal objectives and increased directionality of policies.

2. From research to innovation and R&D performance to innovation performance

Theoretically, the link between research and innovation was a central issue early in the upsurge of innovation studies (Mansfield, 1984; Pakes & Griliches, 1984), and different 'generations' of models for understanding this input to the innovation process were developed during the 1950s and the following decades. These models include linear models, coupling models, networked models, systemic models (see chapter 1 in this book for an elaboration of these models). A large share of public funding for research goes to funding research at universities, and a recurrent issue for debate in connection to these funds is the balance between funding fundamental research and applied research, and related, to what extent the research leads to (immediate) applicable, useful knowledge and innovation. Generally, the road from research to innovation has been thoroughly discussed and described whereas the paths from research system performances and how they

transform into innovation system performances remains a key debate and attention in policy. Following this debate, both the efficiency and the time lag between input factors and output is subject to policy initiatives.

At first sight, it seems simple to relate known, established input indicators such as R&D expenditures to output indicators, such as patenting. Indeed, a number of contemporary rankings pursue this endeavour. For example, the Global Innovation Index¹ calculates for 129 countries a so-called innovation efficiency ratio defined as the ratio of the output sub-index score over the input sub-index score (Denmark ranking 7th in 2019, where input score is 5th and output 12th). Similarly, the European Innovation Scoreboard has a composite index ranking European countries according to their innovation performance. However, such measurements have been criticised. One criticism is around the measurement techniques, for example that the European Innovation Scoreboard mixes input and output indicators for their ranking, which in turn often is interpreted as a performance measure (Edquist, Zabala-Iturriagoitia, Barbero, & Zafío, 2018). Another type of criticism is centred around the mere system performance measure. For example, Liu, Lu, and Ho (2014) argue that one should look at specific parts of the outputs in innovation systems and relate these to specific inputs as the true strengths of innovation systems are their abilities to efficiently induce a process to transform certain inputs to outputs. A third nuance to the debate on system input-output relations is that systems exist in several realms be they regions, sectors, technologies, and the efficiencies of innovation systems should be related to these specific realms (Weber & Truffer, 2017). In this sense too aggregated performance measures risk being flawed and will not capture that specific parts of the system entail so-called system resources, that is, important factors that in a balanced process facilitate the smooth operating of the system and the effective transition of input resources to output.²

Although the central story in this chapter also looks at relations between input and output factors for innovation, we do adopt a critical view on the simplistic measurements and include considerations on specific Danish innovation drivers.

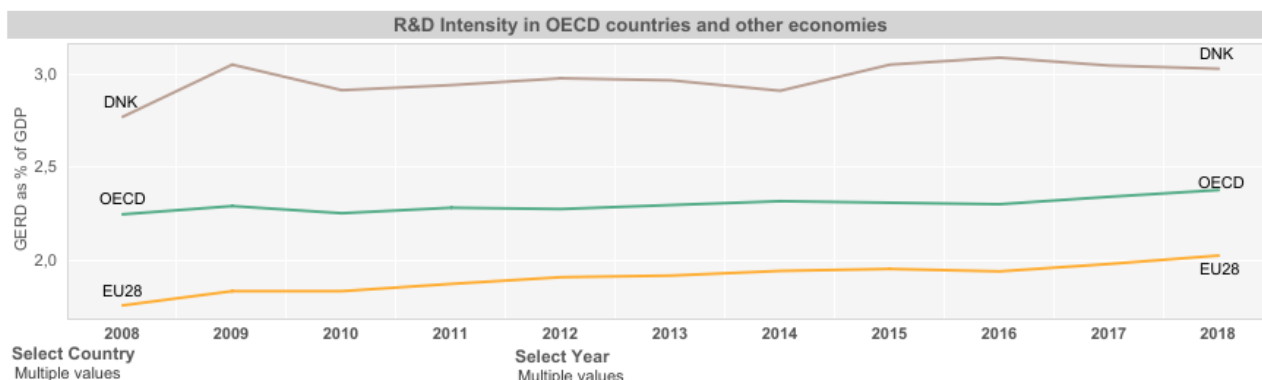
3. Research and innovation performance in Denmark

Research and development (R&D) intensity (expenditure on R&D as a percentage of Gross Domestic Product, GDP) in the OECD area rose from 2.34% in 2017 to 2.38% in 2018, whereas for Denmark we observe a fairly stable R&D intensity above 3% (see figure 1). Danish R&D intensity is therefore relatively high with 3% of GDP exceeding both OECD and EU28. The ratio increased

¹ <https://www.globalinnovationindex.org/gii-2019-report>

² Weber and Truffer (2017) maintain that despite some disagreements in the literature on innovation systems then the majority of studies of innovation systems adhere to the view that six processes are at the core of systems: knowledge generation and diffusion, entrepreneurial experimentation, guidance of search, resource mobilisation, market formation, legitimisation (p.113).

during the financial crisis partly due to decreasing GDP. Public R&D is stable and around 1% of GDP and remains in the EU-top.



