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Governance of science and technology policies

Alan Paic* and Camille Viros*

ABSTRACT

This document provides learnings from 13 case studies on governance mechanisms of national and supranational science, technology and innovation initiatives. As countries strive to resolve societal challenges, "mission-oriented" approaches complement traditional ones centred on national competitiveness, specific industrial sectors or technologies. Governance settings contribute overall to a more inclusive, transparent and responsible STI system, in particular through a whole-of-government approach, the consultation of academia, the private sector and civil society, the implementation of strategies by professional agencies, and the increasingly common use of evaluation. Several critical dimensions facilitate the success of STI policies. They include a commitment at the highest level of government, strong public-private collaboration in R&D, continuous evaluation and improvement, a "mission-oriented" approach, coherence of policies and flexibility in setting priorities, as well as overall harmonisation and rationalisation of programmes in order to maximise efficiency and reduce duplication.

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Executive summary

Science, technology and innovation policies in most developed countries are reaching a third stage: in the wake of market failures and failures in the innovation system, these countries are now experiencing transition failures when attempting to tackle societal challenges. This results in policy layering whereby "mission-oriented" policies designed to solve societal challenges are overlapping with more traditional policies favouring national competitiveness and centred on industrial sectors and specific technologies. The programmes under study also often feature specific instruments supporting researchers, start-ups or small and medium-sized enterprises driving breakthrough innovations which, unlike "classic" or "incremental" innovations, lead to radical transformations.

Governance settings contribute overall to a more inclusive, transparent and responsible STI system: (i) national STI strategies cover aspects of both scientific research and innovation, are increasingly designed following a whole-of-government approach, involving a comprehensive consultation of academic, business and civil society stakeholders, in addition to different governmental entities; (ii) their implementation is almost systematically performed by professional agencies, in order to ensure professionalism and prevent conflicts of interest; (iii) evaluations are becoming more common, even though they remain mostly descriptive since empirical impact evaluation of STI strategies are complex and difficult to realise.

STI initiatives' budgets and durations vary considerably. Budgets cover four orders of magnitude and ranging from under EUR 1 million per year to more than EUR 10 billion per year for large-scale multi-sectoral programmes, such as Horizon2020 in the European Union, and High-tech Strategy in Germany. Duration of the initiatives also varies significantly (from less than 3 years to 20 years and more), but is most often similar to legislative terms (4-6 years). Shorter initiatives are sometimes pilot initiatives aiming to produce longer-term programmes at a later stage, while some initiatives can last several decades, especially in the field of public research.

The STI policy portfolio is diversified but quite concentrated. While there are 26 distinct categories of instruments, half of the initiatives use four main instrument types: national strategies and plans, grants for public research projects, grants for corporate innovation, and clusters and collaborative platforms.

The study of the different national and supranational science and innovation strategies highlight several critical dimensions which lead to successful initiative:

- Commitment at the highest level of government is a crucial means to send a signal to all stakeholders.
- The implication of stakeholders, and in particular civil society and the private sector, is also deemed to be important in the public policy design phase. Government action needs to promote stakeholder networking and co-operation between universities, research institutes, firms and civil society, facilitate exchanges and improve competences in communication and knowledge absorption. Strengthening the links between public research and the private sector is often actively encouraged, whether through commercialisation of public research results, technology transfer, co-creation, or open innovation. Engagement of the civil society is also critical when attempting to solve societal challenges through innovation.

- "Mission-oriented" policies aiming to resolve grand societal challenges are complementing historical approaches designed to support industrial production and the innovation system, creating the opportunity for science, technology and innovation to increase its societal impact.
- Coherence of actions implemented with specific objectives, especially in light of the multiplicity and diversity of instruments used, is crucial to promote synergies and prevent potentially negative impacts.
- Systematic evaluation and monitoring enables governments to continuously improve the policy framework and ensure increasing impact over time.
- Governments need to demonstrate flexibility in setting priorities to be able to respond to increasingly rapid technological and societal evolutions.
- Available programmes are being harmonised and rationalised, to simplify and optimise target stakeholders' access to the available subsidies and programmes. This limits the number of calls and proposes a single "window" for users in order to enhance efficiency in the granting of finance and reduce administrative costs.

1. Introduction

This monograph sheds an international light on governance mechanisms put in place by other countries, in the context of initiatives with similar goals to those of the PIA. Few national programmes can actually be compared to the PIA, both in terms of the funds allocated and the sectors covered. The only comparable programme is the European programme Horizon 2020. However, case studies of national multi-sectoral programmes (Canada, Japan, Singapore), and of research and innovation strategies (Germany, Australia, Korea, Norway), are somewhat comparable, as they are multi-sectoral, and present comparable goals concerning competitiveness and investment for the future. The examples of science and innovation councils (United States, Korea), or even agencies that finance research and innovation, while influencing political orientations with a bottom-up approach (United Kingdom, Sweden, Israel), allow drawing lessons that could prove interesting in the French context. Table 1 presents the case studies.

This paper presents an overview of research and innovation policies, highlighting the main messages concerning the programmes' strategic priorities, their institutional arrangement, the initiatives' budgets and duration, the instruments used and the critical dimensions. The detailed case studies are available online (OECD, 2019[1]).

Table 1. Overview of the programmes studied

Initiative	Country	Type	Period	Annual budget	Main objectives
Horizon 2020	European Union	Multi-sectoral programme	2014-20	EUR 11.2 billion	Reach scientific and technological excellence in order to drive intelligent, sustainable and inclusive growth Three pillars: • Industrial excellence • Industrial supremacy • Response to seven major societal challenges
High-Tech Strategy	Germany	STI Strategy	2018-present (HTS2025)	EUR 14.7 billion in 2016	• Increase R&D expenditure to 3.5% of GDP • Contribute to Germany's attractiveness as a European research centre • Improve Germany's international positioning • Five priority themes: health, environment, mobility, well-being and technology

Cross-ministerial Strategic Innovation Promotion Programme (SIP)	Japan	Multi-sectoral programme	2014-19 (SIP I) 2018-23 (SIP II)	EUR 265 million	• Promote the advancement of science and innovation • Boost economic growth • Strengthen global industrial position • Promote industry-research-government cooperation
Innovation and Skills Plan	Canada	Multi-sectoral programme	2017-present	N/A	• Become a world leader in innovation • Help firms become more competitive • Establish a culture of innovation • Attract investment • Simplify public aid programmes
Long-term plan for research and higher education (LTP)	Norway	STI Strategy	2015-24 (revised every four years)	EUR 70 million	Increase the contribution of research to the transformation of the economy, by: • Developing research • Increasing competitiveness and innovation • Responding to major societal challenges
National Innovation and Science Agenda	Australia	STI Strategy	2015-19	EUR 185 million	• Improve the quality of life of Australians by creating a more innovative and entrepreneurial economy • Promote new ideas to create firms and jobs • Diversify the economy beyond the mining sector
Fourth Science and Technology Basic Plan	Korea	STI Strategy	2018-22	EUR 9.1 billion	• Improve the quality of life of Koreans and contribute to solving societal challenges • Develop capacities in science and technology • Build an innovation ecosystem in S&T • Enhance job creation in S&T
Research, Innovation and Enterprise Plan	Singapore	Multi-sectoral programme	5-year plans (current: 2016-20)	EUR 2.5 billion	• Develop an economy based on knowledge and innovation • Transform Singapore into a “smart nation” • Four technology domains: advanced industry and engineering; health and bio-medical sciences; urban solutions and sustainability; digital services and economy
UK Research and Innovation (UKRI)	United Kingdom	Innovation agency or council	2018-present	EUR 8 billion	• Increase R&D expenditure to 2.4% of GDP by 2027 • Expand the frontiers of knowledge • Contribute to economic and social prosperity • Four societal challenges: AI and Big Data; ageing population; green growth; mobility
The National Science and Technology Council	United States	Innovation agency or council	1993-present	N/A (operational budget)	• Co-ordinate S&T policies at the federal level • Identify R&D priorities that serve as a strategic direction for federal agencies • Ensure that S&T policy decisions are coherent with the President’s priorities • Ensure that S&T is taken into account in the formulation of federal policies

The Israel Innovation Authority Strategy	Israel	STI Strategy	2018-22	EUR 415 million	• Ensure technological leadership • Increase impact of high-tech enterprises • Enhance firms' competitiveness • Promote innovations with social and economic impact
Vinnova	Sweden	Innovation agency or council	2001-present	EUR 280 million	• Promote sustainable growth by improving the conditions for innovation • Stimulate co-operation between firms, universities and public services • Societal challenges at the heart of the strategy
Presidential Advisory Council on Science and Technology (PACST)	Korea	Innovation agency or council	1991-present	N/A (operational budget)	• Advise and help the President define medium- and long-term science and technology policies • Revise the science and innovation policies of the different ministries to ensure they are coherent

