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Foreword

The JRC managed Public Research Funding (PREF) study has collected information on and analyse national public research funding, providing an overview of its evolution and current state in European and selected non-European countries, particularly as concerns funding themes, fields and the types of allocation (competitive project based versus institutional funding). More specifically, the study aims:

- For the countries considered, to collect quantitative and qualitative data (financial data and descriptors) on the evolution of public R&D funding for the period 2000-2014, including robust and reliable estimations of the shares allocated on project basis and as institutional funding;
- To break down and provide a detailed analysis public R&D funding in terms of competitive and non-competitive funding, and of the weight placed on scientific-technological (S&T) fields, Key Enabling Technologies (KETs) and Societal Grand Challenges (SGCs);
- To describe the funding allocation mechanisms, including flows to and from funding agencies and the criteria used as the basis for allocation decisions.
- Using the above-described data, to analyse specific issues in public research policy, particularly concerning the characteristics of national funding profiles and the funding devoted to specific research objectives.

The study contributes to the Research and Innovation Observatory (RIO), and provides support for development and implementation of evidence-based policies in allocation of public research funding.

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The PREF Consortium includes the following partners and teams:

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A number of national experts were also involved in the PREF project; they are:

- Ines Marinkovic, Elke Dall, Klaus Schuch from SNI - Centre for Social Innovation, AT;
- Jan van Steen from Rathenau, NL;
- Federica Rossi from Birkbeck University of London, UK;
- Daphne Getz from SNI- Samuel Neaman Institute, IL.

Elisabeth Pastor (OECD-NESTI WP) was the Quality Expert of the PREF project providing expert advice for the methodology and data collection process.

The Final Report has 40 Public Funding Country Profiles (PFCPs) by different authors, and the PREF Handbook for Data Collection and Indicator Production by Benedetto Lepori.

Serena Fabrizio elaborated the figures and tables based on EUROSTAT and OECD data, and Andrea Orazio Spinello elaborated figures and tables based on PREF data, in the Final Report and PFCPs. Serena Fabrizio and Andrea Orazio Spinello provided the editing of the Final Report and the Annexes.

The PREF team acknowledges the collaboration from NSAs and Ministries of different countries for the support given to the PREF data collection. The PFCPs indicate the contacts in the different PREF countries.

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Abstract

This document presents the Final Report of the PREF study based on qualitative and quantitative PREF data collection, and includes the suggestions and comments emerged during the dissemination workshop held at Commission premises on March 2017.

The aim of the report is to analyse the national public funding for R&D in the 40 countries under study, in terms of share of project versus institutional funding, mechanisms for funding allocation, organisations for research funding, and extent of convergence around the research themes and topics identified in FP7 and Horizon 2020. Some data on R&D expenditures have been put in the Report as background information of the countries analysed.

1 Introduction

The aim of the Public Research Funding (PREF) study is to collect information on and analyse national public research funding, providing an overview of its evolution and current state in European and selected non-European countries, particularly as concerns funding themes, fields and the types of allocation (competitive project based versus institutional funding). More specifically, the study aims:

- For the countries considered, to collect quantitative and qualitative data (financial data and descriptors) on the evolution of public R&D funding for the period 2000-2014, including robust and reliable estimations of the shares allocated on project basis and as institutional funding;
- To break down and to analyse R&D funding in terms of competitive and non-competitive funding, and of the weight placed on scientific-technological (S&T) fields, Key Enabling Technologies (KETs) and Societal Grand Challenges (SGCs);
- To describe the funding allocation mechanisms, including flows to and from funding agencies and the criteria used as the basis for allocation decisions.
- Using the above-described data, to analyse specific issues in public research policy, particularly concerning the characteristics of national funding profiles and the funding devoted to specific research objectives.

The study contributes to the Research and Innovation Observatory (RIO), and provides support for development and implementation of evidence-based policies in allocation of public research funding.

The current project is grounded in the tendering consortium's previous research experience in the study of public R&D project funding as part of the PRIME Network of Excellence (EU Framework Programme 6), and in analytical work for JOREP (Investment in Joint and Open Research Programmes) studies, funded by the European Commission. From these experiences, the partners have gained greater capabilities in: a) developing integrated conceptual frameworks for data collection on public R&D institutional funding and project funding; b) examining policy intentions and results, to provide evidence useful for design and implementation; c) integration of quantitative and qualitative information on the characteristics of different funding streams, using sets of descriptors that categorise the qualitative information for combined use with quantitative data.

This document presents the Final Report, which is the last deliverable of the PREF Project. The report also includes the comments received during the dissemination workshop organised at Commission premises and recommendations from the PREF core team.

Using quantitative and qualitative data, the report analyses the evolution of public funding for R&D in the countries under study in terms of: percentage of project versus institutional funding; main allocation mechanisms for public funding; objectives of research funded; convergence around the research themes and topics identified in FP7 and Horizon 2020. Individual Public Funding Country Profiles are included as annexes to the report. These provide detailed information on national characteristics of public funding for R&D and the evolution of allocation mechanisms.

The report presents a broad comparative analysis of the individual country profiles. The countries under study are the EU-28 plus the accession countries and selected third countries. The issues to be addressed in the analyses are:

- R&D funding intensity, based on GERD, HERD, GOVERD and GBARD statistics as background information of the countries analysed;
- Characteristics of public R&D funding in terms of type of allocation mechanisms and criteria (project funding and institutional funding);
- Proxies of competitiveness of public funding;

- Importance at national level of priorities identified in Horizon 2020, namely Key Enabling Technologies (KETs) and Societal Grand Challenges (SGCs);
- Organisational characteristics of the funding bodies involved - Research Funding Agencies (RFOs) and Umbrella Public Research Organisations (UPROs);
- Evolution of funding mixes and mechanisms used for allocation.

The Report is organised as follows. Section 2 briefly outlines the main literature concerning previous relevant experience in data collection and analysis of national public R&D funding. Section 3 presents the analytical framework and questions, summarises the types of data available (EUROSTAT/OECD, other sources), and the methodological approach for data collection under the current study. Section 4 examines the intensity of R&D funding in the countries examined, in terms of overall dimensions, share of government expenditure, share of GDP and total national research, as well as relative channelling by NABS and FORD categories. This Section is mainly devoted to supply background information on the countries analysed. Sections 5 and 6 analyses the evolution of public funding types (institutional and project), the level of competitive allocation in both types; Section 7 deals with the objectives and strategic research priorities pursued under the country systems. Sections 8 and 9 examine the types of funding bodies involved (RFO, UPRO) and the evolution of the funding mixes in the different countries. Finally, Section 10 discusses the public funding regimes in European countries, while the last section presents conclusions and identifies issues of data availability and analysis still open to further examination.

The following Annexes are also included:

- Public Funding Country Profiles for each of the 40 nations studied, presenting data on national funding devoted to R&D and summaries of the modes of coordinating public funding. Country profiles follow the two templates used for data collection, in keeping with PREF tender specifications. Full profiles are provided for EU-28 and accession countries, while profiles for non-European countries (US, JP, CN, IL) and candidate countries (FYROM, ME, RS, TR) are without analysis of funding instruments (Deliverable D5.2);
- Handbook on PREF Data Collection, including explanations of indicator production, list of S&T funding fields considered, funding categories by socio-economic objectives, fields corresponding to FP7 thematic priorities, KETs and SGCs (Deliverable D4.1).

The structures of the main report and country profiles have been progressively refined on the basis of the emerging data collection and availability, and the resulting real possibilities for robust, confident analysis across the different countries.

2 Government funding for R&D: previous experiences in analysis and data collection

Public spending for research and development is undoubtedly one of the most powerful tools for government policy in areas of science, technology and innovation. On average, public funding constitutes 35% of total R&D spending in European countries. However, despite more than a decade of systematic study, advancement in policy knowledge, coordination, and sharing of common spending targets, there is wide variation in European countries both in terms of relative importance of public funding and the mechanisms and criteria applied for its allocation.

Most European countries face strong fiscal constraints, and governments are increasingly expected to provide greater accountability, transparency and effectiveness in public spending. The expectations for research funding are certainly no exception. Hence, one of the major challenges facing European policy on R&D is how to strengthen quality and increase outputs given limited amounts of resources. Although several studies have already sought to categorise and map the various national funding models (see for instance OECD 2011), these models have changed significantly over the past few decades, and many countries are currently reviewing and modifying their systems (OECD, 2016). It is therefore worthwhile to provide an updated overview of funding patterns and mechanisms currently in place in EU member countries.

Interest in potential variations of funding modes emerged in the 1970s and increased in the subsequent decade, for two main reasons: the stagnation in volumes of public research funding, corresponding with the contrasting emergence of new policy rationales for efficient use of the funding (Lepori et al., 2007b). The conception was that enhancement of competitive allocation mechanisms would stimulate better research performance and more efficient use of resources, through selection of top research groups, promotion of specific research themes and fields, supporting structural changes in the means of knowledge production and application, competition and cooperation between groups (Geuna, 2001; Braun, 2003). Many countries have embarked on reforms in funding in response to new demands and opportunities. They have enhanced their strategic-planning capacities and devoted more attention to the socio-economic environment and evolving expectations of stakeholders. In 2003, an OECD study on transformation of funding modes revealed that at that point, overall volumes of R&D funding had increased, although public funding was generally increasing more slowly than private (Maass, 2003; OECD, 2003).

In the 1990s, the trends toward competitive allocation gained strength. Government funding increased for mission-oriented and contract-based research, which are conceived as being more dependent on output and performance criteria. R&D statistics and analyses indicated that nearly all countries intended to increase public funding, with the increases concentrated in priority areas and new programs where funding would be on a highly competitive basis. Also, competitive allocation of institutional funding emerged as a central issue, but the capability to fully address a performance-based allocation faces several constraints (Hicks, 2012). Despite this trend, there was a lack of data for measuring these types of transformations, and for development of systematic comparisons between countries and through time. The main reason for this was that R&D statistics were designed to record expenditures at the overall levels of state allocations, and then at the level of individual performers. In other words, the interest was in the overall funding flows and research efforts, not the functional matters of how the allocation was enacted (Lepori et al., 2007 b).

Moreover, an empirical analysis of the design of research programs in 34 European countries (Optimat, 2005) showed that "national policies and programmes are being developed without any obvious alignment with the parallel situation in other countries". Transnational research activities were still underdeveloped and there were many barriers involving legal and organisational factors and research capacities. In other words, there

was little evidence of policy convergence, which refers to the tendency for countries to grow more alike, particularly by developing integrated policy instruments for transnational research (Knill, 2005).

Recently there has been increased emphasis on obtaining good statistics and indicators of national public funding for R&D. The EC (2014) document, "Research and innovation as sources of renewed growth", describes the need to increase quality of public spending "by allocating funding on a competitive basis, through open calls for proposals according to excellence, for instance on the basis of international peer review, and by allocating institutional funding on the basis of proven performance". The document also reports on European countries that are currently introducing greater competition in allocation of research and innovation (R&I) funding. Monitoring and assessment of the evolution of research in European countries is clearly very important. For this, it is necessary to have quantitative data revealing the trends towards competitive and performance-based funding, and qualitative information for characterisation of the structure and organisation of the funding streams and instruments.

2.1 Conceptualisation of R&D funding – the basis of data collection and analysis

During the years 2004-2008, the PRIME Network of Excellence, under the 6th Framework Programme, conducted experimental research in analysis of public sector project funding. This important step demonstrated the feasibility of developing new indicators of public funding drawing on pre-existing data sources, and that these indicators could provide useful results for comparative analysis of public research policies (Lepori et al., 2007a). One of the major achievements was to operationalize definitions and methodologies for collecting data on project funding. To this aim, a multi-layered conceptual framework of government funding was developed, which allowed the shift from a performer-based to agency-based approach in data collection. The new approach differs from the one developed in the late nineties by RAND Europe (1999), which differentiated among participants in the R&D system and among flows of funds. In the new approach, the concept of "proximity to research performance" is used to classify participants (funders, intermediaries and performers) and objectives (public or private), and the funding arrangements are differentiated in terms of dimensions of control and competition.

The new conceptual approach began with recognition of the R&D system as a multi-layered and multi-level space (Kuhlman, 2001; see also Rip, 1990) in which interaction among four entities (policy, funding agencies, performing organisations, and research groups) takes place. These entities represent different functions in research funding and are organisationally separate, with some exceptions – particularly the case of vertically integrated national organisations that act as both funding agencies and research performers, such as national academies of sciences in central and eastern Europe (Lepori et al. 2009), and organisations like the CNRS in France (Thèves et al. 2007). The PRIME project identified the wide use of two types of government funding mechanisms: institutional and project funding. Institutional funding can be provided applying different bases for calculation, and can be transferred as lump-sum or budget-line allocations, in keeping with the level of autonomy granted to the research performers (Jongbloed, 2001). In the past, such funding generally came without conditions. More recently there has been a clear trend towards inserting performance or quality-based mechanisms, to enhance the accountability of organisations and stimulate competitive behaviours. Institutional funding can also be routed differently to different types of performers. For example, some countries apply "dual system" funding for HEIs, meaning for both the institutions and their individual researchers and research groups. On the other hand, governments generally do not provide dual funding for public research organisations. Allocations of project funding are generally based on competitive processes, on the basis of "bid" applications submitted in response to calls for tenders and notices issued by a funding agency, with evaluation using different types of peer-review process. Project funding can also be contract based, with specific objectives and milestones. Project

funding has increased substantially in a number of countries in the past decade, including for projects with joint government and industry support, as well as involving governments and agencies from different countries.

Scholars focusing on science policy have also developed a very specific conception of “delegation models” in public funding (Braun, 2003). This approach interprets the relationship between state and scientists as one of delegation and then tries to characterise funding policies and instruments in terms of their underlying delegation models. The current PREF analysis links the instruments used to allocate public research funding to the abstract categories of delegation modes, attempting to reveal the general features of relationships between the state and national science systems. An exploration of this approach-using project funding data (Potì and Reale, 2007), demonstrated that availability of both qualitative and quantitative information is crucial to such policy analysis.

In terms of general strategies for developing indicators and applying them in policy analyses, the PRIME experimental activity yielded a number of relevant lessons (Lepori et al., 2007b). First, the development of indicators (and data collection) should be driven by the underlying policy questions, related to program objectives and intended impacts. Second, the resort to reasonable simplifications is key to the successful development of indicators. This means collecting data on the programs and characteristics that are truly relevant to the underlying questions, as well as using proxies and estimations where there is reasonable confidence that these can provide a correct assessment. Third, when developing indicators in new fields, rather than giving all the definitions and categories “ex ante”, an interactive approach will often be more successful. Starting from fairly general categories, and progressively refining them based on experience in data collection and analysis, assists in getting the right indicators and making data collection feasible. Fourth, careful consideration must be given to the choice of data sources, the means of combining them, and the approaches to actually collecting the data, taking into account availability, problems in quality, as well as the efforts necessary for collection and “cleaning”.

2.2 Building reliable data collection on project funding

The PRIME approach was further developed under a NESTI (OECD National Experts on Science and Technology) pilot project examining government budget allocations for R&D (GBARD). The project aimed at integrating a small core of indicators on project funding into the official statistics produced by the various national services. GBARD data collection is not confined to national statistical offices, and the project extended to other national institutes recording information in this area. The aim of the experiment was “to propose a methodology for internationally comparable indicators on modes of public funding; collecting such indicators and assessing the feasibility of extending their scope by developing guidelines for the implementation of the methodology as part of the regular indicator activities of OECD and other organisations like EUROSTAT” (van Steen, 2012).

The NESTI project involved two rounds of data collection in a total of 18 countries. It demonstrated that, at least for these countries, national data on appropriations and outlays can serve as useful sources for identifying and distinguishing allocations to institutional and project funding, although there can be problems of availability (Steen, 2012). Complementary qualitative data is required to interpret the results, since the quantitative data are insufficient for comparative reasoning, given differences in country R&D funding policies, funding systems, mechanisms and practices. Knowledge in all these aspects is essential for policy analyses; therefore, data collection must be designed to detect such differences at country level. One of the most promising results of the OECD experiment was the reliability of the outcome in terms of data produced, a result demonstrating that the achievement of basic levels of international comparability is an attainable objective. At the moment, data across the OECD nations are not fully comparable, however, EUROSTAT has adopted the project/institutional funding as an

“optional” variable for reporting. The NESTI experiment also provided important input for revision of the Frascati Manual on practices for surveys concerning R&D, for example introducing the notion “funding agencies”, and their relative investigation.

Data collection on public funding for transnational research

The JOREP project (Investments in Joint and Open R&D Programmes) provided further progress in identifying indicators and data for analysis of public funding. The project covered 11 European countries, collecting descriptors aimed at characterizing the features of the different transnational programs, the related funding agencies, and data on funding, modes of allocation and budget management.

The development of transnational public research began as early as the 1950s. Both the form and extent of cooperation have evolved significantly over recent decades, giving rise to a highly differentiated landscape of programs and agencies. Broadly speaking, we can identify a first phase in which the main cooperation mechanism involved creation of intergovernmental research facilities in fields where the scale of investment requires that the European countries joined forces. Examples are CERN in nuclear physics, the European Southern Observatory in astronomy, and the Joint Research Centre of the European Communities in the nuclear sector. In the sectors of nuclear energy (Euratom) and space (European Space Agency), the main function assumed by intergovernmental bodies was as funding agencies, promoting research in member states through financing of projects and contracts. Euratom has since been integrated into the EU framework programmes, but ESA remains by far the largest intergovernmental funding agency in Europe.

In the second phase, beginning in the 1970s, the focus has largely shifted to creating intergovernmental funding schemes for cooperative research, to be realised through networks of national performers. This has involved moving away from creating large-scale facilities towards promoting cooperation by European actors, and establishing critical mass through joint projects. Two broad types of intergovernmental programs have emerged: i) programs coordinated by a European agency, but with funding managed through national agencies (mostly à la carte), and thus without trans-border flows – COST (European Cooperation in Science and Technology, the EUREKA network (launched 1985) and most European Science Foundation schemes belong to this category; ii) programs where both the management and the funding are handled through a European agency – e.g. European Space Agency, and the very obvious cases of the European Framework programmes.

JOREP recommended an approach to data collection based on three critical components: definition of the dataset perimeter, the descriptors, and obtainment of data on funding flows. The construction of a list of joint programs is central to data collection. The list should provide the following information: program name, financial data, participating countries, and participating agencies within each country. The set of descriptors developed under the project proved highly useful in analysing the landscape of joint programs over a period of several years. Given the fact that the organisational characteristics of joint programs remain reasonably stable, the descriptors allowed observation of the landscape changes, the transformations in program characteristics, and the related changes in participating countries.

At the time of the JOREP project, GBARD data had not yet been demonstrated as useful in monitoring funding under joint programs. Sufficient information was at times unavailable from national statistical offices. Instead, expertise was developed in retrieving data on funding flows using web-based sources and by direct collection of information from national funding agencies. Also, rather than the breakdown of beneficiaries described by the Frascati sectors, JOREP recommended provision of a simple breakdown of public and private beneficiaries, as more doable and relevant to understand how the program truly functions (Reale, Lepori, et al., 2013; Lepori, Reale, Laredo, 2014; IUS, 2014).

The JOREP project made important steps in data collection, since it showed how to merge budget data with data useful in identifying the actors' roles and the funders' institutional strategies. Moreover, the project developed techniques for investigating the levels of national integration in joint R&D programs, relative to the characteristics of the individual programs. This provides an empirical basis for representation of the resources mobilised and the opportunities achieved in the areas the policy makers originally intended for the program and funding schemes (Lepori, Reale, Laredo, 2014; Reale, Nedeva, Thomas, Primeri, 2014).

2.3 Other key sources of information on public R&D funding

ERAWATCH was the European Commission's information platform on European, national and regional research and innovation systems and policies, created in 2005. Its main objectives were to support policy-making in the research and innovation field in Europe and to contribute to the realisation of the European Research Area (ERA). ERAWATCH has been the core of the EC information service on R&I, and a unique source of policy intelligence. The launch of the platform benefited from the previous experience of the European Trend Charts on Innovation, and continues to focus on production of yearly country reports and other national reporting templates, some of which contribute to describing the funding agencies and support measures within the different countries. However, ERAWATCH was not limited to the national level, and also gathered and analysed information on regional and European level R&D policies, actors, organisations and programs. The information and analyses were designed to serve policy makers and managers, particularly to assist in identifying policy options and improve the coordination of scientific and technological activities.

ERAWATCH has been discontinued but its experience has been further developed in the Joint Research Centre's (JRC) Research and Innovation Observatory (RIO) (<https://rio.jrc.ec.europa.eu>), which is a new EC instrument to support member states and countries associated with Horizon 2020 in policy design and implementation, as well as for assessment of reforms. RIO makes major efforts to understand changes in the allocation of public and private funding, with particular interest in the emergence of competitive allocation and performance-based allocation modes on the public side (Jonkers & Zacharewicz, 2016).

Project funding is also used for promotion of research in priority areas, and to pursue other specific public policy objectives (e.g. search for excellence, internationalisation) and strategic interests (key enabling technologies, research areas linked to "grand challenges"). An OECD report presents the interesting experience of surveys intended to obtain data and evidence on how governments fund and steer public research in higher education and research institutions through research excellence initiatives (REIs), as a new form of competitive research funding. Three surveys were carried out, reporting on 56 schemes in 20 countries (OECD, 2014). The first survey addressed the government agencies responsible for administering REI funding to higher education and research institutions, seeking to define the characteristics differentiating REIs from other funding streams. The second survey addressed centres of excellence funded by REIs, investigating their management structure, funding schemes, measurements of impact and sustainability, cooperation with public and private sectors, and perceived long-term effects of their research. The final survey addressed the institutions hosting the centres of excellence, inquiring into their administrative arrangements, financial and research objectives, and the impact of the REI-funded centres on the larger institutions.

The above experiences in analysis of public funding provide constructive evidence and suggestions for collection of qualitative and quantitative data on "framework" competitive funding schemes, where several instruments contribute to a specific policy objective, mobilising important volumes of resources in several countries towards what is recognised as a strategic goal, capable of impacting the effectiveness of R&D investment and competitiveness of the economies.

This concludes our brief section on the background of government funding for R&D, and relevant experiences in data collection. The possibility of assessing the overall trends of research policies in the European Union countries, and benchmarking policy developments in the EU against those taking place in key trading partners, clearly emerge as important issues. Such capacities create strong evidence base, useful in creating decisional advantages for the Commission, the EU member states and stakeholders.

This report on the "EC PREF project" now proceeds to analyse public research funding, building on past experience and using original collection of quantitative (financial amounts) and qualitative (organisational descriptors) data.

3 Structure and methodological approach for the analysis

Funding is one of the major instruments accessible to governments for steering science and innovation systems (OECD, 2011). Many countries have introduced reforms of their R&D funding systems, to foster excellence, knowledge transfer and socio-economic innovation, in which the changes typically reduce the proportion of institutional funding in favour of more selective and competitive systems. This trend has been investigated, however the indicators selected for the purpose (see review in section 1) have only been able to partially depict the importance and extension of the two key types of allocation systems: institutional funding, where the majority of resources are allocated directly to institutions according to particular arrangements (e.g. historically based, application of formulae, reference to performance indicators, budget negotiations between actors), and project-based systems, where scientists compete to obtain funding from external sources.

The debate about the various consequences of the shift toward project-based arrangements is still open. Different evidence has been provided in the literature about whether the increasing reliance on competitive funding at the expense of block grant and long-term institutional funding has resulted in an emphasis on short-term low-risk projects at the expense of long-term fundamental research. Other concerns include the extent to which program-oriented funding might hinder possibilities of exploring non-priority areas, or how conditions that generate markets and demand from research users, which are not the same for all scientific and technological areas, could push certain fields while depriving others of vital resources (OECD, 2011).

Despite such debates, the recent policy statements concerning the establishment of the European Research Area stress the importance of making national-level funding systems more effective, and indicate the importance of competition towards this aim. National strategies towards building an integrated European research and technology area have to be improved, and national research agendas and strategies must be better aligned with one another within this overall area. One common feature of the Member States' strategies is support for further implementation of project-based funding, which is now observed in 21 countries (EC, 2015). Moreover, the mechanisms for project funding allocation show a shared trend towards complying with high standards of peer review. Indeed, this emerged as a condition for agreements between the funding agencies operating in different countries, towards engagement in transnational cooperative research programs (Reale et al., 2013).

Nonetheless, a major difficulty in investigating the different national R&D funding systems is the insufficient availability of quantitative and qualitative data on the instruments and actors involved in their management: the specific research funding organisations and/or "umbrella public research organisations", which in the latter case act as funding bodies for their sub-organisations and other providers. The current project for development and analysis of data is intended to contribute to better knowledge on the characteristics of national public funding for research, including the priorities, instruments, actors and their strategies.

The questions to be addressed by the PREF analysis devolve from the main problems, as described above:

- How is public R&D funding evolving in the countries considered (based on data collection over the period 2000-2014)?
- What sectors of performers are funded in the different countries?
- What is the evolution of institutional and project funding allocation mechanisms in the different countries?
- To what extent is the trend towards competitive research funding observed in the policies of European and non-European countries?