Source: OECD estimates based on OECD Main Science and Technology Indicators Database, August 2020.

Figure 1: R&D intensity in Denmark compared to OECD and EU28

Business enterprise R&D expenditure (BERD) as a share of GDP, has in the 2008-2017 period been stable around 1.8%, which is relatively high in international comparison, where the OECD average is around 1.4% and the EU28 average is 1.14% (2017). Denmark is here passed only by countries like Sweden, Switzerland, and Korea, and is substantially above EU average. In terms of number of researchers per thousand labour force talks to the R&D intensity capacity. This figure is for Denmark slightly increasing from 14.5 to 15.2 from 2015 to 2018. This is significantly higher than both the EU28 and OECD averages of 8.06 and 8.1 (2017).

Whereas the aggregate figures indicate a smooth development they hide substantial changes regarding firm and sectoral composition of R&D performers. The higher education sector (HES) is the main beneficiary of public R&D funds. The external share of funding of university research from non-profit private foundations and organizations is the highest in the OECD, and the overall external funding (including also funding from business and international sources) was in 2015 the second highest in the OECD countries (OECD, 2017a; Styrelsen for Forskning og Innovation, 2018). Public funding of R&I is also provided through international programs. The Danish share of total EU funding from the EU framework programs is high relatively to the size of the population, as Denmark is successful in obtaining 122 Euro/inhabitant only exceeded by The Netherlands (Styrelsen for Forskning og Innovation, 2018). Furthermore, a review of the Danish Doctoral Education from 2017 (Styrelsen for Forskning og Innovation, 2017c) found that the Danish system is well functioning, and Danish doctorate theses are of high international standard. In 2016, 399 PhD titles per million inhabitants was awarded (4th in the OECD) and in total 2279 PhDs were awarded in 2016 (OECD, 2020).

A further indicator of R&D performance is obtainment of patents, where Denmark's proportion of applications for World patents normalized by billion GDP was 6.24 in 2015, well above the EU average of 3.53. The patent applications per million population is also high and increasing from

562 to 626 from 2007 to 2017 (WIPO, 2018). This puts Denmark at 7th place in the OECD on top performers. Much of the patent performance originates from energy-related technologies like wind energy where Denmark is highly specialized (WIPO, 2018).

Moreover, scientific publications indicate R&D performance. The number of international scientific co-publications per million population Denmark has obtained an overall increase from 1166.12 (2009) to 2228.92 (2016). According to Styrelsen for Forskning og Innovation (2018) both the volume and citations of Danish publications are in the OECD top-5 in 2012-2016 and has the highest share of publications co-authored between HES and business; a similar top ranking applies to international co-authorship, almost 60% of Danish publications are co-authored internationally. The 2012-2016 period rendered 19755 scientific publications per million Danish inhabitants (3rd in the OECD) and Denmark is in the OECD top regarding the share among 10% most cited publications (19.8 in Denmark).

As the above presentation of the Danish research system demonstrates, Denmark has a top-performing system that strongly engages and succeeds in research output. To engage with the link to the innovation performance, we present in an equal manner, key indicators from the Danish innovation system.

Innovation performance is high and has been so for the past 10 years, as evidenced by the European Innovation Scoreboard (EIS) that has rated the country an innovation leader with consistent and significant performance. Overall, the latest EIS shows that in 2019 the composite indicator is 146 compared to the EU average of 134 (European Commission, 2020). This composite index has been fairly stable since 2012 (ranging from 143 to 147).

Underlying the stability of the composite index, we see some disturbing developments. First of all, since 2013, Denmark's overall score on the EIS has declined by 3 percentage points, in a period when comparable European countries have improved. Supportive of the analysis on the research systems above, Denmark has fared well on input measures like the research system (knowledge creation) and the innovation-friendly environment (establishing supportive framework conditions). For instance, between 2013 and 2019, Denmark improved on attractiveness of research systems, and firm investment. Disconcerting is however the drop across all indicators for *innovators*. Denmark dropped on all three indicators in the period from 2012 to 2019. A decline is also reported in the share of innovating SME's collaborating with others (-31). Further performance drops are reported also on impacts on sales and employment. Again, noticeable is the drop in sales of new-to-market and new-to-firm innovations (-84, which is the largest drop by all EU countries).

