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The Design of Transformative Research and Innovation Policy Instruments for Grand Challenges: The Policy-Nesting Perspective

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Abstract

Several countries have created policy instruments seeking to direct research and innovation (R&I) towards addressing societal challenges. However, the design of such instruments might not always live up to their proclaimed transformative rationale. The aim of this paper is to examine empirically this matter. In a unique cross country comparison of four Grand Challenge-oriented research and innovation programs in the Nordic countries, we ask to what extent the design of new policy instruments for grand challenges are nested according to the rationale of transformative R&I policy. The findings show that, while all have individual transformative elements, they only exhibit weak or medium degrees of nesting. At a time of increasing transformative ambition of research and innovation policies, our findings make an important contribution to understanding and addressing the complexity of designing R&I transformative policy instruments.

Keywords: Innovation policy, Research Policy, Transformative innovation, Grand Challenges, Sustainable Development Goals, Policy instruments.

1. Introduction

The recently emerging policy rationale of "transformative research and innovation policy" (R&I) suggests that research and innovation should address grand challenges and foster the transformation of complex socio-technical systems so that current forms of production and consumption become environmentally, economically, and socially sustainable (Weber and Rohracher 2012) (Sen 2013) (Fagerberg 2018) (Lundin and Schwaag-Serger 2018) (Schot and Steinmueller 2018) (Ghosh et al. 2021). Several countries have introduced new (or re-framed existing) research and innovation policy instruments with transformative ambitions, leading to the rise of what has been called a new generation of policy instruments (Boekholt 2010) (Kuhlmann and Rip 2018) (OECD 2019). These policy instruments are typically programs which fund research and innovation projects carried out by firms, universities and/or other actors performing research and innovation projects that seek to address a range of grand challenges currently associated to environmental, economic and social sustainability challenges.[1]

However, the design of such instruments might not always live up to their proclaimed transformative ambition and policy rationale. While many programs are very ambitious, policy-makers might have understood 'transformative' in a loose manner, designing the instruments without being properly informed by theory. The aim of this paper is to examine empirically this crucial matter about their design.

Recent studies examine specific aspects of policy instruments, for example, how they define and identify 'grand challenges' (Modic and Feldman 2017) (Palmberg and Schwaag-Serger 2017), or how individual projects are managed and implemented (Grillitsch et al. 2019) (Janssen 2019). Others study the transformative nature of entire policy areas, like electronic waste (Akon-Yamga et al. 2021), or smart mobility (Salas Gironés et al. 2019). These studies (see review in next section) offer relevant insights which this analysis builds upon. However, taken collectively, they either tend to "zoom out" (studying very broad policy areas), or to "zoom in" (examining very concrete features of some individual instruments or some individual projects), leaving a number of key questions still unexamined and unresolved. A recent mapping of mission-oriented R&I instruments, reveals important differences among instruments (Larrue 2021); but does not look at their transformative nature in terms of studying the extent to which their design is 'nested' across the three constitutive layers of policy instrument design.

This article addresses this gap. It takes the starting point from the policy-nesting perspective suggested in the literature of policy analysis. This perspective "helps explain some of the real complexity and difficulties involved in successful policy instrument design, while the fact that the choices and decisions made at each layer can usefully be viewed as co-determining each other in a form of embedded or 'nested' relationships helps explain the severely constrained nature of actual policy instrument choices" (Howlett 2018) p.20. The 'nesting' perspective offers insightful analytical clues for studying the overall

[1] This paper studies empirically four funding programs. Hence, following an extended practice in the field of policy analysis, this paper uses the term "program" and "instrument" indistinctively.

design of the instruments in terms of the R&I transformative policy rationale. Hence our research question is to what extent the three layers of the new policy instruments for grand challenges are nested according to the rationale of transformative R&I policy?

Following from that, this paper makes two novel contributions. Firstly, it operationalizes the analysis of the three layers of policy instrument nesting in relation to a series of theoretical elements that constitute the transformative policy rationale (see next section). Secondly, using this new analytical framework, we compare empirically four prominent R&I policy instruments in the Nordic countries, which explicitly fund R&I activities targeting grand challenges and transformation. They are: the "Grand Solutions" program (Denmark), the "Flagship program" (Finland), the "Pilot E" program (Norway), and the "Challenge-driven innovation" program (Sweden). These four programs are ultimate expressions of Nordic countries' traditions of driving socio-technical transformation with the aim of better combining environmental, economic and social sustainability. They lend themselves very well to comparison given the general similarities across the Nordic countries, and across the instruments. We use different data sources, including 35 interviews and 47 documents, coded and analyzed systematically. This in-depth comparison yields several insights that provide relevant inputs to practitioners and that 'speak back' to current academic discussions which have tended to neglect the challenges of designing transformative research and innovation policy instruments in practice.

The next section reviews the literature, and operationalizes the analytical framework to be used in the comparative analysis. Section 3 explains the selection of cases, the data and the methods. Section 4 analyzes the cases under study in a systematic manner; and section 5 compares the cases. The concluding section 6 distills the policy and theoretical implications of the findings. In particular it identifies some crucial policy issues for each of the four programs studied, and a number of contextual issues that are highly relevant for understanding the complexities of designing transformative R&I policy instruments.

2. Literature Review & Analytical Framework

In this paper we use and develop further the 'nesting perspective' of Michael Howlett and his co-authors in the field of policy instrument studies. The core tenet of this perspective is the understanding that policy instruments are nested phenomena (Howlett 2018). In other words, instrument design is anchored in specific political and ideational-historical contexts that define overall policy and governance styles across countries (Howlett and Mukherjee 2018) (Borrás and Edquist 2013). In the field of R&I policy instruments, the nesting perspective has received scant attention so far. A recent single case study of a regional R&I strategy uses this perspective to study "the 'human component' in the translation of politically driven innovation strategies into practice" (Kroll 2019): 644, but did not

examine the transformative features of those R&I policy instruments. Thus, the policy nesting perspective remains an under-utilized perspective in the field of R&I policy.

This article delves into the three layers of nesting suggested by Michael Howlett, namely, the governance, the coordination, and the measure layers (Howlett 2009)[2]. More concretely this paper develops further the nesting perspective in two ways: Firstly, it conceptualizes and positions each of the elements that characterize transformative R&I policy rationale in relation to one of the three constitutive layers of instrument design. Secondly, it operationalizes concretely the notion 'nesting' in order to study empirically the hierarchical alignment of these three layers. Tables 1 and 2 summarize the conceptual core of the analytical framework.

The social science literature has long discussed how to operationalize concepts. Concepts are the link between complex and often open-ended theoretical propositions on the one hand, and the social reality under empirical study on the other. If concepts are too broadly operationalized ('conceptual stretching') they provide poor theoretical guidance in the empirical analysis because 'everything fits under them' (Collier and Mahon 1993) (Sartori 1970). Likewise, if concepts are operationalized very narrowly they might be too restrictive, missing important aspects across cases in comparative studies (Goertz 2006). Our conceptual operationalization aims at striking a balance, avoiding both extremes, by providing clear theoretical guidance. Thus, we provide greater theoretical and analytical clarity, particularly to situations where policy-makers might tend to proclaim all programs to be transformative. Likewise, we point at some idiosyncrasies of the countries and programs under study, in order to avoid too restrictive analytical coding resulting in restricted analysis. We discuss these interpretative issues in the comparative section.