- What are the characteristics of the funding mixes in the considered countries?
- What policy objectives characterise the R&D funding in the countries under study, and how do the different actors allocate the funding?
- Does public research funding show evidence of converging patterns among European nations, as regards priorities and type of instruments?

The report elaborates comparisons of public research funding between countries. Qualitative information, integrated and checked by empirical data, is used to develop an understanding of the characteristics of national systems, including the relationships between government, funding agencies and research actors. The report:

- Identifies evolving patterns of institutional and project funding modes, comparing ERA and non-ERA countries, and countries in western and eastern areas of Europe;
- Maps public funding characteristics by country, to understand what they reveal of national policy and objectives, particularly in the area of public-private collaboration;
- Identifies and compares institutional arrangements, by country (project funding versus core funding configurations, vertically integrated systems);
- Assesses the extent to which national funding instruments integrate European-level strategic objectives, particularly the “cross cutting” Key Enabling Technologies (EC, 2012) and Societal Grand Challenges, defined under Horizon 2020.¹

The analysis takes a comparative approach, examining EU-28 countries, candidate countries (FYROM, Montenegro, Serbia and Turkey) and non-European countries (China, Japan, Israel, US) as far as data are available. The comparisons are based on the national data and information presented in the country profiles (Annexes 1 to 40). Within the EU-28 countries, special attention is devoted to addressing the characteristics of national R&D funding in the eastern, western, northern and southern areas of the European whole.

From a theoretical point of view, the report builds the analysis around examination of coordination modes for research funding, which is the approach best adapted to examination of country differences. Under this perspective, national funding systems are composed of combinations of organisational forms, presenting different characteristics and conditions. The different funding mechanisms generally correspond to coordination modes, which determine the requirements for actors and their means of interaction for achievement of collective action, and scientific, economic and social impacts. In other words, different agents move within the specific interaction spaces of national systems, in correspondence with the different coordination modes for public funding: project-based, mixed, or vertically integrated (Lepori, 2011).

In the project-based mode, we can expect interaction spaces where different research funding organisations (RFOs) coexist. State controls could range from partitioning of funds between the different RFOs to determining allocation criteria, but in any case, the RFO actors retain control over selection of beneficiaries. In contrast, the vertically integrated mode is dominated by: i) “umbrella organisations”, which serve as layers for coordination of funding on the basis of extensive state delegation. Mixed systems feature combinations of project funding and other modes, such as allocations to consortia, networks, or “centres of excellence”, which then regulate the further division of resources among partners; ii) higher education core funding, where the main coordination relationships are between the state and HEIs. The balancing between different modes configures the national research systems and thus influences the European nations’ joint programming of national and transnational research.

¹ <http://ec.europa.eu/programmes/horizon2020/en/h2020-sections>

3.1 Methodological approach - data collection

The current project takes a unified approach to collection of quantitative and qualitative data on national public research funding, building on a conceptualisation of national systems successfully applied in previous data collection on project funding (Lepori et al., 2007). National systems are conceived as consisting of four layers. The first is the state layer, meaning nation and European Union levels. These are the levels at which the overall volume of budgetary appropriations for R&D activities is decided, as well as their division in broad streams. The second layer is composed of "research funding organisations" (RFOs), a broader term than "research funding agencies", meaning all organisational entities assigned by the state to distribute money to research performers. When responsibilities for managing funding are conducted by ministries, this term refers only to the units specifically in charge of distributing funding. The third layer is composed of large, stable "research organisations", encompassing diverse research topics, with operations by various research groups. The fourth layer is composed of the individual research units and groups, of different types, representing the true scientific "production units" (Etzkowitz 2003; Joly and Mangematin 1996).

In some countries, we can also find very large "umbrella public research organisations" (UPROs), with dual functions of both managing extensive parts of the national research system and acting as RFOs for their own laboratories and research groups. Examples would be the CNRS of France, CNR of Italy, and CSIC of Spain (Thèves, Lepori and Larédo 2007).

The analysis considers two main allocation mechanisms for public funding: institutional and project-based. This distinction has long been known in research studies, but has only recently been operationalized in quantitative analyses (Lepori, Dinges, Poti, Reale, Slipersaeter, Theves and Van den Besselaar 2007; Steen, 2012). The conceptual definitions of project and institutional funding are provided in the PREF Handbook (p. 9-10):

Project funding is defined as money attributed to a group or an individual to perform a research activity that is limited in scope, budget and time. It is identified based on three main characteristics: a) funds are attributed directly to research groups and not to whole organisations; b) the scope and duration of research supported are limited; c) funds are attributed by an RFO external to the organisations of the end research groups. "National" project funding is defined as national public appropriations allocated through project funding.

Institutional funding is funding attributed to research organisations (PROs, HEIs) for ongoing activities, usually over unrestricted periods of time. The amount of funding may vary on a yearly basis, but is generally not earmarked for specific activities or organisational subunits. Internal allocation is left to the performing organisation. In most countries of Europe, block transfers to universities are allocated as lump sum institutional funding, and comprise the large part of the individual institutional budgets.

Also, the Handbook provides the conceptual definitions of Research funding Agency (RFO) and Umbrella Public Research Organization (UPRO) as main actors on the funding side (p. 10-11):

Research funding organizations are organizational entities that distribute public funding for research on behalf of the State. The definition adopted is extensive concerning the legal status and the position in respect of the State, covering both independent agencies at arm's length from the public administration, like research councils and ministries, and offices within the public administration, which perform this role. Most research funding organizations distribute project funding, but in some countries, RFOs (like higher education councils) are also in charge of distributing institutional funding. In a few cases, both functions are present, like in the case of research councils managing national facilities.

Umbrella Public Research Organizations are national-level organizations with the mission of organizing research activities in a specific domain. Unlike normal PROs, they mostly host research laboratories distributed over the whole national territory and they are delegated by the State to manage a specific field of national research policy. Umbrella PROs in many cases have a dual function, i.e. to directly manage laboratories and scientist's careers on the one hand, and to provide competitive projects funds on the other hand.

The study methodology draws on the experience of the PREF consortium participants in previous projects, and is based on the following principles.

1. The design of data collection, both quantitative and qualitative, derives from the conceptual scheme illustrated in Fig. 3.1. The scheme identifies the key actors and main funding streams of the system. For each component, we identify the available data sources and organisation of data collection. Information about the public availability of the data are also supplied. Once data for the different parts of the system have been produced they are integrated to yield aggregate indicators characterizing the national systems, which can then also be used in systematic cross-country comparisons. Broad national aggregates and disaggregated data are systematically reconciled to improve the robustness of the data.
2. The main focus of the report is on providing detailed analysis of "policy intentions" and the different mechanisms through which research funds are allocated to performers. The inquiry into the actual research performed is limited to broad research types, topics and the relative volumes of funding, and is only carried to the extent that it serves in analysing public policies. This focus conforms to the goals of the PREF project tender, but is also suited to data availability, since the funding streams are more aggregated at the policy-making and RFO/UPRO levels and hence easier to quantify than R&D expenditures at the detailed, granular level of performers.
3. Standardised descriptors are developed, based on closed sets of categories, concerning funding policies, organisational structure, selection criteria and allocation modes. This approach establishes a data collection task that is reasonable in scope, and improves comparability of the information collected. It also allows statistical testing of associations between program characteristics, which would be problematic using purely qualitative descriptions (Lepori, Reale and Larédo 2014). The approach is particularly suitable given the large number of units being compared, particularly at the program and RFO levels.
4. The study examines only the "larger" funding organisations, programs and streams. In practical terms this means limiting data collection to funding streams representing at least 5% of total government budget allocations for R&D, according to EUROSTAT statistics. The residual amounts, if they represent consistent amounts of public research funding, are viewed as aggregate funding. This solution is supported by empirical evidence from the JOREP project, of strong concentrations of funding in small numbers of streams and agencies, while the rest is divided between large numbers of small RFOs (Reale et al., 2013). The Handbook provides for flexibility in singling out RFO streams below the threshold when they are relevant at national level. The expert-based identification of the funding streams to be included in the study is thus a core aspect of methodology.

The components of data collection methodology deal with the different parts of a national research funding system: public appropriations of funding for research; public R&D procurement; incoming EU funding; characterisation and data on research funding organisations; characterisation and data on research funding instruments; characterisation of umbrella research organisations; analysis of R&D execution.

In this respect, it is useful to recall the general characteristics (and limitations) of GBARD data, which apply by definition also to the PREF data collection. A reference can be made to Chapter 12 of the OECD Frascati Manual (OECD, 2015). GBARD is based on budgetary

information (budget provisions) and not to actual expenditures. The calculation is based on the identification of all the budget items related to R&D, and on measurement or estimation of the funding related to R&D contents. Government perimeter includes funding coming from central/federal government, and regional/state government when funding is relevant. Structural funding therefore is not included as well as indirect funding and funding from public enterprises. Since GBARD is constructed differently in different countries, this may lead to limitations in the comparability of the findings.

According to the Frascati Manual (OECD, 2015) GBARD covers government-financed R&D performed in government establishments and government-financed R&D in the other three national sectors (business enterprise, private non-profit, higher education) as well as abroad (including international organisations). The main advantage of GBARD is that it allows measuring the objectives of public R&D funding, which is relevant information to analyse the evolution and the characteristics of the government R&D policies.

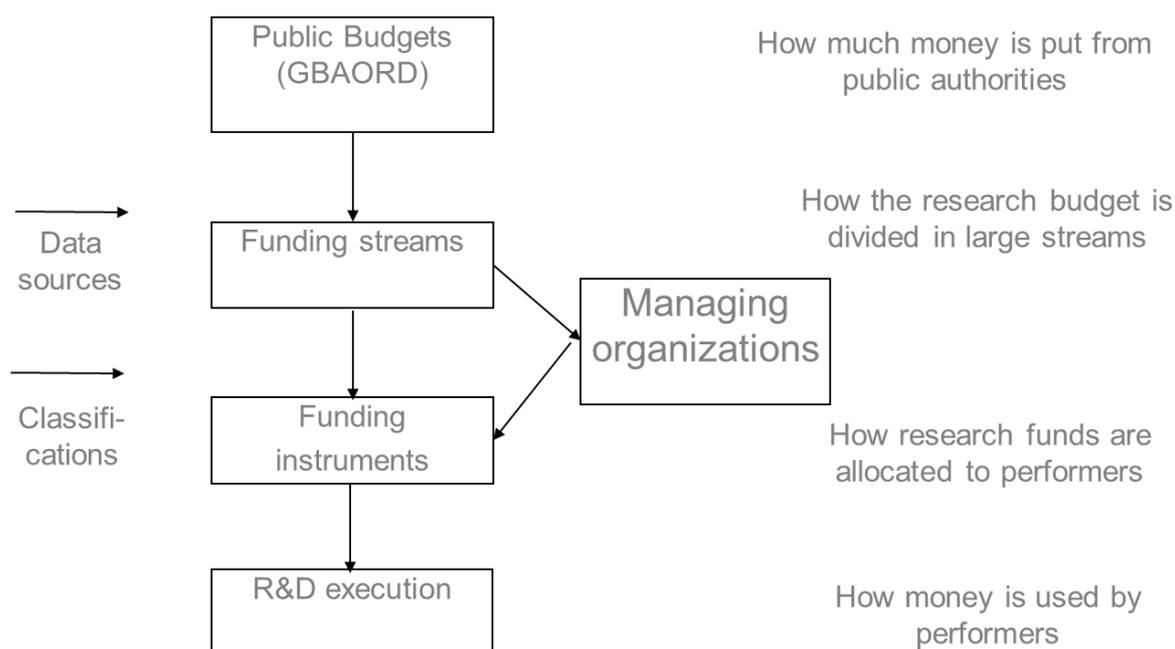
The full methodology, including conceptual scheme, definitions, classifications, indicators, variables and data sources, is presented in the PREF Handbook on data collection and indicator production. The reference perimeter is government budget allocations for R&D. Data on national GBARD, including their breakdown by NABS categories, are derived from EUROSTAT and OECD databases, and are provided in the report as a reference. National public funding is distinguished at two levels:

- Major “funding streams” within the national GBARD, such as core allocations to higher education institutions, allocations to funding agencies and large PROs. The PREF report provides the basic characterisation of these funding streams.
- Concerning project funding, the more fine-grained level of “funding instruments”, using descriptors to identify the main characteristics of government operation. The funding instruments are in turn connected to performing sectors. A given type of funding instrument is not necessarily unique to an individual national program; the same instruments can be used in different programs. The level of granularity in reporting depends on the national funding structure, and in some cases on the capacity to disaggregate the different streams. As a rule, a funding instrument is an articulation of a stream which groups programs of similar structures and objectives. In this report, figures related to i) project funding by beneficiary and type of funding, ii) public private-cooperation, iii) institutional funding, and iv) GBARD for Key Enabling Technologies (KETs) and Societal Grand Challenges (SGCs), are calculated at the instrument level. This means that the amounts can be different from the figures calculated at the stream level, because streams are more complete, and also include state funding to international agencies.

Funding streams and funding instruments are linked to the research funding organisations that manage them, hence revealing the bridges between funding streams and their respective managing organisations. Fig. 3.1 shows the basic data structure.

Detailed information about the process of data collection have been provided in deliverable D2.4 and Annexes of the PREF project.

Figure 3.1 PREF data structure



Source: PREF Handbook, p. 33

3.2 Data sources

The analytical report uses data from the following sources:

- EUROSTAT/OECD data on gross domestic expenditures for R&D (GERD), GERD funded by government (GOVERD), GBARD, business expenditures for R&D (BERD) funded by the government sector, and higher education research and development (HERD), as collected in the First Data Package (Deliverables 2.1). The Report uses the data retrieved from EUROSTAT on April 2016.
- Data from quantitative and qualitative PREF data collection at the national level (Second Data Package, Deliverable 2.4). Data on funding from international research agencies to national performers are also included.

Although the PREF analyses use official statistics on funding and expenditures, they do not attempt to reconcile the total volume of funding/expenditures across levels, therefore the totals by level might be slightly different. Comparability between countries is still assured by calculation of the following data, for each country and year:

- Total GBARD, from R&D statistics.
- Total volume of all funding streams included in data collection (with identification of the funding sources in the relevant countries).
- Total volume of the funding instruments included in data collection.
- Total R&D expenditures funded by the government sector.

Totals 1 and 2 should generally be very similar.² The total at the instruments level should be near the total GBARD, less the amount of funding streams transferring funds to RFOs and performers abroad, and should be quite similar to total R&D funded by government.³

² Differences might come from the inclusion of exchange funds, which are currently not always covered by GBARD.

³ Difference might arise by the fact that funding instrument might also include some PNP or Business Enterprise funding.

The different data from official statistics and PREF data collection serve as complementary sources for mapping the intensity of public R&D funding, and for deepening knowledge of the types of allocation and competitiveness, as well as the responsiveness of countries to emerging R&D priorities at European level.

The issue of public support through tax incentives

Over the past two decades, an increasing number of countries have introduced schemes to promote business R&D through tax incentives. Technically, such indirect support is not considered as public funding, but it in fact constitutes an important part of the policy mix and portfolio of public support for R&D. In many countries, there has been a trade-off between public funding and such indirect support, sometimes involving a remarkable decline in direct funding following establishment of the tax incentives.

Some countries have started to include the calculation of foregone tax revenues in their total amount of public R&D funding. According to the OECD (2013), 27 out of 35 member countries are now practicing some form of R&D tax incentives as part of public support to R&D. However, countries vary widely in terms of the relative importance of these incentives as a share of total public support to business R&D, from above 87 per cent in the Netherlands to only 8 per cent in Italy.

As a result of the widespread use of R&D tax-incentives, the OECD has started to collect harmonised data on the scope, profile and size of national tax-incentives. However, these measurements are still considered experimental in nature. The current report does not describe or analyse tax incentives as part of overall examination of national public funding mechanisms and agencies, since the mandate did not propose inclusion of this dimension, and due to the limitations of existing data collection and analysis. However, despite the experimental nature of the OECD work, it is interesting to look at the available data. These appear to show that in some European countries indirect funding has a very important role in the national R&D strategy. One example is France, where the volume of tax incentives is higher than direct government funding of business R&D, measured as percentages of GDP (Figure 2.1).

Figure 3.2 Direct government funding and tax incentives for business R&D: percentages of GDP (2013)



Source: OECD <http://www.oecd.org/sti/rd-tax-stats.htm#RDtaxincentiveindicators>

Design and sources for qualitative analysis

The use of qualitative data in the descriptors permits analysis of the evolution of public funding in terms of the characteristics of the instruments, which in turn reveal the policy priorities and the intentions of the different actors.

The categories of qualitative information collected are those that serve in characterising the funding streams and instruments. The data include that from desk research on recent developments in funding mechanisms among the countries of the PREF partners. This research complements the development of the descriptors foreseen in the data collection, by integrating other information useful for the data analysis and for the country profiles. In this respect, the most important source is the ERAWATCH database, followed by OECD, European Science Foundation (ESF) and individual country sources.

The combination of different sources aims at gathering contextual and systemic information for each country as background for understanding variations in R&D funding structures. In addition, the network of national experts plays a role in filling in or explaining gaps in data. The table below (Table 3.1) summarises the main categories of indicators.

Table 3.1 Main categories of indicators

Indicators	Main data sources
List of funding agencies per country	Analysis of national systems by country; available evidence from national statistical authorities, funding agencies and annual reports. Other sources: RIO country reports, Stairway to Excellence reports, JOREP, ERAWATCH
Characterisation of research funding organisations and umbrella public research organisations, applying RFO and UPRO descriptors per the PREF Handbook	Analysis of national systems by country, using available evidence from NSAs, funding agencies and annual Reports, complemented by expert assessment on RFOs and UPROs. Available evidence from RIO and Stairway to Excellence reports, ERAWATCH, JOREP, and reports from funding agencies.
Characterisation of research funding (institutional funding and funding programs), applying descriptors on funding streams per the PREF Handbook	Analysis of national systems by country, using available evidence from NSAs, funding agencies and annual reports, complemented by expert assessment on RFOs. Available evidence from RIO and Stairway to Excellence reports, ERAWATCH, JOREP, and reports from funding agencies.
Characterisation of mechanisms, practices and criteria used in funding allocation, applying descriptors per the PREF Handbook	Analysis of national systems by country, using available evidence from NSAs, funding agencies and annual reports, complemented by expert assessment on funding mechanisms. Available evidence from RIO and Stairway to Excellence reports, ERAWATCH, JOREP, and reports from funding agencies.
Qualitative analysis of the shares of modes of funding and themes of funding	Quantitative data collected in the study, complemented with reports and a review of the relevant literature on changes across time.

Source: PREF.

3.3 Problematic issues in data collection

The consistency of the data in the current report with that from official statistics is very good. In particular the total GBARD by country at stream level is consistent with total GBARD from EUROSTAT statistics. Moreover, the quality checks during data collection guarantee very good comparability of data between countries (see Deliverable D2.4 for details on quality checking and data quality).

In general, there is also good consistency of the PREF indicator on project funding allocation with EUROSTAT data, for the limited number of countries that report to EUROSTAT on this funding division. However, the consistency is not good for Luxembourg, Poland and Portugal, where the EUROSTAT calculations show different percentages of project funding out of GBARD compared to PREF data. The PREF method of checking with experts and NSAs in different countries indicated greater reliability in PREF data collection compared to that from EUROSTAT.

However, there were also problematic issues in data collection, one of which was the strongly varying responsiveness of national contact points, particularly the NSAs. Both deliverable D2.4 (Table 1), and the PREF database metadata provide more detailed reports on all the country-specific problems. Under points 1 to 4, we limit ourselves to grouping the countries relative to the different types of problems, and describing how these were managed for the study.

1. Countries providing no or limited data

Despite determined efforts, there were four countries for which the only data obtained on public R&D funding were those from official statistics. These were:

China. The first approaches for data collection received little response and led only to general information and links to Chinese S&I policy documents. However, from this beginning, we were able to retrieve data for elaboration of an overview of the major RFOs and funding streams. The more difficult task was to retrieve official amounts describing the allocations from ministries through single RFOs and funding streams. This challenge becomes still more difficult since China recently initiated an extensive reform of its S&T system. Under the reforms, about one hundred national S&T programs managed by a mix of ministries and departments will be classified into five categories. More importantly, the ministries and departments will then no longer manage specific projects directly. This has implications for the PREF data on structure of RFOs and funding streams, as collected for the current study.

Japan. The first approaches for data collection received little response. One problem seems to be that a range of individual ministries holds strong positions in the funding system, and that there are few persons able to provide consistent funding data across ministries. There is also little material in English, from which to extract an overall picture of funding. It was particularly difficult to link system descriptions with the corresponding funding data over several years. For all streams, data distinguishing between project and institutional remain uncertain.

Turkey. For this country, it was not possible to receive data on amounts for funding streams. Cooperation from national authorities responsible for R&D statistics was very limited. Publicly available sources proved useful for obtaining aggregate data on government R&D expenditures, but little else.

Latvia. Despite a number of approaches by e-mail and telephone, the NSA did not send any information or data about public R&D funding. Data on RFOs and funding streams were developed based on ERAWATCH/RIO reports and external evaluations of the Latvian R&D system, but obtaining data on the evolution of funding streams and instruments over several years remained difficult. We compiled the data on funding agencies, streams and instruments available from external evaluations and obtained a quality check and supplementary data from non-NSA contacts in Latvia, but the analytical results should still be considered with caution.

2. Countries lacking robust data

For some countries, primarily in Eastern Europe, there are problems of robustness and consistency: Bulgaria, Croatia, Estonia, FYROM, Montenegro, Hungary, Serbia, and also to some extent Luxembourg and Romania, where several types of data were missing. The different problems and solutions adopted are detailed in the country profiles. In the current report, we analyse and discuss only those data that are robust enough to guarantee good comparability with other countries, which mainly concern the stream level. Specific details and considerations on data availability are indicated in the text and the notes to charts.

3. Countries with limited time series

The goal of the current report was to obtain data for the period 2000 to 2014. However, for countries where GBARD data collection is conducted at two-year intervals, or where NSAs had not yet released data for 2014, the last year reported may be 2013. In some cases, there were also problems in availability of the full-time series:

- Lack of continuity because the methodology of GBARD data collection changed, most frequently affecting data from 2000 to 2006, sometimes up to 2008;
- Because of lack of resources, some NSAs have not collected data on instruments, and data disaggregated at the level of funding streams. Elaborating this sometimes requires difficult work to build up categories of streams, particularly when reliable alternative sources (e.g. annual reports of RFOs) are unavailable. Where possible, estimations were used to reduce these shortcomings (see public funding country profiles for details). These were always checked with the relevant NSA prior to use in the analyses and report.
- Problems with GBARD data collection and availability at the national level, impeding development of full time series.

These problems are presented in some detail in the country profiles and the PREF database metadata (methodological notes).

4. Problems in breaking down data by fields, classifications and beneficiaries

A final set of limitations concern difficulties in breaking down the data by detailed fields.

For both institutional and project funding, it is impossible to consistently break down the data on public allocations (GBARD) by field of R&D (FORD), either because the allocation is in the form of core funding to specific institutions, who then serve as final actors in deciding distribution, or because the possibility to disaggregate a project funding instrument into separate fields is possible only at the level of execution.

On the other hand, it would seem likely that NABS classification would be used at GBARD level, aimed at indicating the policy objective of the funding streams. However, attributing NABS classification at this level resulted as unfeasible for most countries under examination. In fact, any NABS classification observed is typically the result of estimation made by NSAs, based on their observations of GBARD as whole. The ability to classify all funding streams is limited to few countries, and a large majority can only attribute the funding to categories 12 (General advancement of knowledge-R&D financed by General University Funds GUF) or 13 (General advancement of knowledge- R&D financed by other sources than GUF).

A final limitation concerns lack of information on the breakdown of funding instruments by beneficiaries, a problem already familiar from other projects, such as JOREP. For some countries, it is difficult to disentangle the amounts of funding allocations devoted to different types of beneficiaries, because it is a matter that can only be analysed at the execution level. This means that the availability of statistics from different countries is uneven.