Hence, the innovation indicators concerned with the innovation performance of SMEs stand out as significant. Here, Denmark is much closer to the EU average, compared to most other indicators. For example, 33% of Danish SMEs introduced product or process innovation and only 23% were innovating in-house. This is below the shares of other innovation leaders and is a cause for

concern. Observing these declines calls for a more coherent analysis, where the answers expectedly require a research programme alone to solve. In section 5, we nevertheless propose some plausible hypotheses regarding such explanations.

4. The main R&I Challenge: Ensure Effective Use of High-Quality Public Research and Business R&D for innovation

Section 3 above presented an overarching challenge for the Danish innovation system, which is concerned with the links between research and innovation. In the vocabulary of the international evaluation panel, research and innovation stand out as ‘silos’ in Denmark, and need to be integrated to a higher extent in order to leverage on the excellent Danish research system (European Commission, 2019).

The Danish Government launched a comprehensive and novel Strategy for Research and Innovation on 6th of December 2017 (Regeringen, 2017). One of the two main objectives of the R&I strategy was to increase the *Quality* of Danish research further from its current high level, which was an attempt at focusing the efforts even further to keep up with international research standards. The second objective was that research must benefit society (The *Relevance* goal). These goals were supported by 28 initiatives. For the Research Quality goal, the specific initiatives include creation of individual career paths, recruitment, and incentives for talented researchers as well as a new performance-based funding model for the universities, new research system infrastructures, and stimulating international research collaboration. The Relevance goal was supported by activities related to strategic funds and capacity for technological research, focus on digitalization as well as value creation in firms from research and focus on the connectivity and coordination between public and private funding of research. Moreover, technology transfer from higher education for societal use will be stimulated, and both higher education quality and more STEM graduates are policy objectives. Hence, the R&I strategy, included initiatives to strengthen research in technology and technology transfers from universities to business.

Following the approval in Parliament of the Law on simplification and re-organization of the business support system (see chapter 4 in this book for further details), the Innovation Fund Denmark (IFD) introduced three new programs starting from January 1st 2019 that target commercialization of research by providing incentives for researchers to engage in innovation and entrepreneurship: InnoFounder, InnoExplorer, and Industrial Fellow. The InnoBooster program (established in 2014) aims to support the innovative capabilities of SME’s. In addition to the IFD, support is provided by the Danish Growth Fund for on-going business development in sectors of high societal importance and generally for innovation. The funding of such investments through the Danish Growth Fund is stimulated by an increased financial volume and new funding instruments.

According to the Law on re-organizing the business support system The Danish Growth fund should in the future have even more focus on early stage/seed funding of entrepreneurs and have clearer borderlines to the Innovation Fund. This has spurred The Growth Fund to introduce four new initiatives that address this ambition: a matching-facility for business angel investments; early engagement loans; increased co-investments with early stage investors; adjustments of existing growth loans to target earlier stages³. The strategy of the Danish Growth Fund is to co-invest with private actors. Currently funding for innovative start-ups is also provided through the Innovation Fund (grants) and Innovation incubators.

Denmark has four Innovation Incubators, which offer a combination of traditional incubator services and early stage gap-funding for start-ups some of which stem from university spin-outs or university knowledge. The Innovation Incubators invest €10.000 (DKK 74.400) in pre-seed funding for proof of business and a subsequent seed capital accompanied by counselling for entrepreneurs. The funding of approximately €25m (DKK 185m) annually is provided by DASTI, but with the re-organization of the business support system these organizations are phased-out over a 3-year period from January 1st 2020 that allows the current 300 portfolio companies to still be guided by the Innovation Incubators.

To further incentivize private firms to carry out R&D, the Government increased the tax credit for R&D-expenditures progressively from 100% to 110% in 2026. Moreover, the Researchers Tax benefit scheme, where specialists from abroad can work for a period in Denmark and enjoy a tax benefit, was extended from 5 to 7 years. It also improved coordination between the different funding instruments, between universities, and simplified the administration of R&D programs. The concentration of business R&D (see section 5) is recognized in Styrelsen for Forskning og Innovation as a potential problem, which calls for research to understand the impact of it. Styrelsen for Forskning og Innovation has therefore initiated research to understand reasons for and implications of this phenomenon (Styrelsen for forskning og innovation & DASTI, 2019).

The R&I strategy has been followed by separate strategies for Digitalization and Growth in Life Sciences. Moreover, Denmark is a member of the European Spallation Source (ESS), which is part of a European investment in research facilities oriented towards research in new materials. Denmark is committed to invest DKK 2b (€ 269m) from 2014-2022 on this initiative.