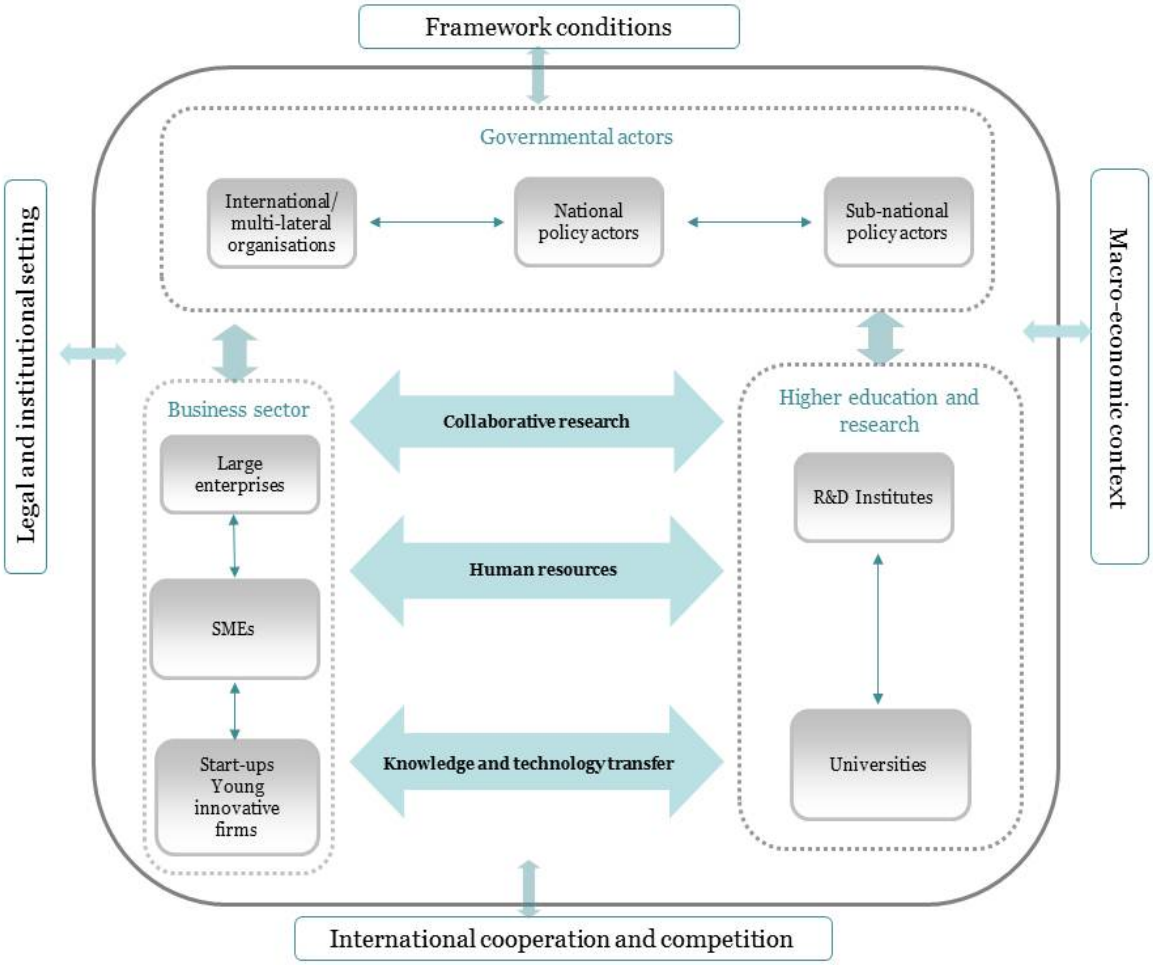
Source: OECD.

2. A growing complexity of public policies for research and innovation

After market failures and failures in the innovation system, the policy system in most developed countries is now facing transition failures (Weber and Rohracher, 2012[2]):

- **Market failures**: In the first instance, innovation policies attempt to compensate for market failures, resulting in sub-optimal investment in research and innovation. As knowledge is a public good, it is only very rarely possible for a private actor to appropriate the entire benefits of an invention (Arrow, 1962[3]). Moreover, the technological risk incurred is very high, meaning that market mechanisms will produce a level of investment in research that is well below the socially optimal level. This is especially true in the upstream phase of basic research, whose results are openly published for the good of all and where the risks of failure with regard to technological barriers are the highest. This situation justifies an important intervention by the State in the financing of basic research, as well as in some aspects of innovation.
- **Systemic failures**: The national innovation system (Figure 1) explains the role of the actors who contribute to the final result of skill creation and commercialisation, as well as the relationships that must unite them. This framework, introduced by Freeman in 1987 (Freeman, 1987[4]), has been studied in detail by the OECD (OECD, 2002[5]), and has served as a benchmark for the OECD country reviews of the last two decades (OECD, n.d.[6]). This approach develops an overview and seeks to identify "bottlenecks" in order to promote a more fluid functioning overall. These "bottlenecks" or systemic failures can apply in the first place to knowledge dissemination mechanisms, and even co-creation and innovation mechanisms. Indeed, the linear model that consists in "driving" knowledge from basic research to innovation and the market is outdated at the present time. Instead, there is talk of creating networks of actors who all take an active role in co-creation (Guimón and Paunov, 2018[7]). In this case, government action therefore consists first in facilitating exchanges between groups of actors and improving capacities for knowledge communication and absorption.

Figure 1. National innovation system



Source: OECD.

- **Transition failures**: The growing focus on resolving societal challenges such as the United Nations Sustainable Development Goals has led to an increased role for research and innovation – research and innovation must not only support competitiveness and economic growth, but also contribute to resolving societal challenges (Weber and Rohracher, 2012[2]). Some technological transitions are in fact vectors of societal transformation and contribute directly to resolving societal challenges – such is the case of the mobility transition, where electrical power replaces internal combustion, helping to limit carbon emissions. This encourages governments to go beyond market failures and system failures to attempt to drive (rather than be subject to) technological transitions that support societal challenges.

The new paradigms complement, rather than replace, the old ones – a "multi-layer" vision of public policies should be adopted, where "transformative" innovation policy superimposes itself on traditional science and technology policies on the one hand, and on the innovation system on the other hand (Diercks, Larsen and Steward, 2019[8]).

This results from a superposition of policies where "mission-oriented" policies – supposed to contribute to resolving societal challenges – overlap with more traditional policies supporting national competitiveness, centred on industrial sectors and/or specific technologies.

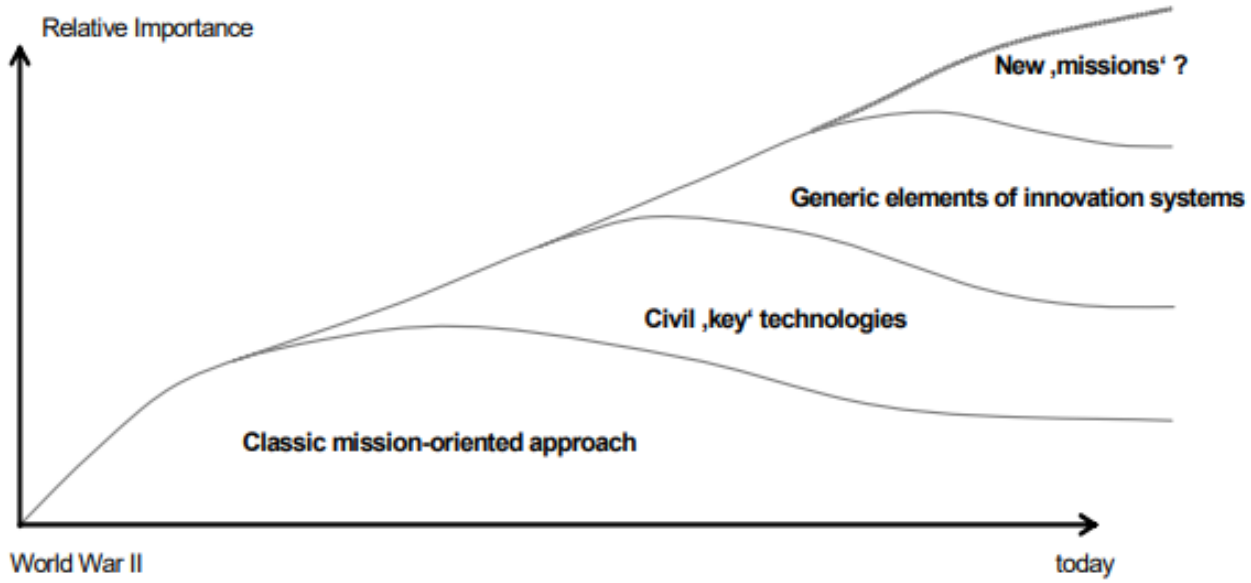
Indeed, Gassler, Polt and Rammer distinguish four phases in the history of science, technology and innovation policies (Gassler, Polt and Rammer, 2007[9]):

1. "Traditional" mission-oriented policies, centred on defence applications in the years 1940/50
2. Industrial policy, which expands this approach towards key civilian technologies in the years 1960/70
3. A systemic approach focusing on the construction of a national innovation system
4. A "new" approach to "mission-oriented" policies that attempt to mitigate societal challenges".

At first glance, the top-down approach of new mission-oriented policies can resemble the great programmes of yore, where a powerful government determined the winners and fostered a policy promoting "national champions". In reality, the new mission-oriented policies have quite different characteristics:

- They are top-down initiatives responding to needs that are perceived as urgent by society (societal challenges), with strong political support (which has both advantages and disadvantages).
- These are not specific technologies – rather, they are multidisciplinary approaches around a given theme, like the issue of climate, which touches on energy, mobility, recycling, technologies and many others.
- These initiatives are not limited to technological obstacles that would then be "driven" towards application: diffusion and adoption are central to realising new missions.
- The initiatives must be designed in close collaboration with stakeholders, including civil society, scientists and the private sector.
- Governance challenges include a co-ordination phase with three dimensions: (i) government sectors; (ii) research disciplines; and (iii) increased international co-operation.

Figure 2. Trends in science, technology and innovation priorities



Source: (Gassler, Polt and Rammer, 2007[9]).