The limitations described above do not affect the comparability of the data, which is very good, and consequently the robustness of the analysis presented in the report. For more

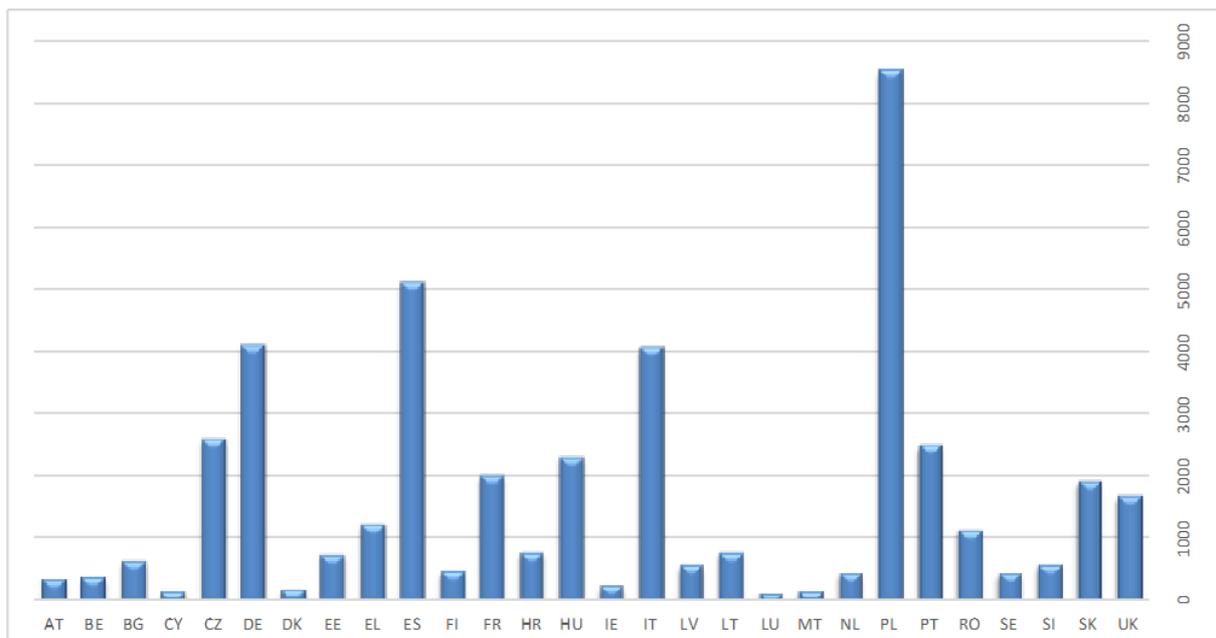
information on the characteristics of the data collected in the different countries the reader can also refer to the Data Quality Report and to Section 2 of the Public Funding Country Profiles.

3.4 Data on EU structural funding

EU structural funding is an important source for the R&I budgets within the individual member states. The intention of the PREF project was to obtain data on structural funding directly from the EU, for a full overview of funding arriving in the different countries over the years, however after determined attempts, our observation is that it seems impossible to receive such data. In January 2015, the Commission provided the consortium a link to a DG REGIO database with information on planned financing under the different ESI Funds for 2014-2020. The data was provided as a financial table and broken down by fund, program, priority axis, thematic objective and category of region (more or less developed, etc.) However, these data refer to planned and future allocations, which are not directly useful for PREF. Furthermore, the historic and current allocations of structural funds have also been determined below the EU level, based on priorities and considerations. Therefore, the PREF project had to proceed from nationally reported data on past use of SFs, developing these in a manner suited to the study aims and analyses. The problems in deciphering EU funding descended to the analyses at national level. For many eastern countries, structural funds constitute a substantial share of total funding. Since internal ministries and other public funding agencies, often combined with national funding, allocate SFs, it is difficult to disentangle the shares of state and structural funding at the stream and instrument levels. In this case, data have been included in the dataset only when contacts at NSAs were able to assist in solving the problem.

Figure 2.3 below shows the volume of EU funding for research and innovation in EU member states (planned amounts for period 2014-2020), and reveals the important role of structural funds in some countries. However, the data cannot be further commented, since they include funding for both R&D and innovation and no possibility to separate them.

Figure 3.3 European Structural and Investment Funds for Research and Innovation projected for EU member states (2014-2020)



Source : EU cohesion data available at : <https://cohesiondata.ec.europa.eu>. Unit: million Euro.

4 Intensity of public funding for R&D in European countries

This section diagrams the evolution of intensity of national public R&D funding over the years considered in the PREF study. The analysis is based on EUROSTAT/OECD data⁴ and information from PREF data collection on funding streams.

This section of the report summarises the changing intensity of public funding, including distribution to public and private sector, and the distribution to fields of higher education (FORD classification). Section 4 will delve more deeply into issues of institutional versus project funding, policy objectives and beneficiaries (Indicators 9.1.1 and 9.1.2). The different analyses also provide evidence of congruence between official statistics and PREF data.

4.1 Evolution of intensity of public R&D funding, 2000-2014

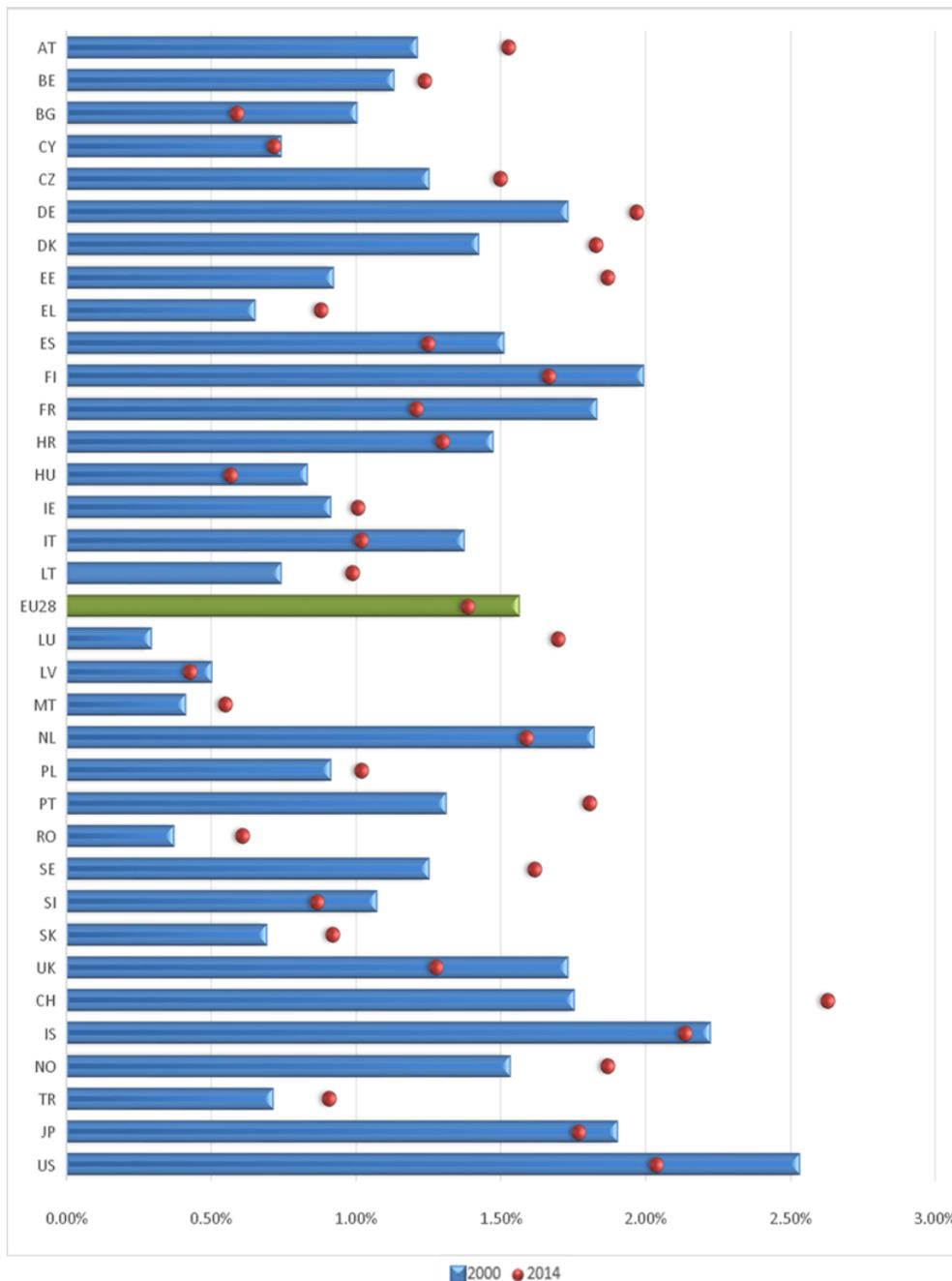
According to the Frascati Manual (OECD, 2015), “government budget allocations for R&D” (GBARD) is a measure of the public investment in R&D based on analysis of the public budget. The indicator relies on identification of the specific budgetary lines intended for R&D, such as transfers to RFOs or research organisations. The indicator is considered particularly suited to revealing policy intentions behind the mobilisation of public funding for research, and the policy objectives pursued by different governments using R&D allocations.

National funding for R&D has changed through the first years of the 2000s due to general reductions in the public budgets in times of economic crisis, and through modification in modes of allocation. Almost all European governments have reduced R&D funding, except for a few cases showing strong counter-cyclical behaviours, generally aimed at stimulating economic growth and encouraging private investment in R&D. Figure 3.1 shows GBARD for the years 2000 and 2014 in the 40 countries covered under the PREF project, as percentage of general government expenditures. This indicator reveals that funding allocations have grown in different countries, mobilizing a higher share of public expenditures than at the opening of the period examined.

We observe a group of countries in western Europe with positive evolution of public investment, where government expenditures became much more important over 2000-2014. These include Germany, Switzerland, Austria, Denmark, Luxembourg, Portugal and the nordic countries, except Finland, which shows a strong reduction in this indicator. Other western European countries instead show reductions in GBARD as percentage of state expenditures, in some cases quite substantial (e.g. France, Spain, Italy, UK and Netherlands). Eastern countries generally show positive trends in percentages of public funding for R&D; for the Czech Republic, Estonia, and Slovakia this is particularly strong. We also observe that average annual real growth of GBARD during the 2008-2011 economic crisis shows highly disparate trends among European countries, with strong to very strong negative values in NL (-0.9%), BE (-1.1), FR (-1.3%), UK (-3.7%), IT (-5.2%) and ES (-5.3%), contrasting with strong to very strong growth in some other countries (FI +0.6%, SE +2.8%; DK and AT +3.6%, DE +4.1%). Apart from these specific countries, the remainder of the European nations observed show negative values (-1.4% on average) (IUC, 2013).

⁴ EUROSTAT, release of April 2016.

Figure 4.1 GBARD as percentage of general government expenditures: PREF countries (2000/2014)



Source: EUROSTAT.

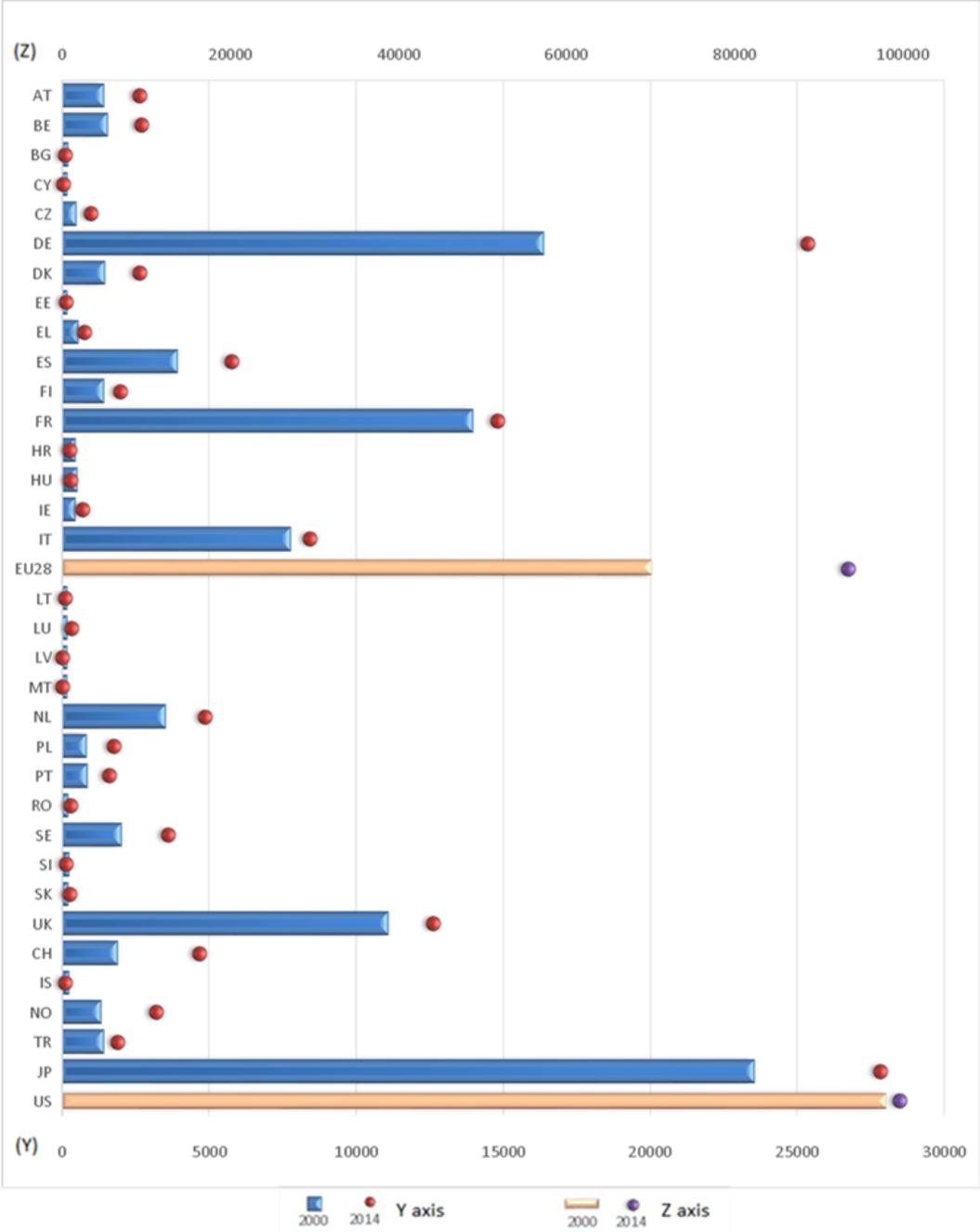
Note. Start year is 2001 for EU28; 2004 for CY and MT; 2005 for HU; 2008 for HR, TR, JP, US. End year is 2011 for TR; 2013 for JP, US. Data for CN, FYROM, IL, LI, ME, RS are not available.

Fig. 4.2 presents the absolute values of total GBARD in the PREF countries, plus the total GBARD of EU-28 in 2000 and 2014 (in Euro, current prices).

We can immediately note two meaningful aspects in evolution of public R&D funding. First, growth in the GBARD of the EU-20 countries from 2000 to 2014 (current prices) pushed the European area towards an absolute value of public investment close to the total GBARD for the USA. However, even considering all EU-28 countries, factoring in the data from Fig. 4.1, the overall investment in GBARD did not fully achieve US levels of public funding, despite the policies aimed at 3% targets which were to be adopted by countries as a consequence of the Lisbon strategy. Second, the unique position of a small

number of countries within the EU becomes very clear: those with very high values of GBARD in 2000 actually reinforced this position over the interval to 2014, showing the highest increases in this indicator. The most striking examples are Germany, among larger European countries, and Switzerland among smaller ones. The counter-cyclical policy on public R&D investment in these countries, observed in the previous section, is confirmed. Austria, Denmark, Sweden and Norway also continued strong policies on public investment, although for these countries the growth was not as great. If we consider the values of the other countries in combination with the evidence from Figure 4.1 we can conclude that in many cases, growth of GBARD fom 2000 to 2014 has been weak.

Figure 4.2 Total GBARD: PREF countries and US (2000/2014)

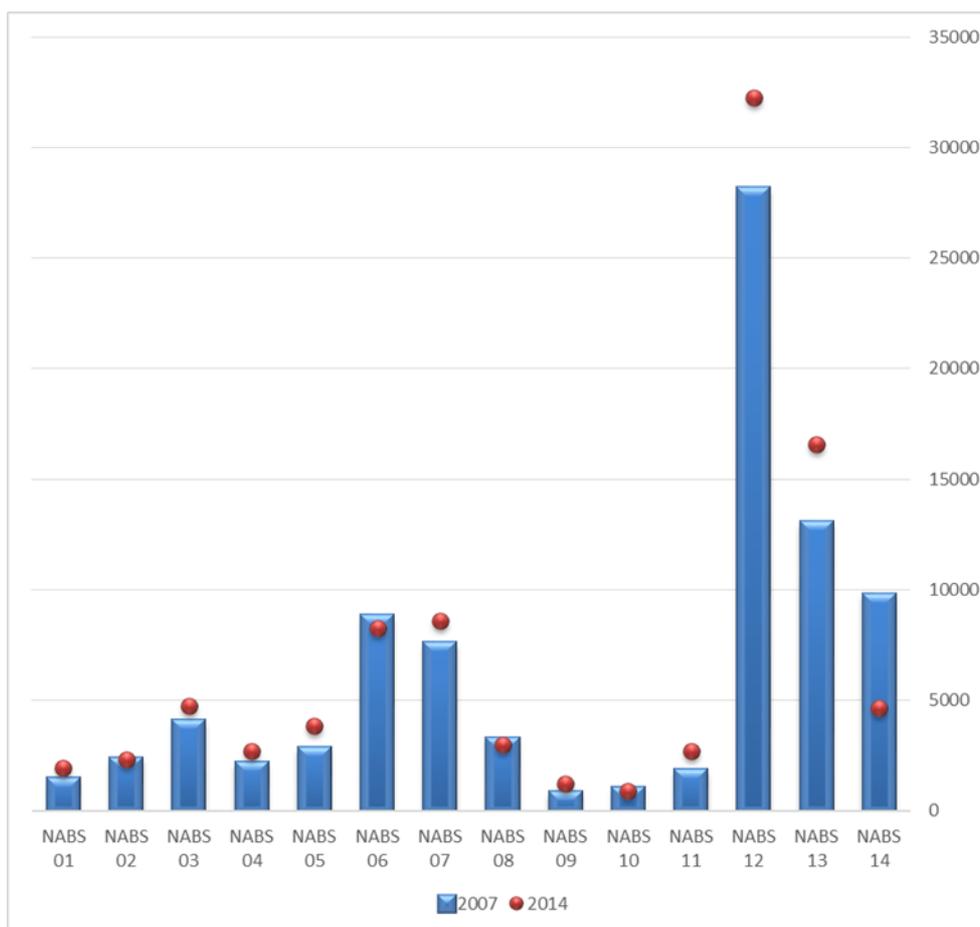


Source : EUROSTAT. Unit : million EUR (current prices).
 Note. Start year is 2001 for EU28; 2004 for CY and MT; 2005 for HU; 2008 for HR, TR, JP, US. End year is 2011 for TR; 2013 for JP, US. Data for CN, FYROM, LI, IL, ME, RS are not available.

Fig. 4.3 shows distribution of GBARD by policy objectives, classified according to Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets (NABS), for indication of the policy intentions of R&D funding.

The figure illustrates that the relative importance of different policy objectives has remained very stable over 2000-2014, with exceptions. In particular, a significant reduction in funding for Defence R&D (NABS 14) has been matched by an overall increase in funding for “general advancement of knowledge”, implemented through both general university funding (NABS 12) and other channels (NABS 13).

Figure 4.3 GBARD classified by NABS: EU-28 countries (2007/2014)



Source : EUROSTAT. Unit : million EUR, current prices.

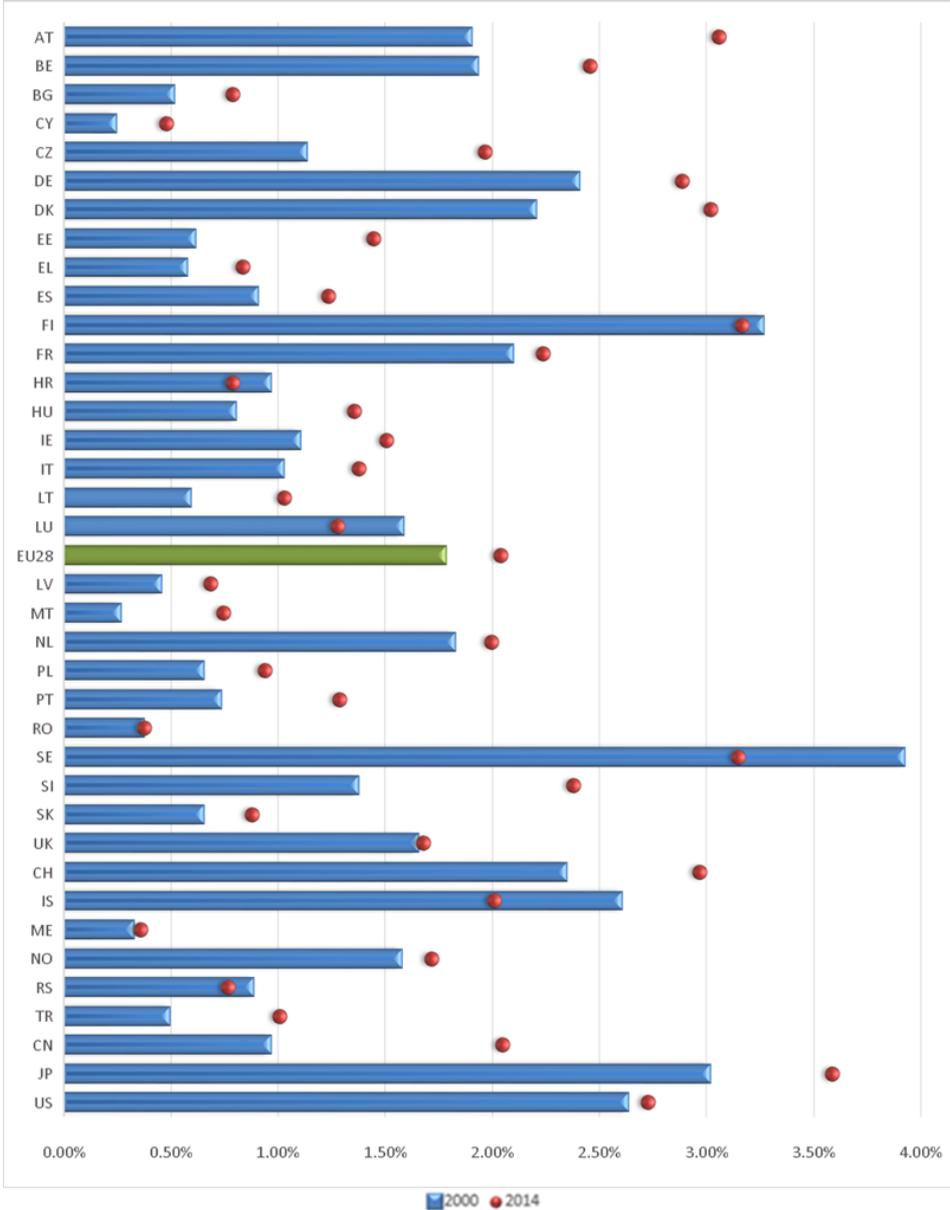
NABS 01: Earth, NABS 02: Environment; NABS 03: Space; NABS 04: Transport, telecommunication and other infrastructures; NABS 05: Energy; NABS 06: Industrial production and technology; NABS 07: Health; NABS 08: Agriculture; NABS 09: Education; NABS 10: Culture, recreation, religion and mass media; NABS 11: Political and social systems, structures and processes; NABS 12: General advancement of knowledge: R&D financed from General University Funds; NABS 13: General advancement of knowledge: R&D financed from other sources than GUF; NABS 14: Defence.

4.2 Public/private sector performance of research, using public R&D funding

In examining R&D expenditures, it is interesting to see the evolution of the government’s role in enacting the actual gross expenditures on research (GERD) illustrated in Fig. 4.4. The average GERD in EU-28 in 2014 is about 2% in percentage of GDP; European countries showing higher percentages are DE, DK, FI, FR, SE, SI, and CH. There is a general tendency toward increasing the total GERD –but with different rates between countries; few exceptions are visible of countries reducing the importance of R&D expenditures as percentage of GDP (FI, HR, LU, SE, and IS).

Figure 4.5 provides the data for years 2000 and 2014 on “government intramural expenditure on R&D” (GOVERD), as percentage of GDP. Several countries, particularly Austria, Finland, France, Sweden and Iceland, show remarkably high shares of government sector performance of research out of total gross domestic product. In all of these countries, GOVERD was near to or greater than .80% of GDP in 2000; GOVERD then grew over the years until 2014, except in Iceland, where there was a very important reduction, dropping the share to .62% of GERD. Other countries showing a reduction of GOVERD are Netherlands and United Kingdom, as well as Bulgaria, Croatia, Lithuania and Serbia.