As the description above also highlighted a particular challenge is related to the linkages for innovation as these are important gateways to access and transfer knowledge, but clearly also connected with the overall challenge of the “unconnected silos” as the main driver in the research system is the university whereas the main driver in the innovation domain are businesses.

Compared to the EU average, the European Innovation Scoreboard 2020 (European Commission, 2020) indicates that Denmark has experienced a significant decline in the indicator on linkages

³ www.vf.dk

from 164.1 in 2010 (EU index 100 in 2010) to 149.7 (2019), while the index for the EU has only changed slightly in the period from 95.3 to 99. An important share of the drop can be attributed to *Innovative SMEs collaborating with others* (from 215.5 to 120.7). A second observation is that TTOs at universities experienced in 2016-2017 small decreases in patenting, license agreements, partnership or funding agreements with businesses, and spin-outs. However, in a longer-term perspective, the tech-transfer from HES to business is relatively stable and seems to have reached a consolidated level of output and a significantly increased experience base. These indicators speak to the overall connectivity of key actors in the innovation system, which has been a policy focus for many years, but improvements continue to be needed.

Public funds contribute around €300m for innovation infrastructures primarily the 17 innovation networks, the 7 Approved Technology Group (ATG) institutes (consultancy companies, who are certified for receiving a grant and contract for specific work (and a small share of operating costs) demanded by government). Further initiatives include 4 innovation incubators, and the schemes of the Innovation Fund Denmark (IFD), including the InnoBooster, Industrial PhD, Grand Solutions, and Eurostars schemes. In 2018, the funding of the networks expired, and a new 2-year funding worth 190 mDKK (2019) was granted to the networks (2019-2020).

A strengthening of parts of the Research and Technology Organisations (RTO) system (including the "GTS – Advanced Technology Group Institutes") has also previously been prioritized. A view to include private actors in the development of the ATG institutes and consolidation of the number of publicly supported business clusters are among the policies. In Denmark, business support is provided at both national, regional, and municipality levels. Mainly, institutions at the regional level will in the new organization of the system be severely reduced at the expense of strengthened efforts at especially the national level. At the same time as simplifying the system, the re-organization of the business support system can challenge possibilities to maintain and strengthen the interactions between actors and knowledge flows in the system, something that has been emphasized as highly important⁴. An elaboration and further assessment of this policy reform can be found in chapter 4 in this book.

5. A set of explanations for the inefficiency of links between research and innovation

The main challenge pointed to the partially inefficient links between research results and innovation. But what are possible explanations for this missing link? Are policies inadequate or missing the target, are there structural and/or behavioural explanations? Answering these questions begs a large research program, therefore we only provide some selected explanations

⁴ In particular, The Danish Council for Research and Innovation Policy (Danmarks Forsknings- og Innovationspolitiske Råd, 2016) points to inadequate links between key actors and a fragmented innovation infrastructure. The Council recommends a more holistic, systemic approach to innovation policy.

and urge for more research into these specific problems, which are not only observed in the Danish innovation system.

The first of these possible explanations relates to the fact that Danish R&D is highly concentrated and increasingly so. Looking at specific industries, Pharmaceuticals and Biotechnology are by far the largest R&D performing sectors in Denmark, and Denmark is on a global scale (relative to size), the leading investor in this industry. On a firm-level, among the R&D performing firms in Denmark, the global producer of insulin, Novo Nordisk is dwarfing the rest of the firms in terms of the R&D volume. In fact, it invests more R&D than the rest of the top-ten firms combined, is no. 22 in Europe among all R&D performers, and no. 80 globally⁵.

Moreover, the general trend over the past decade is that R&D is increasingly concentrated in fewer, large firms, as evidenced by the following. The number of firms investing in R&D decreased between 2009 and 2015 by 25%, and a small group of 64 firms increased their share of overall BERD from 35% to 56% in that period (Styrelsen for Forskning og Innovation, 2017b). The top-20 firms increased their share from 2008-2016 to 54.7% of total BERD (Styrelsen for Forskning og Innovation, 2018). 190 firms in Denmark are large R&D-performing firms (more than 250 employees) and they make up 8% of the population of R&D-performing firms but perform 72% of total BERD. Moreover, the R&D-intensity of large firms is much higher than in SMEs and increased in the period by 50% whereas it remained more or less constant in other firms (Styrelsen for Forskning og Innovation, 2018).