3. Strategic priorities

The vast majority of OECD countries (33 out of 35, or 94%) have national science, technology and innovation strategies (which go beyond the sole domain of research or the sole domain of industrial innovation) (Paunov and Borowiecki, 2018[10]). These strategies often put forward quantitative targets, primarily linked to total expenditure on R&D, expressed as a percentage of GDP (as in Germany, whose High-Tech Strategy aims to increase R&D expenditure to 3.5% of GDP and in the United Kingdom, where UK Research and Innovation aims to increase R&D expenditure to 2.4% of GDP by 2027), but also private-sector expenditure on R&D, the number of PhDs, the number of publications in the most-cited journals, patents, corporate researchers, participation in international programmes (for example, in Horizon 2020, international co-operation is included in the programme's transversal challenges, the goal being for country-specific objectives to support policy dialogue on research and innovation between the EU and third countries/regions[1]), as well as mobility between science and industry.

In line with the evolution of the policies discussed in the previous section, strategies often state goals combining scientific excellence, the development of key technologies to support competitiveness and resolving societal challenges:

- The traditional sectoral approach remains central, identifying priority sectors on which research efforts must focus, particularly as they relate to the third industrial revolution: digital, green growth, medical innovation and new cutting-edge industrial methods (nanotechnologies, biotechnology, space, etc.).
- A "mission-oriented" approach is increasingly complementing this traditional approach. Governments seek to achieve economic growth that is inclusive and sustainable in the context of major societal challenges like climate change, population ageing and digitalisation. Thus, 91% of countries have strategies that address societal challenges, and 76% of these strategies aim to support a sustainable economy (Paunov and Borowiecki, 2018[10]).

This is, for example, the case of the German High-Tech Strategy, which aims not only to contribute to Germany's attractiveness as a European research centre and improve its competitiveness on the international stage, but also, in its latest version (HTS2025), to tackle a number of societal challenges: health; environment; mobility; well-being; and technology. It should be noted, however, that the budgets of the High-Tech Strategy are still allocated by sector and not by challenge.

Similarly, in Norway, the Long-term Plan for Research and Higher Education combines three goals: achieve research excellence; increase the country's competitiveness; and resolve major societal challenges.

In Japan, the inter-ministerial Strategic Innovation Promotion (SIP) programme, which complements the science and technology strategy (Fifth Basic S&T Plan), aims to strengthen the country's economic growth and enhance its global industrial position. The SIP adopts a pragmatic approach, by defining objectives resulting from a compromise between societal challenges and the more short-term objectives of the private sector. For example, one of the objectives of the first phase of the SIP, "innovative combustion technology", while industrially oriented, should also contribute to the societal challenge of reducing greenhouse gas emissions.

In some countries, "mission-oriented" innovation policies become systemic public policies that drive research and innovation to respond to these grand challenges. They set bold strategic

directions and cause different sectors and stakeholders to interact (European Commission, 2018[11]). In his speech on the future of research and innovation in Europe in 2017, Carlos Moedas, Commissioner for Research, Science and Innovation of the European Commission, said: "We need to define missions that break down silos (…) We need to set our eyes on a specific target, and drive our scientific efforts towards reaching that target" (Moedas, 2017[12]).

The EU Horizon 2020 programme orients research and innovation towards providing a response to grand societal challenges, rather than focusing only on scientific disciplines or technological sectors. These seven grand societal challenges are: health and well-being; food security and sustainable use of resources; smart, green and integrated transport; climate action, environment, resource efficiency and raw materials; inclusive, innovative and reflective society; and secure societies. In the United Kingdom, the Industrial Strategy Challenge Fund of UK Research and Innovation must primarily invest in projects addressing the four grand challenges identified in the UK Industrial Strategy: Artificial Intelligence and Big Data; population ageing; clean growth; and future mobility.

To meet the programme priorities, special mechanisms promoting breakthrough innovations are often introduced. "Breakthrough innovations", unlike "classic" or "incremental" innovations, are decisive advances that lead to radical transformations by introducing a new product or service that has either strong growth potential or the capacity to render existing technologies obsolete (Egli, Johnstone and Menon, 2015[13]).

In the programmes under study, specific mechanisms supporting researchers, start-ups or SMEs that promote breakthrough innovations are often specifically present. The Enhanced European Innovation Council pilot, a transversal programme of Horizon 2020 in Europe, aims to support top-class innovators, start-ups, SMEs and researchers with radically different ideas who can create high-risk, breakthrough innovations with a strong potential to scale up internationally. In Germany, an agency dedicated to breakthrough innovations (Agentur zur Förderung von Sprunginnovationen) should be launched during the summer of 2019, following the model of DARPA in the United States. In the United Kingdom, Innovate UK (one of the agencies belonging to UKRI) allocates a budget of 20 million sterling pounds (22.5 million euros) to breakthrough innovations through its "Smart Grants". In Japan, the ImPACT (Impulsing Paradigm Change through Disruptive Technologies) programme, endowed with a budget of 450 million euros, aims to address societal challenges by supporting high-risk and high-impact research and development. Canada offers "Challenge Programmes" to catalyse high-risk transformative research with the potential to produce innovative scientific discoveries and technological breakthroughs, totalling 150 million Canadian dollars over five years. Singapore offers "NRF Investigatorships", grants up to 2 million euros over five years that allow mid-career researchers to undertake innovative, high-risk research and to become scientific leaders. Israel proposes assigning ratings to projects that promote high-risk ideas with a high potential for technological diffusion; it also supports "upstream" co-creation of projects between research and industry. In Sweden, Vinnova proposes a programme called "Ground-breaking Ideas on Industrial Development – Sustainable Industry", which finances feasibility studies for breakthrough ideas.

4. Institutional framework

4.1. The institutions responsible for defining the strategies – a necessary co-ordination

Different types of institutions are responsible for defining national science and innovation strategies. In 32% of OECD countries, a single ministry sets national science and innovation priorities, with specific ministries for research and innovation in 18% of OECD countries (Paunov and Borowiecki, 2018[10]). When a single ministry is responsible for designing science and innovation policies, this ministry often collaborates with other ministries. Such is the case in Norway, where the Ministry for Education and Research was responsible for designing the Long-term Plan for Research and Higher Education (LTP) in 2014 and revising it in 2018, in collaboration with other ministries. In Germany, The Ministry for Education and Research (BMBF) is the main ministry in charge of the High-Tech Strategy, but a number of other ministries were involved in the design of HTS2025, reflecting a pan-governmental approach.

Some OECD countries (32%) rely on national innovation councils to define science and innovation strategies. This is notably the case in the United States, where the National Science and Technology Council is charged with identifying R&D priorities that will guide federal agency programmes, as well as ensuring that policy decisions related to research and innovation are coherent with the President's objectives. In Korea, the Presidential Advisory Council on Science and Technology (PACST) helps the President define mid- and long-term policies on science and technology. In Israel, the Innovation Authority, in close collaboration with the Ministry of Finance, defined the county's main innovation strategy, which aims to transform Israel from a "start-up nation" to a "smart nation".

4.2. Implementing institutions: Quasi-generalised use of professional agencies

The mechanism for implementing public policies for science and innovation shows a quasi-systematic recourse (in 89% of OECD countries) to professional agencies for allocating project-based subsidies based on competitive calls for tender, according to a phenomenon of "agencification" that draws from the public policy theory of "New public management" (Egeberg and Trondal, 2009[14]). Between 2005 and 2016, ten OECD countries created new dedicated agencies to this aim. In about 40% of cases, a single national agency fulfils this role, while in the majority of countries there exist two or more agencies. This often depends on the disciplines, the most widespread example being the health field, which has a dedicated agency in Australia, the United States and Canada. In Germany, the Deutsche Forschungs Gemeinschaft (DFG) agency issues calls for projects, but some financings, like those provided by the hospital excellence centres, go through research institutes, in this case the Helmholz Gesellschaft, which itself obtains its financing from the Ministry of Education and Research. In the context of the European programme Horizon 2020, implementation is mostly done by agencies outside of the European Commission Directorates-General according to delegation agreements (Executive Agency for Research, Executive Agency for SMEs, Executive Agency for Innovation and Networks, and Executive Agency of the European Research Council), as well as the European Investment Bank in the context of the SME instrument. In some countries, the agencies have merged to create synergies, including in Denmark, Estonia and the United Kingdom, where UK Research and Innovation (UKRI) was created in 2018 following the publication of the report by Sir Paul Nurse recommending more synergies between the different research councils. UKRI brings together these seven councils, as well as Research England and Innovate UK.

As for institutional financing, it is primarily (~80%) allocated by ministries. Performance contracts are increasingly popular, introduced in 13 OECD countries (i.e. 37%) and in some regions in other countries (Scotland, some German *Länder*).

4.3. More widespread use of evaluations

Evaluation is increasingly important in order to justify public expenditure. In general, regulatory impact analysis (RIA) enabling ex-ante evaluation of the impact of the reforms is progressing in OECD countries, particularly with regard to the adoption of primary legislation. In the 2018 iREG ranking of RIAs, France ranks among the OECD average, whereas in 2015 it ranked slightly above the average. Between 2014 and 2017, Chile, Israel, Italy, Japan, Norway and Slovakia adopted enhanced RIA measures (OECD, 2018[15]).

More specifically in the field of science, technology and innovation policies, the ministries of education, research and/or innovation of 23 OECD countries out of 34 (68%) have set precise criteria and assessment protocols relative to the performance of higher education institutions, whether ex ante or ex post. Moreover, 19 OECD countries (56%) have set up agencies specialising in the assessment of tertiary education institutions as well as public research institutions, while in 11 countries (32%) this task is performed by ministries.