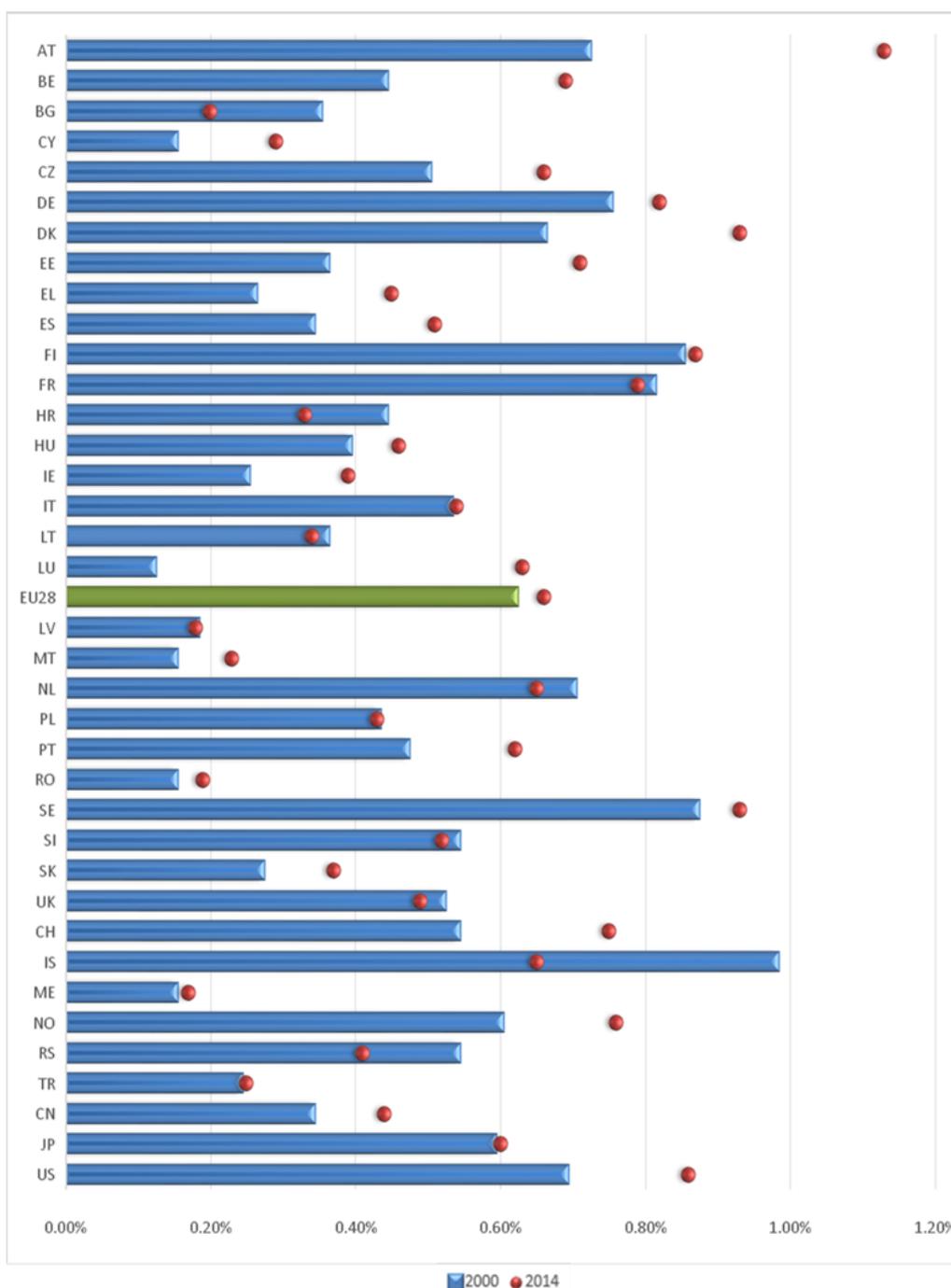
Figure 4.4 Total intramural R&D expenditure (GERD) in percentage of GDP (2000/2014)



Source: EUROSTAT.

Note. Start year is 2001 for EL, SE, CN; 2002 for HR, MT; 2009 for RS; 2011 for ME, NO. End year is 2012 for CH and 2013 for US. Data for FYROM, IL, LI are not available.

Figure 4.5 GOVERD (government intramural expenditures on R&D) as % of GDP: PEF countries and US (2000/2014)

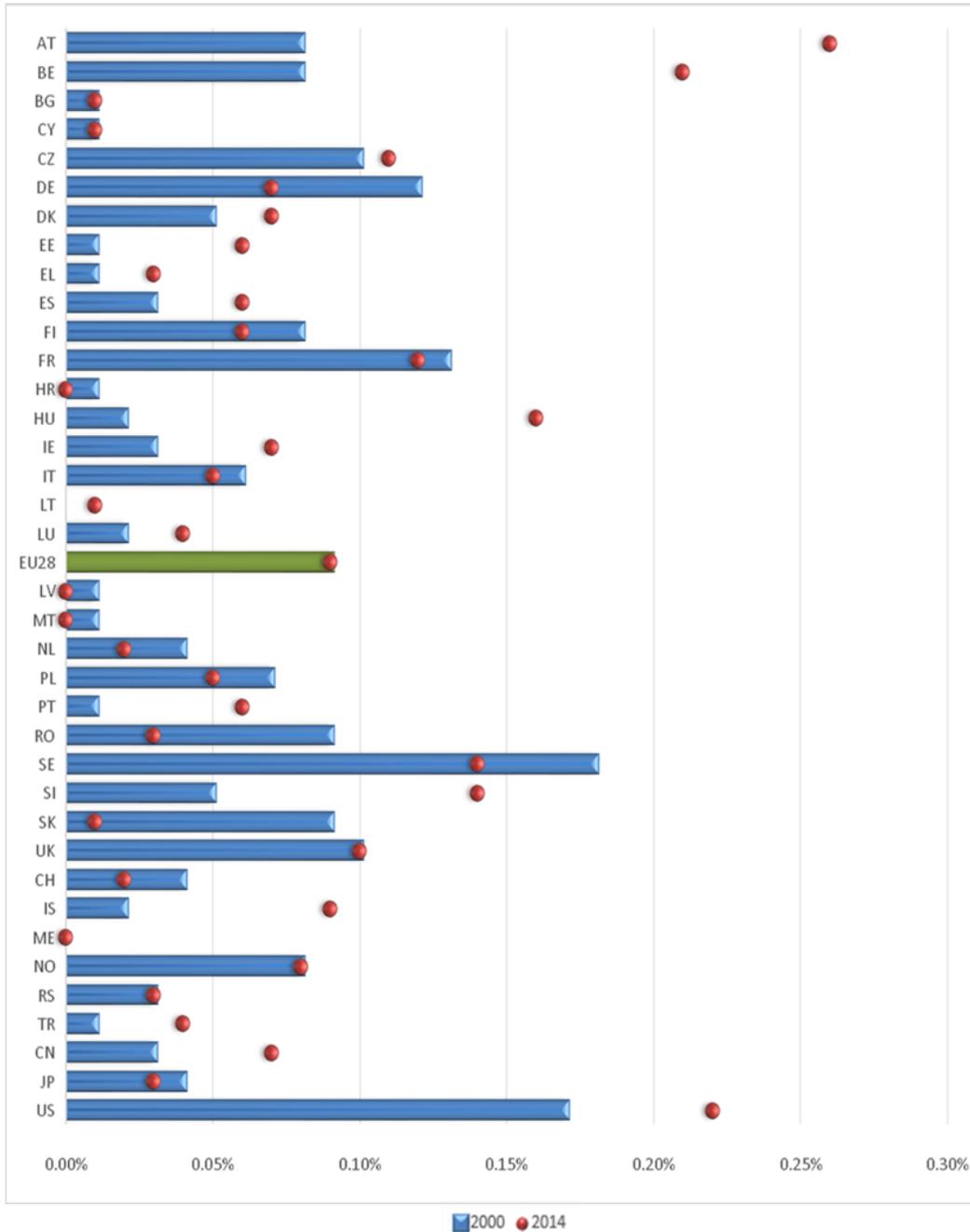


Source: EUROSTAT.

Note. Start year is 2001 for DK, EL, NL, SE, IS, NO; 2002 for HR, MT; 2003 for CN; 2005 for IT; 2009 for RS; 2011 for ME. End year is 2012 for CH, US; 2013 for BE, BG, CY, DE, FR, IT, LU, EU28, PT, SE, IS, NO, CN, JP. Data for FYROM, IL, LI are not available.

On the other side, Fig. 4.6 provides figures on the share of gross business expenditures on R&D (BERD) funded by government, again as percentage of GDP. The table clearly shows different strategies among the countries considered: some of them increase the percentage of government funding to business over 2000-2014 while others reduced it, irrespective of the volume of government funded GOVERD and HERD. The average value of BERD as funded by the EU-28 governments remains stable in the considered years.

Figure 4.6 GOV-BERD (BERD funded by government) as % of GDP: PREFER countries and US (2000/2014)

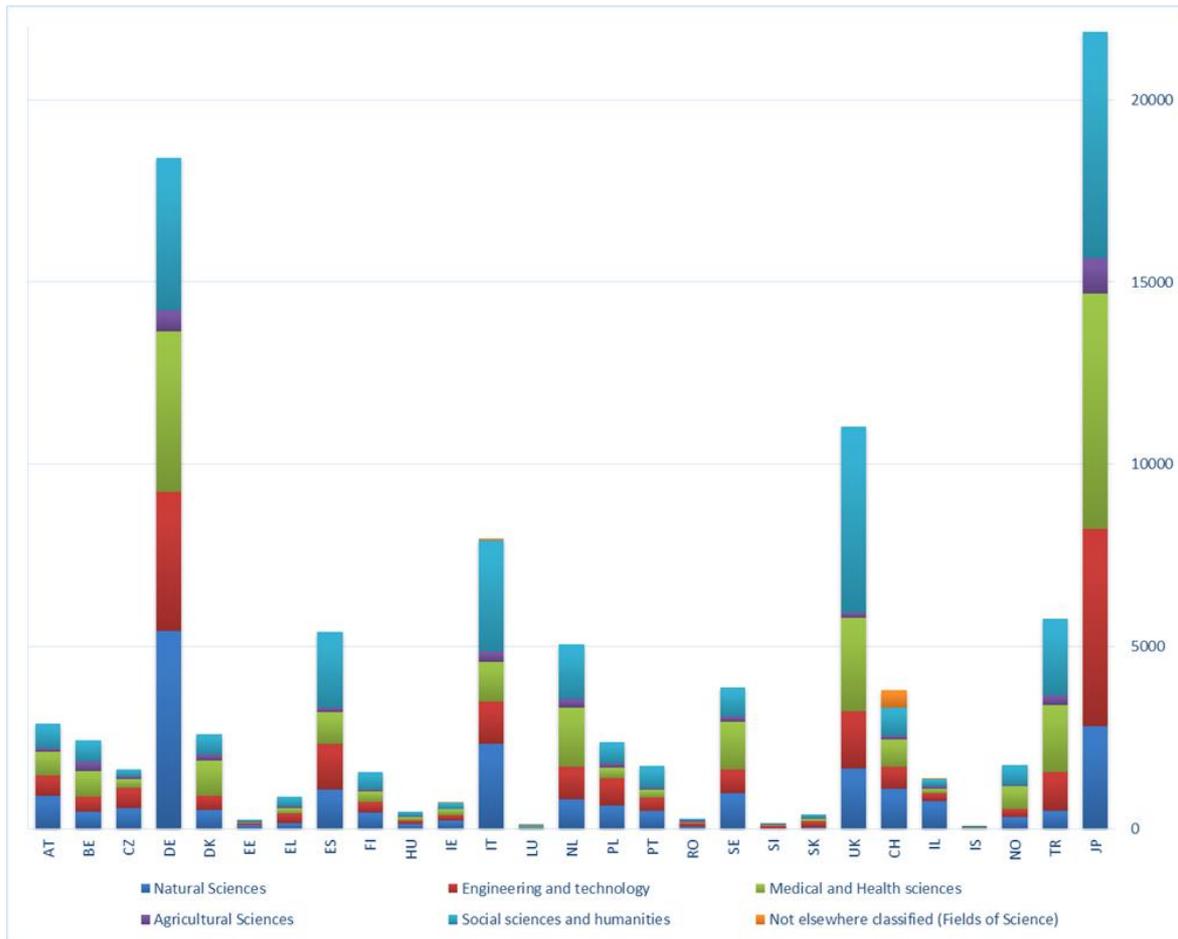


Source: EUROSTAT.

Note. Start year is 2001 for DK, HR, MT, NL, SE, IS, NO; 2002 for AT; 2003 for EL, CN; 2009 for RS. End year is 2009 for LU; 2012 for EU28, CH, US; 2013 for AT, BE, BG, CY, IT, PT, SE, IS, CN, JP.

Finally, it is useful to consider the distribution of public expenditures for research in higher education by fields of R&D (FORD). This data can also serve as a good approximation of the breakdown of overall national public R&D funding, for countries where the most important beneficiaries are HEIs. Figure 4.7 shows that the distribution is roughly oriented towards investment equally balanced across all fields. Despite this balance, some countries devoted greater shares of investment to natural sciences than to other fields (e.g. Austria and Germany), while other countries tended to emphasise the social sciences and humanities more than other areas (e.g. United Kingdom, Spain, Italy).

Figure 4.7 HERD by fields of R&D: PEF countries (2013)



Source: OECD; Unit: PPP Dollars - Current prices.
 Data for BG, CY, FR, FYROM, HR, LI, LT, LV, ME, MT, RS, CN, US are not available.

5 Evolution of public R&D funding in European countries: institutional vs. project, policy objectives, beneficiaries

This section examines the different arrangements of public funding for R&D in the countries considered under the PREF project. In principle, institutional funding is intended to provide research organisations with a stable basis for research activities; it serves as a starting point for acquisition of funds from other sources, and ensures a degree of autonomy in selection of research topics. Institutional funding was traditionally allocated using block funding practices, meaning with only general provisions on spending. A criticism of this approach is that it can de-incentivise organisations and researchers from entering competition in which demonstrations of quality and productivity assist in qualifying for other funding. Institutional funding would thus generate less effective research performance than project funding.

As described in Section 3, the PREF project collected data on national public funding allocated to R&D in terms of categories of funding within overall GBARD. We examine the data in this section of the report. It should be noted that public R&D funding is composed of both direct and indirect measures, such as tax incentives, which have increased remarkably in importance over recent years, even more so in specific countries (e.g. NL, FR; see IUC 2013). However, tax incentives are not included in the PREF data collection (see Section 3.2 of this report). EU funding within the nations is on the other hand included in PREF data collection, except for structural funds, because of problems in availability of information on funding devoted to R&D (see section 3). This is an important element to consider when examining the data, for two main reasons: i) in some countries, particularly of eastern Europe, structural funding is an exceptionally important component of public R&D investment; ii) the period covered by the PREF study includes the 2008-2011 interval of global economic and financial crises, which in Europe generally involved sharp cuts in public budgets. Concerning this, when the analysis of the PREF data show countercyclical increases in national public R&D investment, it must be kept in mind that the observation does not capture all the components of the public R&D investment. In fact, several countries enacted such countercyclical policy by combining direct and indirect measures, as well as by strategic use of support from EU structural funding (IUC, 2013).

5.1 Characterisation of public research funding in the different countries

Drawing on the PREF descriptors and categories, this section analyses the characteristics of national public R&D funding streams in terms of objectives, aims and goals, types of allocation and budget. Where data are available, it also examines the amounts of funding instruments allocated to the different beneficiaries (public, private, higher education, government).

5.1.1 The funding streams: project/institutional, recipients, research areas

The most important change in national public R&D funding over recent decades is considered to have been the reorganisation of policy and objectives and the related change in forms used to allocate the funds (Lepori et al. 2007). The growth in importance of project funding has been recognised as a key aspect of transformation in R&D policies, affecting all European countries, but with different “pace” and to different degrees. Thus far, it has not been possible to effectively monitor the change, using indicators. The PREF project is intended to fill this gap.

Figure 5.1 presents national public R&D funding (expressed in EUR) for the year 2014, in the institutional and project streams, in the countries covered by the PREF study.⁵

⁵ The analysis does not include LV, RS, China, JP and TR, due to limited availability of data (see Section 3.3).

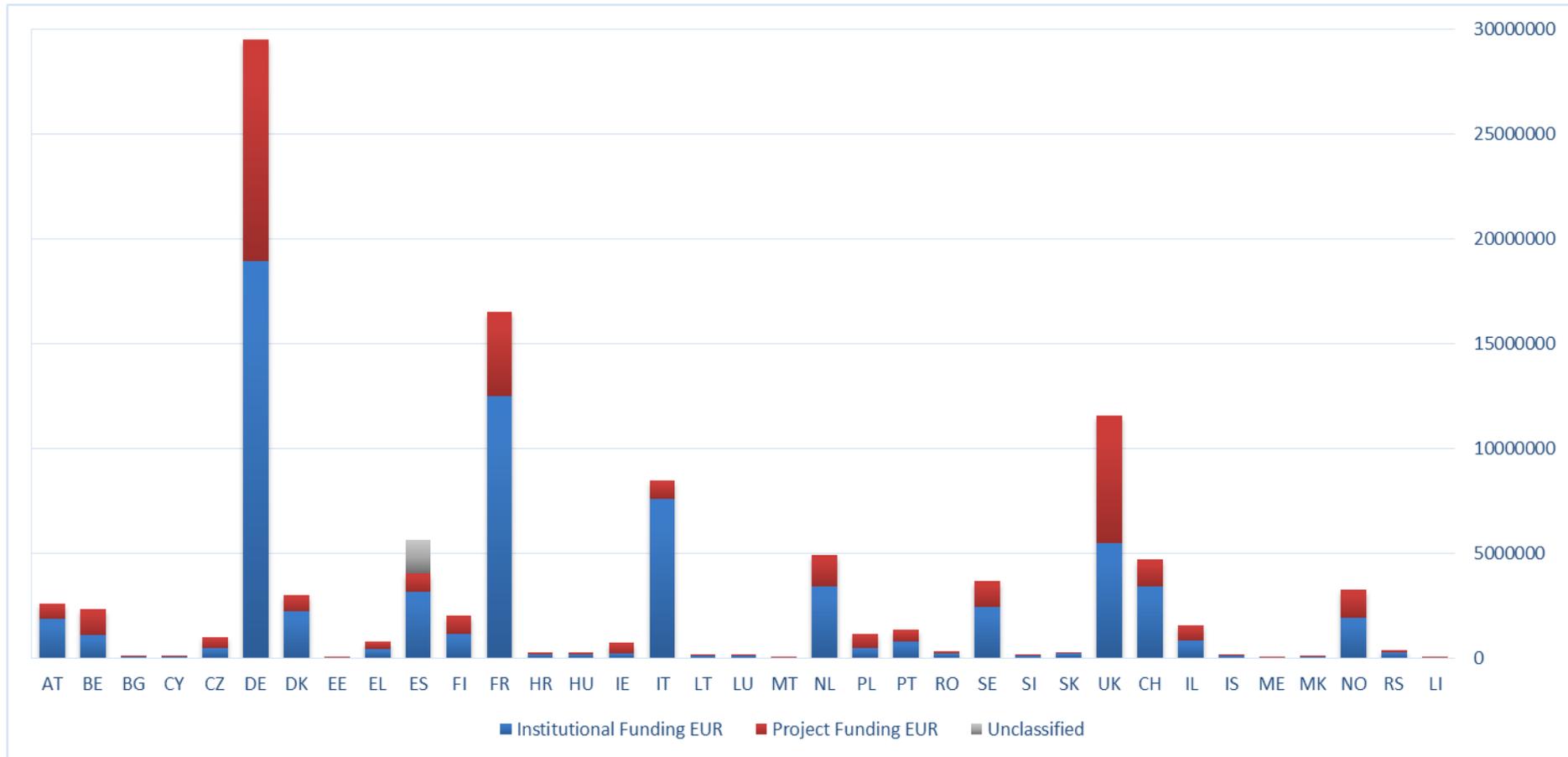
Despite the different overall levels of public R&D funding, we see that project funding is visible in all countries. USA data are not charted, but in this case are: 37.1 billion Euro for institutional funding; 64.9 billion for project funding; total 102 billion GBARD (2014).

Figure 5.2 plots the shares of project and institutional funding out of the overall public R&D package, per country, again for the year 2014. A first observation is that despite a general movement toward increasing the project funding allocation, present in all the European countries, the shares of funding mobilised for this area are heterogeneous. Two further considerations are: i) the UK, Poland, Belgium, Czech Republic, Estonia and Ireland are the countries in Europe with the highest percentage of project funding out of total national public R&D funding (more than 50% of GBARD; ii) within both the western and eastern areas of Europe, large and small countries show remarkably different percentages of project funding in the year considered. Thus, neither the geographical position nor the size of the country seem to influence the amount of funding allocated in the project stream, which would thus seem to be driven by nationally developed strategies in R&D policy.

Figure 5.3 presents the breakdown of funding streams by category of recipient, expressed as percentage of total GBARD, in the different countries. The dominant category across almost all the countries is that of higher education institutions, for which funding is mainly awarded by institutional allocation. The second category in order of dominance is the share allocated to research funding organisations (RFOs), which then generally provide funds on a project basis. The quota of funding to public research organisations (PROs) varies remarkably between countries because of the differing profiles of this type of performer within the structural organisation of the national R&D systems. The allocation to umbrella public research organisation (UPROs) deserves special consideration. These are essentially PROs with dual function, both management of research activities and provision of competitive project funding (see PREF Methodological Handbook). In countries where UPROs are present, the share of allocation to this category is substantial (e.g. Germany, Spain, Hungary, Italy); the sum of funding to PROs and funding to UPROs therefore provides a measure of the importance of these non-academic actors in the public research systems.

Finally, Figure 5.4 shows the breakdown of GBARD funding streams by NABS classifications. As described in Section 3, it has been difficult to break down the national streams in this regard. In fact, there are several countries where the data is unclassified, and many others that can only estimate the funding as falling in NABS categories 12 and 13 (both concerning general advancement of knowledge). However, for countries where a more complete breakdown has been accomplished using PREF data, these data show good concordance with the available EUROSTAT data.

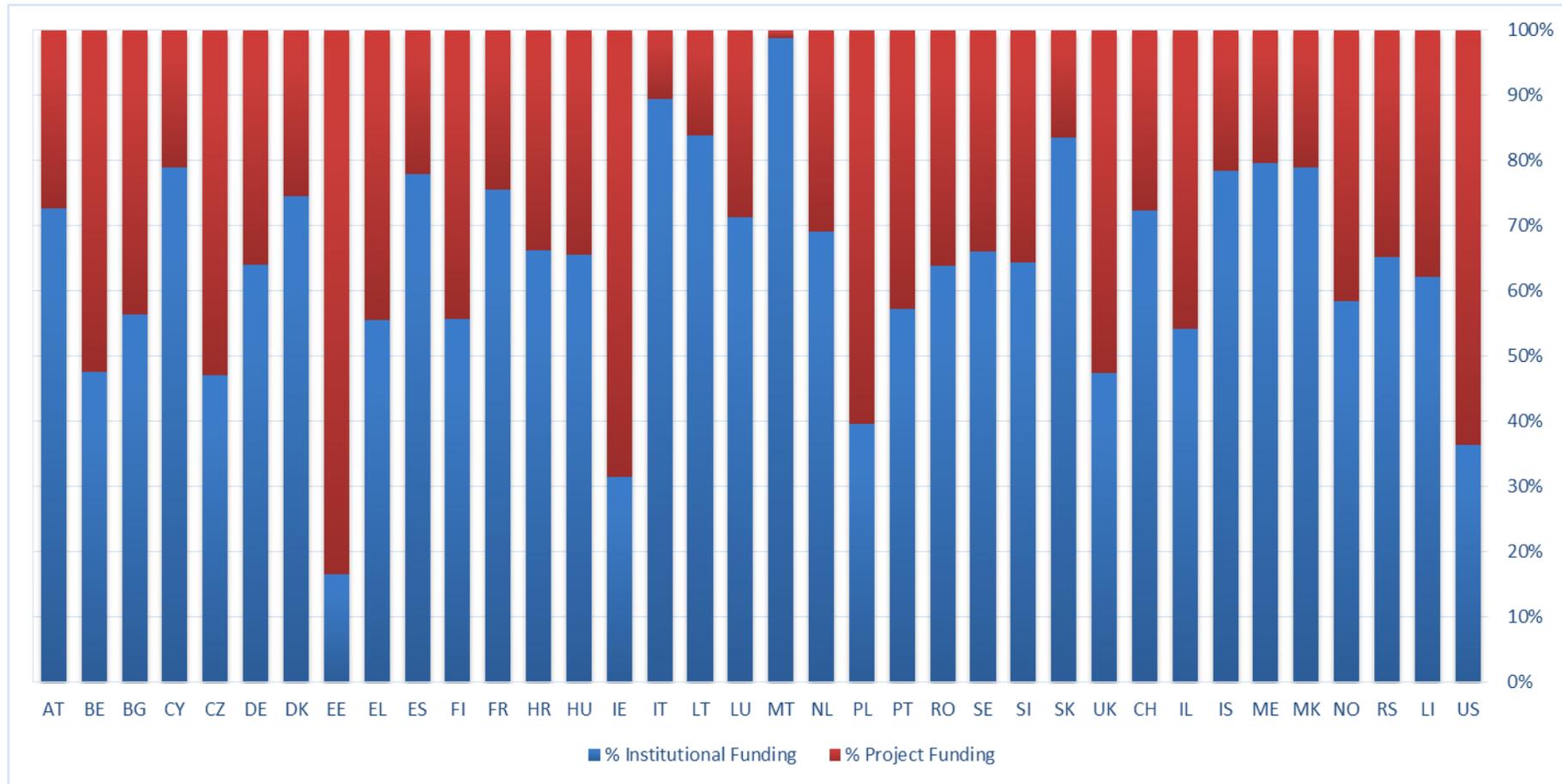
Figure 5.1 Amounts of institutional and project R&D funding: PREF countries (2014)



Source: PREF. Unit: thousand EUR.

