

Introduction. Understanding vertical and horizontal complexities in public research funding

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To be cited as:

Lepori B., Jongbloed B., Hicks D. (2023), Introduction. Understanding vertical and horizontal complexities in public research funding, In: Lepori B., Jongbloed B., Hicks D., Handbook of Public Research Funding, Edward Elgar Publishing, forthcoming in 2023.

1 Background and objectives

Scientific research requires resources – financial, human, infrastructural, legal, social, and cultural, whose provision is an ever more expensive and complex undertaking. This Handbook explores the financing of scientific research by national governments and the European Union. Since WWII, the increasing importance of knowledge for society and the economy has encouraged governments to adopt research policy and funding as a 'new' core task. Research policy bridges the state and the science system (Guston, 2000) mainly through the distribution of public subsidies (Braun and Gilardi, 2006). According to OECD estimates, OECD governments spent \$497 billion on research and development in 2020, an amount that doubled over the past 15 years (OECD, 2021). This expanding commitment speaks to governments' hopes that research will support economic growth, create jobs, enhance social welfare, protect the environment, and expand the frontiers of human knowledge.

The level of public resources invested in science differs between countries (Larrue *et al*, 2018) depending on the challenges the country faces, its government's ambitions, and political leaders beliefs about the function of the state in research and innovation systems – on how much direction should be given by the state and how much funding should be made available for which objectives (and challenges). This Handbook discusses the underlying ideas and rationales for investing public funds in the research activities carried out by universities, public research organizations (PROs), and government labs. It compares the political economy of science funding (e.g., Martin and Nightingale, 2000) and the various coordination roles governments play in research funding systems (Lepori, 2011) to better understand countries' research funding regimes.

Government provides research funding to universities, the leading research performers, as recurrent funds, selective, competitive funds, or combinations of the two. Various governmental agencies working at (or in-between) different levels, semi-public organizations, and research councils are involved in deciding on research resources and the purposes and conditions attached (Larrue *et al*, 2018). This Handbook analyses the types and channels of funding, modalities to distribute funds, eligibility requirements, and other conditions connected to the research funds. The chapters also discuss how resource allocation functions at the level of the research performers – the universities, PROs, research groups, and individual researchers – and what strategies these entities employ in reaction to trends and reforms in their funding environment. Universities and PROs are encouraged to generate and (to different degrees) compete for these financial resources (Krücken, 2019). However, they are increasingly required to collaborate with other public and private partners and work across disciplinary borders to develop social and technological innovations.

Most governments aim to achieve multiple goals by funding research-performing organizations. In broad terms, they look for: (1) excellent ('breakthrough') research (Dasgupta and David, 1994), (2) research used by society (e.g., Hessels and Freeman, 2010), (3) the build-up of research capacity and research skills (Boud and Lee, 2009), and (4) efficiency in the use of public resources (Hicks, 2012). In this mix, fostering excellence in science has been a critical objective of many governments (Moore *et al*, 2017). The funding instruments employed to encourage breakthroughs in research and the creation of clusters of excellence are therefore also discussed in this Handbook, along with the accompanying excellence initiatives and their effects – intended as well as unintended.

The objectives of encouraging excellence in science and, simultaneously, encouraging research that contributes to technological and social innovation are closely connected to the balance between a top-down versus a bottom-up approach in science funding. The top-down approach relates to funding earmarked by funding agencies for specific research projects. In contrast, bottom-up approaches leave considerably more degrees of freedom to researchers and research groups to set their own research agenda.

The top-down approach is finding favor as research and innovation systems worldwide undergo fundamental change due to new societal challenges. To tackle those challenges – also known as the Sustainable Development Goals (SDGs) – governments are enlisting universities and PROs using targeted research programs and other financial incentives. Researchers and their organizations are challenged to reposition themselves – even transform themselves – in this new funding environment to perform their public duty. Here the idea of mission orientation has become increasingly popular (Mazzucato, 2018). Mission-oriented research and innovation policies address the grand societal challenges, such as climate change, energy transition, or the digital divide in societies. Mission-oriented funding encourages stakeholders from different backgrounds (both public and private) to collaborate on tackling big challenges ('missions').

The contributors to this book offer a critical analysis of the changing rationales for public support for research. They present insights into how the mechanisms of public research funding have changed over time and how funding arrangements interact with other elements in national research and innovation systems. The authors employ a range of theoretical perspectives, using approaches from economics (e.g., innovation economics, institutional economics, principal-agent theory), sociology (i.e., sociology of organizations, sociology of science), political theory, and public administration.

Handbooks that collect the multiple perspectives, strategies, and viewpoints related to the public funding of science do not exist. There are handbooks on science and public policy (e.g., Simon *et al*, 2019a), on innovation (e.g., Fagerberg *et al*, 2005), and on the economics of innovation (Hall and Rosenberg, 2010). And this Handbook overlaps with them, for example, regarding the governance of science, technology, and innovation systems (e.g., Kuhlmann and Ordóñez-Matamoros, 2017). Still, these books primarily focus on the role of public funding and R&D tax incentives for industrial innovation or on support for entrepreneurship and innovators. Therefore, we believe that this Handbook fills a critical gap given the state's prominent role in supporting science.