In itself, a high concentration of R&D is not necessarily a problem for the innovation system, if knowledge dissemination and widespread use of R&D is well established. However, the concentration, potentially challenges a wider use and application of both public and privately performed R&D, because effective dissemination and use of R&D often require both a strong system for dissemination of knowledge and absorptive capacity among firms to absorb and utilize knowledge from other sources for commercial purposes (Cohen & Levinthal, 1990). With only a small share of firms doing substantial intramural R&D, the absorptive capacity at the system level is likely to be smaller compared to a situation with more equal distribution.

A second, related explanation would question if the demand and capacity for using R&D is present in the SMEs. The Danish Council on Research- and Innovation Policy (Danmarks Forsknings- og Innovationspolitiske Råd (Danish Council on Research and Innovation Policy), 2019) introduced the concept of 'Innovation ready' firms to characterise firms that have the necessary preconditions and capacity for utilising R&D-based knowledge. These firms demonstrate higher growth than other, comparable firms, and they are more likely to get more out of business promotion efforts. Therefore, a recommendation following the analyses was that business promotion should be

⁵ <https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard>

targeting these firms and should be aimed at increasing other firms' capacity to become 'innovation ready'.

Third, the policy changes we've described such as closing of the innovation incubators and several other related programs; having fewer, more centralised cluster organisations; eliminating the regional tier in business promotion, indicates that over time, policies have been less focused on maintaining links in the innovation system. The diminishing systemic approach in policies encouraged the Danish Council on Research- and Innovation Policy (Danmarks Forsknings- og Innovationspolitiske Råd (Danish Council on Research and Innovation Policy), 2016) to call for more systemic innovation policies. Likewise, the international evaluation panel points to bridging the silos in Danish innovation policies and to work towards a more holistic policy that targets the system's functioning (European Commission, 2019). They claim in particular that research and innovation are more independent than in several other countries, and that increased performance may be obtained by seeking to integrate elements in a systems perspective. Chapter 4 in this book is supportive of these arguments as it demonstrates a move towards fewer actors in the business promotion system and more distant links between these actors, and between the actors and their 'client' firms.

6. Steppingstones towards maintaining high innovation performance

Even as we point to weaknesses in the link between research and innovation, Denmark has kept its high rank in the European Innovation Scoreboard and similar rankings. Turning to some of these strongholds in the following may stimulate other countries in their policy development. These do not only provide some explanation as to the previous high performance but can also potentially be future innovation drivers. We therefore label these steppingstones.

Innovation steppingstone 1: Public sector innovation

Christensen and Fagerberg demonstrate (cf. chapter 1 in this book) that the definition and measurement of innovation has developed over time from a narrow focus on technological product and process innovations to encompass organizational innovation and marketing innovation. Simultaneously, studies of the carriers of innovation processes has widened beyond the private sector firms by pointing to the role of innovation in the public sector and the civic society. Particularly, these are important to the total innovation system (see also chapter 7 of this book). The Danish innovation system has through deliberate policies on public sector innovation been upgraded.

The specific Danish policy approach to public sector innovation has forged a close link between digital access and use of information and technology. The stated objectives are to promote good

governance, strengthen democracy, and use digital technology to improve society⁶. Historically, Denmark has applied a shared digitalization strategy across the public sector. From its beginning in 2001, where citizens could send emails to public offices, until 2020 where the fifth shared digitalization strategy is now at its conclusion, a range of initiatives has supported the public sector in being efficient and increasingly digitalized. The strategies envisage that the use of new technology and media facilitates citizens and businesses in accessing public information and technology, which in turn should increase collaboration between the public sector and civil society, hence contributing to the public sector innovation culture.

An example of a Danish policy initiative is when Denmark for the first time appointed a Minister for Public Sector Innovation and Modernisation with the objective to improve public sector innovation, digitalization, and governance (2016). In addition to innovating how the public sector operates, Denmark also used public procurement extensively to spur innovation. Denmark's strategy on intelligent procurement entails several initiatives aimed at stimulating innovation, such as the scheme Innovative public-sector purchases⁷, which aims to make it easier for public-sector institutions to obtain innovative new solutions (Gallup, 2010). The report shows that Denmark performs well on using public procurement to stimulate innovation as Denmark is rated the best in the EU.

Another part of public sector innovation is how it interacts and supports the private sector, including businesses. It is often debated whether administrative burdens and regulations are hindering small business development, which is why this is also subject to internationally harmonised measurement and ranking (e.g. as in the EU SBA Fact Sheet). Regarding the interaction between SMEs and public administration, Denmark performs generally better than EU average on nearly all parameters. This good performance is reflected in the World Bank Global Indicators of Regulatory Governance⁸ where Denmark scores the maximum of points on their measurements.