Note. US not included. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR. The consistency between PREF data and ESTAT data on GBARD for each country are presented in the Public Funding Country Profiles (see Annexes)

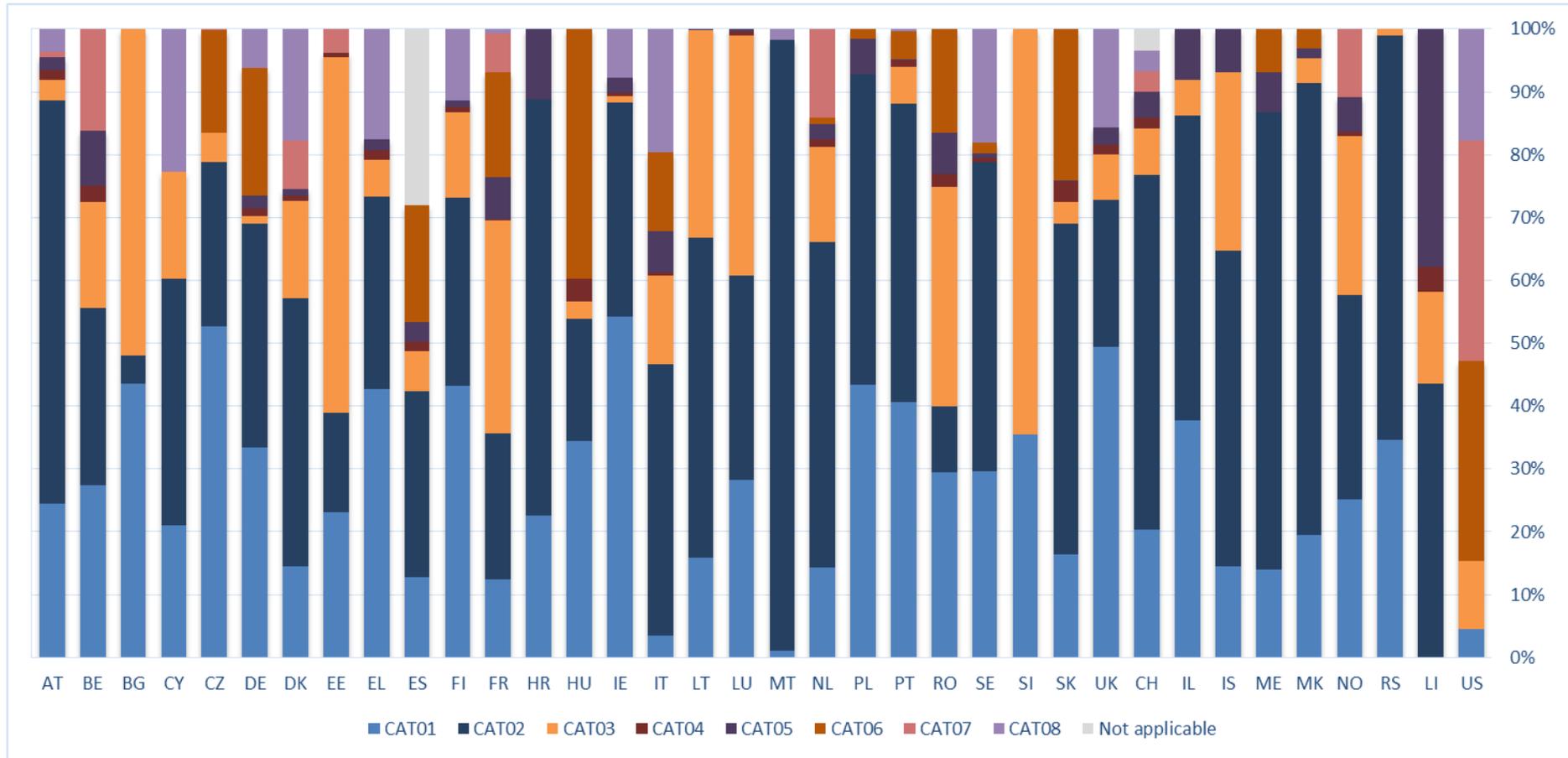
Figure 5.2 Percentages of institutional and project funding out of total GBARD: PREFER countries (2014)



Source: PREFER.

Note. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

Figure 5.3 GBARD by funding stream category (% , 2014)

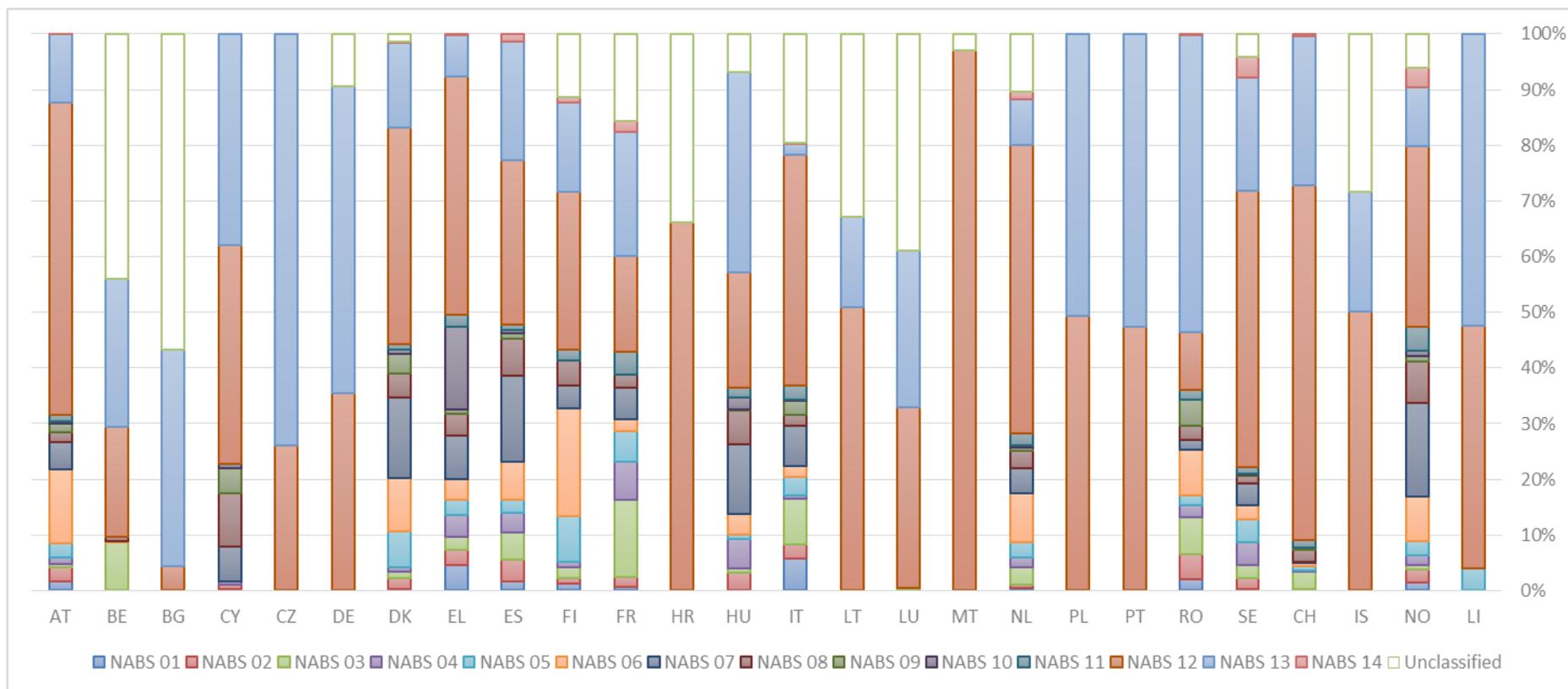


Source: PREF.

Note: CAT01=Funding to RFO; CAT02=Funding to HEIs; CAT03=Funding to PROs; CAT04=Funding to international performers; CAT05=Funding to international funding agencies; CAT06=Funding to UPROs; CAT07=Exchange funds; CAT08=Intra-mural R&D of the government.

Note. Reference year for AT, ES, LT, UK is 2013, and 2015 for FR.

Figure 5.4 R&D funding streams by NABS category, per country (% , 2014)



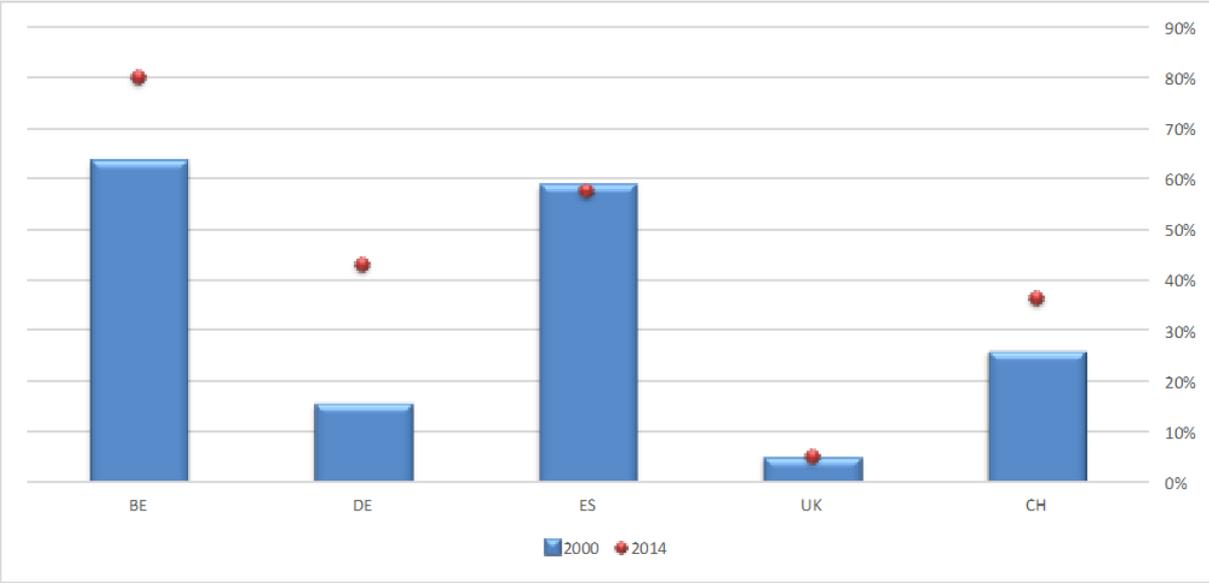
Source: PREF.

Note: NABS 01: Earth, NABS 02: Environment; NABS 03: Space; NABS 04: Transport, telecommunication and other infrastructures; NABS 05: Energy; NABS 06: Industrial production and technology; NABS 07: Health; NABS 08: Agriculture; NABS 09: Education; NABS 10: Culture, recreation, religion and mass media; NABS 11: Political and social systems, structures and processes; NABS 12: General advancement of knowledge: R&D financed from General University Funds; NABS 13: General advancement of knowledge: R&D financed from other sources than GUF; NABS 14: Defence.

Note. Reference year for AT, ES, LT is 2013. EE, IE, SI, SK, UK, FYROM, IL, ME, RS, US are not charted, due to impossibility of breaking down GBARD by NABS based on PREF data collection.

The regions play an important role in R&D funding in countries with federal structures, or where decentralisation has otherwise increased possibilities for regional administrations to fund R&D policies. Figure 5.5 shows the cases of countries where information on regional funding could be extracted under the PREF project, and had reached levels that registered in data collection. Apart from Spain, which presents a stable situation, all such countries showed a significant increase in regional allocations over 2000-2014. This holds true also for Italy, for which the PREF data cannot be presented in the current report, because of NSA confidentiality rules.

Figure 5.5 Regional R&D funding by countries, as % of total GBARD (2000/2014)



Source: PREF.

Note. Countries with very limited evidence from data are not included. Start year is 2004 for UK and 2012 for ES; end year is 2013 for ES and UK.

5.1.2 Characteristics of Project funding

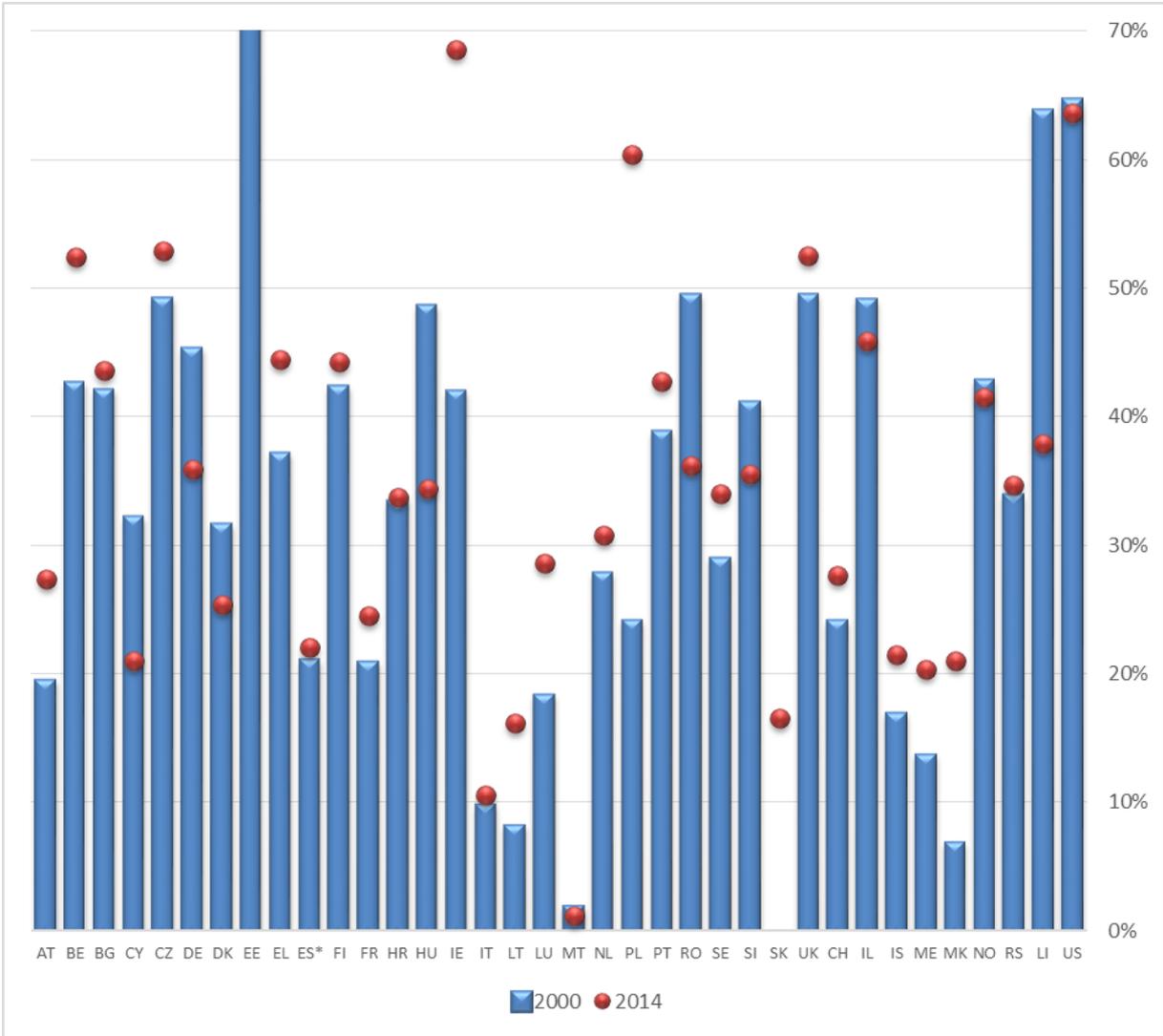
Although many countries have promoted a shift in the balance of block and project funding, most European research systems retained a higher share of block funding than observed in the United States, well into the first decade of the century (Lepori et al. 2007). More recently, and after severe cuts in public R&D budgets following the financial crises, several countries have introduced performance-based approaches in distribution of institutional funding (OECD, 2010). This creates an element of competition even within block funding, based on factors such as relative research performance, operations in doctoral training, acquisition of project and other external funding, and it stimulates changes in organisational allocation criteria and methods.

A second trend is the use of project funding to target progress in specific research fields and sectors, or for strategies such as incentivizing collaborations between public and private actors, pushing development of transnational research activities, or focusing on the quality and reputational standing of efforts produced by research performers, particularly the country’s universities and public research organisations.

Figure 5.6 plots project funding as a share of national allocations for R&D (% of total GBARD) for years 2000 and 2014, thus illustrating the changes in allocations over the period. In the majority of countries there has been growth in project funding. Only Cyprus, Germany, Denmark, Hungary, Malta, Romania, Slovenia, Israel and Lichtenstein show important declines, while others remain virtually stable at beginning and end of the period (Bulgaria, Spain, Estonia, Croatia, Norway, US). The most remarkable growth is in

Ireland and Poland; in other countries, the positive trend of project funding as percentage of total GBARD is less relevant.

Figure 5.6 Project funding as % of total GBARD: European countries and US (2000/2014)



Source: PREF.

Note. Start year is 2004 for FI, NL, PL, IS, ME, LI; 2008 for BG, CY, DK, EE, EL, HU, LT, MT, SE, IL, FYROM (MK); 2010 for CZ, IT, RO, SI; 2011 for FR; 2012 for ES, and 2013 for HR. End year is 2013 for AT, ES, LT, UK and 2015 for FR. Data on SK are available only for 2014.

The percentage % of project funding in ES is calculated only on classified amounts (unclassified excluded).

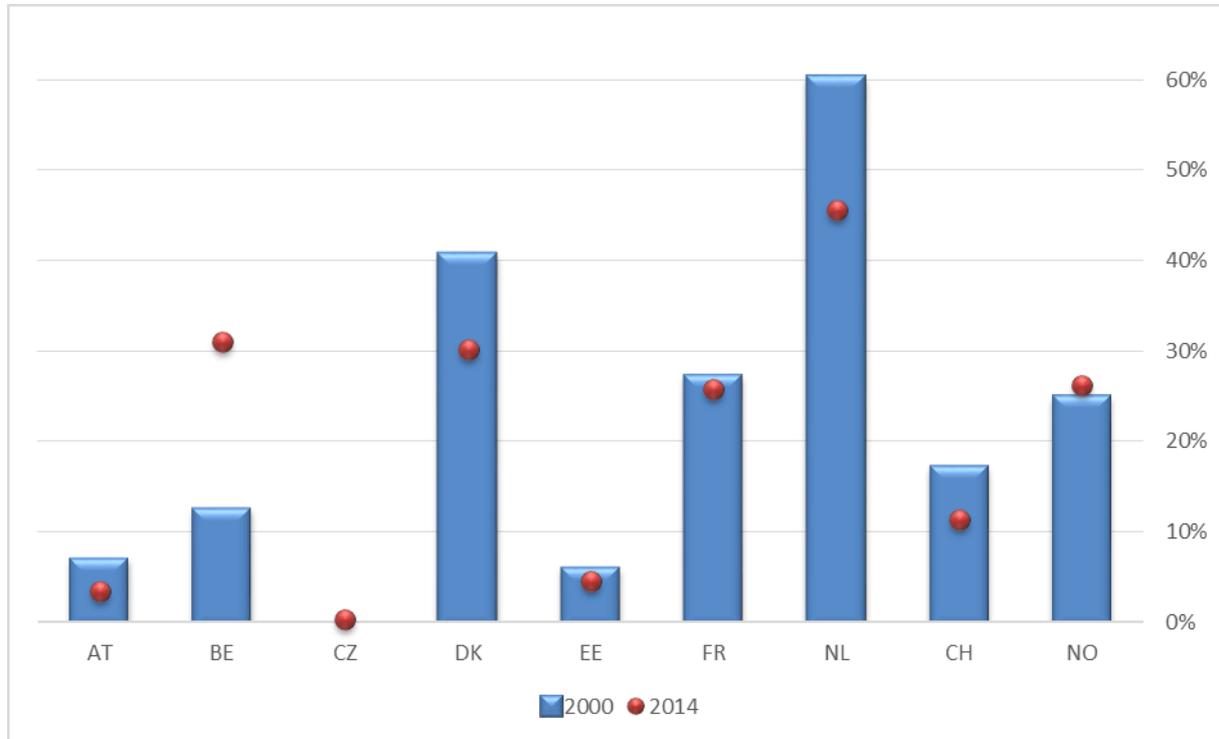
“R&D exchange funds” represent a specific category of project funding in which the flows are from one statistical unit to another, in return for R&D performance or delivery of specific outcomes. Examples of exchange funds activities include R&D purchases, R&D outsourcing, and contributions in the context of collaborative R&D agreements. The procurement of R&D is one of the most common forms of provisions of R&D exchange funds. It includes funds paid to research services firms or other units performing R&D under contract (see PREF Handbook).

For most European countries, data on R&D exchange funds are either unavailable or the flows are so low that they do not appear in PREF data collection.⁶ Figure 5.7 shows the countries for which data are available. The trends are heterogeneous: in Austria,

⁶ PREF does collect this data for the countries with the reduced data collection (see Section 3).

Denmark, the Netherlands and Switzerland, shares of exchange funds out of total project funding have declined, while five other countries show growth in exchange funds, and for Belgium the growth in share is very substantial.

Figure 5.7 Exchange funds as % of total project funding: countries with available data (2000/2014)



Source: PREF.

Note. Countries with reduced data collection not included. Note: Start year is 2004 for NL, 2008 for DK and EE, 2010 for CZ, 2011 for FR. End year is 2013 for AT and 2015 for FR.

Public R&D project funding can also be classified by the orientation of the research instruments. This indicator is used to observe the policy intentions of the funding instruments, rather than the actual research developed. Funding can thus be devoted to the general advancement of knowledge, "policy oriented" when designed to further specific topics, typically related to national strategy in R&D, or "innovation oriented", when the instrument is toward policies of innovation and creation of market value (pre-competitive R&D). A residual "mixed" category is identified when instruments are very heterogeneous and no specific categories are clear (see PREF Handbook).

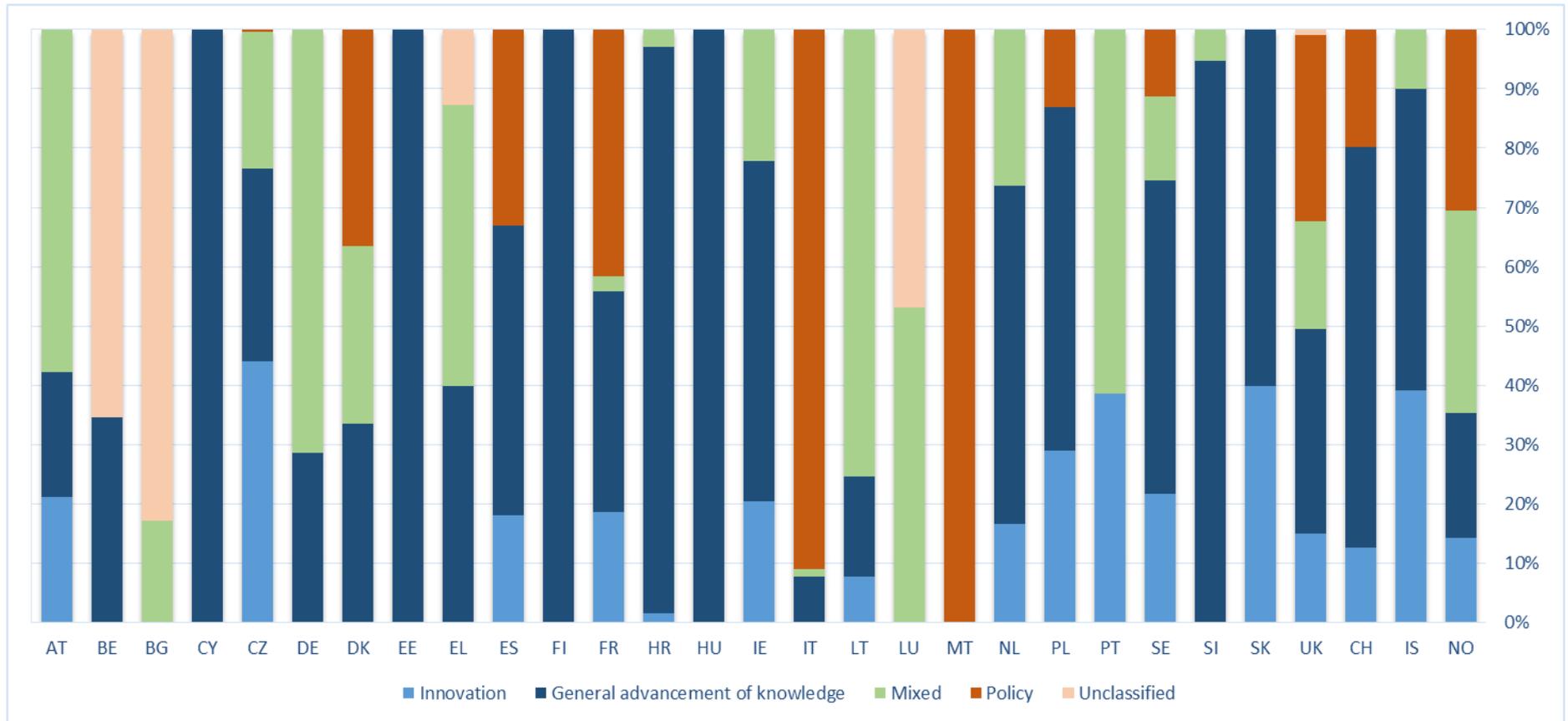
Figure 5.8 shows national public project funding by type of orientation. Somewhat surprisingly, the category "policy oriented" does not dominate the project funding instruments, meaning that in general, the orientation of these instruments is no more related to national strategic priorities in R&D than it is to general advancement of knowledge, or to innovation and market value. In fact, the orientation toward the general advancement of knowledge receives the heaviest weight of project funding instruments in the majority of the countries considered. Thus, in the majority of countries, while project funding includes orientation towards strategic policy sectors and economic priorities, the orientation remains more supportive of non-oriented research. "Policy oriented" instruments play a greater role in countries where there are substantial numbers of PROs and UPROs, such as in Spain, France and Italy, but they are also relevant in Denmark and Malta. Finally, the "innovative" or economic orientation of national public R&D funding receives heavy weighting in only a few countries, such as Iceland, Slovakia, Portugal, Poland and the Czech Republic.