We start by operationalizing the three layers defined by Michael Howlett; and thereafter we operationalize the concept of 'nesting'.

At the highest degree of abstraction, **the governance layer** has to do with how policy instruments are related to the general preferences about forms of governance, that is, preferences about general forms of interaction between government and the society (Borrás 2012). Hence, great variation exists across countries, and R&I policy instruments can ultimately be understood as specific reflections of such overall dynamics. Looking into transformative R&I policy (Cagnin et al. 2012), we identify two concepts which are widely mentioned in the literature as governance-related elements characterizing transformative R&I policy, namely: directionality, and 'experimentation and risk-taking'. **Directionality** is the focus on problem-identification with the intention of contributing actively to the transformation of sociotechnical and innovation systems in a holistic way (Weber and Truffer 2017) (Borrás and Edquist 2019). This belongs to 'governance' given the overall encompassing nature of 'directionality' in the definition of the

[2] We would like to point out that Howlett uses originally the term 'level', not 'layer'. However, the notion 'multi-level governance' (MLG) is a widely used concept in governance and political science studies, referring to the interactions between various jurisdictional and politico-administrative levels like international, national, regional, and local levels. MLG refers to something different than the object under study in this article. Therefore, in order to secure the readers' clarity, this article uses the term "layers" when referring to the nesting of policy instruments.

overall nature of the policy instrument. Some scholars argue for the need to translate grand challenges into specific missions using a recursive political process of pre-defined top-down problem identification and researcher-defined bottom up problem-definition (Robinson and Mazzucato 2019). Others argue in terms of specific contribution to the UN Agenda 2030 (Lundin and Schwaag-Serger 2018). A highly relevant paper acknowledges the plurality of societal challenges according to whether there are divergent or convergent views on problems and solutions. (Wanzenböck et al. 2020). For these authors, research and innovation policies of transformative nature "should be viewed as a process oriented policy that provides directionality and aims at supporting the process towards convergent problem–solution constellations" (Wanzenböck et al. 2020): 475. Building upon the discussions in the literature about directionality, and endorsing the approach proposed by Wanzenböck et al 2020, we examine the extent to which policy instruments are designed envisaging clearly the processes for defining the grand challenges and solutions that they aim to address, as opposed to policy instruments that do not include such processes.

Experimentation and risk-taking also belongs to the 'governance' layer because it refers to the general forms of interaction between government and society, expressing the general aims of transformative R&I policy instruments at creating spaces for experimentation in the search for new solutions to collectively identified grand societal problems (Schot and Steinmueller 2018) (Kuhlmann and Rip 2018). Experimentation entails a more risk-taking perspective to R&I policy instruments than conventional R&I policy instruments. It also comprises processes of reflexivity and learning about experiment outcomes. Our analytical framework operationalizes experimentation and risk-taking in terms of the extent to which policy instruments embody new ways of approaching collective challenges, as well as the extent to which they include reflexive and learning mechanisms from the experimentation, allowing a rapid adaptation of the instrument.

The second layer, coordination, addresses how policy instruments relate to each other and to their organizational environment. Since transformative research and innovation policy aims at fostering socio-technical change in sectoral systems like health, transport, energy, etc., transformative R&I instruments must include substantive and explicit coordination efforts with other policies[3]. Conceptual efforts to define instrument mix in R&I policy (Flanagan et al. 2011) and sustainability transformation (Edmondson et al. 2018) have not yet been used to study empirically the design of R&I policy instruments according to the transformative R&I rationale. Our analytical framework examines the extent to which the individual instruments are designed operationally so that they are embedded into dedicated **policy mixes.** Such policy mixes could include linking R&I funding instruments with regulatory instruments that test new solutions, or public procurement instruments as means to generate new markets for innovative solutions resulting from various funded projects (Rogge and Reichardt 2016). Furthermore, transformative policy instruments require coordination across different agencies that are relevant for transformative change. That is, transformative policy instruments should be the object of explicit collaboration across agencies, in their explicit efforts to generate synergies when addressing the grand challenges (Link and Hayter 2020). Hence, we define the concept **cross-agency collaboration** as the way

[3] Howlett refers to this as the 'operative level'. In the context of transformative R&I policy this operative layer refers to coordination.

in which R&I policy instruments are the object of regular cross-agency collaboration. This might play out differently across different policy instruments: Whereas some programs would envisage collaboration for the entire program, others would envisage it for specific challenges. In any case, it is fundamental that programs include explicitly cross-agency collaboration as an element, as opposed to programs which do not include it at all. Cross-agency collaboration is relevant in view of the literature discussions about the intermediary role that governmental agencies might take in transformative processes (Kivimaa et al. 2019) (Mazzucato et al. 2019).

Last but not least, **the measure layer** refers to the way in which the policy instruments are designed in practical terms regarding their specific actionable elements, typically in terms of project funding. This is the 'ground floor' regarding the practical deployment of the instrument (Howlett 1991). In particular we examine four important concepts, namely, epistemic boundary spanning, wide stakeholder involvement, flexible time-frame of project funding, and project clustering. Regarding **epistemic boundary spanning** transformations are complex processes requiring the mobilization and pooling of different knowledge bases and epistemic communities (Cagnin et al. 2012). Hence, at the measure level, the R&I transformative instruments should be designed with a view to facilitating and explicitly endorsing the convergence of existing/new technologies and knowledge-bases with new perspectives expanding the current epistemic boundaries, including a closer collaboration between the 'hard' (technical) and 'soft' (organizational/social) sciences. A **wide stakeholder involvement** is the second concept related to the 'project measure layer' in transformative R&I policy instruments (Kuhlmann and Rip 2018). Knowledge production is no longer confined to traditional academic and industrial actors, but increasingly distributed across different actors in society (Gibbons et al. 1994). This mode-2 understanding of knowledge production and utilization envisages a wide engagement of stakeholders (university, industry, philanthropies, NGOs, public organizations, citizens, regulators, etc). The active engagement of a broad set of stakeholders in the projects is associated to the demand-articulation and definition of user needs, which are a defining feature of transformative R&D policy (Boon and Edler 2018). The third element is the extent to which **the time-frame and flexibility of project funding** has been designed in a way to take into consideration fundamental aspects of transformation. This has to do less with a specific or minimum number of years of project funding, and more with the explicit design of the instrument in terms of envisaging the potentially medium-long time frame needed for inducing transformations, and/or linking the funding frame with other future possible funding. Last, the fourth element is the **clustering of projects into portfolios** to strengthen the collective transformative thrust across projects (see, for example, Ramboll 2020). In particular, this relates to the aim of generating interactions and mutual complementary dynamics (synergy) between the funded research and innovation projects with the intention to increase their potential transformative effect. Table 1 summarizes.