As we highlight in the following sections, the research policy and funding landscape has become increasingly complex and differentiated in terms of the underlying rationales (Elzinga, 2012), of the mix of instruments adopted to implement policies (Flanagan *et al*, 2011; Capano *et al*, 2020) and of actors and organizational arrangements involved in the management of funding (Simon *et al*, 2019b). We offer this Handbook as a first attempt to grapple with the full complexity developing in research systems in the hope that it will help ground future work developing analyses able to encompass this complexity.

2 Ideas and narratives. From the endless frontier to grand challenges

The chapters in this handbook address questions raised by structural shifts in the research funding system over the past several decades (Elzinga, 2012). After the success demonstrated by science in

World War II with the invention of penicillin, radar, and the nuclear bomb, governments came to believe that supporting research was essential and would lead to health and prosperity. Spurred by Vannevar Bush's work in WWI and his subsequent report *Science: the Endless Frontier*, the US government established research grant funding in many agencies and founded the National Science Foundation as the focus for basic research across all fields of science. European governments provided universities with core, block, or institutional funding based on historical factors and a size-based formula. Under these arrangements, the research community had professional autonomy. Competitively awarded research grants were also available to fund specific, expensive projects. The post-war era is often looked back upon as a kind of golden age for science when growth in budgets could accommodate growth in the scientific community, and university expansion offered faculty jobs for most new PhDs (Stephan, 2013).

At this time, the foundational justifications for public science funding were articulated in the seminal work of Nelson (Nelson, 1959) and Arrow (Arrow, 1962). Their research pointed to market failures in the production of scientific research and stressed the need for governments to support research – in particular, the types of research for which there is little immediate demand in the market. Governments allocate public funding to researchers and to the universities and PROs that employ them in hopes of societal benefits, and scientists were granted autonomy to pursue those goals with integrity. Governments' expectations of something in return, high-quality research and useful knowledge, meant a mutual dependency between funders and research performers developed, with mutual benefits. This relationship has often been referred to as a social contract (Guston and Keniston, 1994).

The classic classifications of research activity were also established in this era. In 1963 a group of OECD and science indicator experts met in Frascati, Italy, and produced the first edition of the Frascati Manual to set out a standard methodology for collecting statistics about research funding. The Frascati Manual classification of research activities into basic, applied, and development has featured in research funding statistics ever since (OECD, 2015).

After several decades, international economic competition heightened, government budgets tightened, and research funding arrangements evolved in directions less congenial for the research community (Geuna, 2001; Martin, 2003). Concepts such as 'academic capitalism' (Slaughter and Rhoades, 2004) and New Public Management (Ferlie *et al*, 2008) emerged to frame thinking on how to allocate public research funding. These policy models promoted the notion that competition and economic incentives are better ways to achieve policy goals, even in research and higher education (Capano, 2011). They generated a move from institutional funding based on block grants (with significant degrees of freedom for those receiving the funds) to funding increasingly tied to measures of performance and policy goals (Geuna, 2001; Stephan, 1996; Hicks, 2012). At the same time, a tendency could be observed to make research performing organizations rely more on funding for research projects, awarded based on competition between proposals submitted by investigators. Such project funding is limited in scope, budget and time (Lepori, Van den Besselaar *et al*, 2007). With the increase in project funding, we see the emergence of a mixed model, where universities and public research organizations are increasingly competing for funds and therefore influenced by research priorities and conditions set by funders.

When the emphasis on project grants increased, so did the competition, resulting in lower overall success rates for grant proposals (Lepori *et al*, 2007). Funders' increased research evaluation and specification of goals reduced researcher autonomy (Whitley *et al*, 2018). Many chapters in this Handbook examine the resulting tensions: concentration of resources (Bloch, Kladakakis and Sörensen, chapter 8; Jappe and Heinze, chapter 13), increased competition (Arora-Jonsson, Brunsson and Edlund, chapter 11), effects on universities (Kivisto and Mathies, chapter 12) and public research institutes (Cruz-Castro and Sanz, chapter 14) and researchers (Laudel, chapter 16) as well as the complexities of designing such public funding instruments (Sivertsen, chapter 6).

Governments also began to focus on the results achieved by national research enterprises (Reale, Scherngell and Gulbrandsen, chapter 7). In the US, the discussion was of the changing social contract, expecting university research to develop a more direct relationship to innovation and the market, for example, universities patenting their research results. In Europe, the European Framework programs exemplified government interest in new technology and innovation, funding projects directed to specified goals. The classic basic, applied, and development classification began to seem too limited. Alternatives were proposed, such as Pasteur's Quadrant, which recognized that research could be motivated by both the quest for fundamental understanding and considerations of use (Stokes, 1997), or Mode 2, which emphasized research conducted in the context of application (Gibbons *et al*, 1994). Both frameworks transcended the basic/applied research categorization and allowed for research that addressed combinations of intellectual and practical problems (Hicks, 2016).

Through the Framework program, the EU also hoped to raise European research spending to 3% of GDP; strengthen the research efforts of weaker countries, and close the technology gap with the US and Asia. In chapter 4, Ulicanic tracks the advent and growth of these programs attending to the extent to which their goals were achieved. In Asia, countries successfully built high-tech economies through strategic support of applied research and innovation. Kim (chapter 22) explores the extent to which current research funding programs in Asian countries reflect these historical origins and the tensions that result. The differences between funding systems and their evolution can be understood with reference to broader differences in the type of capitalism and governance in each country (Begin-Caouette, Nakano Koga and Maltais, chapter 20).