We can also examine the share of funding oriented towards promotion of public-private collaboration, out of total national project funding. The PREF definition restricts this identification to funding instruments with main goals of fostering cooperation between public and private performers, enforced through specific rules, e.g. types of partnerships eligible for funding (see PREF Handbook). Fig. 5.9 shows that this orientation of project funding is not widespread among European countries, and that from 2000 to 2014 there was in fact a reduction in the share of such funding, particularly in those countries where the orientation towards public-private cooperation was initially quite high (Austria, Belgium, Bulgaria, Romania, Iceland, Sweden).

However, countries not included in the Fig. 5.9 chart of instruments oriented toward public-private collaboration might also pursue such policy directions, in ways not detectable by the restrictive PREF definition. As well, the actions in this area could exist but be too low for capture in PREF data collection.⁷

⁷ It is useful to remind that PREF for practical reasons adopts a threshold of 5% of total GBARD, but exceptions might apply depending on the political visibility of the stream and the duration of the managed programmes (see PREF Handbook, section 6 and p. 19 in this Report).

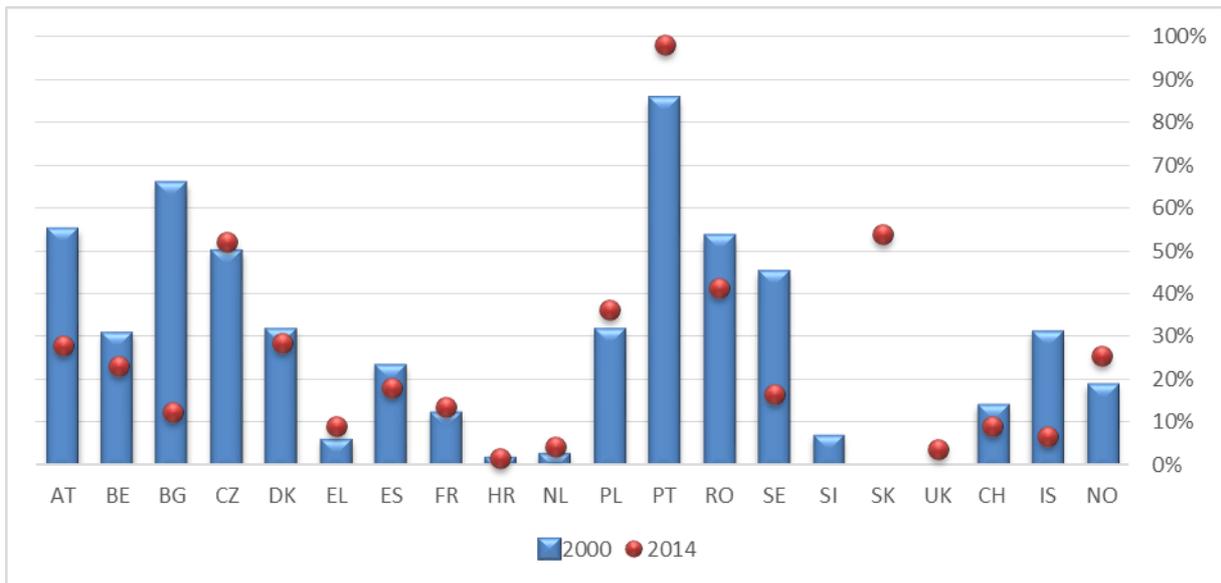
Figure 5.8 Project funding instruments by research orientation (2014)



Source: PREF.

Note. Countries with reduced data collection not included. Countries with all funding unclassified not included (LI and RO). Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

Figure 5.9 Percentage of “public-private” orientation within total national project funding instruments (2000/2014)

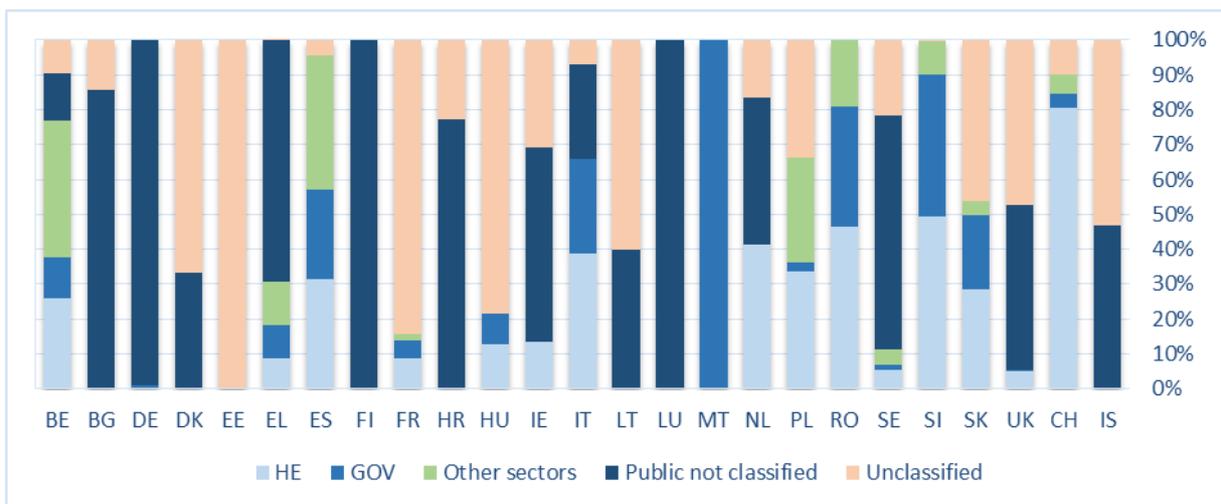


Source: PREF.

Note: Countries with reduced data collection not included. Start year is 2004 for IS, 2008 for BG, SE, 2010 for CZ, RO; 2011 for FR; 2013 for HR. For AT, EL, NL, PL, LI, start year is the first year in which public-private values appear in PREF data collection (respectively 2008, 2012, 2013, 2012, 2010). End year is 2013 for AT, ES, UK and 2015 for FR. Data on SK available only for 2014.

We also examine the type of beneficiaries addressed by project funding. Data useful for this breakdown are not always available (see section 3) as Fig. 5.10 illustrates. Figure 5.10 shows also that for the countries where data collection obtained sufficient results, public organisations (universities and government combined) are the most important beneficiary of project funding. Funding to other beneficiaries (e.g. companies, non-profit organisations) is relevant in only a few countries (Belgium, Spain, Poland, Romania).

Figure 5.10. Project funding instruments by beneficiary (2014)



Source: PREF.

Note: HE=Higher Education; GOV=Government; Other=Business enterprises and Non-for Profit. Note. Countries with reduced data collection not included. Reference year is 2013 for ES, LT, UK and 2015 for FR.

6 Evolution in criteria and procedures for allocation of public research funding

The attention toward the procedures for the allocation of public R&D funding grew up in the last fifteen years, because of the interest on the value of competitive allocation as a mean to improve quality, efficiency and effectiveness of the R&D performance (Jonkers et al., 2016). Some adverse effects of competitive allocation are outlined, which mainly refer to the short-term perspective that might affect the research topics, the gender biases and the disfavour towards young scholars of the selecting procedures, and equity problems in the funding distribution (OECD, 2014). A further problem is the drafting of definitions to be used for a data collection devoted to measure the level of competitiveness in funding allocation; making reference to the performance orientation of public R& funding allocation is a way to approximate the competition for funding, although the mentioned proxy has some limitations due to the different systems, criteria and methods used by the managing organizations in the different European countries (Jonkers et al, 2016; Hicks, 2012).

The PREF analysis elaborates two indicators to measure the extent of performance-based orientation of national public R&D funding. One of these is based on modes of allocation, distinguishing between those operated on a historical or negotiated basis versus those operated under formulas or competitive bidding. Historical and negotiated allocations are typically not performance-oriented, while allocation by bidding clearly is. "Formula" allocation can take on very different structures, thus having highly varied levels of orientation towards performance. A second indicator distinguishes between competitive allocation and performance-based allocation. Performance-based allocation refers to funding allocated using criteria that are not strictly competitive between institutions, but instead detected using ex-ante (for project funding) or ex-post performance assessments (for institutional funding).

It is important to remind oneself that the proposed approach is an experimental one, which is based on a pilot study; thus, data must be handled carefully considering the limitations of the proposed methodology and the different contexts of application.

This section also characterises project funding using descriptors of the level of openness of the funding instruments, and the modes of delegating the funds (free projects and grants, programmes, contracts). The first of these indicators is intended to reveal the extent to which funding are moving towards European Research Area objectives. The second is intended to reveal the relationships between funders in terms of the way the funds and responsibilities are delegated.

6.1 Proxy of competition in public R&D funding

Project funding is always allocated through competitive bid. Institutional funding could also be partially allocated on competitive basis, however detection of the extent of this faces several constraints. In general, the possibility of measuring competitive funding is questioned in the literature, and it is difficult to find a definition useful for planning data collection. Furthermore, there are diverging understandings of competition, particularly concerning whether it can refer to institutional funding as well as to project funding. Finally, the mechanisms of implementing performance-based funding are extremely different among countries (Jonkers et al., 2016).

In recent years, particularly beginning in 2008, national provision of institutional funding earmarked for R&D⁸ has generally undergone deep reform processes, introducing mechanisms aimed at increasing excellence, and selection within the research systems based on merit and performance. The reforms were applied to universities and public

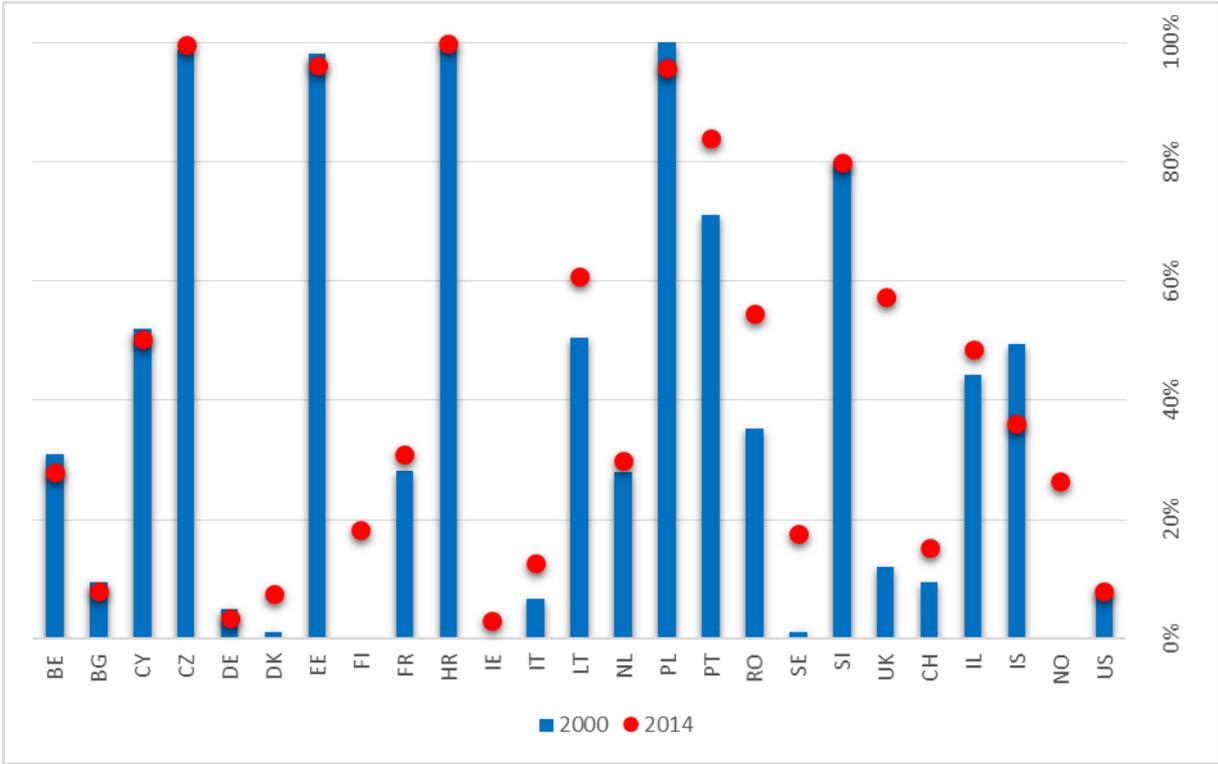
⁸ Institutional funding can be direct also to sustain other non-research activities that are part of the performers' mission (e.g. HEIs institutional funding is composed by teaching funding and R&D funding). PREF data only include R&D funding.

research organisations, adopting very different mechanisms and solutions. A proxy of the degree of performance orientation within institutional funding is therefore very important to shed light on how different countries have enacted the transformation of public funding allocation, towards more effective systems. PREF deals with the challenge of finding an indicator that could approximate the presence of a selective mode of allocation for public R&D funding.

Drawing on the PREF database, we can characterise the procedures and criteria for allocation of R&D funding in the different countries. The PREF handbook distinguishes four types of allocation procedures: formula-based, competitive bid, negotiated, historical basis. Formula and bid allocations are 'competitive', meaning that they foresee a selection between the beneficiaries on the basis of the results obtained. Negotiated and historically based allocations are non-competitive: the former involves negotiations of level of allocation between funder and beneficiary but not a real selection process; the latter is based on amounts transferred to the beneficiary in previous years, subject to potential modification.

Fig 6.1 presents the share of total institutional R&D funding allocated by formula and competitive bid in the PREF countries, in the years 2000 and 2014.⁹ The countries not included in the figure use neither formula nor competitive bid as modes of allocation for institutional funding. In several cases the first year of reference is not 2000: either the country has a limited time series (see Section 3), or although competitive allocation exists, it did not mobilise volumes of funding sufficient for capture by PREF data collection.

Figure 6.1 Institutional funding allocated through formula and competitive bid, as % of total institutional funding: PREF countries (2000/2014)



Source: PREF.

Note. Start year is 2004 for FI, NL, PL, IS; 2008 for BG, CY, DK, EE, LT, SE, IS; 2010 for CZ, IT, RO, SI; 2011 for FR; 2013 for HR. End year is 2013 for LT and UK and 2015 for FR.

⁹ Allocations by competitive bid are in fact present only in a few countries.

The chart shows that as of 2014, many countries apply formulas to allocate institutional funding, although there are notable absences of countries with neither allocation by formula or the less common competitive bid: among these are Austria and many countries in Eastern Europe. The spectrum of countries having formula/competitive bid allocation ranges from Germany and Ireland, where this represents only a very small part of institutional funding, to countries with very high percentages of formula/competitive bid funding out of total institutional allocations (Lithuania and UK¹⁰, at about 60% of total, Portugal and Slovenia at about 80% of the total, and countries such as Estonia, Check Republic, Poland, Croatia, close to 100% of total). Between 2000 and 2014 there has clearly been a trend towards increasing the percentage of allocation through formula, with only a few exceptions, among these Belgium¹¹, Germany, Iceland and Bulgaria.

6.2 Performance-based funding

The PREF analysis elaborates a “performance-based indicator” to detect the volume of funding allocated through performance-based mechanisms (PBF). This complements the indicator for “competitive allocation” of institutional funding, which is immediately determined from the mode of allocation (historical, negotiated, competitive bid, formula), and cannot detect how much the formula allocation based on formula derives from a performance assessment –thus it is output oriented, or from the existing level of resources –thus, it is historical oriented.

The performance-based indicator distinguishes between direct allocation of funding, and organisational performance-based allocation, the latter occurring when criteria are applied to assess performance, either ex-ante in the case of project funding, or ex-post in the case of institutional funding. We can thus distinguish between:

- Performance-oriented allocation of project funds, where allocation is based on ex-ante assessment of expected performance;
- Performance-oriented allocation of institutional funds based on ex-post evaluation, including for example formulas based on research outputs, or allocation based on evaluation of other past performances.

and:

- Non-performance-oriented institutional funding, including historical allocation and negotiated or formula funding based on inputs or role in education.

While the assessment of performance-orientation for some schemes is straightforward, for institutional instruments it can be a complex task, which we have also noted as being contestable. These figures should therefore be considered as an approximation of selection procedures in public R&D funding.

The information available on the PREF countries in fact reports very different models of allocation for public R&D funding, but a limited representation of competition in the allocation of institutional funding, since it could only be identified as being via formula or bid types of allocation. Thus, a pilot study of a potential new approach was developed, studying fourteen countries (Austria, Czech Republic, Germany, Denmark, Finland, France, Italy, the Netherlands, Poland, Portugal, Sweden, UK, Norway, Switzerland). The composite indicator used in the pilot study and reported here is based on some of the descriptors elaborated from PREF data collection, but also leaves room for national experts to apply their knowledge, improving the reliability of the measures. The characteristics of the indicator are summarized as follow (see the PREF Handbook for a full description of the methodology).

¹⁰ UK is a special case of formula funding based on peer review (see Country Profile in Annexes).

¹¹ Please note that in Belgium there are important differences between regions in means of distributing institutional funding, with some regions like Flanders where institutional funding is mostly allocated using a formula based on research outputs, and regions such as Wallonia where formula is mainly based on education metrics. (see the Public Funding Country Profile of Belgium in the Annexes).

Range: 0 to 1 (low to high level of competitiveness) to 1 (high level of competitiveness). The scale is ordinal, in the sense that the indicator is used to rank countries on a single scale, but there is no assumption that the scale is linear (e.g. that a value for competitiveness indicator of 0.6 is double a score of 0.3).

Calculation: The indicator is calculated as the product of two criteria: Competitiveness indicator = (allocation mode) * (allocation criteria).

As said, in the PREF data collection there are four types of allocation mode: formula, negotiated, historical and competitive bid. These are scaled as follows: 0 = allocation is entirely historical; 0.5 = indicative score for negotiated allocation; 1 = allocation is entirely formula-based. Particularly for negotiated allocation, the national expert can set slightly different scores to take into account country specificities. The same might happen for formula, for example the expert could set the score below 1 when formula have been implemented but along with other allocation mechanisms to avoid the potential of strong fluctuations.

The allocation criteria are scaled as follows: 0 = only input criteria, such as previous years' costs or staff; 0.5 = indicative score for education-based criteria, such as number of students or graduates; 1 = only research-output criteria, such as attainment of third-party funds, numbers of publications, scores in evaluations. The national expert can assign a score weighting the different components, particularly in the presence of a basket of different criteria.

The method of calculating the indicator allows the differences between national allocation systems to emerge. For instance, when purely historical allocation occurs the indicator score is 0; when there is allocation by formula based on the number of students the calculation of the score ($1*0.5$) is 0.5; in case of negotiation based on research performance the score ($0.5*1$) is 0.5; allocation by formula (1) based on number of publications (1) scores 1.

Level of granularity: The score should be computed individually for every institutional funding instrument identified in national data collection. The composite national score is then computed based on the average of the individual scores (both by sector and for the whole national funding system).

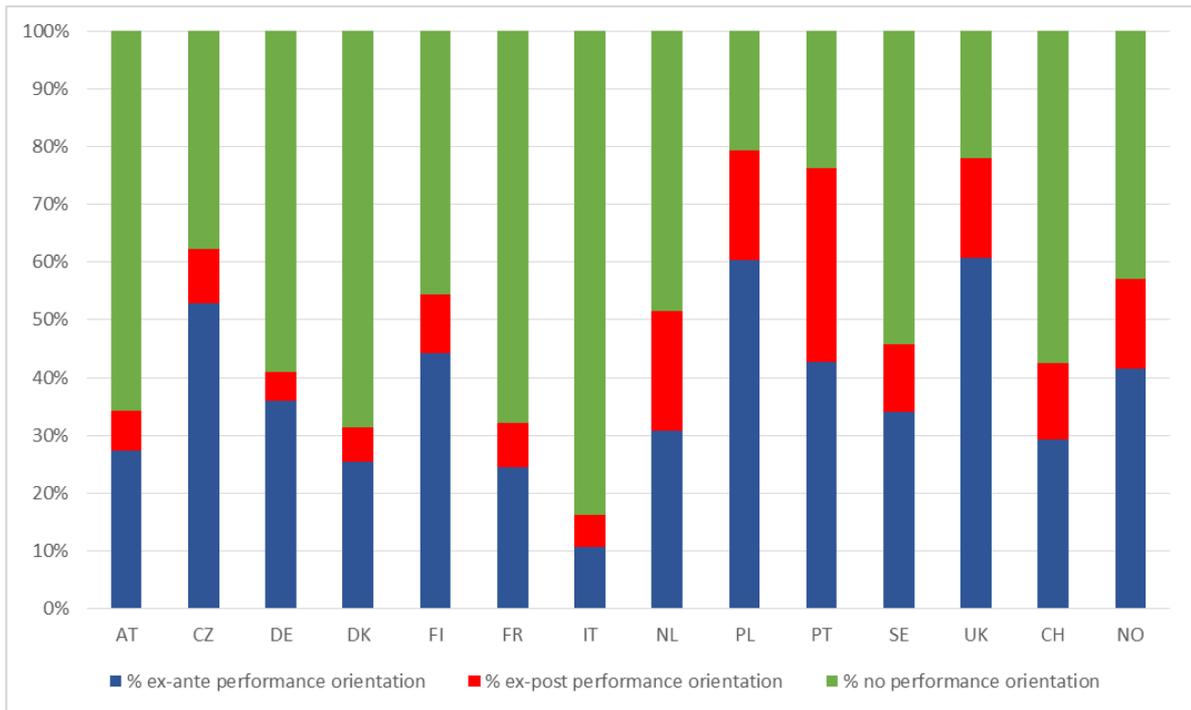
Data storage: For each institutional funding instrument, the database includes the allocation mode and allocation criteria score, as well as the aggregated score. This allows ready computation of the summary scores.

Timeline: Scores are computed for each individual year, even if it is expected that they remain stable over a comparatively long period.

Figure 6.2 charts the performance-based orientation of funding allocation in the countries analysed, as percentage of total public R&D funding in 2014. Figure 6.3 instead charts the volume of performance-based orientation of institutional funding for the same year, in Euro.

Four countries (UK, PL, PT and CZ) show a strong orientation toward both ex-ante and ex-post performance-based allocation (more than 60% of the total public R&D funding); other four countries (AT, DK, FR, IT) are less oriented toward performance-based allocation (less than 40% of the total public R&D funding).

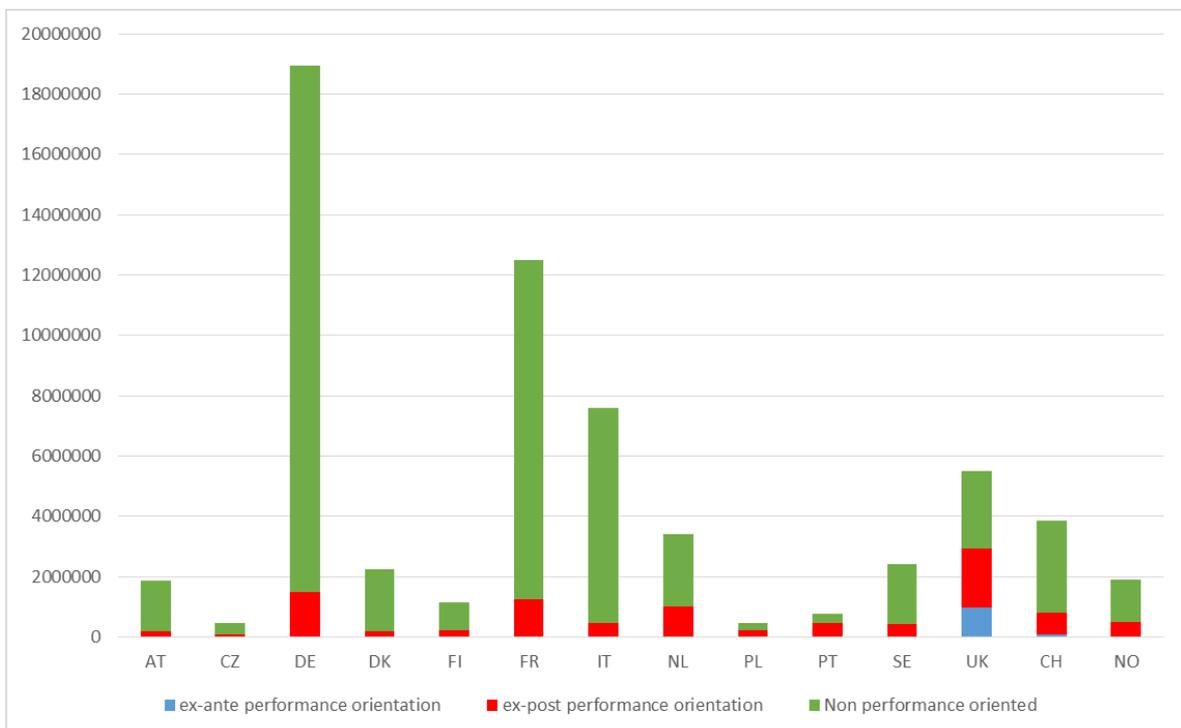
Figure 6.2 Performance-based orientation of funding as % of total public R&D funding: 14 countries (2014)



Source: PREF.