Table 1: Operationalization: Codes for analysing the transformative nature in the design of a policy instrument

Layer	Concepts' operationalization into analytical codes
Governance preferences layer	**'Directionality'**: The R&I policy instrument includes processes for defining the specific problems and solutions that it targets. **'Experimentation and risk-taking'**: The R&I policy instrument envisages experimental approaches to grand challenges and includes learning mechanisms from the experimental outcomes, allowing a rapid adaptation of the instrument.
Coordination layer	`**Policy mix embeddedness':** The R&I policy instruments forms part of an explicit policy mix that aims at transforming socio-technical systems. '**Cross-agency collaboration**': The R&I program and/or the specific grand challenges it targets, are coordinated through continuous cross-agency collaboration.
Project measures' layer	**'Epistemic boundary spanning'**: The R&I policy instruments emphasizes or requires multi-disciplinarity, particularly between technical and organizational/social sciences. **'Wide stakeholder involvement'**: The R&I policy instrument envisages wide consortia of R&I-performing actors beyond the traditional university-industry nexus. '**Flexible and/or possible extension of time-frame of project funding'**: The R&I policy instruments provide sufficiently long and/or adaptive funding to accommodate time-related aspects of transformation. **'Project clustering'**: The R&I policy instrument clusters projects in portfolios in order to generate interactions and synergies with the intention to increase projects' potential transformative effects.

Having operationalized the transformative concepts related to the three layers, we now focus on operationalizing the concept 'nesting'. Michael Howlett refers to 'nesting' in terms of the hierarchical interlinkages embedding the three layers into each other. He mentions the notions 'alignment' and 'embedding' as synonyms of 'nesting', but without providing further guidance on how to operationalize 'nesting' for empirical analysis. In order to develop this, we revert to recent studies about policy instruments which have dealt with associated matters. We find particularly inspiring the discussion around the notion of 'consistency' in studies of policy mixes, defined as "capturing how well the elements of the policy mix are aligned with each other, thereby contributing to the achievement of policy objectives" (Rogge and Reichardt 2016): 1626. 'Consistency' is about horizontal alignment in policy mixes, rather than to hierarchical alignment across the three layers in a single policy instrument. Hence, obviously, 'consistency' refers to horizontal aspects, and is not 'nesting'. Other authors

distinguish the horizontal 'consistency' from the vertical 'coherence': "Coherence between strategic agenda setting and thematic orientation describes whether the selected thematic areas of action correspond to a well-founded understanding of the overall ambition" (Kroll 2019) p 639. It is important to acknowledge however that both notions address issues of alignment (horizontal or hierarchical), and therefore previous authors have faced similar difficulties to find a suitable operationalization that grasps variations of degree. For this reason, we find inspiration in Rogge and Reichardt's discussion about how to operationalize the horizontal alignment in terms of different degrees (Rogge and Reichardt 2016): 1626. Hence, in the current paper we focus on aspects related to the presence of contradictions across layers, as indicating variation in the intensity of hierarchical alignment, and on this basis we suggest various possible degrees of nesting (see table 2).

Table 2: Operationalization of 'nesting'

Nesting	The three layers (governance, coordination, and measure) of the policy instrument might be: (1) **Not nested** when the different layers show lack of hierarchical alignment due to significant contradictions across layers. (2) **Weakly nested** when their hierarchical alignment shows some contradictions across the layers. (3) **Medium nested** when their hierarchical alignment is free of contradictions across the layers. (4) **Strongly nested** when their hierarchical alignment is working together in a clear synergetic fashion.

Before engaging in the empirical analysis, it is worth considering some general assumptions about what one might expect to find from the nesting perspective in relation to the transformative elements in R&I policy instruments. We would suggest that we are likely to encounter at least the following three. Firstly, we expect that it is rather difficult to encounter newly-created R&I policy instruments to be 'strongly nested' because the hierarchical alignment in a clear synergetic fashion is very demanding. Howlett emphasizes repeatedly the complexity of policy instrument design. Since the transformative R&I policy rationale is relatively new, we expect that there might be a time-lag between the theoretical formulation of the policy rationale on the one hand, and the practical design of the policy instrument on the other. By the same token, when we compare the 4 programs under study, we expect that the oldest programs will be those with comparatively higher degree of nesting.

Secondly, the nesting perspective suggested by Howlett also emphasizes the relevance of previous historical traditions in policy making. The literature has previously established important cross-national differences in policy styles, particularly distinguishing between countries following mainly a diffusion-oriented or a mission-oriented tradition (Ergas 1987). The four Nordic countries under study have different traditions, with Sweden, Norway, and Finland arguably having a strong tradition with targeted programs and/or missions, than the more diffusion-oriented tradition of R&I policy making in Denmark

(Weinberger 1997) (Eklund 2007) (Borrás 2015) (Schwaag Serger and Palmberg 2022). We would expect these variations in national policy styles to manifest themselves in differences in the hierarchical nesting of the policy instruments studied.

Thirdly, when looking at the hierarchical alignment across the three layers, we acknowledge the general complexity of putting coordination into practice. Problems of coordination are frequent, as breaking through administrative silos is never easy (Braun 2008). This is because the diverse nature of agency mandates and budgets is a real difficulty for inter-agency operations and for the actual embedding of specific policy instruments into mixes. Hence, we expect this layer to be the 'Achilles' heel' for achieving a stronger degree of nesting in our 4 policy instruments under study.

3. Data and Methods

We conduct a qualitative case study of four policy instruments (in four Nordic countries) following a "most similar" comparative research design (Seawright and Gerring 2008). This is one of the oldest and most widely recognized methods for small-n qualitative comparative research (Lijphart 1975), according to which cases are similar across all background conditions, but differ in few variables (Anckar 2008).

We use a purposeful sampling technique (Suri 2011) to select the four cases according to the following: a) country-based background conditions (the Nordic countries share similar layers of socio-economic development, politico-administrative and socio-cultural contexts), b) explicit focus on grand challenges and transformative ambition (according to their own descriptions), c) availability of and access to information and data; and d) overall characteristics (they are all relatively recently created programs, managed by prominent funding agencies in their corresponding research and innovation policy systems, etc.). See basic descriptors in Table 3.

The analysis unfolds in three steps. In section 4 we conduct a within-case analysis of the design of each policy instrument, first according to the three-layer framework developed in this paper (following table 1), and secondly, according the degree of nesting (following table 2). Third, in section 5 we undertake a cross-case comparison of the four instruments.