Currently, we are witnessing another addition to research funding rationales, with attention turning to grand societal challenges, UN sustainable development goals (SDGs), and fostering a transition to a greener energy mix (Simon *et al*, 2019; Mazzucato, 2018). Research funding statistics increasingly include breakdowns by purpose of funding. Bozeman (chapter 2) reminds us of the importance of this move towards framing research in terms of more than economic gain and addressing broader public values. However, the complexity of engaging research with these goals raises challenges for the design of funding programs. Previous, similarly motivated, research programs to develop cures for neglected diseases have not lived up to expectations. Coburn, Yaqub, and Chataway (chapter 10) identify their many challenges. The lessons learned should be heeded by those attempting to solve other societal challenges through research. Bühner, Seus and Walz delineate exactly how much a substantial funding program can by itself transform research into a transdisciplinary effort addressing grand challenges and argue for broader efforts to reform research institutions and incentives (chapter 9).

Research funding is also challenged to incorporate other dimensions into program design. Diversity, equity, and inclusion are receiving increased attention as well as responsible research. Several chapters examine the current state of support and programs that target different types of researchers. Cruz-Castro, Ginther and Sanz (chapter 18) provide a thorough review of our understanding of the extent to which women and underrepresented groups are disadvantaged under current funding policies. Melkers, Wooley and Kreth (chapter 17) itemize the American and European programs that offer support targeted to different stages of research career development.

None of these rationales has gone away; each shift simply adds another element to the mix. The complexity of funding program design is thus increasing (Reale, Gulbrandsen and Scherngell, chapter 7; Thomas and Ramos-Vielba, chapter 15). Scholars and policymakers tend to take for granted the high level capacity needed to administer constellations of modern research funding instruments. Rogers (chapter 21) makes visible this complexity in examining cases of countries that struggle to implement the programs that characterize modern research systems. As we demand that research funding address ever more dimensions of research systems, Rogers' chapter is a helpful reminder that we demand ever more capacity from government agencies.

3 Policy mixes and the complexity of funding instruments

As highlighted in the previous section, current science policies have become layered in their conceptual content and goals. While supporting basic science remains essential, funding systems also aim to foster economic innovation and enable societies to respond to grand challenges such as climate change. Moreover, while research inherently requires risk-taking and accepting failures and duplications, the research funding policy discourse also focuses on efficiency and evaluating the return on investment in public research. These inherent tensions generate complexities in the design of policy interventions that have to serve multiple ideologies and goals. Diversity of national contexts (Bégin-Caouette, Nakano Koga and Maltais, chapter 21) and the tendency of policy interventions to persist and accumulate over time further increase complexity. Therefore, current research funding systems are by and large incoherent accumulations of instruments (Aagaard, 2017) that have been mostly reformed rather than replaced as thinking shifted (Reale, Gulbrandsen and Scherngell, chapter 7).

Therefore, beyond individual interventions, the 'policy mix' matters for achieving policy goals (Kern *et al*, 2019). Reale, Gulbrandsen and Scherngell (chapter 7) suggest that differentiation of instruments and organizational settings is an important strategy to keep apart the potentially conflicting logics and goals of science policy (Skelcher and Smith, 2015). Yet most studies of research funding focus on single funding instruments, while how different instruments complement each other and interact at the performers' level remains under-investigated. The notion of 'funding configurations' put forward by Thomas and Ramos-Vielba (chapter 15) may represent a helpful tool in this direction. However, we still lack systematic studies of policy interactions in research funding and analytical categories to reduce the observed complexity (Capano and Pritoni, 2019; Cocos and Lepori, 2020).

As for individual instruments, a prominent characteristic of research funding instruments is the complexity of their 'delivery package' (Salamon, 2002), i.e., the concrete ways in which the instrument works. As shown extensively by Reale, Scherngell and Gulbrandsen (chapter 7), research funding programs vary in their goals and modes of intervention to select proposals, manage projects and evaluate results. These functions are managed in a complex setting characterized by different types of research funding organizations. Care is required when comparing national systems because the delivery of seemingly similar programs can be quite different (Flanagan *et al*, 2011). In the Handbook, Sivertsen (chapter 6) provides a rich account of the delivery of performance-based funding to universities. He demonstrates that how a university involves faculty and implements a national scheme largely accounts for the effects of the government's instrument and for its ability to affect research performers' behavior.

Along the same lines, both Kivistö and Mathies (chapter 12) and Reale, Gulbrandsen and Scherngell (chapter 7) display the lasting influence of principal-agent theory in the design of policy interventions in research funding and argue that in most situations encountered in research funding its core behavioral assumptions are not warranted, therefore potentially jeopardizing the achievement of policy goals. When analyzing the processes leading to the launch of research initiatives on rare diseases (Coburn, Yaqub and Chataway, chapter 10), and the impact on research of programs oriented towards ecological transition (Bührer, Seus and Walz, chapter 9), the authors indeed show that the assumption that research performers do what is requested by policymakers is simplistic. Instead, researchers deploy a wide range of strategies to 'capture' programs and exploit them to their own benefit (see Laudel, chapter 16).