Initiatives under Canada's Innovation and Skills Plan are required to be evaluated on a programme-by-programme basis once every five years, while there is no evaluation of the overall Plan. These programme-specific evaluations will enable a government commitment to obtaining valid results and communicating them to Canadian citizens. To this end, defining the targets, indicators and evaluation stages allows assessing the progress accomplished. In the European Union, the interim report published in 2017 evaluates the progress of H2020 against its objectives and was prepared by the Evaluation Unit of the Commission's Directorate-General for Research and Innovation. In Germany, evaluation is performed by each ministry in charge of implementing the different components of the HTS.

4.4. Stakeholder participation takes place through research and innovation councils

Research and innovation councils are in place in 89% of OECD countries. In Germany, the High-Tech Forum, comprising 20 experts from research, the private sector and civil society, is the government's main advisory body on matters of research and innovation, and advises and accompanies the implementation of and developments in HTS. In the context of the Japanese SIP, collaboration with industry is strongly encouraged, not only in defining the programme's strategy and priorities, but also in participating in and contributing to projects. Civil society is active in the innovation councils of 15 OECD countries, and the private sector is active in 26 countries. Stakeholders can also sit on universities' supervisory boards. Civil society is also represented in the university advisory boards of 68% of OECD countries, while the private sector is represented in 74% of countries. Finally, with the development of the digital sector, online consultations have become the newest participatory mode. Thus, six OECD countries have resorted to online consultations during the process of defining their strategy. Canada, in particular, launched national consultations on the digital economy and data in 2018 in order to define the new data economy. In the Netherlands, the government launched a "National Research Agenda" strategy based on a consultation of Dutch citizens, who were invited to send science-related questions to a dedicated online platform. In total, 12 000 questions were sent by Dutch citizens; these questions were then analysed and grouped under 248 categories thanks to a word-processing software. Conferences were subsequently organised to aggregate these categories of questions into a final group of 140 questions, which then were used to define the priorities of

different national research organisations. When the National Research Agenda was published, over half of those who had sent in a question had received invitations to participate in the seminars, public meetings and online forums (OECD, 2017[16]).

4.5. A more inclusive, transparent and responsible mechanism

Despite difficulties, governments seek to implicate all stakeholders to dispel the "ivory tower" image that often accompanies science and technology. The point is to demonstrate that science, technology and innovation work for the population and can have an impact on daily life. These themes are often repeated in national strategies, which are increasingly "mission-oriented", aiming to resolve societal challenges (see the next section). This is also why evaluation is increasingly important, as shown by the comprehensive example of the Research Evaluation Framework (REF) in the United Kingdom (OECD, 2019). Professional implementation organisations for STI-related public policies, notably agencies, which are autonomous compared to ministries and thus run no risk of conflict of interest, further guarantee increased responsibility.

5. Budget and duration of initiatives

The initiatives' budgets are particularly important, particularly: what is the minimum budgetary level required to have a significant impact on policy objectives? Is there an ideal level of resource allocation? What budget level must be allocated to evaluation? What is the optimal duration of a programme? And so on. These are difficult questions, which it is not possible to answer precisely at this stage.

This study will nevertheless ty to bring a new light to this topic, given the levels of financing observed in the cases studied in this series of monographs. It is clear this does not represent a sample that is statistically significant or representative of all the policies – which is why any interpretation must be considered with caution.

Figures 3 show the distribution of initiatives by annual budget. Figure 3a represents the distribution of budgets over the population of the 74 cases studied in the six monographs, while Figure 3b reproduces their distribution over the entire STIP Compass database. A large dispersion can be observed, amounting to over more than four orders of magnitude. Indeed, the most modest initiatives mobilise annual budgets under 1 million euros, while the largest initiatives exceed 10 billion euros annually.[2] This dispersion is comparable when measured as a percentage of public expenditure on R&D (Figure 4).

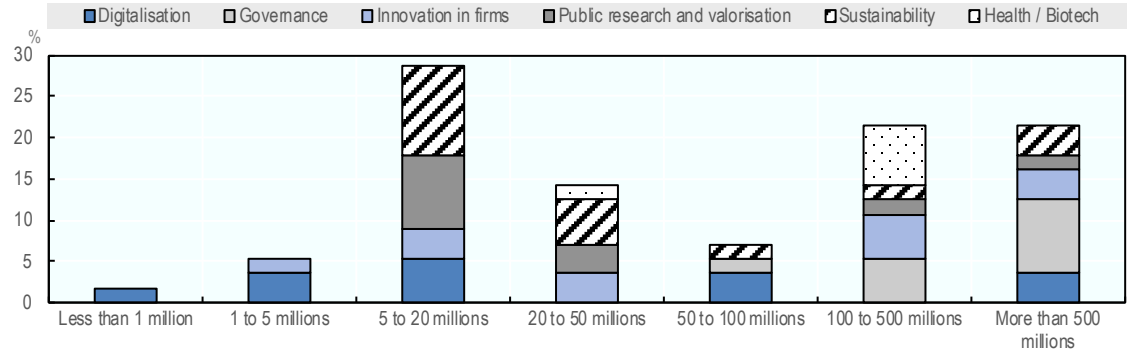
The comparison between Figure 3a and Figure 3b shows that the sample initiatives studied in the monographs focus more on initiatives with large budgets (100-500 million euros per year and more than 500 million euros per year), notably in the fields of governance, business innovation, health and research excellence. Initiatives with a limited budget (less than 5 million euros per year) are under-represented, and mid-sized initiatives (between 5 and 20 million euros per year) are over-represented, notably in the digital, sustainable development (smart cities) and research commercialisation fields.

The thematic monographs presented in this report show that:

- Digital initiatives amount to less than 20 million euros per year, except for some larger-scale recent initiatives on artificial intelligence (particularly AI Made in Germany and AI sector Deal in the United Kingdom).
- Initiatives related to the commercialisation of public research are modestly sized, between 7 and 30 million euros per year, while initiatives pertaining to research excellence have budgets reaching hundreds of millions of euros.
- The sustainable development field is also split in two, between initiatives ranging from several million to tens of millions of euros in the field of mobility, while larger-scale initiatives in the fields of energy and the energy transition can reach several billion euros (notably Energiewende in Germany).
- The corporate domain comprises different-sized programmes, from 3.5 million euros for the Danish MADE programme to 2 billion euros per year for the Small Business Innovation Research programme in the United States.
- Initiatives in the field of health are mostly endowed with budgets amounting to several hundred million euros per year.
- The governance field has the largest programmes, mostly exceeding one billion euros per year, with two initiatives exceeding 10 billion euros per year (the European Union

programme Horizon 2020 and the German High-Tech Strategy). The governance category also features some more modest programmes, such as the Japanese Strategic Innovation Programme and the Australian National Innovation and Science Agenda. The comprehensive STIP Compass database also includes a great number of more modest governance initiatives, amounting to less than 20 million euros.

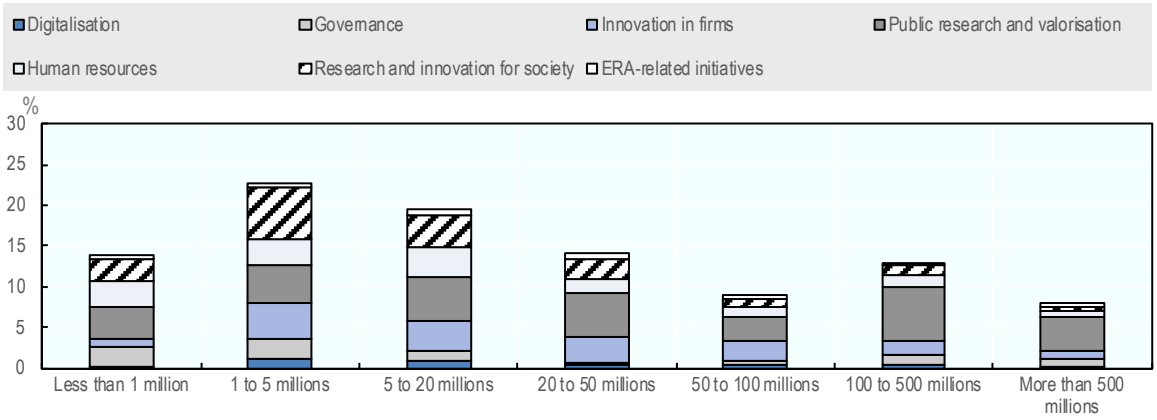
Figure 3a. Distribution of initiatives by annual budget – initiatives selected for the monographs



Source: OECD.

Figure 3b. Distribution of initiatives by annual budget – initiatives in the STIP Compass database for a selection of countries

Percentage of total number of initiatives



Note: Distribution by budget of initiatives informed by Australia, Austria, Canada, Germany, Denmark, Finland, Israel, Japan, Korea, Netherlands, Norway, Sweden, Switzerland, United Kingdom and United-States, fractional counts. This is not a sample that is statistically significant or representative of all the policies.
Source: OECD, based on the STIP Compass database (EC/OECD, 2018[17]).

Measured as a percentage of public expenditure on R&D, programme dispersion is almost as significant, with some programmes representing less than one-thousandth of total public expenditure, and others (mostly governance) programmes representing more than 50% of such expenditure (Figure 4).