Table 3: Basic descriptors of the four programs (the four policy instruments under study)[4]

Program	Funding organization	Est.	Calls for proposals / Funding / projects funded	Funding method	Characteristics	Program Objective
Grand Solutions Program (DK)	Innovation Fund Denmark	2014	1-2 calls per year 100m € per year (new funding) 168 projects funded 2016 - 2019	2-5 years (5-30 m DKK per project; up to 75 %)	Embedded in national research strategy (R2025) Top-down directionality Thematic and open calls	”collaborative projects based on excellent research focused on solutions of considerable societal value. Based on societal and business challenges, opportunities and innovation needs, Innovation Fund Denmark wants to enable cross-disciplinary investments in knowledge institutions and companies – private as well as public.” (Website)
Flagship Program (FI)	Academy Finland	2018	2 calls in total 54m € total for 2019-2022 6 flagships selected	4+4 years	Only universities and government research institutes can apply Strong focus on embeddedness in host organization (eco-system) Open calls	“supports future knowledge and know-how and sustainable solutions to societal challenges and advances economic growth by developing new business opportunities” (OECD description)
Pilot E (NO)	Research Council Norway, Innovation Norway and Enova	2016	1 call per year (several missions) 9-10m € per year (new funding) 24 projects funded 2016 - 2019	2-3 years	Aimed at companies Thematic calls and concrete missions	Accelerate development and implementation of new products and services in environmentally friendly energy technology to contribute to reduced emissions in Norway and internationally
Challenge-driven innovation program (SE)	Swedish Government Agency for Innovation (Vinnova)	2011	1-2 calls per year 22 m € average annual funding Around 500 projects funded so far	Stage-gate funding Three funding layers	Relatively open calls (with Agenda 2030 as framework) Strong focus on systemic perspective (beyond R&D) Significant participation of municipalities Additional related initiatives run by Vinnova	collaborative projects which seek to provide solutions to societal challenges and thus contribute to the SDGs in Agenda 2030

[4] Status at the end of 2020

We use three data sources: interviews, written documents and observations. Between February and August 2020 we conducted 36 interviews in the four countries. All respondents had first-hand knowledge of the respective programs, and we secured that the different groups of respondents are represented with a minimum of 15% overall. We have interviewed at least one program manager and one project leader per case. The four types of respondents are: program managers (of the corresponding program), project leaders (research leaders of funded projects under the corresponding program), civil servants (public employees in other organizations/agencies), and external experts (national experts who know about the program, and about the national R&I policy landscape). Almost all interviews were recorded (with the consent from the respondents), and all of them transcribed (with translation into English). Given one of the author's previous affiliation to Vinnova, all interviews with that organization were undertaken by the other author. All interviews followed a pre-defined interview guideline, asking questions about the concepts of interest. When relevant aspects emerged from the answers, additional questions were posed by the researchers in order to allow for new perspectives. The interviews lasted 30-60 minutes, and were conducted using IT-video conferencing (or telephone). Table 4 shows the number and distribution of the respondents.

Table 4: Interview respondents by country and type of respondent

By country	**No.interviews**	**Percentage**
Denmark	9	25
Finland	8	22,2
Norway	8	22,2
Sweden	11	30,6
Total	36	100.0
By type of respondent	**No.interviews**	**Percentage**
External expert	9	25
Program manager	14	38,9
Project leader	6	16,7
Civil servant (not from program)	7	19,4
Total	36	100.0

We collected 47 written documents, and organized them according to three categories of direct relevance for the study: First, documents directly about the program (with basic information, external evaluation reports, self-evaluation reports, power point presentations, project summaries, or administrative documents like calls for proposals); second, documents about country-layer R&I policy (OECD country reports, RIO country reports, Policy Support Facility reports, etc.); third, other relevant documents about grand challenges in R&I policy in the countries of relevance, and in Europe (e.g. the "Swedish presidency Lund declaration", conceptual studies about evaluation frameworks on grand

challenges, etc.). Only the first group of documents forms part of the primary data analyzed (read below). The other two categories of documents are secondary, and were used as background material.

Last, a number of participant observations were undertaken by one of the authors of this paper, during the evaluation of the Innovation Fund Denmark, evaluation of applications to the Flagship program (10 applying consortia) and OECD innovation reviews of Norway and Finland. These observations were relevant during the analysis of the data, as a form of tacit knowledge resulting from formal and informal conversations during the evaluation process. These observations were used as background material, rather than as primary data source in the analysis. Given the independent assessment of the evaluations, these observations cannot be considered co-creation participatory 'action research' (Wittmayer and Schäpke 2014).

The data has been coded and analyzed using N-Vivo software package, a useful tool for large qualitative datasets. We have used a coding procedure (Saldaña 2009) to produce contextually-based and generalizable findings that 'speak' back to theoretical considerations (Ayres et al. 2003). This coding procedure follows the 'structural method', which organizes text data according to its content-meanings related to a series of pre-structured codes (Saldaña 2009). We developed a code book according to the operationalized concepts (see Table 1). We used N-Vivo to locate the passages that matched the codes, by using text search queries, coding queries, and matrix queries.

We pursued a number of concrete strategies to secure the rigor in our research (Houghton et al. 2013). Firstly, in order to secure the 'completeness' of the cases, we had a prolonged engagement with our data and stopped collecting more data when we achieved 'data saturation', meaning the point when no new evidence was emerging from new data. Secondly, we triangulated the data gathered from different sources, in order to check its accuracy. When discrepancies were found (e.g. when program managers tended to 'forget' less positive aspects of the program) alternative views were contrasted, and nuanced views prevailed. Thirdly, we conducted a 'respondent checking' of data collection and analysis: we sent a draft version of the paper to all our interviewees asking them about whether important data were missing, whether they recognized the accuracy of the analysis, and whether they had additional remarks. We gave them six weeks to respond. We received clarification remarks from nine interviewees and incorporated most of these. Fourthly, we engaged in 'peer debriefing' with external experts from each country (who had not been interviewed) asking for their feedback, and securing the validity of the findings. We sent 23 requests, and received feedback from 12 national experts who were not interviewed. We introduced most of their comments or clarification points.

4. The Four Cases under Analysis

4.1 Denmark's Grand Solutions Program

The Grand Solutions (GS) Program is the largest program of the Innovation Fund Denmark (IF), an agency created under the Ministry of Higher Education and Science, following a reorganization of the Danish research and innovation policy in 2014. It is also by far the largest of the four Nordic programs analysed here. With a strong industrial anchorage, the program focuses on creating commercial value and wider social value creation, transforming production and consumption systems. The Grand Solutions program has been adapted to the strategy of the Danish government to mitigate climate change[5].

Examining the **governance layer**, the **directionality** of the program is rather top-down, issuing calls according to very specific themes, inspired by a catalogue of research priorities from the Danish Government entitled Research2025 (Innovation_Fund_Denmark 2018). 20% of the calls of GS are non-thematic. In 2021, the IFD defined "Innomission-roadmaps", "to be used as a basis for mission-driven green research and innovation partnerships within four areas"[6]. In addition to testifying to learning and reflexivity at the program layer, recent changes, such as roadmaps and partnerships, generate more spaces for **experimentation and risk-taking**. The introduction of 'missions' in Denmark is very new, and is in itself the outcome of learning mechanisms in the policy instrument.

Regarding the **coordination layer**, there seems to be no real **cross-agency** collaboration between the IFD and other agencies. In Denmark, important development and demonstration programs are run by sectoral agencies (like the "Energy Development and Demonstration" program, run by the Danish Energy Agency), but there seems to be little collaboration with these. "IFD claims that it is part of a chain, but it has no real overview of that, nor takes part in systemic interactions." (External expert 3). Studying the GS program in the context of the **policy mix**, there is also a lack of connection at larger scale. "Within the Innovation Fund's own remit there is complementarity [in the policy mix], and a certain overall logic of how the programs fit together; but there is a lack of integration across the whole [Danish] eco- system (e.g. no clear link to other instruments like regulations or tax incentives)" (External expert 1). Similarly, a recent evaluation of the IFD underlines: "The strategy of IFD is not sufficiently coordinated and nested within the strategies of other important actors in the Danish innovation system" (Ministry of Higher Education and Science 2019: 37). Thus, in its current form, the GS program cannot be considered to be part of a wider policy mix seeking transformation. A new topic that emerged from the coding of our data relates to the fact that IFD is a relatively new agency, which has been relocated geographically, and has had a high personnel turnover. This has resulted in a number of organizational challenges, as exemplified in the following: "Our point of contact at IFD has changed three times, which

[5] In Spring 2020 the Innovation Foundation Denmark opened a call for innovation project proposals on green transitions. The Danish Climate Law from December 2019 was the beginning of a renewed long-term ambitious plan for climate mitigation policy initiatives. For an overview: https://ens.dk/en/our-responsibilities/energy-climate-politics/danish-climate-policies (accessed June 2021).