As suggested by Capano (chapter 5), these remarks call for analysts of research funding systems to make use of concepts developed by political science to analyze policy mixes and instrument systems (Salamon, 2002) and their behavioral effects on performers (Vedung *et al*, 1998). Reale, Gulbrandsen and Scherngell (chapter 7) observe that research funding instruments are not just practical measures to distribute resources but are social institutions that convey cultural and normative contents to the actors in the field (Lascoumes and Le Galès, 2007). These institutional effects might be more potent

than (and not always aligned with) direct economic incentives and, for instance, provide legitimacy to the notion that scientists are competing against each other (Arora-Jonsson, Brunsson and Edlund, chapter 11; Squazzoni *et al*, 2013). Horta and Li (chapter 19) show that the adverse effects of such a competitive culture might well outweigh the direct benefits of economic incentives.

4 Structural disparities and actors' strategies

Public funding is not an end in itself. The financial transfers that governments make to research funding agencies, universities, PROs, and researchers are meant to advance knowledge and contribute to technological and societal innovation. However, funding allocations will also affect the distribution and concentration of financial resources across researchers and organisations. Some of these effects may be welcomed and are indeed intended by the entities responsible for funding allocations. This is the case for performance-based funding systems, which send research funds to places where performance is outstanding, or where there is the promise of excellent research. However, funding allocations may also lead to other, less desired and unintended effects. We suggest that policy and instruments' design should try to anticipate these unintended effects.

Quite a few of the chapters in this *Handbook* note disparities and inequities created by research funding policies that may favor certain types of institutions, research teams, researchers – and possibly also regions and countries. Competition for research funding may lead to a concentration of funds among fewer researchers.

Promoting excellent research is paramount in an increasing number of financing instruments (Basri and Glass, 2014). The excellence initiatives undertaken by national governments (e.g., in Germany, France, Australia, and in several Nordic countries) aim to increase research quality within the science system by providing selective support to a limited number of researchers or organizations that perform exceptionally well or show the potential to do so. These initiatives to concentrate resources coincide with a tendency toward increasing grant sizes and larger grant forms such as Centres of Excellence (see the chapter by Bloch, Kladakakis and Sörensen, chapter 8).

The concentration of resources and the increased competition for research grants might reinforce the Matthew effect (Merton, 1968; Bol *et al*, 2018) – the tendency for a scientist's past success to generate yet more success. This exacerbates uneven resource distribution, favouring those with early funding success and coming at the expense of less-well-established researchers. The distribution of research funding thus inevitably creates disparities at different levels: at the level of the science system, as well as at the level of individual researchers, institutions, regions, and disciplines. Alternative models for status-based competition aiming at redistributing resources in ways that can counteract the "Matthew effect" (the so-called "Mark effect", Bothner *et al*, 2011) have been proposed and would be worth exploring,

The tension between the goals of research excellence in science and an egalitarian distribution of resources is fundamental in science policy (Diana Hicks and J. Sylvan Katz, 2011). It appears in several places in this *Handbook*. For instance, the chapter by Jappe and Heinze (chapter 13) discusses prestige hierarchies at the organizational and individual levels in university systems that tend to predict funding concentrations (e.g., Lepori *et al*, 2015). The inequities in access to research funding for researchers in different stages of their careers are addressed by Melkers, Wolley, and Kreth (chapter 17). The chapter by Cruz-Castro, Ginther, and Sanz-Menéndez (chapter 18) reviews the relationship between research funding applications and grant recipients, on the one hand, and socioeconomic characteristics such as gender and ethnic background, on the other.

To prevent uneven funding allocations across institutions and regions, the stratification in research systems would need to be taken into account when designing research funding policies, such as the ones employed by the European Commission for allocating its Framework Programme funds and its structural funds across institutions and recipients located in the various EU Member States (Quaglio *et al*, 2020). To curb tendencies toward uncontrolled resource concentration, funding agencies may

design grants policies in ways that provide a more equitable allocation of funding, for instance by targeting researchers at different career stages, both for purposes of broader inclusion and to satisfy distinct career-building objectives. As argued by Cruz-Castro, Ginther, and Sanz-Menéndez (chapter 18), research remains largely inconclusive as to whether disparities are mainly the result of structural differences, self-selection, or the effect of different types of discrimination or bias during the review and allocation processes. This prompts a further examination of the sources of the disparities.

At the level of the individual researcher, Laudel (chapter 16) argues that the strategies employed by individual researchers for securing research funding are all about balancing the research portfolio with the external interests expressed in the funding instruments. The outcome will have consequences for the direction and quality of research. Therefore, she argues that the researchers' strategic responses – but also the potential strategies of research organisations (i.e., HEIs, PROs) – would have to be taken into account when funding instruments are designed.

Furthermore, organizations and scientists are not just passive recipients of policy interventions, but help shape the research and resource environment and, to some extent, co-design the funding policies (see the chapters by Sivertsen and Laudel in this *Handbook*). For instance, although public authorities can influence the intensity of the competition for research funds, the research community itself very much defines the criteria for and indicators of excellence. Researchers – again, overwhelmingly the more established and senior researchers – sit on funding councils and assessment committees and help decide who should be awarded grants and receive tenure or other forms of recognition (see also Braun, 1998). The degree and origin of the competition for funding and the resulting disparity in funding allocations for different types of researchers and institutions is an issue discussed, for instance, in the chapter by Arora-Jonsson, Brunsson and Edlund (chapter 11).