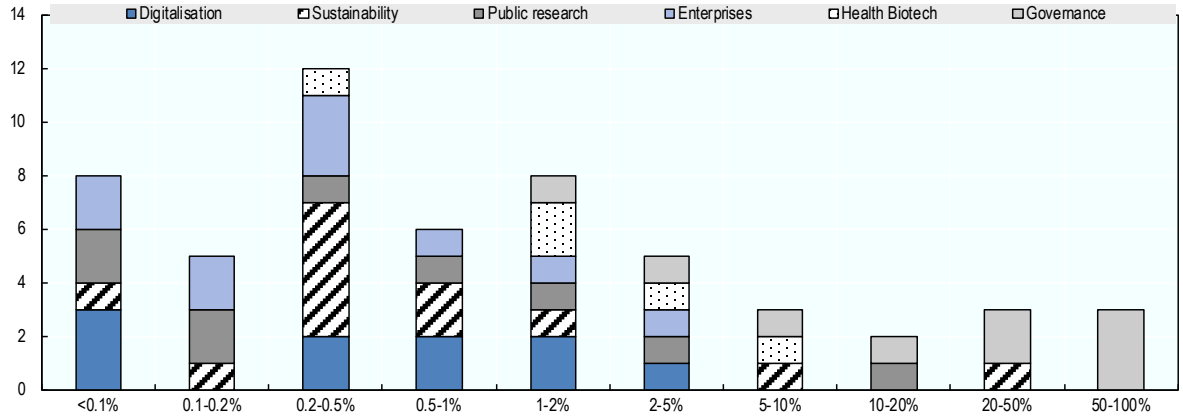
As concerns the budgets allocated to evaluation, the data are much less accessible and in most cases, precise numbers are not available. In fact, most evaluation initiatives are self-evaluations,

whose cost has not been calculated. Most of the initiatives observed show a weakness in the evaluation system, and respondents express the desire to enhance this mechanism in the future.

In the case of the Research Excellence Framework (REF)[3] deployed in the United Kingdom, which represents the most advanced effort to evaluate not only academic performance but also the socio-economic impact of research, the cost of the 2014 campaign was estimated by Technopolis at 246 billion pounds sterling, i.e. about 300 billion euros (Farla and Simmonds, 2015[18]). This cost is borne for the most part by the higher education community (94%) and in small part by financing agencies (6%). The cost borne by the higher education community represents about 1% of the total payroll costs over the measured period (six years).

Despite this relatively high cost, the report concludes that this mechanism has a strategic value added, which notably allows adding external evaluation as a complement to traditional performance evaluation tools. Moreover, the REF allows evaluating the socio-economic impact of research, which enables better steering, notably for mission-oriented policies.

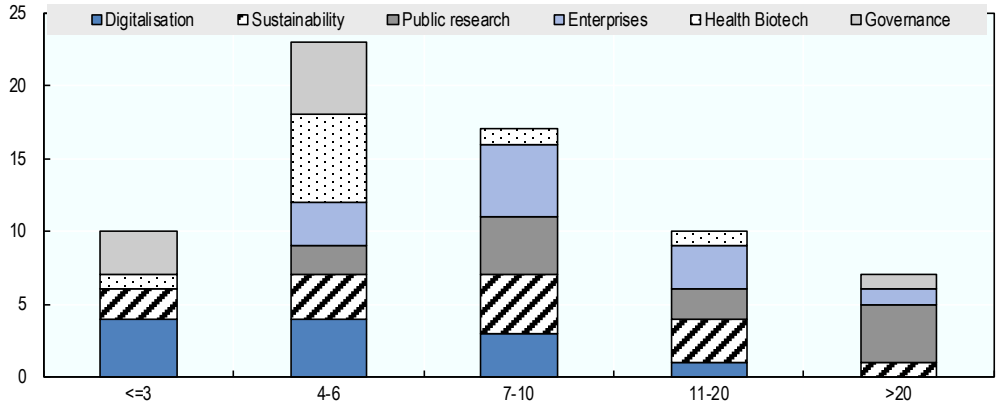
Figure 4. Distribution of initiatives as a fraction of total public expenditure on R&D



Source: OECD.

As regards the duration of the initiatives, the majority of the initiatives studied last between four and six years. In some countries, the initiatives' cycles are linked to legislative terms. Shorter initiatives are sometimes pilot initiatives aiming to produce more long-term programmes at a later date. A large number of long-term initiatives exist, some lasting several decades, especially in the field of research commercialisation (Figure 5).

Figure 5. Duration of initiatives



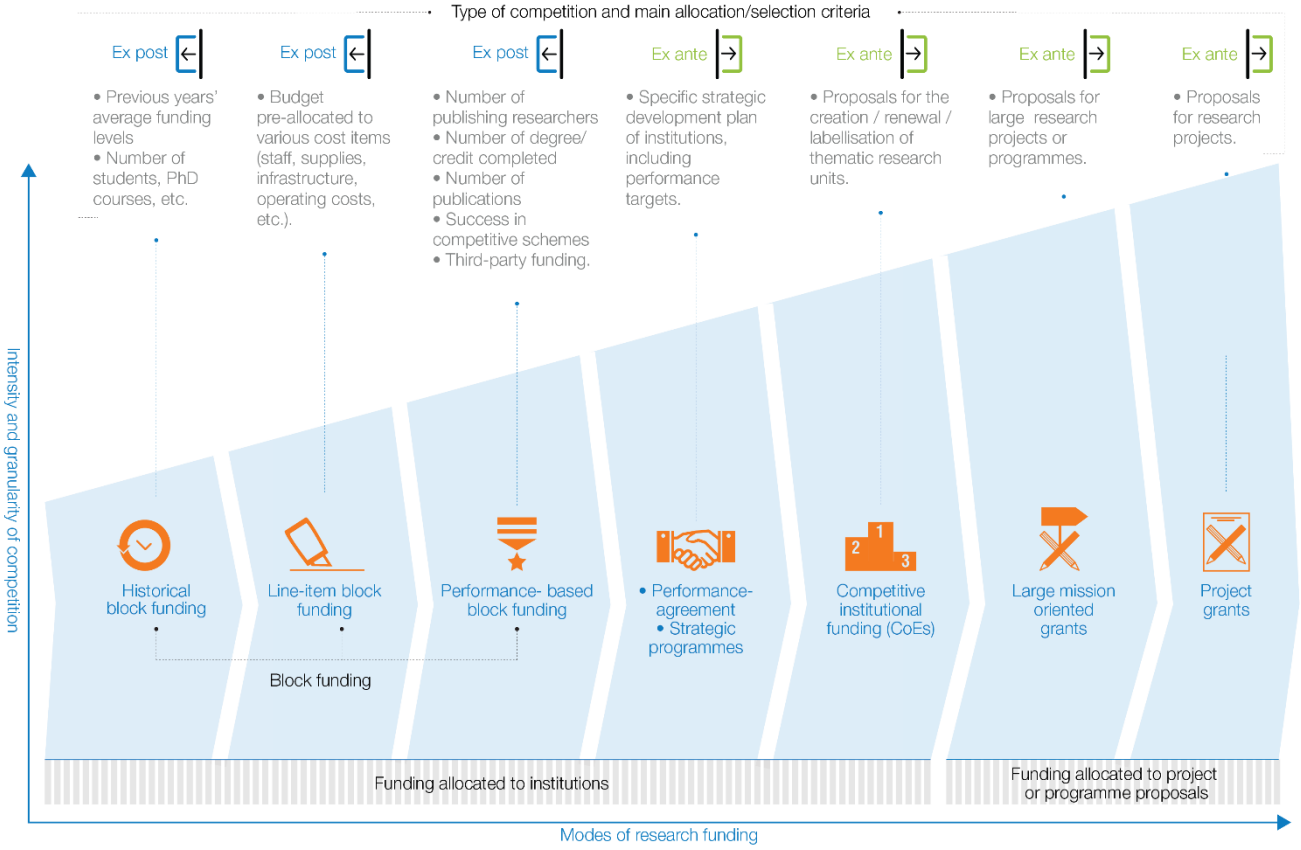
Source: OECD.

6. Instruments used

Numerous instruments are used to support science and innovation. They include direct subsidies, tax credits, loans, financial instruments, support for access to financial markets, regulation, intellectual property protection, public markets, networking support, competitiveness centres, training and other accompanying measures. According to the OECD-STIP database, the most popular instruments are direct financial support mechanisms, followed by collaborative platforms and infrastructures (networks, competitiveness centres),[4] regulatory instruments and finally, indirect financial support instruments, including tax credits (the following section proposes a detailed analysis of the evolution of instrument portfolios).

While the studied programmes rely on numerous instruments to support science and innovation, **direct subsidies** represent the bulk of the financing granted. They can take numerous forms and include block grants to universities and research institutes, with the possibility of performance contracts (notably in Germany and the United Kingdom), long-term financing and competitive project-based financing. These different instruments can be classified according to the financing mode, the degree of competitiveness for obtaining the financing and allocation criteria (ex post or ex ante) (Figure 6).

Figure 6. Classification of research-financing instruments



Source: (OECD, 2018[19]).

In the United Kingdom, for example, the Industrial Strategy Challenge Fund grants subsidies by issuing challenges linked to the four grand societal challenges identified by the government. In the European Union, research and innovation funding is offered to collaborative projects aiming to develop new knowledge. As for the SME Instrument, it specifically finances highly innovative SMEs. In Japan, in the context of the SIP, direct subsidies are granted to universities, research institutions or companies through calls for projects.