[6] https://innovationsfonden.dk/en/programmes/green-missions/roadmaps-mission-driven-green-research-and-innovation-partnerships (accessed June 2021).

is a pity; there is a strength in having continuity in the people / points of contact in the projects" (Funded project leader 1).

At the **measure layer**, the **epistemic boundary spanning** of the GS program has until recently been rather limited: the GS program calls for interdisciplinary perspectives, but this does not seem to be reflected in the projects funded (IRIS_group 2019):50. Several respondents, as well as a recent evaluation, advocate more interdisciplinarity, particularly regarding social sciences: "The Grand Solutions program focuses heavily on technical, life and natural sciences, but should involve other disciplines. The GS program focuses too little on how solutions are implemented which almost always requires involvement of social sciences" (External expert 1). The IFD's new strategy seeks to rectify this[7], introducing more focus on engaging social sciences. The GS program shows limitations in terms of wide **stakeholder involvement**, particularly with regard to civil society and other relevant stakeholder participation in project consortia (Ministry of Education 2019, p.37). As one respondent puts it: "The way the Grand Solutions program has been funded has not taken enough account of the users, too few citizen science programs and programs where you involve the end users (unless you define a company as an end user). GS is focused on solving problems for particular companies. You could/should involve the public more on what do they want or need" (External expert 2). Regarding the **time-frame**, projects typically run 3-5 years, with a declared expectation of projects to "reach implementation 2-10 years after project end" (Innovation Fund Denmark 2018a, p.26). The projects are rather large (average grant size was 13.5 million DKK in 2015-17 (Iris Group 2019 a). Whereas the full implementation of the project is considered from a relatively long-term perspective, the GS project funding is not flexible or adaptive, something which is criticized by several of the experts we interviewed (external expert 1 and 4). Looking at the **clustering of projects** for transformative purposes, the IFD strives to apply a portfolio perspective by clustering GS projects thematically, with the aim to "identify gaps and to guide future investments" (IFD 2018a: 33). It also shares information of its portfolio distribution with "key stakeholders such as other ministries, universities and industries confederations" (ibid). However, the clustering is not geared towards transformative purposes in the sense of cross-fertilization or identifying system and transformation failures related to, for example, market creation, regulations, or resistance to change; rather it is an administrative perspective where one public administrator monitors the progress of a group of projects, and helps disseminate the projects' results.

Regarding its hierarchical nesting, the program displays **weak nesting** because some contradictions are visible in the elements across the three layers. A number of changes have recently been introduced at the governance layer (clear directionality, and growing experimentation), yet the program could be more strongly nested by paying more attention to the coordination and measure layers, because some contradictory elements are visible within those layers and, most importantly, across them.

[7] https://innovationsfonden.dk/da/nyheder-presse-og-job/innovationsfonden-efterlyser-flere-humanistiske-og-samfundsvidenskabelige (accessed June 2021).

4.2 Finland's Flagship Program

The Academy Finland, a central actor in Finland's science policy, launched its Flagship Program in 2018, as part of government initiatives towards "economic and societal renewal", to promote strategic research and the commercialization of research, and to strengthen ecosystems (European Commission 2018b). The program seeks to address concerns about the fragmentation of Finnish research (OECD 2017b), and requires that flagships target "sustainable solutions to societal challenges and advancing economic growth".

Regarding the **governance preference layer**, the Flagship program is an example of limited **directionality**. Following three rounds of applications between 2018 and 2020, ten flagships were selected covering very diverse areas. The last four flagships show an increasing orientation towards addressing grand challenges: on atmosphere and climate; chronic disease treatment through gene, cell and nano therapy; the immune system; and forest-human machine interplay. The program focuses strongly on scientific excellence, and therefore is somewhat less oriented towards creating spaces for **experimentation and risk-taking** in a transformative manner. It is worth noting that the program has recently put more emphasis on the need of the Flagships to establish "close connections to the business sector and society at large" to secure their commercial and their societal impact. While this denotes some learning and reflexivity, it is still rather generic and aspirational rather than concrete or tangible.

At the **coordination layer**, there is no apparent integration with, or linkages to, sectoral policies or agencies, and no indication of conscious efforts to view or describe the flagship program as part of a **policy mix**. Yet, some indirect policy mix discussions are taking place at the flagships, like for example, the flagship on the welfare state is collaborating with regulators on new developments and combinations of welfare interventions and regulations. Regarding **cross-agency collaboration**, there is very limited coordination. Some managers of the Academy of Finland mention that there is some form of collaboration with Business Finland (another key R&I funding agency) at Flagship level: "We have 2-3 meetings every year with Business Finland. We know that 'one size fits all' does not work, so collaboration is related to each of the flagships' nature and their leaders. We take one flagship at a time." (Program manager 1). The very limited collaboration points to a more general problem of a growing divide or even disconnect between highly commercially oriented R&D and innovation support programs, run previously by Tekes and currently by Business Finland, and programs for funding excellent academic research: "If you want to break down silos, you need to move people around. Cross-sectoral cross-organizational mobility. The Academy of Finland has a lot of people with science and research background, but little with other backgrounds with other areas, incl. business." (External expert 5).

Regarding the measure layer, the program can be argued to aspire to some **epistemic boundary spanning** in the sense that it encourages consortia to "pool expertise from different fields", but it does not explicitly call for collaboration between technical and social sciences. Nonetheless, most of the flagships display some epistemic boundary spanning, though mainly from within neighboring fields. As a respondent put it: "This is not so ambitious. It should bring very distant disciplines together, thinking more boldly and outside the box" (External expert 5). Also, **stakeholder involvement** can be argued to be limited in the way the program is designed since only universities and public research organizations

can be funded in this program: "We have to show that we will have business impact, even if firms were not allowed to join the consortium" (Funded project leader 2). Illustrating this challenge, a flagship leader explained: "To overcome this, we are generating new projects of applied nature, which are associated to our flagship, were we involve actively other stakeholders. These projects are funded by H2020. It is paradoxical that we need to raise additional funding to cover activities that should be core to the flagship." (Funded project leader 3). The Flagship program is designed with a clear long-term transformative ambition as it offers funding for eight years, which is a longer **time-frame** than for any of the other programs compared (four+four with the second period funding contingent upon a satisfactory scientific mid-term evaluation). The program places strong emphasis on the flagship's embeddedness in the host organization, in order to secure organizational commitment and competence building of the eco-system, which usually entails an important education component.[8] The program does not itself **cluster funded projects** thematically. Given the individual flagships' large size and the range of activities they cover, it could be argued that flagships constitute a form of implicit project clustering. However, the flagships do not seek to create synergies between projects in view of enhancing their potential transformative effect because the focus of the flagships is not on transformative dynamics, but on excellence of scientific research. "These [the flagships] are big consortia, with well-connected researchers for key issues for firms and government. There might be a potential for (long term impact on) specific issues. But this would need to be designed and achieved" (Civil servant 1). Yet, "Is it fair to expect them [the projects/flagships] to make the systemic changes? This is the key of research and innovation policy: how much can you steer by providing funding and by the institutional set-up? Out of all of the flagships, if one makes a real scientific breakthrough, would be worth it". (External expert 5).