Note. Reference year is 2013 for AT, UK and 2015 for FR.

Figure 6.3 Volume of performance-based orientation of institutional funding in 14 countries (2014)



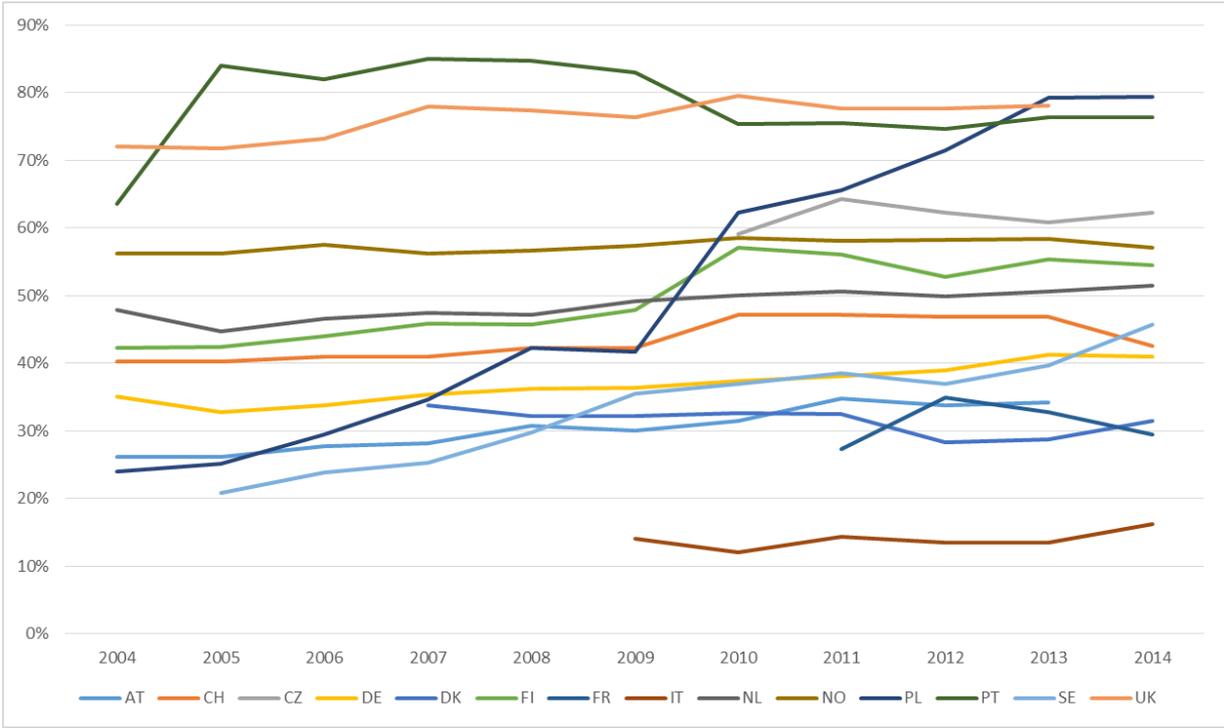
Source: PREF. Unit: thousand EUR.

Note. Reference year is 2013 for AT, UK and 2015 for FR.

Examining figure Fig 6.2, we observe interesting differences in the shares of funding allocated by performance-based orientation in the countries analysed, mainly due to different levels of project funding. On the other hand, Fig. 6.3 shows that institutional funding remains largely allocated without performance-based mechanisms; the sole exception is the UK, where performance-based orientation is very important.

Fig. 6.4 presents the performance-based orientation (both ex-ante and ex-post) in allocation for the fourteen countries analysed as percentage of total funding from 2004 to 2014. Important changes are not visible, and they are generally driven by reform of R&D public funding.

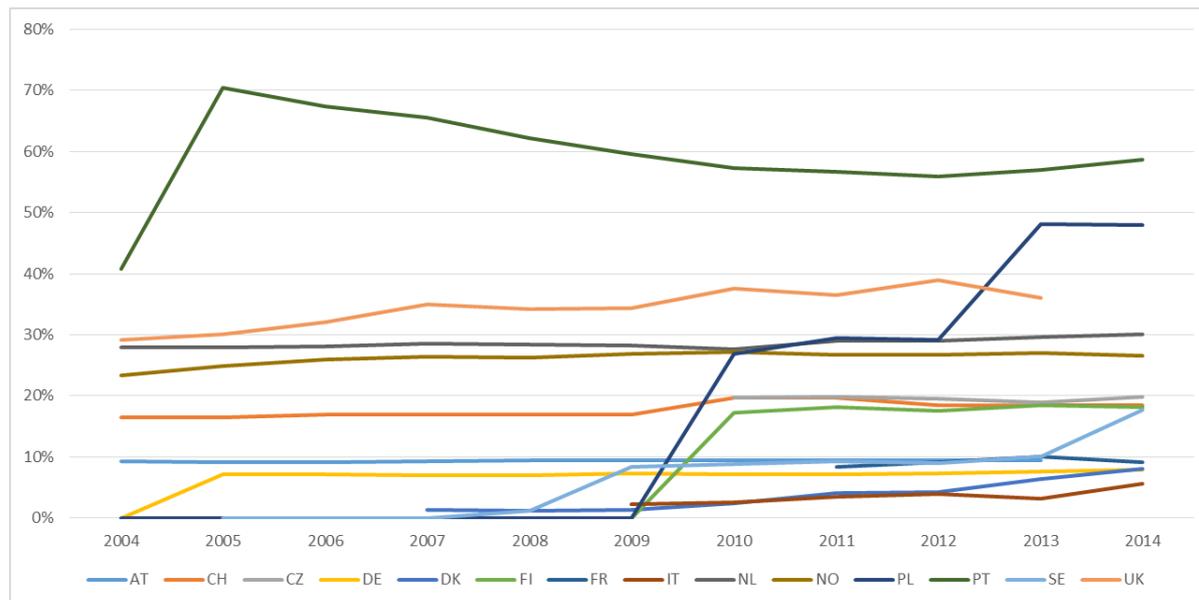
Figure 6.4 Ex ante + ex post performance-based orientation as % of total funding in 14 countries (2004-2014)



Source: PREF.

Fig. 6.5 shows the evolution of ex-post performance-based orientation as percentage of institutional funding, from 2004 to 2014. In Poland, Finland, Austria and Norway there were spurts of sudden growth, mostly linked to national reforms (e.g. when ex-post evaluated institutional funding for higher education was introduced). Other countries, such as Switzerland, do not show such abrupt changes over the period. Italy is a latecomer to performance-based orientation, and shows a significant increase beginning in 2013, following reforms in allocation of institutional funding to universities.

Figure 6.5 Ex-post performance orientation as % institutional funding in 14 countries (2004-2014)



Source: PREF.

6.3 Openness of funding to non-nationals

A key issue in improving the integration of the national research system within the European Research Area is the extent to which the national programs are open to participation by researchers from abroad. Openness is also a way to improve competition in research funding allocation. In the current analysis, this item is explored using the data collected during the JOREP project (Reale et al., 2013; see also OECD, 2016).

Concerning the data analysis, one of the conclusions from JOREP was that instead of trying to detect open programs on the basis of a formal definition, a more fruitful approach is to understand the level of openness of the different national R&D programs based on the presence of key characteristics (Primeri et al., 2014). Benefitting from this experience, the PREF methodology includes a descriptor aimed at assessing the level of openness of the funding instruments by drawing on experts' considerations, signalling the extent to which the instrument foresees funding for research by organisations not located in the country. There are three possible categories: "yes in general", "yes with limitations", or "no" openness. Resources allocated for travel related to R&D are not considered.

Figure 6.6 presents the project funding instruments by level of openness in funding as percentage of the total, in the year 2014, for the countries for which this information is available. Despite the fact that a large part of the instruments is still not open, the chart shows that instruments characterised by "openness with limitations" are increasing, and some countries also present good levels of "open" funding instruments (Ireland and Malta have all project funding instruments open, Spain has 80% of the total open, UK about 70%, Portugal about 60%. The Netherlands also has all instruments open, if we include instruments that are both fully open and "with limitations"¹².

6.4 Delegation modes for project funding

It is also important to note whether there has been evolution in the instruments for project funding in terms of changes in the modes of delegating funds and responsibilities from the state to the research performers, shifting from "free" projects and grants (a sort of blind delegation from funder to performer) to more direct or indirect types of steering

¹² Data derives from the regulations related to the instruments, so they must be carefully considered.

through contracts or network allocation. The latter modes of delegation would at least partially replace “responsive” public funding, largely driven by what the institution or investigator wants to research (Potì and Reale, 2007). PREF data collection distinguishes between four types of categories of transfer: i) block transfer, generally applied for institutional funding; ii) project transfers, for project funding; iii) personal grants, provided to individuals for career development; iv) network transfers, meaning funding granted for cooperative research by different research organisations, usually broader in scope than projects (see PREF Handbook).

Figure 6.7 shows no significant variations between countries as to mode of transfer. Block grants for institutional funding and “responsive” project funding remain the most important modes, meaning that funding on the basis of blind delegation is maintained. Personal grants still have a limited role, except in some countries. On the contrary, network transfer is visible only in Cyprus and the contract mode does not emerge in any countries. An interesting question would be whether contract transfers do in fact exist, but in the form of exchange funds, thus under a special area of national R&D public funding, outside of institutional and more typical project funding.

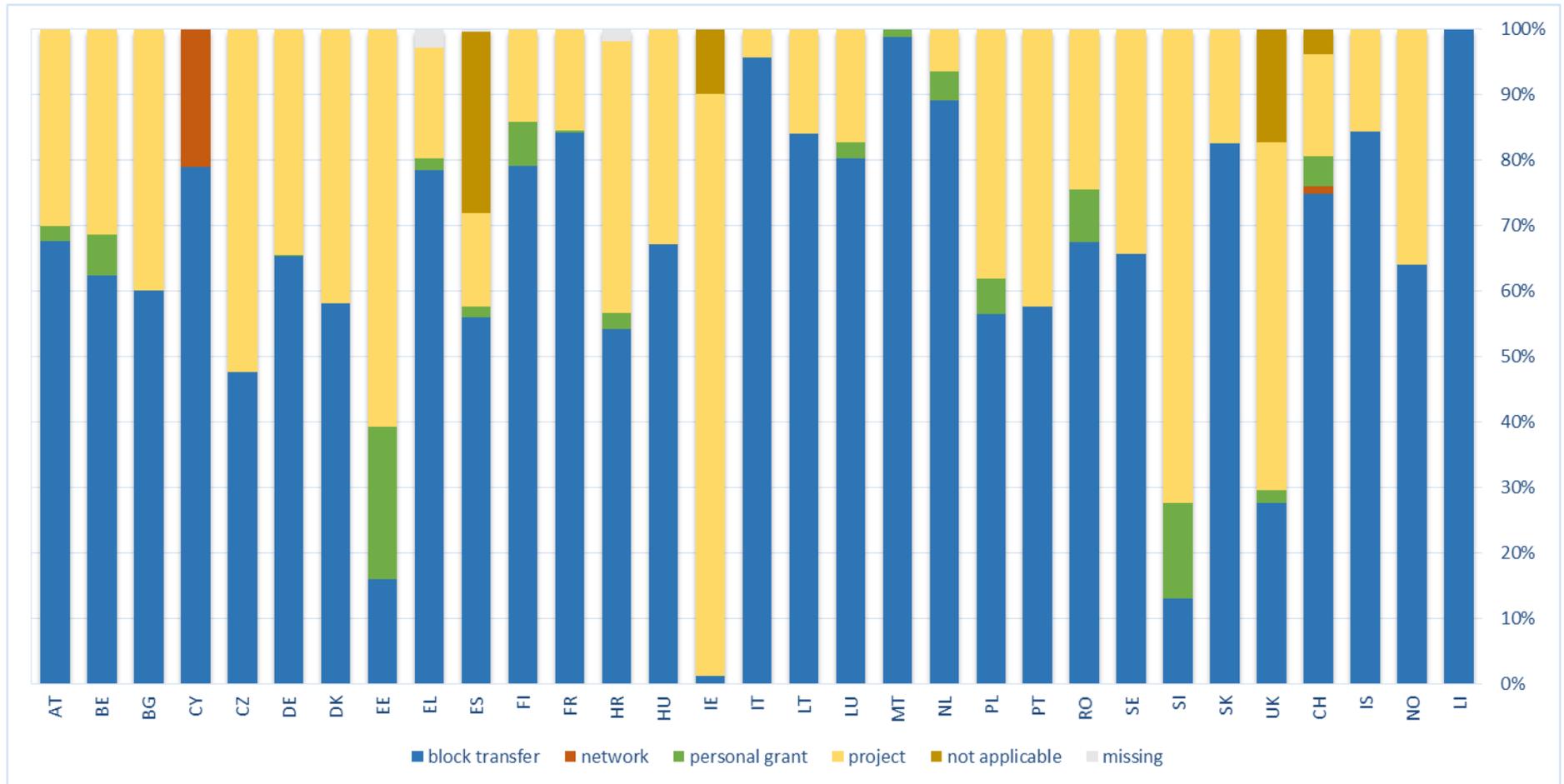
Figure 6.6 Project funding instruments by level of openness to non-nationals (% of total, 2014)



Source: PREF.

Note. Countries with reduced data collection not included. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

Figure 6.7 Funding instruments by mode of transfer (% of total funding, 2014)



Source: PREF.

Note. Countries with reduced data collection not included. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

7 Relevance of KETs and SGCs in national objectives and research priorities

In this section, data and information collected on the relevance of Key Enabling Technologies (KETs) and Societal Grand Challenges (SGCs) in national R&D public funding are summarised and discussed only for countries where data were sufficiently robust. PREF data collection involved consultation of national reports retrieved from web-based databases, for evidence of policy intentions. In any case, identification of KETs and SGCs orientations is difficult, especially in institutional funding, so the figures calculated must be considered carefully. Data collection might in fact underestimate the level of the national commitment towards KETs and SGCs, which could now be strengthened in light of recent events (e.g. launching of Horizon 2020).

A general caveat must be pointed out to interpret correctly the following data. It can be stated that:

- Data do not represent all funding devoted to SGCs and KETs research in the countries since even though it is not possible to classify the exact share, institutional funding may also be used for research that is relevant to the challenges of some countries may even have incentive systems such as performance contracts in place to stimulate this type of research;
- The amounts (or percentage of GBARD) presented in the figures are heavily reliant on the share of countries GBARD that is allocated in the form of project funding.

7.1 Key Enabling Technologies

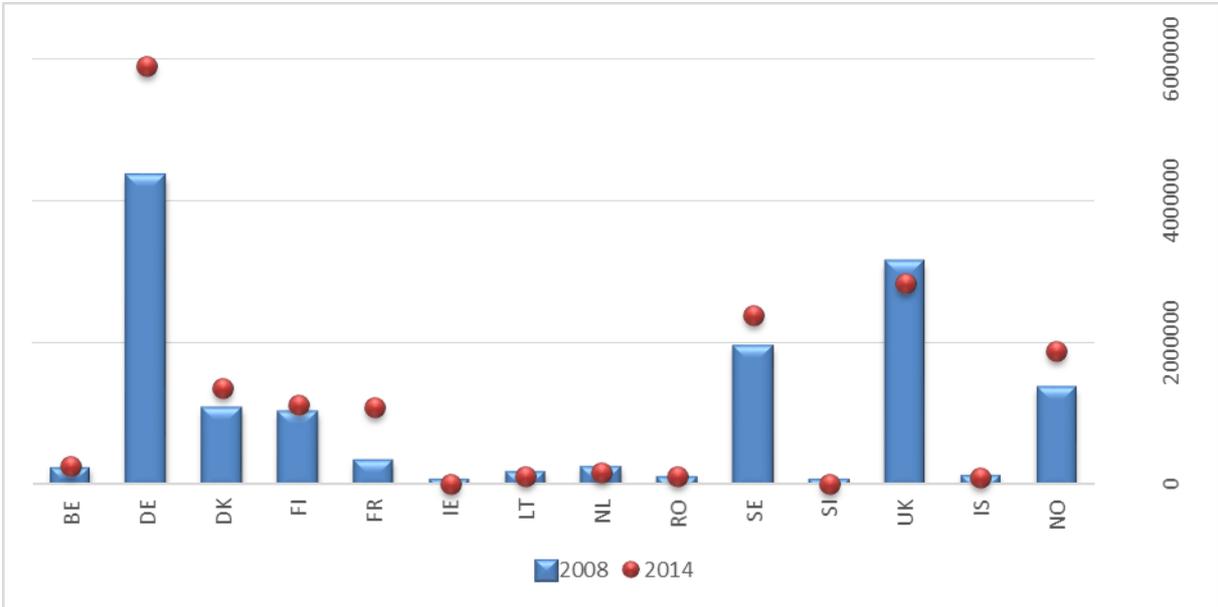
The European Commission defines key enabling technologies as “knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration.” KETs can also assist technology leaders in other fields to capitalise on their research efforts. Development in KETs is considered a key strategy for fostering innovation and competitiveness in European countries. Recently a High Level Expert Group (HLG) appointed by the European Commission analysed the situation of KETs implementation in European countries, and provided several recommendations for national policy makers (EC, 2015), among these: i) development of closer cooperation between European technology infrastructures and industry; ii) more industrial innovation programs at EU, national and regional levels; iii) actions to ensure that the growth potential of KETs is not hindered by lack of a skilled workforce. These recommendations suggest the importance of having indicators that can assist in identifying the extent to which KETs are central or relevant in public institutional and project funding for R&D. To this aim, the PREF study characterises funding instruments using a scale indicating whether the KETs topics are “central”, “relevant” or “not relevant” in the use of each national instrument. Being “central” means that the mission for the funding instrument explicitly mentions KETs and that most of the research topics covered involve KETs (see PREF Handbook). Being “relevant” means that the instrument mission and definition cover KETs but the reference is not so strict. However, it is important to remind that it might be very difficult to classify institutional funding under a specific research topic such as those of KETs and SGCs. So, data must be carefully considered.

Figure 7.1 shows the volume of institutional funding where KETs are central and relevant, in 2008 and 2014, per country. Figure 7.2 shows the corresponding analysis for project funding. We use 2008 as starting year instead of 2000 because this is the year when KETs appear in most countries as an issue in R&D policy (see country profiles). In the area of institutional funding, KETs are highly relevant in Germany and grew strongly from 2008 to 2014. The positioning of this kind of investment in Germany is particularly

remarkable in light of the much lower volume of similar investments in the UK, the second European country in terms of KETs relevance. KETs are also important in Denmark, Sweden and Norway, all of which show growth of KETs relevance in institutional allocation over the period considered. As to centrality and relevance of KETs in project funding, UK leads in 2014, followed by France. UK shows growth from 2008 to 2014, as do Norway, France and Sweden. In contrast, Germany and Denmark maintain low relevance of KETs in project funding over the years. The high position of France is mainly related to the special program "Investissement d'avenir", which is not part of official GBARD, but is included in PREF data at the instrument level.

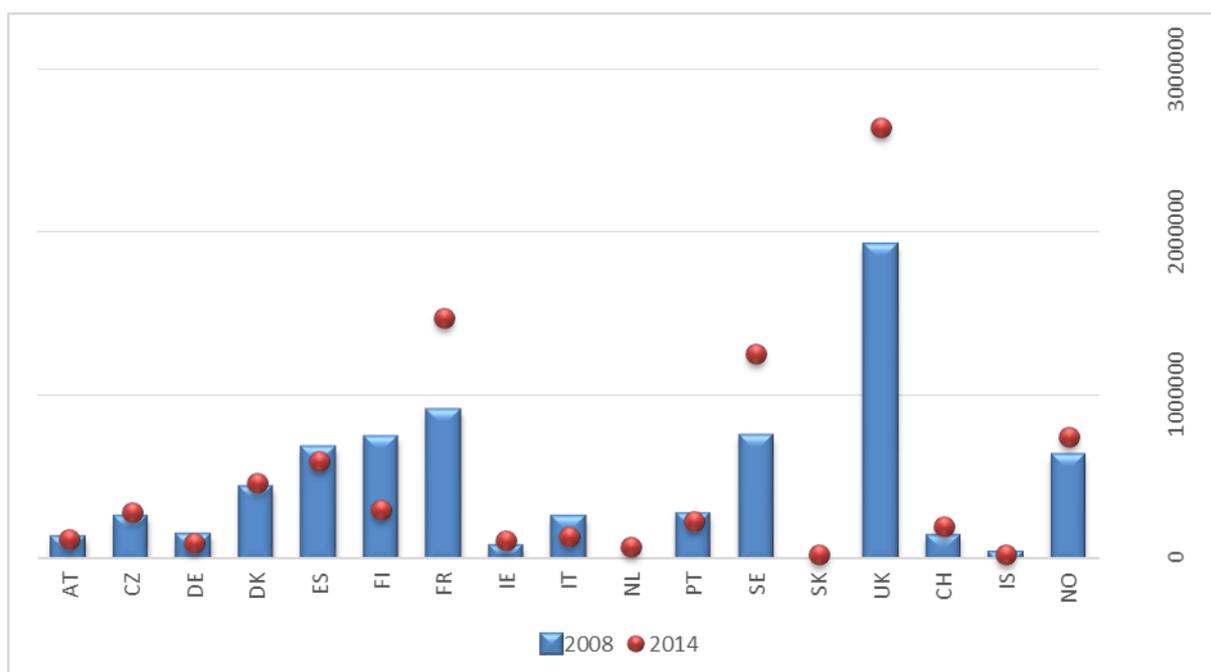
The choices of Germany and France, the former mainly investing in KETs through institutional funding, the latter using project funding, are a further addition to the various differences that characterise the organisation of national public R&D funding in these two countries, as already seen in some of the previous analyses.

Figure 7.1 Institutional funding instruments with KETs priorities relevant or central, in European countries (2008/2014)



Source: PREF. Unit: thousand EUR.
 Note. Start year is 2010 for RO; 2011 for FR. End year is 2013 for LT and UK and 2015 for FR.

Figure 7.2 Project funding instruments with KETs priorities relevant and central, in European countries (2008/2014)



Source: PREF. Unit: thousand EUR.

Note. Start year is 2010 for CZ, IT; 2011 for FR; 2012 for ES. End year is 2013 for AT, ES, UK and 2015 for FR. Data for SK available only for 2014.

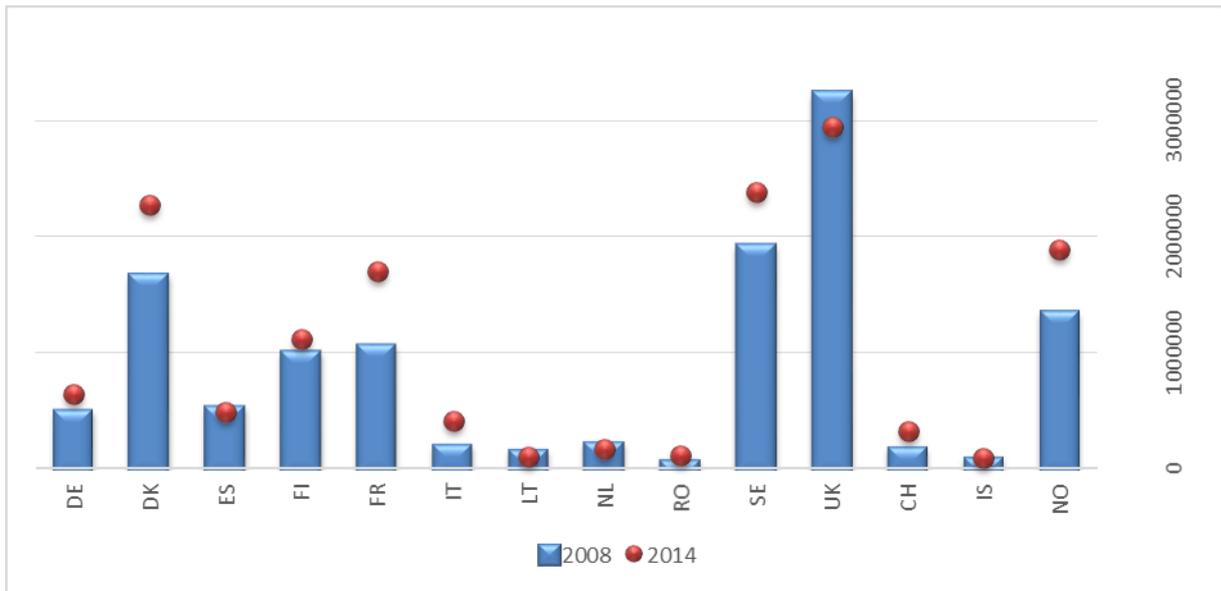
7.2 Societal Grand Challenges

The Europe 2020 strategy identifies societal grand challenges as the major problems to be confronted European society over the coming years, or in a more positive sense, the main pillars of the Horizon2020 EU Programme, the successor of FP7. The European Union focuses on six Grand Challenges: "Health, Demographic change and wellbeing; Food security, Sustainable agriculture, Marine and maritime research and the Bio-economy; Secure, clean and efficient energy; Smart, green and integrated transport; Climate action, Resource efficiency and raw materials; Inclusive, innovative and secure societies". Improving investment in these areas is a key priority in European strategy for growth and competitiveness. Several authors dealing with the problem of SGCs implementation in national policies recently examined the "challenge of Societal Grand Challenges" (Kuhlman and Rip, 2014). They conclude that policy makers and actors need to develop a policy mix and facilitate system changes drawing on "classical priority setting and implementation approaches, on transformation in science (systems) or breakthrough innovation, and demand-side and procurement policies, but will have to focus on system-oriented strategic interventions, tentative and experimental in design, including out-of-the-box approaches like new combinations of actors and alliances".