In addition to direct financing, OECD countries often rely on **tax credits** to support innovation. In many countries, tax credits represent the bulk of the aid granted for R&D performed by the private sector (OECD, 2019[20]). These tax credits can be extended to the firms themselves or investors who invest in innovating companies (as in Korea or Australia, for example). In Germany, one of the rare OECD countries that did not yet offer a tax credit, the High-Tech Strategy 2025 introduced a tax credit programme for R&D targeting important SMEs, which should be in place by January 2020.

Loans for SMEs are often included in the instruments used by the initiatives under study. In the United Kingdom, "Innovation Loans" granted by UKRI support SMEs that want to proceed to the final testing phases of their project. The amounts borrowed vary between 100 000 and 1 million pounds sterling.

Other financial instruments are offered to SMEs, such as **credit guarantees** and **equity and quasi-equity investment**. Although access to financial markets presents numerous advantages for SMEs (access to capital, increased visibility and credibility, access to a larger investor base, etc.), numerous obstacles exist, notably linked to narrow financial markets characterised by a lack of liquidity, a low number of participants and limited exit options for investors (OCDE, 2018[21]). This constitutes a market failure and justifies public investment in equity or credit guarantee to facilitate access to financing. In Europe, the InnovFin SME Guarantee and InnovFin Equity instruments offer credit guarantees and equity to SMEs and allow overcoming some of these difficulties. Mechanisms through which public investments encourage private investments also exist. In Australia, for example, the National Innovation and Science Agenda foresees co-investing in innovation funds to drive private investment. In Canada, the venture capital catalyst initiative increases venture capital financing for innovative companies while mobilising the private sector and other capital. Still in Canada, private-sector contributions are strongly encouraged through the innovation superclusters initiative, which requires that the requested project financing be accompanied by an equivalent contribution from industry.

Other types of instruments are also used:

- **Regulation**, with the establishment of standards, criteria or the introduction/amendment of laws supporting innovation: in Japan, for example, "sandbox" mechanisms with a differentiated and more flexible regulatory framework exist for innovative programmes, notably for experimenting with autonomous cars.
- **Strategies for protecting intellectual property**: in Canada, for example, the Intellectual Property Strategy aims to help Canadian entrepreneurs better understand and protect intellectual property, as well as obtain better access to shared intellectual property, notably by amending laws to eliminate obstacles to innovation and creating an independent oversight body.
- **Public markets:** they allow the public sector to support research and innovation by stimulating demand through public markets. This can be done in several ways: (i) functional tender specifications, rather than mechanisms allowing firms to propose innovative solutions (example: public tender for a solution to securely lock up schools, rather than for locks themselves); (ii) attribution of additional points for the development

of an innovation solution to public tenders; (iii) specific tender for "pre-competitive" innovations that open new markets (for example, for "green technologies"). This trend is growing. Indeed, while supply-side policies currently dominate policy composition, instruments related to public markets progressed faster than other instruments supporting firms between 2014 and 2016, and demand-based support should further develop in the five coming years (OECD, 2016[22]). In Canada, for example, Innovative Solutions Canada is a supply programme through which the government acts as the largest client of innovative SMEs, by proposing grand challenges and inviting innovators to find solutions. In Australia, the Business Research and Innovation Initiative asks SMEs to develop innovative solutions answering challenges in public policy and public-service provision.

- The **creation of networks** connecting firms and research, like the Catapult Centres in the United Kingdom, which are research centres specialising in specific technological domains and connect firms with the academic world in order to drive innovation and the development of new products and services until commercialisation ; or the creation of **competitiveness clusters**, as in Canada with the innovation superclusters.
- **Trainings and support**: for example, the Marie Sklodowska-Curie Actions within Horizon 2020, the ICURe (Innovation to Commercialisation of University Research) in the United Kingdom to help researchers commercialise their ideas and the Industrial Research Assistance Programme of the National Research Council Canada.

7. Evolution of the portfolio of science, technology and innovation policies

It is important to consider the evolution of the policy portfolio. Are the same policies being perpetuated over the years, or can new trends be detected? To attempt to answer this question, the STIP Compass, the joint science, technology and innovation database of the OECD and the European Commission (EC/OECD, 2018[17]), has been used.

Although the STIP Compass is not a longitudinal database, as it currently only features a sample of the public policies collected between 2012 and 2017, it is possible to identify policy portfolios according to the year of implementation of the policy. Two distinct portfolios could be identified: (i) the portfolio of policies initiated up to 2014 (some policies were initiated in 2000, or even before); (ii) the portfolio of policies initiated between 2015 and 2017. In a sense, the first represents the "heritage" of policies inherited from the past, while the second represents the portfolio of policies implemented in recent years.

Comparing the two portfolios by measuring the number of initiatives is a crude tool – it treats the initiatives on an equal footing and does not consider either the size or the complexity of the initiatives.[5] In the current state of the STIP Compass database, budget data are still insufficiently provided to allow refining the analysis.

Nevertheless, such a comparison allows observing a certain continuity between these two portfolios – with, however, some evolutions (Figure 7). Figure 8 shows the progression in the share of each instrument. These figures show coherent representation of the majority of policy categories, taking into account statistical errors. Significant differences are indicated with asterisks (*) when they have been determined with a confidence level above 90% and by a double asterisk (**) when the confidence level exceeds 99%.

Figure 9 combines both dimensions; it shows simultaneously each type of instrument's share in the recent portfolio (2015-17) on the horizontal axis, and its progression between 2014 and its current share on the vertical axis.

It is apparent that the portfolios are strongly concentrated: out of a total of 26 types of instruments, four types concentrate over 51% of all policy initiatives. These are the following categories: (i) strategies, agendas and national plans; (ii) subsidies for public research projects; (iii) subsidies for corporate R&D and innovation; (iv) clusters and other collaborative platforms and networking.

Among these four main types of instruments, a significant evolution can only be observed in the category of strategies, agendas and national plans, which represented 25% of the portfolio's initiatives in 2015-17, a relative progression of 40% compared to its share in 2014. This result must be interpreted with caution, as the number of existing strategies in 2014 may have been underestimated.[6] Still, this corresponds to an observed trend consisting in a multiplication of strategies in the case studies presented in these monographs: if historically there indeed existed science, technology and innovation strategies, current strategies cover precise topics, for example open science strategies or plans, artificial intelligence strategies, or bioeconomy strategies.

The three main instruments regarding subsidies and clusters do not show any significant evolution, and their representation in 2015-17 is statistically comparable to that observed in the existing portfolio in 2014.

For their part, public markets for research, development and innovation have progressed significantly, and their share has doubled from 1.7% of the portfolio in 2014 to 3.4% in 2015-17. As with the strategies, a bias owing to insufficient longitudinal coverage cannot be excluded – however, the effect is of such magnitude that it cannot result entirely from this bias.

The increased focus on demand policies has already been discussed in regard to policies aiming to address transition failings. Historically, policies targeting the innovation system focused on supply policies, but governments are increasingly resorting to public markets to find innovative solutions to societal challenges. The government acts as a buyer to initiate demand for solutions linked to the climate, population ageing, the decarbonised economy, biodiversity and other issues (Weber and Rohracher, 2012[2]).

Other types of instruments are growing as well, but in a less statistically significant manner. This is notably the case of innovation coupons, research tax credits for individuals and companies, stakeholder consultations, and public policy observatories and monitoring.

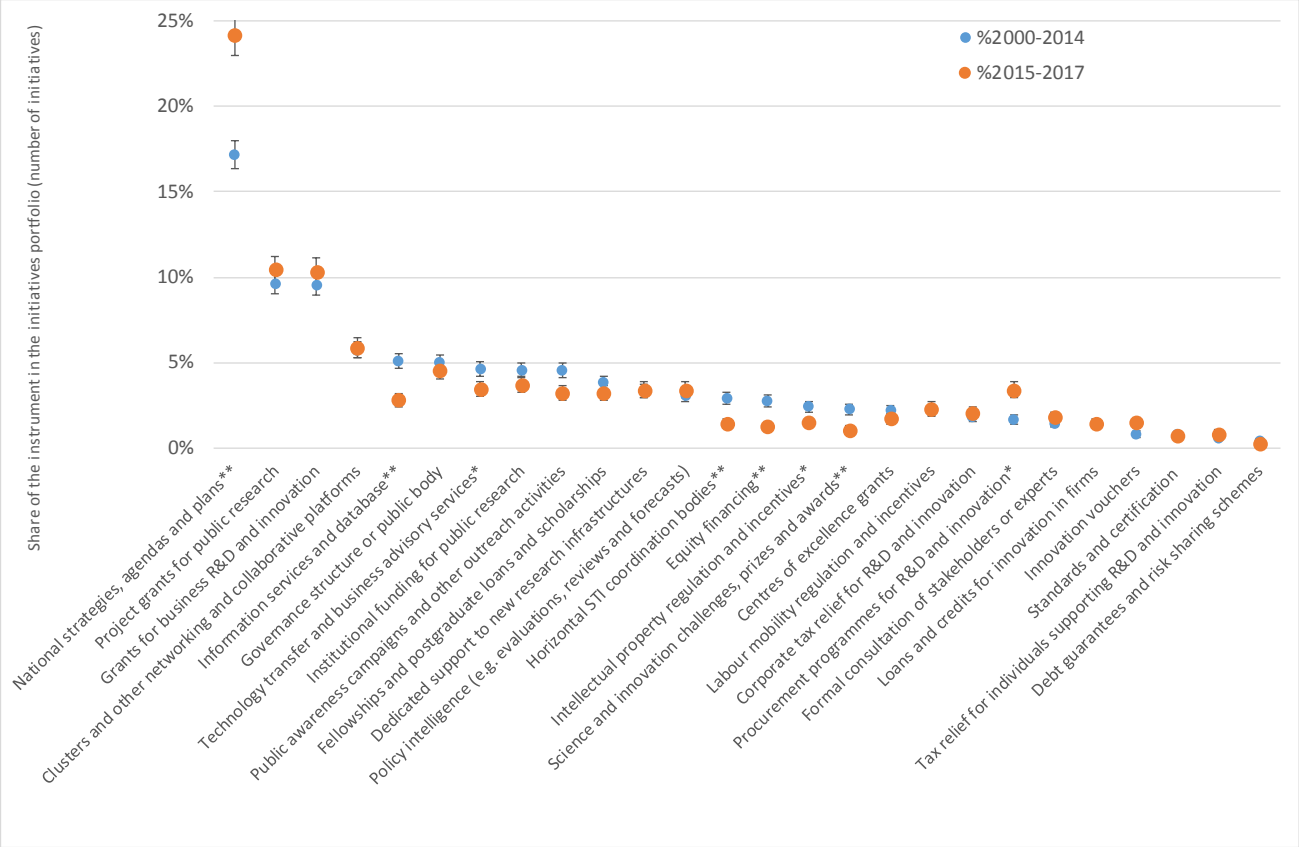
Several instruments are less represented among the 2015-17 initiatives, as follows:

- Technology transfer and business consulting have decreased by 25%. This may stem from the fact that the current approach favours "co-creation" between public research and industry over the historic approach of technology transfer inherited from the linear model of R&D and innovation. Indeed, governments are putting in place structures that allow public- and private-sector researchers to co-operate and co-create, such as the Catapult Centres in the United Kingdom, the university-industry collaboration centres in the United States and the collaborative laboratories CoLAB in Portugal (Guimón and Paunov, 2018[7]).
- Regulation and incentives related to intellectual property have decreased by 39%. It can be argued that regulation concerning intellectual property has reached a certain level of maturity and that the need to introduce new initiatives in this field has decreased. Moreover, incentive policies for individuals filing patents can generate undesirable effects, such as rewards for low-quality patents, thereby limiting their interest (Giarratana and Mariani, 2018[23]).
- Information technology and database services have decreased in relative terms by 45%, from 5.1% of the portfolio in 2014 to 2.8% between 2015 and 2017. After a very dynamic launch of the movement to open public data in 2008, the movement is slowing down somewhat; the watchword is no longer to open government data "by default", but to do so with a view to "publishing with purpose", taking into account the cost/benefit ratio.
- The creation of horizontal co-ordination agencies for STI has dropped by half – this can stem from the fact that almost all OECD countries (89%) have such a mechanism in place.
- Equity financing is also slowing down. Government intervention on the venture capital market is only justified in situations of market failure wherein private initiative is not yet developed. On the other hand, as soon as private actors take root, such an intervention is no longer justified and would constitute an eviction of the private sector.
- Finally, the introduction of competitions, prizes and distinctions for science and innovation is also strongly decreasing, as these mechanisms are already well established and do not require new reforms.

Finally, a great number of instruments continue to be represented today at similar levels than in the past, particularly such pillars of STI policy as subsidies for public research and corporate innovation, support for clusters and other networking platforms.

Figure 7. Portfolio of instruments as a share of policy initiatives

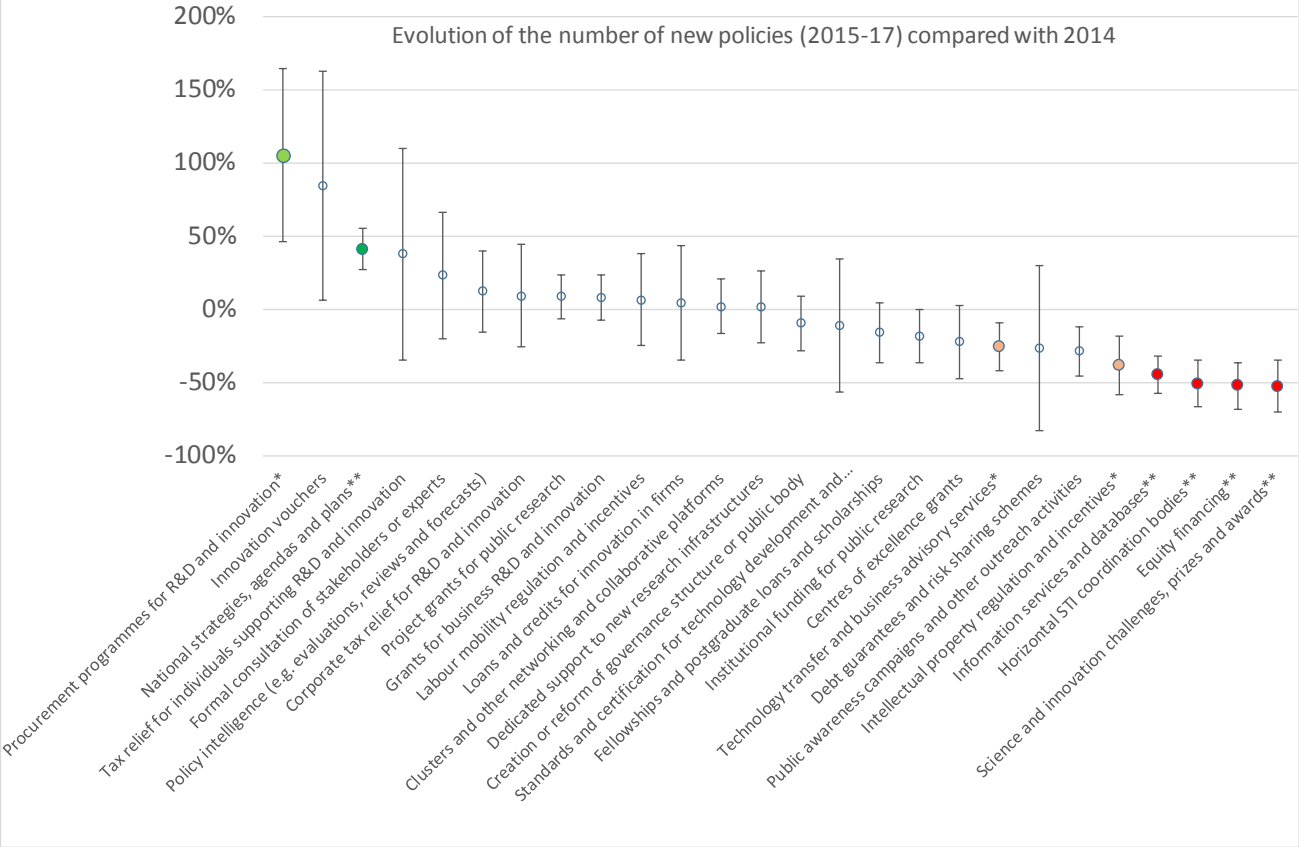
The figure compares the portfolio of policies introduced in 2015-17 to the composition of the portfolio in 2014 (percentage of the number of initiatives)



Note: The error bars represent statistical deviations. An asterisk (*) indicates policies that have progressed or regressed to a confidence level of 90% or more; two asterisks indicated policies that have progressed or regressed to a confidence level above 99%.
Source: STIP Compass database, OECD analysis.

Figure 8. Evolution of the number of policies, by instrument

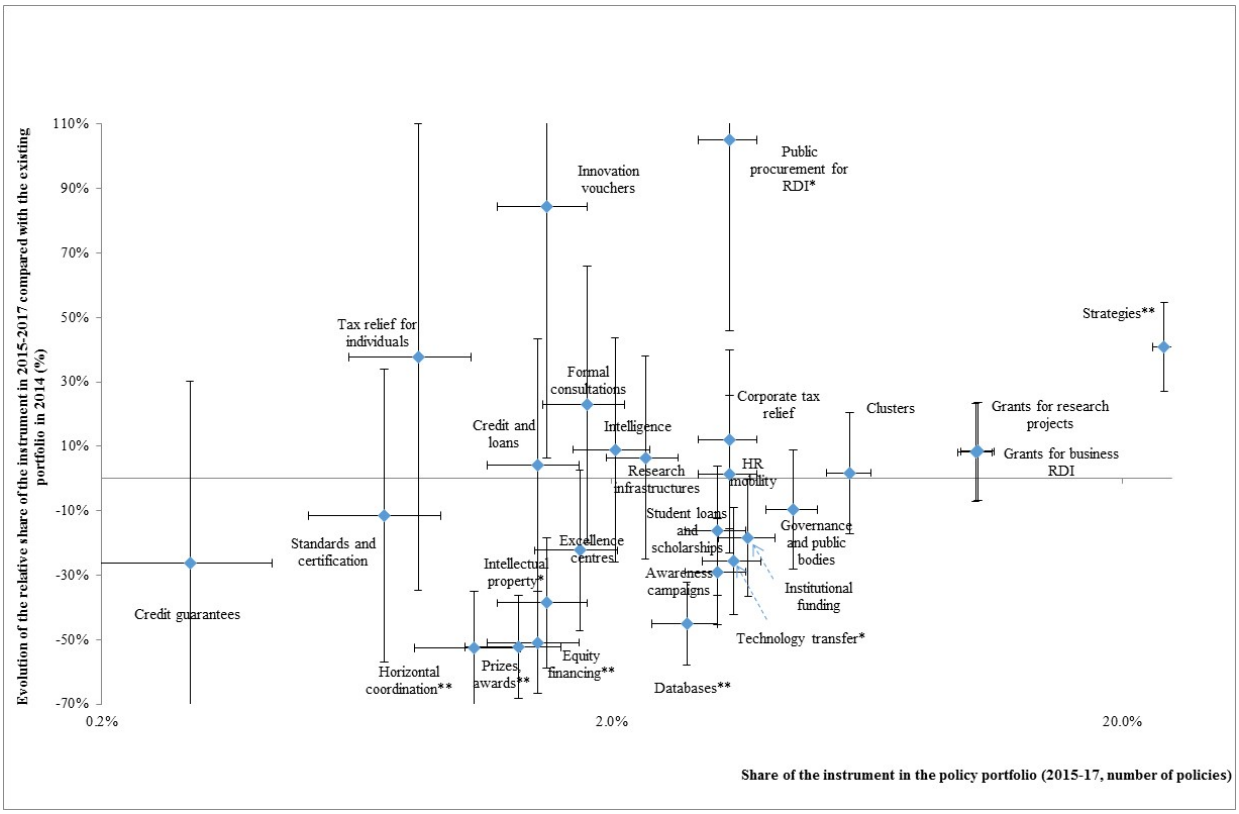
The figure represents the evolution (percentage) of the number of policies introduced in 2015-17 compared to the composition of the portfolio in 2014