Regarding its **nesting**, the Flagship program shows some contradictions across layers, and is therefore **weakly nested**. The Flagship program is designed as an ambitious and strategic program for transformation, putting strong emphasis at the measure layer to deliver that. Its implicit assumption is that scientific breakthroughs from the individual flagships will bring transformative effects. The flagships (at measure layer) receive long-term funding. Hence, the program seems to rely on flagships' internal structures, and their ability to stimulate transformation in their eco-systems, but does not envisage epistemic border spanning, or wide stakeholder involvement. The limited directionality at the governance layer, and the limited cross-agency collaboration and lack of policy mix complementarity, show some contradictions across the layers.

4.3 Norway's Pilot-E Program

Pilot-E is a relatively small funding scheme run jointly by Research Council of Norway, Innovation Norway, and Enova[9]. The program is anchored to a larger ambition to strengthen the ability of the Norwegian research system to tackle societal challenges and to transition the economy away from its

[8] https://www.aka.fi/globalassets/10rahoitus/liiteet/fp_review_form_scientific-excellence.pdf, accessed May 14, 2019.

[9] Enova is a public company owned by the Ministry of Climate and Environment with task of promoting Norway's transition to clean energy generation and use. https://www.enova.no/pilot-e/ (accessed June 2021)

dependence on fossil fuels (OECD 2017a). It is also directly related to one of the six prioritized thematic areas for Norwegian appropriations for research and higher education in the Long-Term Plan for research and higher education 2015-2024 (Norwegian_ministry_of_education_and_research 2014).

Regarding the **governance preferences layer**, the design of Pilot-E displays clear **directionality** through thematic calls targeting specific challenges. Examples of thematic calls are 'zero-emissions maritime transport', or 'zero-emissions construction and facilities'. The logic of Pilot-E is to define specific missions in the field of green energy technologies. The themes are carefully defined in rounds of informal consultations with various stakeholders. "Pilot-E is break-through innovation, it is clearly mission-oriented and it is very technology-oriented and commercially oriented. It is designed to accelerate the development of zero-emission technologies into concrete solutions" (Program manager 2). Regarding **experimentation and risk-taking**, Pilot-E creates spaces for experimenting with new solutions, with a focus on technological solutions. It has a rather risk-taking perspective developing new solutions that were not available earlier, within specific technological areas. The program has also clear elements of reflectivity and learning, as it has rapidly adapted through time.

The **coordination layer** is relatively strong given that that the Pilot-E is jointly run by three public agencies (Research Council of Norway, Enova, and Innovation Norway). "In [the] area of energy we have a complete chain of agencies, from basic research, to research-driven innovation, and to commercialization, and so it is natural that we want to do this collaboration." (Program manager 4). Pilot-E was inspired by the USA's ARPA-E, and was set up as a one-stop shop for applicants across the three agencies: "We are less bureaucratic than the normal operations of our agencies, we are like a small innovative group, slightly outside and in-between the agencies." (Program manager 2). Hence, "It is a very tight and very operative [**cross-agency] collaboration**. We do more or less everything together" (Program manager 4). Pilot-E is partly embedded in a **policy mix** in the sense that it is a special tool within larger programs, like the program ENERGIX within the Research Council of Norway [which] targets transformation towards low emission society as a whole and as long-term. (…) Less than 10% of the ENERGIX funding is allocated to Pilot-E. So Pilot-E is a special tool." (Program manager 2). Beyond that, the Pilot-E-scheme is not designed explicitly to be part of a broad policy mix. However, there is an incipient policy mix in the sense that Pilot-E identifies needs for green energy solutions according to national future public investment plans in energy-related areas. Hence, Pilot-E anticipates green R&I solutions to be included in public procurement bids according to public investment plans. "Some of the projects have been considered by public authorities in their public procurement, and have been taken up in the direct implementation of the solution." (Program manager 4).

At the **measure layer**, the design of the program exhibits limited **epistemic boundary spanning**, e.g. it does not explicitly encourage multidisciplinarity, particularly between technical and social sciences. "Multidisciplinarity is defined on the basis of the needs of each project, not a direct requirement in the call for proposal" (Program manager 3). Regarding wide stakeholder involvement, Pilot-E places clear emphasis on projects implementing market solutions ("from idea to market")[10], and promotes

[10] https://www.enova.no/pilot-e/utlysning-2019/ (accessed June 2021)

collaboration between firms. Collaboration with a university or research institution is optional. Hence, the program seems to promote traditional R&I consortia among firms, with limited types of **stakeholder engagement**. A program manager makes the distinction between problem-owners and problem-solvers: "Problem solvers are those putting the solutions into the road. Problem-solvers are part of the Pilot-E project" (Program manager 4). Hence, problem owners (those using the solutions, and/or suffering the problems) are not part of the consortia supported by Pilot-E. "Some consortia have included NGOs, i.e the electric car society has been involved. But Pilot-E does not focus on the end-user side of technology" (Program manager 2). The Pilot-E program funds consortia projects on a short **time-frame**. The aim of the program is to commercialize solutions quickly and to provide efficient and flexible support for a specific type of projects. "The projects should have a proof-of-concept before getting funding through Pilot-E because it is a 3-5 years is a short-time to put up workable solutions." (Program manager 3). Regarding the **clustering of projects**, the Research Council has recently created 'portfolio boards', bringing together projects across different funding schemes in order to create synergies. These boards have more responsibilities than previous boards. They are positively perceived by managers who observe that "This takes down the silos across programs, as they oversee different instruments." (Program manager 4). Rather than evaluating ongoing projects, program managers monitor closely their progress: "There is no mid-term evaluation, we assess the projects on-going through their own milestones. We are not doing any assessment. If they reach the milestone then we say 'go ahead'" (Program manager 5). Several respondents remarked that program managers had long-term and outcome-oriented ambitions which extend beyond the funding period and which are the basis for this form of monitoring projects' progress. The shared long-term visions thus appear to provide a compensatory transformative anchoring of Pilot-E that mitigates the relatively short term funding period of projects.

From a **nesting** perspective, there are no contradictions across the three layers in the Pilot-E program. The elements across all three layers create a transformative thrust, albeit within a relatively narrow thematic focus (environmentally-friendly energy technologies). In particular, a clear directionality and elements of experimentation at governance layer; an explicit and well-developed cross-agency coordination, incipient elements of policy mix at coordination layer; and a well-articulated way of clustering projects in portfolios at the measure layer, are testimony of no contradictions. However, weakness at project measure layer in terms of limited epistemic boundary and limited stakeholder engagement weakens the synergetic effect of the hierarchical alignment. For this reason, the Pilot-E program shows **medium degree of nesting**.