Involving the academic community in designing funding policies is vital to achieving policy goals. From the chapter by Coburn, Yaqub, and Chataway (chapter 10), we learn that the different degrees of involvement of particular communities and representatives in determining national research agendas are central to explaining the researchers' attention to particular grand societal challenges. Their chapter examines research programs targeting neglected tropical diseases that affect developing countries but receive relatively little funding support in rich countries. Research funding priorities thus can lead to disparities because priority setting is embedded in a wider governance system where multiple actors have different degrees of power to influence research agendas and public budgets.

Normative issues, political will and power, stakeholder interests, prioritisation, and the role of international donors and multinational corporate actors are addressed in a few places this *Handbook*, such as in the chapters by Coburn, Yaqub, and Chataway (chapter 10) and Bozeman (chapter 2). In many ways, this is about the political economy of science funding (e.g., Tandberg, 2010). One could argue that, similar to the discussion around innovation policy (Kuhlmann *et al*, 2010), the priorities, rationales, and instruments of research policy are the result of interactions between the actors involved in research, policy-making, and studying and overseeing research. As argued in the chapter by Bozeman, the research enterprise does not generally seek solutions to problems of broader public concern, as opposed to problems faced by corporations or the military. Hence, the calls for research funding that addresses the grand societal challenges (see above) and pays attention to the world's structural inequities. The chapter by Rogers (chapter 21), in particular, addresses the challenges faced by countries that do not possess a well-resourced and well-equipped research system and where there are multiple governance deficiencies in the research and innovation systems.

Internationally, disparities in scientific progress at the country level and – partly due to that – economic performance are evident and lead to the question of how countries that lag can catch up with the rest of the world. The targeted public investments in education, research, and innovation made by some of the countries in Eastern Asia have often been studied. The chapter by Kim (chapter 22) and also the chapter by Rogers (21) highlight the different elements in the development strategies and trajectories of these countries, such as priority setting for research funding in terms of foci and

the different types of public research, as well as the need to build up sufficient analytical and professional capacity in the (government) institutions supporting the academic research enterprise.

Countries and equally research organizations at various levels must make multiple trade-offs between the objectives of excellence, equity, relevance, efficiency, selectivity, and diversity in research funding. The chapters in our Handbook provide multiple examples of strategies and research policies to address these objectives while trying to remedy the disparities that might result from the distribution of research funds.

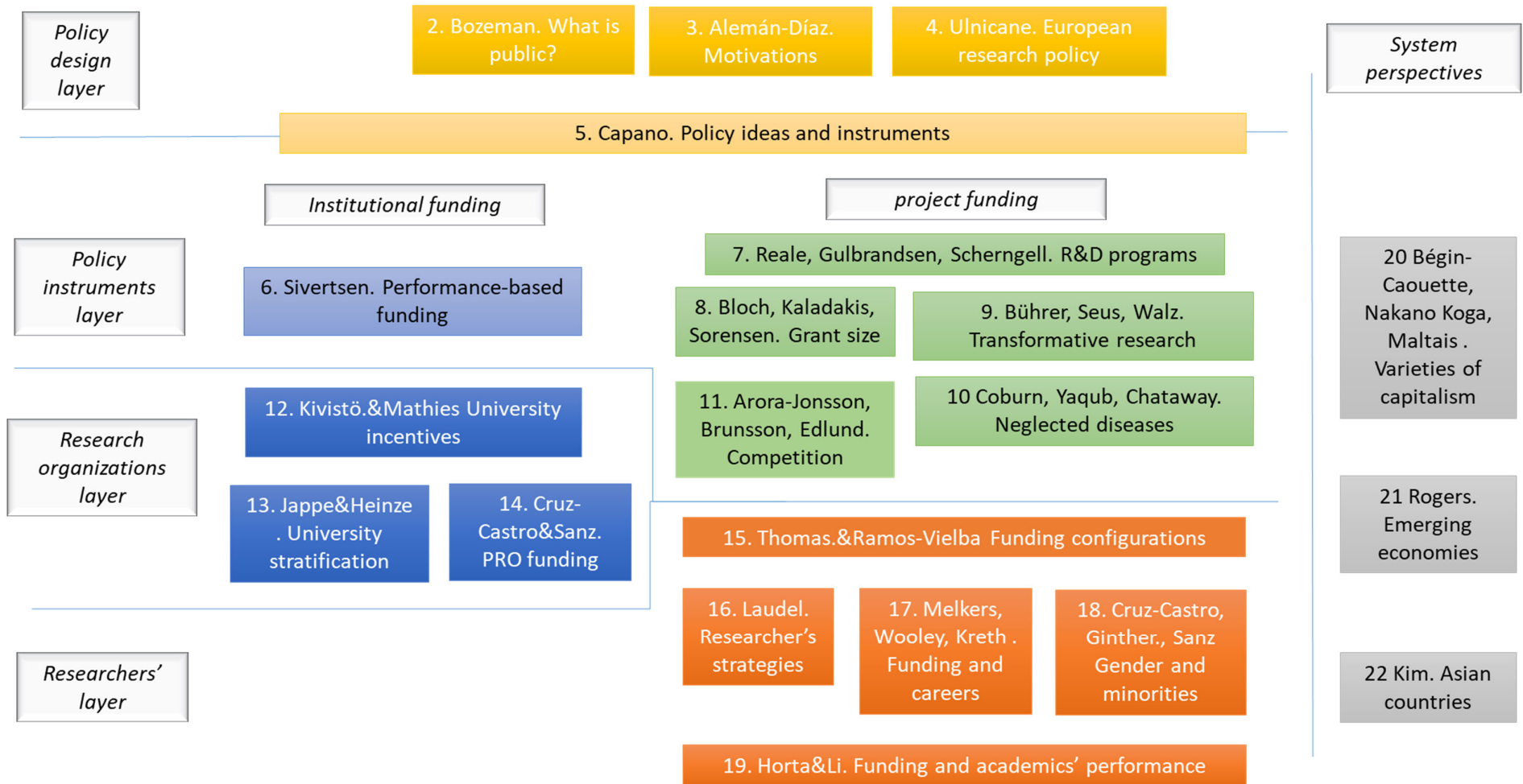
5 Public research funding: a primer and a guide to the Handbook