Together, the various efforts to increase public sector innovation has meant that the public sector is not only well-functioning, it is also constantly changing in response to demand. In turn, this is a stronghold in the innovation system, and potentially also a steppingstone for new innovative efforts, as it constitutes a part of the framework conditions for private sector innovation. In this way, the public sector innovation may be part of re-establishing strong links through e.g. public-private innovation partnerships.

⁶ www.digst.dk

⁷ http://markedsmodningsfonden.dk/innovative_purchases

⁸ <https://rulemaking.worldbank.org/>

Innovation steppingstone 2: National innovation strategy

The Danish Government launched a comprehensive second strategy for research and innovation in 2017 (Regeringen, 2017). This strategy was preceded by the first national innovation strategy, “Denmark – a nation of solutions” in 2012. The first strategy was seen as facilitating a paradigm shift in innovation policies. The three main focus areas of this strategy were:

1. *Innovation driven by societal challenges*
Demand for solutions to concrete societal challenges must be given higher priority in the public sector innovation effort.
2. *More knowledge translated to value*
Focus on more effective innovation schemes and better mutual knowledge transfer between companies and knowledge institutions.
3. *Education as a means to increase innovation capacity*
A change of culture in the education system with more focus on innovation and value creation.

The second strategy had two main goals:

1. Danish research must be at the highest international quality (*The "Nobel" goal*).
2. Research must benefit society (*The Relevance goal*).

These goals were supported by 28 initiatives. It is part of the Nobel goal to set up a ‘Nobel pact’ with the objective to reach the highest level of research quality and rewarding excellence. For the Nobel goal, the specific initiatives include creation of individual career paths, recruitment, and incentives for talented researchers as well as a new performance-based funding model for the universities, new research system infrastructures, and stimulating international research collaboration. The Relevance goal is supported by activities related to strategic funds and capacity for technological research, focus on digitalisation as well as value creation in firms from research and focus on the connectivity and coordination between public and private funding of research. Moreover, technology transfer from higher education for societal use is stimulated, and both higher education quality and more graduates from STEM educations are policy objectives.

The strategy is based on high public R&D investments for support. Nevertheless, public R&D investments dropped slightly below 1% in 2016 because of budget cuts and stayed below the 1% target in 2017 (OECD, 2020). The Government has confirmed its commitment to keeping public R&D investments at 1% of GDP.

The national innovation strategy formulated in 2012 was the first national strategy to be formulated in a comprehensive manner to grasp the multidimensionality of innovation. However, even if strategies, and the broad involvement of businesses and other stakeholders in the creation of innovation strategies, is a steppingstone for further collaboration, the need for more directionality in the policies and a systemic perspective on innovation policy remain clear as is the need to address the connectivity of the system and of the individual initiatives. Hence, despite

these early attempts at framing innovation policy in an overarching strategy framework, the Peer Review of the Danish R&I System in 2019 forcefully argued for and recommended:

The second set of recommendations addresses the opportunity to further elevate Denmark's innovation performance by outlining an overarching innovation strategy. Despite many individual strategies and action plans, Denmark currently lacks such a strategy, which is limiting the country's ability to create positive, system-wide effects from the alignment of individual innovation policy actions (European Commission, 2019: 2).

It is therefore positive to notice the policy intentions, but the realization and the path towards a comprehensive and systemic innovation policy driven by an overarching strategy framework remains to be realized. The COVID-19 pandemic is further challenging such a development as the short-term drop in GDP may influence the absolute public investment levels in R&D following the pandemic. At the time of writing, it does seem that R&D investments will be maintained as the Government intends to allocate substantial public research grants to research in green transitions.

Innovation steppingstone 3: The Quality and Availability of Human Resources

It has been a standing phrase in the debate on Danish industrial competitiveness that Denmark has few natural resources therefore is heavily dependent upon the human resources of the work force. Education, training and life-long learning has consequently been prioritised and an adequate supply of skilled and highly skilled labour is a prerequisite for raising Danish innovation performance. Recently lack of highly qualified labour has spurred labour market reforms to increase the supply, and labour import have alleviated problems with shortages of skilled labour. However, there are limits to how much labour supply responds to further labour market reforms, and demand for labour from neighbour countries (especially Poland) is not fulfilled because demand for surplus labour is now at least as high within the countries that usually contribute with immigrant workers as in Denmark.