4.4 Sweden's Challenge-driven Innovation Program

The Challenge-Driven Innovation program (CDI) is designed to support collaborative initiatives seeking to provide solutions to grand challenges and thus contribute to the UN's Sustainable Development Goals (SDGs) as defined in Agenda 2030. The program is strongly related to strategic initiatives by the Swedish government and was launched two years after the Lund Declaration of 2009 adopted at a conference

under the Swedish EU Presidency, which emphasized the importance to focus research and innovation on society's 'Grand Challenges'. [11]

Regarding **directionality**, at the **governance preferences layer**, the program has a strong bottom-up and non-prescriptive character – encouraging stakeholders to identify challenges they wish to address within an overall framework set by Agenda 2030. However there is a widespread view that it is currently too broad and undefined, and more targeted areas are needed. "We need to balance the top-down and the bottom-up elements" (Program manager 6); see also (Ramboll 2019) and (Ramboll 2020). The CDI program displays several **clear elements of experimentation and risk-taking** in different ways. The open-ended nature of the problems defined, and the stage-gate funding (described below), indicate willingness to create very open spaces of experimentation in search of new solutions. The lessons learned from having run CDI for several years have resulted in the development of other programs, like the "Policy Lab" or "Social innovation" programs, and have served to adapt the program along the way, demonstrating learning and reflexivity.

At the **coordination layer**, CDI is not clearly coordinated with other policy instruments in specific **policy mixes** for transformation. **Cross-agency collaboration** seems relatively limited and occurs mainly at project layer. Other agencies are invited to project selection boards, and some are partners in funded projects; but in general, there is little collaboration. Hence, the linkages of the program to other relevant policy areas – such as environmental, social, healthcare and budgetary policies, procurement and regulatory activities – is limited.

At the **measure layer**, the **epistemic boundary spanning** of CDI is high, because it places a strong emphasis on multidisciplinarity, though not specifically on linking hard and soft sciences or on integrating social sciences and humanities more in innovation projects. Overall, there is a clear focus on 'boundary-transcending collaborations', on achieving systemic change and on an international reach.[12] As to **stakeholder involvement**, Vinnova requires applicants to interact, involve and collaborate with 'problem owners' in defining challenges and developing projects, and Vinnova organizes workshops with relevant stakeholders on specific themes. There is some indication that this is not always positive, as these new actors are not used to being part of R&I projects. "NGOs [and other types of new stakeholders without direct research experience] have their own incentives and structures, which are not the same as a SME [Small and Medium-sized Enterprises] or university, as they are working on different premises" (Program manager 7). Moreover, diverse consortia imply a higher organizational risk, beyond the technological risk. Vinnova's efforts to promote wide stakeholder involvement aims at ultimately contributing to building knowledge and capability, but is not exempt from difficulties. One of the most significant features in the design of the Challenge-Driven Innovation program is its **time-frame**. The program funds projects according to 'a stage-gate perspective' consisting of three phases: initiation, cooperation and implementation. As projects progress through the stages, Vinnova (the agency

[11] The declaration can be found here https://www.vr.se/download/18.6969eb1a16a5bec8b59337/1556886557434/The+Lund+Declaration+2015%20final.pdf (accessed June 2021)

[12] According to a Vinnova presentation from September 2018 https://www.youtube.com/watch?v=lmMEWejVjZU, accessed June 2019.(accessed June 2021)

managing the program) increases the funding per project (from a maximum of 50 000 € in stage one to a maximum of 2 million € in stage 3), while the number of projects funded decreases, and Vinnova requires a larger share of co-funding from other actors. The stage-gate perspective encourages more long-term thinking than traditional projects, and projects that progress through all three stages are likely to last five years or more. It also allows Vinnova to fund more risky (and thus potentially more transformative) projects initially. As to the **clustering of individual projects** thematically, Vinnova is considering a more targeted focus: "Perhaps we will select some missions, and build project portfolios around them. We also want to be more pro-active, with an active portfolio thinking/management" (Program manager 8). "One project cannot solve everything. We need to work with portfolios to be able to scale the solutions to be sure to get the outcome we want." (Program manager 9).

Regarding the **nesting**, just like the Pilot-E program, the CDI shows **medium degree of nesting**. CDI is one of the earliest R&I programs designed to explicitly focus on addressing grand challenges. The program has changed character over time, starting with a focus on 4 areas, followed by a reorientation towards the 17 SDGs. The transformative elements across its three layers are free of contradictions. The program has very clear transformative elements at project measure layer. However it shows weaknesses at the governance and at the coordination layers. A recent evaluation concluded that – due to, among other things, a strong focus on technological development, rather than demand orientation and market creation, as well as a lack of policy coordination – the program does not yet live up to its transformative ambition (Ramboll 2019 and 2020; see also Schwaag Serger and Palmberg 2021). These weaknesses in the governance and coordination layers prevent a stronger nesting.

5. Comparative Findings

The previous section has offered an in-case analysis about the policy designs of these programs according to the three layers of nesting for each of the four programs under study. This section conducts a cross-case comparison by looking at the four programs at once, and analysing the findings in relation to the three expectations defined in section 2. Table 5 summarizes the empirical findings.

Table 5: Summarizing the empirical findings

	Grand Solutions (DK)	**Flagships (FI)**	**Pilot-E (NO)**	**Challenge-Driven Innovation (SE)**
Governance preferences layer	Clear directionality. Currently introducing experimentation.	Limited directionality. Currently introducing experimentation.	Clear directionality. Clear experimentation.	Limited directionality. Clear experimentation.
Coordination layer	Limited cross-agency collaboration. No policy-mix complementarity.	Limited cross-agency collaboration. No policy-mix complementarity.	Strong cross-agency collaboration. Incipient policy-mix complementarity.	Limited cross-agency collaboration. No policy-mix complementarity.
Project measures' layer	Currently broadening its epistemic boundaries Limited stakeholder involvement. Short-term funding with little flexibility. Lack of clustering projects for reinforcing their potential transformative effects.	Limited epistemic boundaries and stakeholder involvement. Long-term funding with little flexibility. Lack of clustering of projects for synergies reinforcing their potential transformative effects.	Limited epistemic boundaries and stakeholder involvement. Short-term funding with flexibility. Strong clustering of projects in portfolio boards.	Broad epistemic boundaries and wide stakeholder involvement. Stage-gate funding providing flexible and long term funding. Currently considering clustering projects for synergies reinforcing their potential transformative effects.
Degree of Nesting	**Weak nesting** The recent changes at the governance layer, are weakly embedded in the coordination and measure layers, as some contradictions are visible in the elements across layers.	**Weak nesting** The hierarchical alignment of the layers show some contradictions. The program seems to rely strongly on flagships' internal structures to deliver transformation, with contradictory elements in the other layers.	**Medium nesting** The layers have no signs of contradictions. Yet, weakness at project measure layer makes the hierarchically alignment not to work strongly into a synergetic fashion.	**Medium nesting** The layers are not contradicting each other; however, weaknesses in the coordination layer hamper a stronger nesting in a synergetic manner.