A helpful way to map the contents of this Handbook locates components of public research funding systems in organizational layers and allocation channels. More precisely, Figure 1 (based on Lepori, 2011) distinguishes between:

- *Four organizational layers:*
 - at the top, a policy design process where the amount of public research funding is decided and funding instruments are devised
 - next, a layer of instruments where funding schemes by the state and dedicated Research Funding Organizations (RFOs) are administered,
 - followed by recipients and allocators, research organizations such as Higher Education Institutions (HEIs) and Public Research Organizations (PROs) obtain research funds from governments and disburse them.
 - and, finally, research performers, research groups, and individual researchers acquire funding (from institutional and project funds) to conduct research.
- *Two main allocation modes:*
 - institutional funding allocated to research organizations (primarily HEIs and PROs) as part of their 'regular' budget
 - project funding, awarded directly to research groups and individuals for research activities limited in scope and duration (Lepori, van den Besselaar *et al*, 2007).

While we have highlighted cross-cutting themes in the previous sections, it is helpful to locate the individual chapters of this Handbook in such a map to visualize the book's structure.

Figure 1. Mapping the handbook chapters



a) The *policy design layer* deals with the overall public funding policies within countries and/or at the international level. While the design of policy and the associated regulatory frameworks have been seen as a struggle between actors and actor coalitions for power and resources (Sabatier, 2007), policy scholars also highlight the central importance of the ideational dimension, i.e. the cultural assumptions, the norms and policy goals, which (should) underlie the design of policy interventions (Surel, 2000). In Chapter 5, Capano takes stock of the political sciences literature to elaborate on the roles of policy ideas in policy design and to show the impact of managerial ideas such as performance evaluation in the selection and design of policy instruments and, specifically, of performance-based funding (Hicks, 2012).

Focusing more specifically on ideas and narratives driving public research funding, the chapter by Alemán-Díaz (chapter 3) analyzes the competing motivations for research funding as a persistent tension between the 'autonomy of creativity' and the 'politics of purpose' (see also Stephan, 2013). In turn, Ulicane's chapter (chapter 4) analyzes how these motivations came into play in developing EU funding policies and programs, showing that a plurality of motivations spurred the rapid growth of EU engagement with research.

The policy layer also deals with politics, i.e. the processes and negotiations that decide goals, priorities (Thurmaier and Willoughby, 2001), funding levels (Li and Zumeta, 2015) and the distribution of funding between different types of performers and agencies (Tandberg, 2010; Weerts and Ronca, 2012). While several chapters deal with priority setting and the underlying rationales, such as Coburn, Yaqub and Chataway (chapter 10), this Handbook does not include a chapter on the politics of public research funding. i.e., how actors' interests and power influence the competition for funding between science policy and other policy domains (Thurmaier and Willoughby, 2001; Li., 2017). Such a chapter might have explored why changes in policy rationales and funding instruments do not necessarily imply shifts in the final allocation of funding, noting how the relative power of the involved actors shapes outcomes. There is indeed empirical evidence of such political games in US higher education funding (McLendon, 2003). Nevertheless, we have a better understanding of how the science budget is embedded in national political contexts (see Larédo and Mustar, 2001; Chubin *et al*, 1990) and how it reflects the vested interests of actors.

b) The *policy instrument layer* deals with the mix of channels and instruments through which funding is allocated (Flanagan *et al*, 2011), the allocation criteria applied, as well as the respective organizational arrangements (Lepori and Reale, 2019). A broad distinction has been drawn between recurrent institutional funding provided to research organizations (Lepori and Jongbloed, 2018) and project funding awarded to research groups and individuals for specific activities (Lepori *et al*, 2007). However, within these broad categories, differentiation has occurred (Larrue *et al*, 2018; Cocos and Lepori, 2020) as an outcome of layering processes (Aagaard, 2017).

The Handbook includes two chapters dealing with institutional funding and the introduction of performance elements in higher education funding. Sivertsen (chapter 6) and an overview of project funding schemes and research funding organizations by Reale *et al*. (chapter 7). Additionally, three chapters deal with emerging issues in grant funding. Bloch, Kladaakis and Sörensen (chapter 8) discuss whether the observed trend towards large grants and centers of excellence is beneficial to research. Bührer, Seus and Walz (chapter 9) examine the potential and risks of program funding to support the transformation of research systems and to address societal needs. Coburn, Yaqub and Chataway (chapter 10) analyze the history of efforts to develop treatments for neglected diseases. These chapters highlight deep questions about the policy mix in research funding raised by the (re-) emergence of societal topics in research policy and funding (see section 2).