Regarding highly skilled labour Denmark has strengthened the Industrial PhD and Post-Doc programmes and pushed students to complete studies in time. The development of innovation-related and entrepreneurial skills has been enhanced in courses and programmes throughout the education system. STEM related studies have been upgraded as all projections (e.g. Økonomi- og Indenrigsministeriet, 2018) show that there will be a shortage of skilled labour including people with STEM skills and skilled craftsmen, and that general problems of shortages of labour in all areas are increasingly observed. The shortage of skilled labour is primarily felt in the peripheral regions. For increasing innovation it is not only a matter of deep technical skills like STEM, but also the future requirements of the skills profile of workers, which require more 'soft' competences like collaborative capabilities to function in increasingly networked environments (European Commission, 2016; OECD, 2017b; Vækstforum Nordjylland, 2016). The chapters in section 3 of this

⁹ For a more general discussion of the contribution of skilled labour and professional training to the performance of the Danish innovation system see Section 3 of this book.

book focuses on this problem area and provide detailed information on the future, needed skills profiles in light of increased digitalization, AI, robots/cobots, and automation.

In an innovation system perspective, the links between actors and alignment between research and innovation programmes, as discussed above (and by the Evaluation Panel) requires competences among actors in the system to actually provide bridges between silos. This was also recognised by the evaluation panel, and points to a need for learning and competence development not only in businesses, also in the policy system.

Innovation steppingstone 4: Innovation for Sustainability and the Environmental Challenge

Denmark has for decades been strong in technological development and industrial use and sales of 'green' products and services. Much of this stronghold has been driven by policies and regulation, and this is still the case. As part of the 2014 Climate Act, Denmark established The Danish Council on Climate Change, who provides recommendations on climate initiatives in the transition to a low-carbon society¹⁰.

Their tasks are:

- evaluate the status of Denmark's implementation of national climate objectives and international climate commitments,
- analyze potential means of transitioning to a low-carbon society by 2050 and identify possible measures to achieve greenhouse gas reductions,
- draw up recommendations to help shape climate policy, including a selection of potential mechanisms and transition scenarios,
- to contribute to the public debate.

In this way, The Council on Climate Change provides recommendations to the Danish Parliament on the EU goals for reduction of CO₂. This is partly accomplished through independent analyses presented in policy-oriented reports. The Danish Government has over a longer period focused strongly on developing and utilizing new technology for sustainability and climate change. It is widely agreed that technology constitutes the single-most important solution to accomplish the goals for carbon emission reduction. In 2019, the Danish Parliament took a strong step in signing a new Climate Act focusing on the continued green transformation of the Danish economy. This Act was confirmed in a law in June 2020 and sets a framework for Danish climate policy based on binding intermediate targets every five years towards the target of climate neutrality by 2050. One of these targets is a 70% reduction in carbon dioxin emissions by 2030 (compared to 1990) (see chapter 13 in this book for a discussion on the problems with measurement and evaluations in this area).

¹⁰ <https://klimaraadet.dk/en/frontpage>. Chapter 12 in this book examines the role of skills development in the capacity of Danish firm to undertake green innovation and Chapter 13 focuses on measuring the performance of the Danish innovation system in meeting the environmental challenge.

These targets are ambitious and require strong political focus, but are the same time deeply ingrained in the Danish political DNA through active policies developed and implemented over the last 30 years pursuing a green transformation through support for replacing traditional fuel sources with renewable sources. While ambitious obtaining the goals is also a complex task. Not all sectors can contribute equally, therefore the government established in November 2019 13 sectoral Climate Partnerships (Klimapartnerskaber). These are expected to define their contribution and roads to achieving goals for reduction of emissions and are governed by a Green Business Forum involving a wide range of stakeholders.

As all relevant stakeholders in the national system of innovation agree that technology is the main driver for achieving the goals for green transformation and the climate challenge, the focus by the Government has been a strong investment strategy. This investment strategy is implemented through the European Horizon 2020 program and the Danish Innovation Foundation. This has been stimulated through financing of research towards this agenda. In 2020, the Innovation Foundation has 700 mio. Dkr. dedicated to grand solution projects directly targeting the 70% reduction target. These funds were part of the dedicated funds by the Danish Parliament of 1,542 mio. Dkr. towards the 70% reduction target out of a total reserve of 1,925 mio. Dkr. In this way, 80% of the reserves are directly dedicated to the green transformation. Although political negotiations are still to be finalized the proposal for the 2021 fiscal budget entails 750 mio. Dkr. for research into green transition and carbon-dioxin emission reductions.

With regards to the driver for sustainability and climate change, a strong historical focus on green transformation as seen in the Climate Acts and dedicated funds for research in technologies enabling the green transformation and reduction of carbon emission are the core ingredients (seen from a policy perspective) constituting the steppingstone.

7. Concluding Remarks

The Danish innovation system is performing very well. This is despite the observation that with respect to some innovation output measures the innovation potential of the system is not fully utilized, and that emphasis must increasingly be placed on the main challenges regarding leveraging the high-performing research system for innovation (cf. section 4).