In line with our expectations regarding the 'nesting' of the instruments examined, we find that the oldest programs, CDI (from Sweden) and Pilot-E (from Norway) are more nested than the newer programs such as the flagship (from Finland) or GS program (from Denmark). This suggests that there might be a time-lag between the endorsement of a new R&I policy rationale, and the time that it takes for their design to become strongly nested.

Likewise, our second expectation about 'goodness of fit' regarding national policy styles seem to be partly relevant. The comparatively stronger degree of nesting of the Swedish CDI and the Norwegian Pilot-E programs vis-à-vis the Finnish and Danish ones, is partly consistent with our expectations that countries with relevant track records of technological, industrial or societal missions – such as Sweden, Norway and Finland – might provide a more conducive context for nesting policy instruments in transformative R&I rationale, than countries with traditionally diffusion-oriented tradition (Ergas 1987). Finland might be considered a noteworthy outlier in this context, as we initially expected a stronger degree of nesting given its tradition with targeted technology programs and centers in the 1980s, 1990s and early 2000s (OECD 2017b). The significant changes in Finland's more recent research and innovation policy (Deschryvere et al. 2021) – in particular the stark drop in R&D expenditure combined with significant governance changes – might partially explain the weak nesting of the Flagship program (Schwaag Serger and Palmberg 2022).

Last but not least, when looking at the variation in the nesting of the four programs, we note that the coordination layer seems to be particularly puzzling. Coordination is a challenge in policymaking in general, but even more so in R&I programs with transformative ambitions about grand challenges cutting across various policy areas. This is because coordinating across agencies and finding policy mixes complementarities requires not only overcoming the budgetary and regulatory rigidities of bureaucratic silos, but most importantly, to find ways of articulating strategically-oriented forms of coordination (Braun 2008). We do not see this happening in the Danish, Finnish or Swedish programs, and only partly in the small and highly-focused Norwegian program.

6. Conclusions

This article studies four new and ambitious Nordic R&I programs, as high-profile examples of R&I policy instruments that seek to address grand challenges and foster the transformation of production and consumption systems towards environmental, economic and social sustainability. This article asked to what extent the three layers that constitute the instruments (governance preferences, coordination, and project measures' layers) are nested into each other according to the rationale of transformative R&I policy.

Overall, the empirical findings show that the four programs have different degrees of nesting. Denmark's Grand Solutions program aims at creating tangible commercial and societal value in a short-time span in specifically targeted areas. This directionality, together with the recent efforts to become

more experimental and risk-taking, bears transformative aspects at the governance preferences layer. However, the governance layer is weakly nested with the other two layers (coordination and measure layers) given some contradictions across them. The Flagship program is part of the Finnish government initiatives towards "economic and societal renewal", requiring flagships to target "sustainable solutions to societal challenges and advancing economic growth". Its transformative design is weakly nested, and its transformative thrust is mainly at the project measures' layer; with some contradictions with the governance or coordination layers. For its part, the Norwegian Pilot-E shows a medium degree of nesting across the three layers because there are no contractions across them. Particularly relevant is the strong cross-agency collaboration fast-tracking solutions, and its incipient policy-mix at the coordination layer. However, the transformative weakness at project measure layer do not generate a strong synergy across the three layers. Last, but not least, the Swedish Challenge-Driven Innovation program is also exhibiting medium degree of nesting. This program has no contradictions in the transformative elements across the various layers. However, there is an obvious transformative weakness in the coordination layer, and therefore there is no strong (synergetic) nesting across them.

These findings serve to identify a series of **policy implications**, which are burning issues for each of these programs. The Danish GS program would need to nest better its governance layer with its coordination and measure-layers. Developing cross-agency collaboration, a deliberate policy-mix, more flexible funding of projects, and the clustering of projects in order to promote synergies among them, would be four concrete aspects to consider. The Finnish Flagship program would need to strengthen its transformative features at all three layers, and particularly at the governance and coordination layers, in order to nest it more solidly with its measure-layer. Features that could be addressed include directionality regarding problems or challenges to be addressed, more experimentation and risk-taking, expanding the epistemic boundaries and widening the stakeholder engagement; likewise, it might consider cross-agency collaboration, and a policy-mix perspective, to strengthen the prospects of the flagships ultimately being transformative beyond their scientific breakthroughs. The Norwegian Pilot-E is the program with most transformative features compared to the other three cases. Yet, from the practical implications perspective, our findings show that it could benefit from considering expanding its currently limited epistemic boundaries and stakeholder involvement, in order to nest the three layers strongly into each other. Last but not least, the Swedish CDI program would need to strengthen its coordination layer, nesting it better with the governance and measure-layers. In particular, the CDI program would benefit from more cross-agency collaboration, and from being nested in an explicit mix of policy instruments.

Our findings suggest some **relevant theoretical considerations.** First of all, we note that **there are some important trade-offs in the design of transformative policy instruments**. Whereas cross-agency collaboration is positively associated with transformative rationale, it comes with a cost. We observe this in the Norwegian case, which is much coordinated, but which also bears some costs in terms of 'heavy administration' as mentioned in our interviews with project leaders. Another trade-off is related to the bottom-up or the top-down definition of directionality. This is currently debated in the literature: "The higher the contestation, complexity, and uncertainty of the problem underlying a particular challenge, the higher its wickedness and the more difficult it might be for (innovation) policy to derive

legitimate, clear, and well-informed missions from it" (Wanzenböck et al. 2020): 477. We observe in that in the Danish and Norwegian programs, the problems are formulated rather specifically by a small number of policy-makers. So far this has not generated much social or political contestation. Another trade-off might be between across layers. In Sweden, the limited directionality of CDI (currently addressing the very broad Agenda 2030) has triggered some discussions, as the high diversity of funded projects hampers the efforts of clustering them at the project measure layer. This is the reason behind current plans to focus CDI funding into three or four specific areas.

Secondly, we have noted the relevance of the organizational context in which these instruments operate. Cross-agency collaboration is crucial in view of exploiting opportunities seeking transformation, which follows recent calls for more horizontal coordination (European_Commission 2020), and for more agency interaction regarding public procurement (Chicot and Matt 2018). However, cross-agency collaboration might be more difficult/costly if those agencies are located under different ministries (as there could be different political and policy logics), than if they are under the same ministry. Likewise, small unitary countries like the Nordics, might be more 'agile' in cross-agency collaboration than large complex (semi-)federal politico-administrative structures, simply because there are less organizations to deal with, and hence lower barriers. Last, but not least, in some countries, agencies might enjoy more arms' length administrative discretion from their ministries than in other countries, and this is also crucial for cross-agency collaboration.

Last but not least, we would like to mention some limits of our empirical study, in view of suggesting future lines of research. Our cross-country comparative study of four cases has brought relevant findings forward, but it is not able to grasp the more subtle and implicit aspects related to the individual and idiosyncratic nature of single case studies, to bring quantitative hypothesis testing results from large-n studies, or to explain the reasons behind why these instruments are weakly nested. For this reason, we suggest future research to undertake such studies, paying particular attention to the different trade-offs, the different organizational contexts we have identified, and the possible reasons behind weak nesting, in order to deepen our understanding about the design of these ambitious and crucial transformative research and innovation policy instruments.

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