Note: The error bars represent statistical deviations. An asterisk (*) indicates policies that have progressed or regressed to a confidence level of 90% or more; two asterisks indicated policies that have progressed or regressed to a confidence level above 99%.
Source: STIP Compass database, OECD analysis.

Figure 9. Composition of the STI policy portfolio and recent evolution

Results from the analysis of public policy portfolios in the STIP Compass database.



Note: The error bars represent statistical deviations. An asterisk (*) indicates policies that have progressed or regressed to a confidence level of 90% or more; two asterisks indicated policies that have progressed or regressed to a confidence level above 99%.
Source: STIP Compass database, OECD analysis.

8. Critical dimensions which facilitate success of governance initiatives

The study of different national or supranational – in the case of the European Union – science and innovation strategies allows identifying several critical dimensions that are common to the cases studied in these monographs:

- **Commitment at the highest level of government**. Implication at the highest level sends a signal to all the stakeholders that will follow, all the more so when the champion is in a high position. The success of the Japanese SIP initiative owes to the personal engagement of the Prime Minister and the fact the initiative falls under his purview, but also to the major role given to the programme directors, who enjoy a high level of autonomy. In the case of the Korean Presidential Advisory Council on Science and Technology (PACST), this entailed taking it to a higher level by subordinating it directly to the office of the President of the Republic, rather than the office of the Prime Minister, to grow its influence. In the case of the National Science and Technology Council (NSTC) in the United States, the agency's authority was deemed insufficient to allow it to stand its ground against the federal agencies, owing to a certain ambiguity pertaining to the roles shared with the White House's Office of Science and Technology Policy.
- **The implication of stakeholders, particularly civil society and the private sector,** in the design phase of public policies and the focus on co-operation between government, universities, research institutes, firms and civil society. Government action must aim to promote stakeholder networking and co-operation, smoothing exchanges between stakeholder groups and improving communication and knowledge absorption competencies. The active implication of stakeholders in the policy design phase is necessary to guarantee success during the implementation phase, which increasingly depends on multi-stakeholder co-operation to achieve objectives, notably those linked to societal challenges. The Norwegian government, for example, organises annual meetings to discuss the evolution of the implementation of the Long-Term Plan (LTP). The NSTC in the United States engages stakeholders in consultations and roundtables dedicated to different aspects of STI policies. In the case of the Israeli and Swedish innovation agencies, the policy design approach is bottom-up rather than top-down. This is the also the case of the Japanese SIP initiative, where the private sector is invited to co-build and co-finance the programme.
- **Strengthening the links between public research and the private sector.** Greater public-private collaboration in R&D is strongly encouraged, whether through approaches focusing on the commercialisation of the results of public research, technology transfer, open innovation or the concurrent implication of civil society. This is a strong trend, observed in all of the cases studied. For example, the RIE in Singapore uses performance indicators that measure the commercialisation of research results, the evolution of business investment in R&D and the creation of start-ups stemming from the plan. In Canada, such co-operation relies on innovation superclusters, whereby the requested project financing is accompanied by industry contribution at a one-to-one ratio. The downside of the private sector's strong implication can be a focus on short-term objectives to the detriment of a long-term vision, which should be monitored vigilantly by governments.

- **A definition of "mission-oriented" policies** aiming to resolve grand societal challenges, complementing historical approaches designed to support industrial production and the innovation system. This is meant to generate increased motivation among the actors – beyond remuneration and academic recognition, the awareness of contributing to a great and noble cause is an incentive for surpassing oneself. Motivated by the historical approach, which led to the conquest of space and advances in the field of defence or nuclear energy, mission-oriented policies today seek to orient programmes towards the resolution of challenges linked to the climate, ageing, sustainable mobility, biodiversity and other grand challenges. The European programme Horizon 2020 emphasises major societal challenges rather than disciplines. For the purpose of the 9th EU Framework Programme for Research and Innovation (FP9), stakeholders (particularly the Lamy report and the United Kingdom) recommend a more generalised adoption of a "mission-oriented" approach. The British agency UKRI also has an approach that is strongly oriented towards the resolution of societal challenges and missions.
- **The coherence of actions** implemented with specific objectives, particularly in light of the multiplicity and diversity of instruments used and the numerous interactions between the involved sectors. Indeed, policy coherence is essential, because it promotes synergies between actions and prevents potentially negative impacts. A policy's coherence can be defined at two levels: [7]
  - Institutional: ensure political engagement around objectives; establish co-ordination mechanisms at the governmental level (ensure horizontal co-ordination between ministries and horizontal co-ordination between the local, regional, national and international levels) and the different stakeholders;
  - Sectorial interactions: ensure that the measures implemented in different sectors are complementary.

  To ensure the coherence of science, technology and innovation policies, some OECD countries have established innovation councils. This is the case in the United States in particular, with the National Science and Technology Council, whose main purpose is to guarantee the coherence of all the measures implemented at the federal level with the President's objectives for STI. In Korea, the Presidential Advisory Council on Science and Technology (PACST) helps the President define medium- and long-term science and technology policies. In Israel, the Innovation Authority, in close collaboration with the Ministry of Finance, developed the country's main innovation strategy, whose purpose is have Israel evolve from a "start-up nation" to a "smart nation". In the case of the United Kingdom, the creation of a single agency, UKRI, following the merger of several sectoral research councils ensures sectoral coherence.
- **Continuous evaluation and improvement.** Major programmes operate in cycles (adoption-implementation-evaluation-adjustment). Indeed, adjustments based on evaluations of previous programmes are a critical dimension. However, evaluations are rarely complete and are often based on qualitative and semi-quantitative analyses, rather than empirical analyses with use of a counterfactual. In reality, the quantitative impact of research is very difficult to determine; even in the British case of the Research Excellence Framework (REF), which mobilised in 300 million euros in resources for a single evaluation, the result is descriptive and presented in the form of case studies.
- **Flexibility in setting priorities.** Increasingly rapid technological and societal evolutions call for quick reorientations of policies. Policy development sometimes

requires consultations and long consensus-building processes, but parallel working groups and ad hoc committees must have room to manoeuvre in order to react more quickly to contextual evolutions. Thus, the action plan for the Korean Basic Plan is revised every year, the NSTC in the United States allows for creating working groups in crisis situations (for example, Ebola), and Singapore reorients sectoral priorities. The European programme Horizon 2020, on the other hand, is not very flexible and is lagging considerably in some technologies.

- **Harmonisation and rationalisation of available programmes**, to simplify and optimise target stakeholders' access to the available subsidies and programmes. The large number of instruments and programmes available in most of the strategies studied makes it difficult for users to navigate among them and increases the risk of duplication. Rationalising and simplifying the programmes, limiting the number of calls and proposing a single "window" for users are ways to enhance efficiency in the granting of finance, reduce administrative costs (for participants and programme administrators), and maximise the impact of the strategy put in place. The European programme Horizon 2020 was able to reduce administrative delays and costs by relying on executive agencies to implement the programmes. Canada harmonised and simplified federal innovation support programmes by concentrating programmes (2/3 reduction in the number of programmes, with an increased total budget) and establishing the "Innovation Canada" platform, which proposes a single window for entrepreneurs and innovators. The Israeli innovation agency also aims to reduce administrative delays by calling on its network of technical experts capable of rapidly assessing applications.

Endnotes

[1] http://www.horizon2020.gouv.fr/cid76675/les-mesures-specifiques-cooperation-internationale-dans-horizon-2020.html.

[2] Indeed, the category above 500 million euros includes the European programme Horizon 2020, with more than 11 billion euros, and the German High-Tech Strategy, with 15 billion euros per year.

[3] Case described in Monograph 3: Public research.

[4] For a discussion on clusters and networks, see Monograph 4.

[5] The analysis was done for 43 countries and the European Union. Some countries such as the United States and Israel for which too few data are available, are not included in the analysis.

[6] Indeed, as strategies are instruments with a typical duration of four-five years, it is possible that an important number of strategies devised before 2014 had expired in 2017 when the questionnaire was filled and are therefore not mentioned. Only a longitudinal follow-up of the STIP Compass database could validate or invalidate this observation.

[7] The notion of coherence is particularly important in development policies and principles to ensure the policy coherence for development (PCD) have been defined by the OECD (OECD, 2018[24]).

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