We follow the voices stating that the road from research to innovation is not linear; rather it is long, complex, and highly dependent on the functioning of the innovation system. Some examples include the distribution of the research activities, the links between core actors in the system, and the importance of the 'soft' factors, illustrated for instance with public innovation. Somewhat related, we point out that the variables behind the composite innovation index often used in the European Innovation Scoreboard (EIS) only captures parts of the complexity.

An extensive debate unravels discussing whether the EIS is not only partial, but maybe also flawed (Edquist et al., 2018). Moreover, the link between the EIS position of a country and explicit and instructive normative policy implications is less than trivial. We propose that a broader view of innovation and relevant innovation system actors include public sector innovation, civic society innovation, generally a holistic, societal engagement, and the incorporation of informal institutions governing the functioning of the system. This is argued to be decisive to societal coherence, which in turn is an important prerequisite for innovation.

With these more general remarks on the challenges of measuring and diagnosing the innovation system, we return to the recommendations. Where to take the next generation of Danish innovation policies? Different types of innovation policy have recently been extensively discussed (Kuhlmann & Rip, 2018; Robinson & Mazzucato, 2019) often taking an approach, which is in stark contrast to the traditional market-based rationale in which the state has a very limited role. On the contrary, much of the discussion on 'mission-oriented' and 'challenge-oriented' policies¹¹ is centred around the argument that the state, and other public actors, should provide direction for industrial and technological development through policies. In its extreme consequence, the Corona crisis spurred extensive and strong state interventions and directives to enhance research and innovation as the pandemic unfolded.

In their underlying theoretical understanding of innovation, mission-oriented policies are not fundamentally different from system-oriented policies. Proponents of these policies also adhere to the evolutionary, system-oriented view of innovation. But in the normative dimensions, there are clear differences as the policy advice in the mission-oriented approach is given a more pro-active role and to a larger extent provides new direction rather than merely attempting to fix failures. A key feature of the understanding of innovation and evolution in this approach is the role of experimentation. It is likely, and acceptable, that firms and policies alike fail, in fact it is by experimentation and learning from both successes and failures that policy developments occur. It might sound somewhat contradictory that experimentation and system are key features of this approach. This is not necessarily so, as experiments do in fact benefit from being embedded in a well-functioning system (Lindholm-Dahlstrand, Andersson, & Carlsson, 2019) where knowledge on policy learning diffuse effectively¹².

The idea that policies should be guided by 'Grand challenges' and that the state is able to give directions for the development is also found in Danish policies. For example, the program

¹¹ There are differences between mission- and challenge-oriented policies. For example, there were well-defined paths for technological development associated with the clearly formulated mission to put a man on the moon. Regarding the societal challenges like maintaining welfare during changes in demography, global warming and climate change etc., solutions are not pre-defined and may require several different missions (Boon and Edler, 2018).

¹² A prominent regional policy approach, smart specialization, likewise has this emphasis on experimentation. In the way smart specialisation was originally formulated, the key features was that it is a policy processes involving experimentation, recognising and utilising locally embedded resources and existing strongholds, and involvement of key stakeholders in an entrepreneurial discovery process (Foray et al., 2009).

RESEARCH2025 defines areas where future problem areas are addressed and the strategy from the former government explicitly point to societal challenges as an important guide for policy formulation (Styrelsen for Forskning og Innovation, 2017a). The RESEARCH2025 catalogue provides sectoral priorities in line with the smart specialization priorities and was created in a process involving a variety of stakeholders including businesses, organizations, ministries, and Danish knowledge institutions. Moreover, through Innovation Fund Denmark, the Grand Solutions program is part of RESEARCH2025, and the fund allocates means towards these targets such as climate change and green solutions.

The societal challenges in Denmark include alleviating the climate change crisis as discussed above, but also rising costs of serving an ageing population combined with a demand to maintain quality of the social welfare system, increased regional disparities, and pressures on the labour market. Although policies increasingly are oriented towards meeting 'grand' societal challenges, these challenges are to a varying degree only partially or indirectly linked to the specific R&I challenges. Almost by definition, R&D can have direct effects on societal challenges, for example, 'welfare technologies' are promoted to alleviate the demand for human resources in health and elderly care, 'telecare' technologies are used to allow easy medical treatment in geographical areas without sufficient coverage of medical doctors, and 'energy-efficiency' technologies are being integrated to support smart cities for the reduction of pollution. Thus far, these are however not directly linked and awaits further integration. Hence, a further call for a comprehensive and holistic innovation policy for Denmark.

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