Finally, the section on policy instruments includes a conceptual chapter on the meaning and construction of competition by Arora-Jonsson, Brunsson and Edlund (chapter 11). Competition has become a 'mantra' in public research funding. Competition's benefits are expected to include inducing responsiveness to funders' priorities and greater efficiency (Musselin, 2018; Krücken, 2019). Yet,

sociological theory suggests that competition is not given but socially constructed by the actors in the field (Arora-Jonsson *et al*, 2020) and, indeed, researchers and research organizations are involved in the design and implementation of research funding programs (Braun, 2003). The state does play a distinct role in organizing competition, but chapter 11 argues that its concrete enactment also depends on how research actors engage with the state-defined rules (Edelman *et al*, 1999). The chapter, therefore, highlights a critical bridge between policy design, implementation and the strategies of research organizations and researchers.

c) The *research organizations layer* deals with how research organizations such as higher education institutions and public research organizations obtain institutional funding from the state and distribute it to their research groups. The construction of public research organizations, notably HEIs, as organizational actors capable of their own strategies (Brunsson and Sahlin-Andersson, 2000) and of competing for resources (Deiaco *et al*, 2010) represents a significant change in European public research systems in recent decades, where HEIs had tended to be rather weak strategic actors (Whitley, 2008).

Core concerns are funding strategies and resourcing differences between organizations (Sanz-Menéndez and Cruz-Castro, 2003; Lepori *et al*, 2019) and whether research organizations follow national strategic priorities and criteria when distributing money internally (Moll and Hoque, 2011). Kivistö and Mathies (chapter 12) review the empirical evidence on how HEIs respond to national incentivization schemes, whose design is discussed in Sivertsen's chapter (chapter 6). They show that performance-based funding builds on strong assumptions about behavioral responses of the treated organizations based on mainstream economic thinking; if these are not warranted, there is no guarantee that incentives trickle down as expected (Aagaard, 2015). Taking a structural perspective, Jappe and Heinze (chapter 13) show how the allocation of public funding is driven mainly by persistent reputational hierarchies within higher education systems and by competition between HEIs for talented academics. They argue that the supply side of funding (White, 2001) should be taken into account to avoid funding reforms simply ending up strengthening inherited disparities.

Finally, while most of the research on changes in public research funding has focused on HEIs, public research organizations (PROs) remain a vital research actor in many countries in basic and applied research (Crow and Bozeman, 1998; Larédo and Mustar, 2001). Cruz-Castro and Sanz (chapter 14) argue that the PROs' funding model fundamentally differs from that of HEIs in being closely aligned with their underlying mission and authority structure (Cruz-Castro and Sanz-Menéndez, 2018). Their exploratory chapter identifies an important gap in our understanding of public funding systems.

D) At the level of the *research group and individual researchers* funding is transformed into scientific output, generating cumulative cycles of reputation, which may lead to a very unequal distribution of resources (Latour and Woolgar, 2013), the so-called Matthew effect (Merton, 1968). The contributions in this Handbook section focus exclusively on individual researchers. While there have been some studies of funding strategies and portfolios of research groups (Latour and Woolgar, 1979; Joly and Mangematin, 1996), we lack a systematic overview of how research groups are funded. Research groups are challenging to study because their research domains, missions, and organization vary widely and because they can be fluid, with membership shifting between projects. Many groups, especially within universities, are led by a senior professor who acquires funds for their graduate students and junior colleagues. Hence, the chapters explore individual researchers' funding strategies. Yet, with the increase in project funds, we also witness professionalization of funding acquisition and the tendency of group leaders to act as project managers, a particularly strong tendency in natural and medical sciences.

Laudel argues that researchers and research groups should be considered strategic actors, developing different funding acquisition strategies (Laudel, 2006) and juggling different funding sources, such as projects and institutional funding (Lepori *et al*, 2016). Understanding how researchers might drive funding helps explain the outcome of funding policies and potentially unintended effects.

To bridge funding instruments and funding strategies, the chapter by Thomas and Ramos-Vielba (chapter 15) introduces the concept of *funding configurations* to connect the multiplicity of project funding schemes with researchers' strategies for acquiring funding analyzed in Laudel's chapter (chapter 16). Two additional chapters focus on specific aspects and dimensions of researchers' funding: Melkers, Wooley and Kreth (chapter 17) provide an extensive review of grant schemes targeting different career stages, while Cruz-Castro, Ginther and Sanz (chapter 18) analyze in a differentiated manner the empirical evidence on gender and minority gaps. The last chapter in this section, by Horta and Li (chapter 19), assumes a broad view of the impact of funding changes on academic work, covering the consequences for research outputs and other scholarly activities such as teaching and research collaboration.

Finally, the Handbook includes three chapters adopting a broader national systems' perspective. Bégin-Caouette, Nakano Koga and Maltais (chapter 20) adopt a comparative perspective, showing how similarities and differences between OECD countries in the organization of research funding can be associated with the emergence of academic capitalism (Slaughter and Rhoades, 2004) and with institutional variation associated with different country's welfare regimes (Esping-Andersen, 1990). They provide a nuanced approach to the ongoing debate on the convergence of national research policies. In the same vein, two chapters highlight challenges and institutional structures for specific groups of countries. Kim (chapter 21) discusses the strong commitment of Asian countries to science and technology, rooted in their successful latecomer developmental strategies executed through multi-year S&T plans. Rogers (chapter 22) shows how the lack of specific competencies in the administrative structures of middle-income countries hampers the development of the research system.

6 Final remarks: understanding complexity and its implications

It has been observed that public research funding systems have moved from relatively simple configurations with a clear division of tasks, for example, between universities and mission-oriented research centers, to more complex structures with overlapping functions (Aagaard, 2017). As documented in this Handbook, complexity has been appearing at the level of ideas and policy rationales (Aléman-Díaz, chapter 3; Ulnicane, chapter 4), in the mixes of instruments adopted (Reale, Gulbransen, and Scherngell, chapter 7), in the ecology of research performers such as universities (Jappe and Heinze, chapter 13) and public research organizations (Cruz-Castro and Sanz, chapter 14), and in the positions and strategies of researchers competing for funding (Laudel, chapter 16; Melkers, Wooley and Kreth, chapter 17; Cruz-Castro, Ginther and Sanz, chapter 14).

Our Handbook provides evidence that vertical interactions across layers also generates complexity - an aspect frequently disregarded in a literature primarily organized by levels (Cocos and Lepori, 2020). Examples of such cross-level relations are the recursive interaction between policy ideas and policy instruments (Capano, chapter 5), the enactment of competition organized by the state (Arora-Jonsson, Brunsson and Edlund, chapter 11), researchers recomposing different funding instruments in coherent funding portfolios (Thomas and Ramos-Vielba, chapter 15) and universities becoming involved in the design and implementation of performance-based funding (Sivertsen, chapter 6).

Beyond this general observation, our final remarks concern challenges and pathways in dealing with forms of complexity at the scholarly level, in policy design, and in the management of research funding instruments.

As scholars, to move beyond "a night where all cows are black", we suggest developing theoretical lenses so that concepts such as policy narratives, policy instruments, funding markets, and competition can be delineated and disentangled analytically into their different dimensions to become amenable to empirical investigation. Some chapters in our Handbook suggest adopting theoretical lenses from related fields, such as the sociology of markets (Arora-Jonsson, Brunsson and Edlund, chapter 11) or public policy (Capano, chapter 5). Many concepts used in the study of research funding,

such as strategy, stratification, and policy mixes, have been the object of in-depth theoretical development in other fields. While acknowledging that research policy and funding differs from management or other policy domains, we contend that much more can be borrowed from studies in other areas. We also recommend moving beyond the descriptive and inductive approach that characterizes many studies in our field towards more theory-led empirical designs, and theoretically informed definitions of objects of study. This, too, will help disentangle the complexity

As for the design of policies and the selection of instruments, we suggest devoting more attention to a) the complementarities and interactions between different (funding) instruments and b) designing policies based on a realistic conceptualization of the instruments' interaction with strategic responses of performers. On the former, the traditional policy perspective of attempting to address a single policy goal with a dedicated instrument and then evaluating the effects of that instrument in isolation is generating decreasing returns. In the real world, performers interact with multiple instruments and create dependencies between them. For instance, funding instruments targeting the transfer of knowledge from universities to companies critically depend on the working of instruments that support the production of new knowledge. In contrast, excellence instruments for advanced researchers build upon the outcomes of support to early career researchers. This is not to say that all instruments should be designed and analyzed together, but that it is essential to identify the most critical interdependencies for each (new or redesigned) policy intervention. On the latter, we feel that policy design and evaluation still largely rely on a (uniform) top-down action logic derived from principal-agent theory. Many chapters of this Handbook suggest that project funding markets may work upstream from the existing hierarchy of performers (White, 2001), while performers, such as research organizations, have considerable leeway in responding to policy interventions. A more realistic representation of this interaction would acknowledge that the "agents" face a range of often conflicting incentives and, therefore, seek to pursue their own goals within a complex technical, legal, bureaucratic, and cultural landscape. Recognizing this might help in designing more effective public policy (and in understanding what works in research funding).

Finally, we feel that the traditional recipe of multiplying research funding organizations and instruments to target ever more policy goals and performers might be reaching its limits. We ground this view on three observations. First, the long phase of growth in public research funding, which started with WWII, has ended (Lepori and Jongbloed, 2018). Therefore, resources for new instruments are becoming scarce, and, accordingly, there is a risk of launching instruments with such limited budgets that management costs are likely to exceed benefits. Second, in many countries, multiplying funding instruments increasingly overlap, with the result that similar projects might be submitted to different instruments – at the expense of targeting and increasing the burden on the evaluation system. In the US, Federal agencies are increasingly pushing this administrative complexity onto performers by funding large, multi-year networks and demanding performers meet ever more goals and be responsible for managing the yearly allocation of funding and accountability.

Third, perhaps, more importantly, new challenges, such as achieving Sustainable Development Goals, can be addressed only by synergistic action combining different instruments and through hybrid instruments, targeting both the development of new knowledge and its orientation to broader societal goals. Hence, we suggest that managing the funding instruments portfolio (at the system's and research funding organization level) might require very different approaches than in the past.

These final remarks emphasize the Janus-faced nature of our Handbook. On the one hand, it looks back to provide colleagues with a synopsis of the existing body of knowledge on public research funding, thereby filling a notable gap in our domain. On the other hand, it looks forward to new questions and challenges generated by a changing context and suggests some pathways to begin to address them.

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