As for KETs, PREF data collection attempts to capture the importance of SGCs in public R&D funding by identifying the amount of institutional and project funding that can be considered relevant or central to SGCs objectives. The warning expressed in Section 6.2 about institutional funding applies also in the case of SGCs.

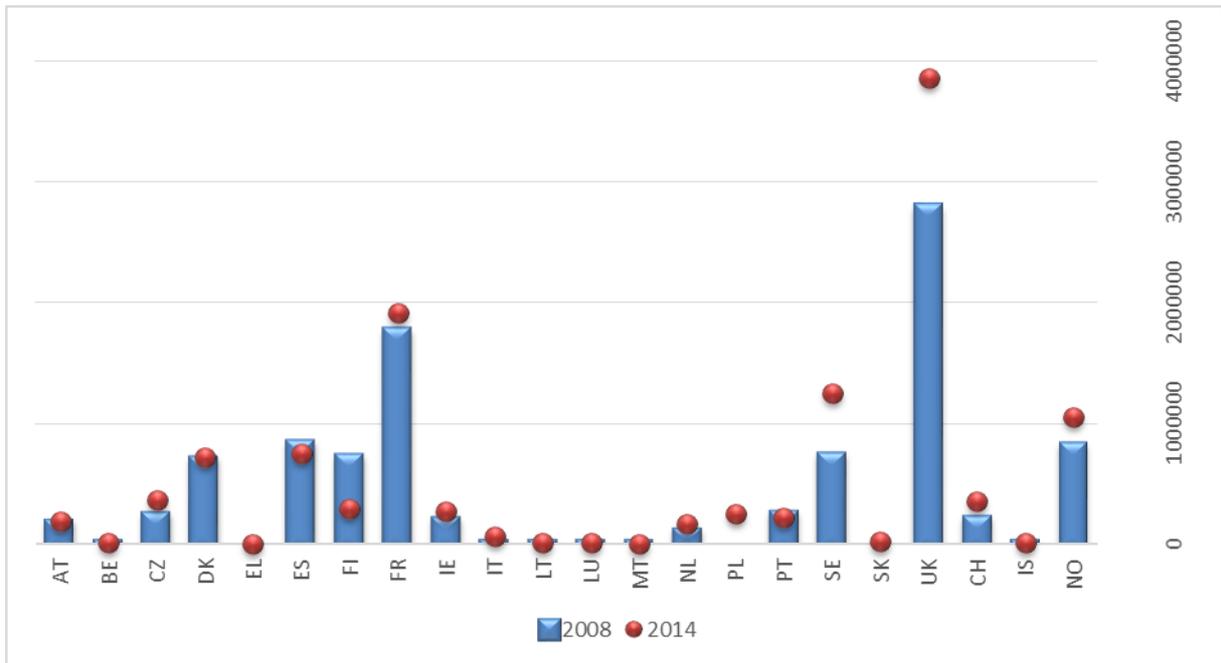
Figures 7.3 and 7.4 show that the UK has the greatest orientation of public R&D funding toward SGCs, considering both institutional funding and project funding: this orientation decreased in institutional funding between 2014 and 2008, but increased substantially in project funding. Other countries with strong investment in SGCs under institutional funding are Sweden, Norway, Denmark, Finland and France. All of these show growths in this type of investment between 2008 and 2014.

Figure 7.3 Institutional funding instruments with SGCs priorities relevant or central, in European countries (2008/2014)



Source: PREF. Unit: thousand EUR.
 Note. Start year is 2010 for IT, RO; 2011 for FR; 2012 for ES. End year is 2013 for ES, LT, UK.

Figure 7.4 Project funding instruments with SGCs priorities relevant or central, in European countries (2008/2014)



Source: PREF. Unit: thousand EUR.
 Note. Start year is 2010 for CZ, IT; 2011 for FR; 2012 for ES. End year is 2013 for AT, ES, LT, UK; 2015 for FR. Data for SK available only for 2014.

Following the UK, the country investing the highest amount of money in project funding instruments with SGCs central or relevant is France, then Sweden and Norway. AT, CZ, DK, ES, PT and CH show some importance of such funding instruments, which would be expected to become more visible in the forthcoming years. Differently than for funding instruments focusing on KETs, significant investments in SGCs do not emerge in Germany.

8 Transnational research funding

This section elaborates on: a) incoming European Union funding to national performers; b) national funding for international research performers and funding organisations (“international funding”). The analysis serves in exploring the level of the different countries’ integration within the larger European system, and their investment in transnational research activities.

8.1 Incoming European funding

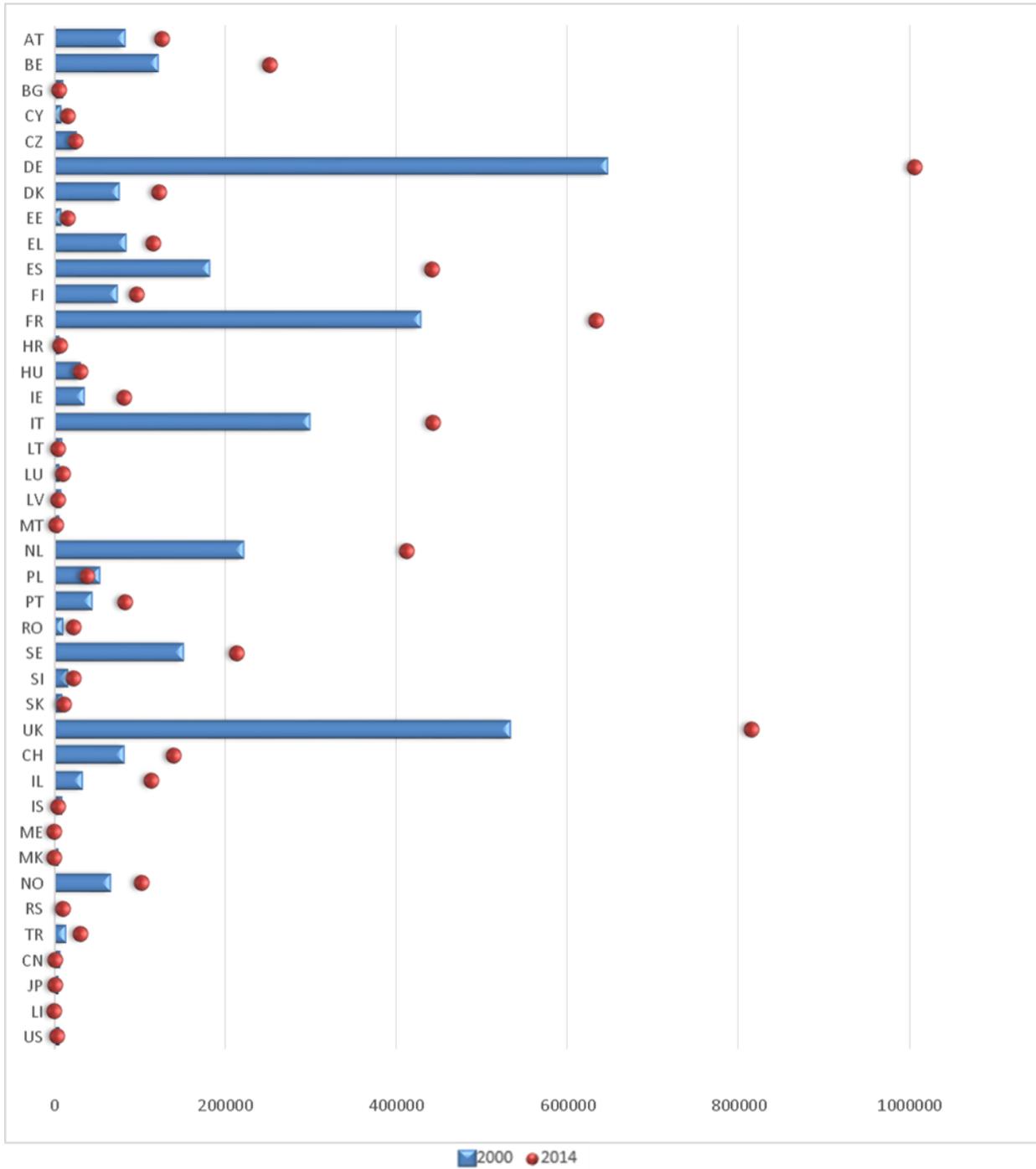
Incoming European funding includes that from European Framework Programmes (FP5, FP6, FP7), Horizon 2020 and Euratom. The PREF project retrieved the relevant data from the eCORDA dataset. Data on FP5 are not present in the eCORDA dataset, and have been calculated from the program’s annual reports.

The current report does not consider structural funding as part of the incoming EU funding. As explained in Section 3 of this report, structural funding is also not included in the GBARD calculations. This funding is project type, and over the years considered under the current study, mobilised a substantial part of the funds for R&D and innovation expenditures in the EU member states (see IUC, 2013). However, disentangling the amounts of structural funding used for R&D is not simple, and for this reason the stream is not included (see section 3.3 in this Report).

Figure 8.1 shows EU funding from FP5, FP6, FP7, Horizon 2020, in the years 2000 and 2014. The data indicate the well-known phenomenon of concentration of EU funding in a small number of western countries, present in 2000 and reinforced by 2014. The countries with the greatest capacities in attracting EU funding are Germany and UK, followed by France, Italy, Spain and the Netherlands. All of these countries showed growth in incoming funding between 2000 and 2014. Despite positive 2000-2014 trends, most countries in eastern areas of Europe still have very low levels of incoming EU funding. Concerning this, the reader is referred to the Joint Research Council “Stairway to Excellence” project, which analysed the important problems facing eastern countries in attracting EU funding (EC, 2015).

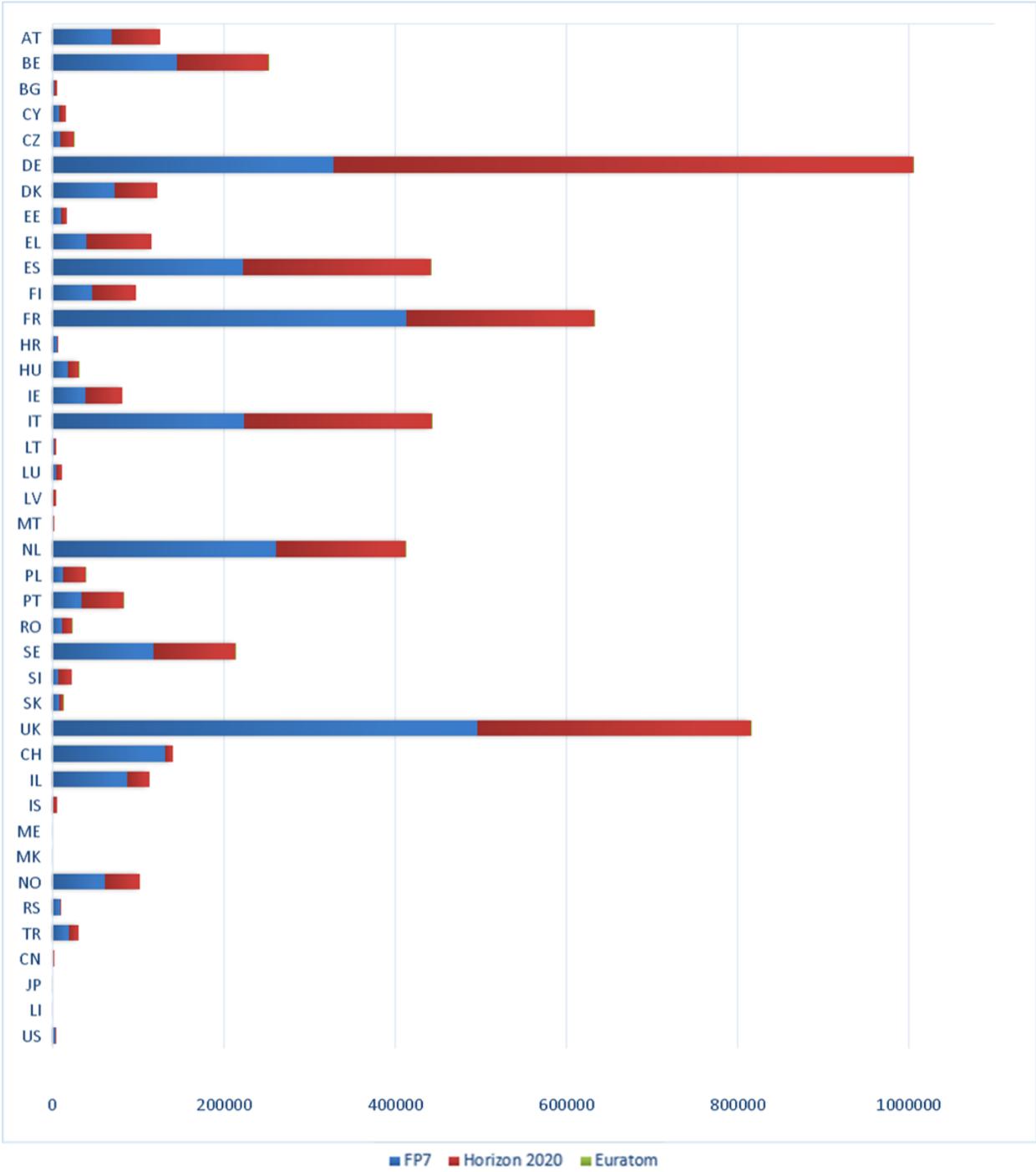
Figure 8.2 presents the EU incoming funding by type for the year 2014, showing the importance of Horizon 2020 at that moment. It is interesting to see that in addition to the high total levels achieved by Germany, the positive results from Horizon 2020 represent a much greater share of EU funding in this country than they do for other cases.

Figure 8.1 Incoming EU funding (2000/2014)



Source: eCORDA. Unit: thousand EUR.

Figure 8.2 Incoming EU funding by type (2014)

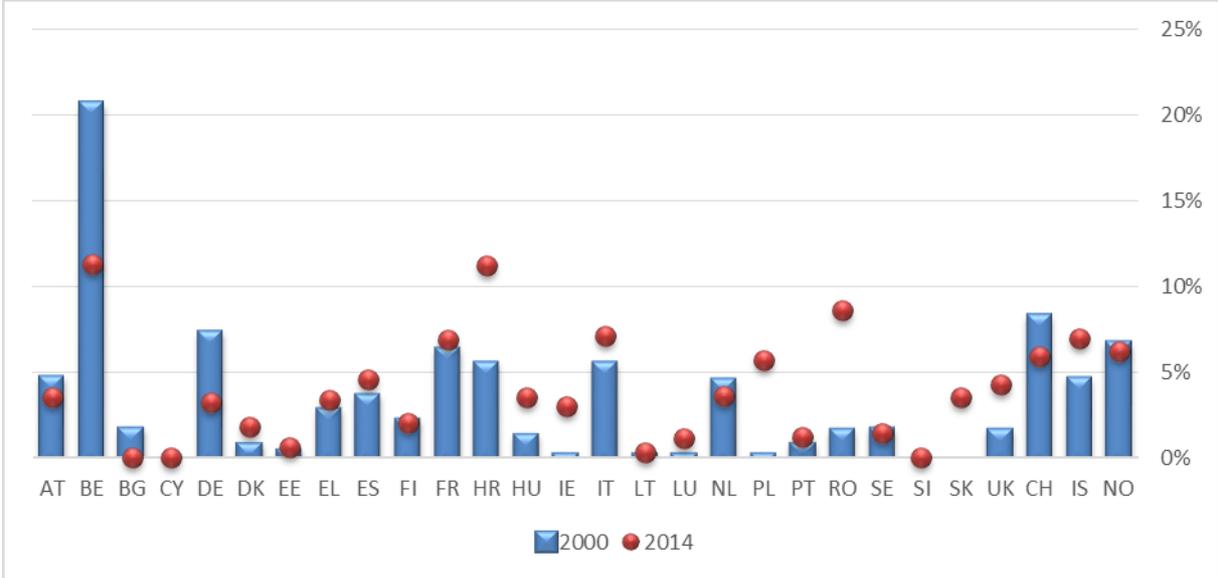


Source: eCORDA. Unit: thousand EUR.

8.2 National funding to international performers and agencies

Figure 8.3 presents national funding to international performers and international agencies as percentage of GBARD. Expressed in these terms, the most important contributions are from Belgium, at 20.5% of GBARD in 2000, and 11.3% in 2014; despite leading in terms of relative contribution to international performers/agencies, the 2000-2014 drop in investment is an important reduction for this country. Austria, Germany, Estonia, Switzerland and Norway also show negative trends, in all cases quite substantial. Lichtenstein is not included in Figure 8.3 because the country has a special situation with respect to the others: 63.6% of national funding went to international research performers and agencies in 2000, and 41.8% in 2014 (this consisted largely of contributions to SNF and CSEM-NTB, based in Switzerland, and to FWF in Austria).

Figure 8.3 National funding to international agencies and international performers as % of GBARD (2014)



Source: PREF.

Note. Countries with reduced data collection not included. Note: Start year is 2004 for FI, NL, PL, IS; 2008 for BG, CY, DK, EL, HU, LT, SE; 2010 for IT, RO, SI; 2011 for FR; 2012 for EE, ES and 2013 for HR. End year is 2013 for AT, ES, LT, UK and 2015 for FR. Data on SK available only for 2014.

9 Funding bodies; evolution in management of funding mixes

One of the building blocks of a national public research funding system consists of the actors installed as funding bodies, each of which will have a portfolio of funding streams and instruments under their management. Analysis of this area of the national system faces several problems in accessing data. For example, there is no overall register of public funders and research performing organisations in the different European countries (EC, 2015). One of the aims of the PREF project was to carry out data collection to respond to this gap, thus allowing investigation of the organisations managing public R&D funding. These same organisations also play an important role in directing the action of the research performers.

This section develops a characterisation of the research funding organisations (RFOs) and umbrella research organisations (UPROs) operating in the different countries. The immediate objective is to develop a typology useful for comparative analysis. This must take into account:

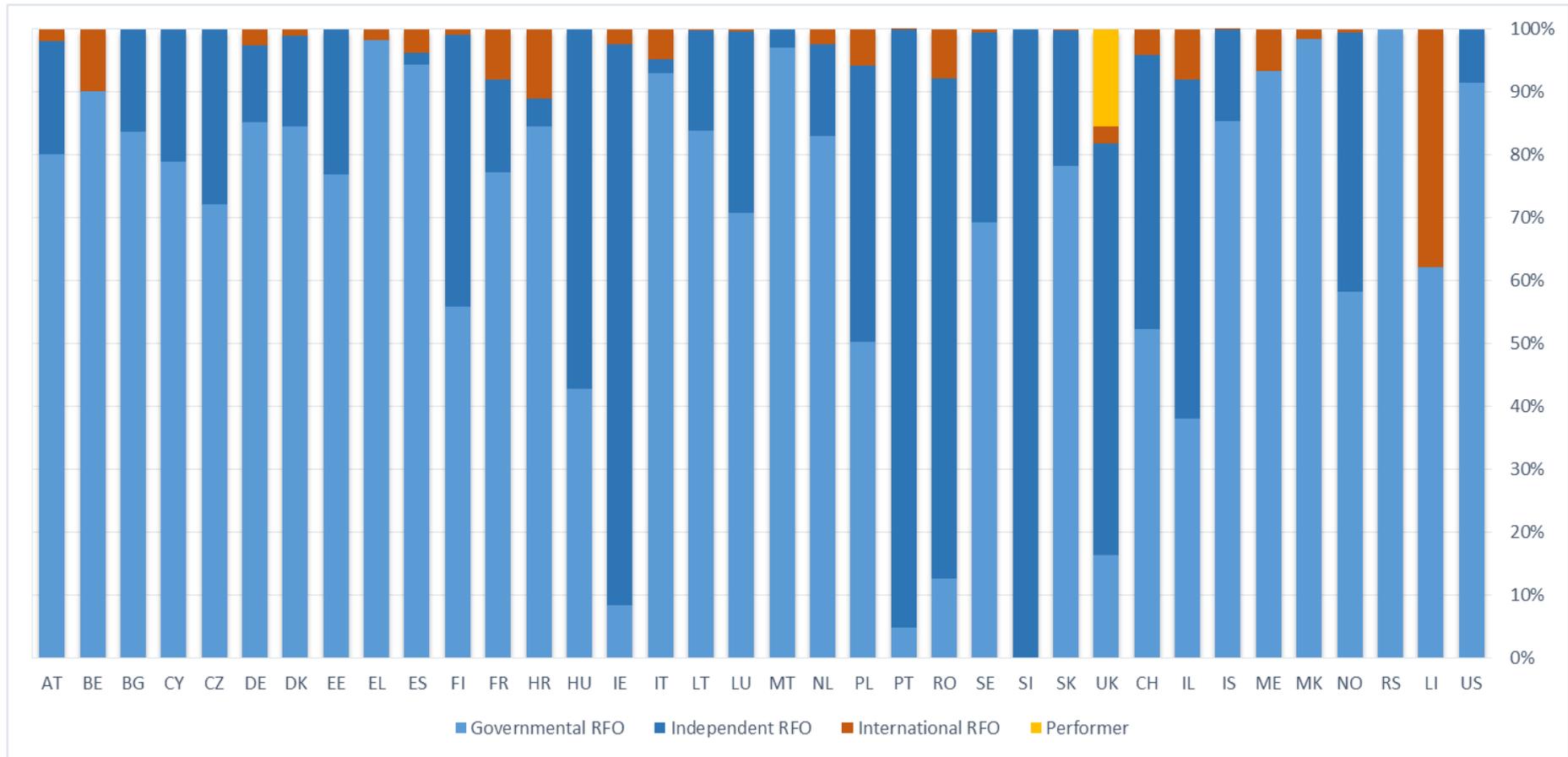
- Funding body classifications (1st level of characterisation);
- Organisational features of UPROs (2nd level of characterisation)
- RFO/UPRO mission (components scaled as 'important' and 'very important').

The aim of the country by country analysis is to deepen knowledge of the funding mix managed by the different RFOs and UPROs, and the structure of these actors - number, size, diversification, organisational features, and power relationships with the state (independence, autonomy). The analysis sheds light on the different configurations of national systems in terms of RFO/UPRO characteristics and the volumes and types of funding these actors manage.

In terms of organisational features and relationship with the state, the RFOs are classified as "government", "independent", "international", and "performer" (see PREF handbook). Fig. 9.1 presents the funding streams by these types of RFO, as percentage of the total GBARD for the year 2014, in the PREF countries. In most countries, the national configuration is dominated by governmental RFOs, meaning research ministries and other actors that are functionally part of public administration (ministry divisions, ministerial committees, etc.). There are exceptions where there is more prominence of independent RFOs in the national system, meaning organisations with a large degree of independence from the state in managing their activities and selecting projects. Ireland, UK, Portugal, Slovenia, Romania, Israel and Finland stand out among such cases.

Independent RFOs would normally have greater autonomy in strategies and operation than governmental actors, potentially sanctioned under terms of law. A key feature in distinguishing between "independent" and "government" RFOs is to observe whether the state retains the final decision on granting money for projects (see PREF Handbook). "Performers", or organisations whose main mission is to perform R&D activities, but who also have some funding functions, emerge only in the UK, where the various institutes of the Medical Research Council manage around 15% of total GBARD. "International" RFOs emerge in a number of countries but with limited roles in terms of volumes of funding. Exceptions include Belgium, Hungary, Croatia and Israel, where the streams managed by international RFOs represent around 10% of total GBARD.

Figure 9.1 Funding streams managed by different types of RFOs (%), in PREF countries and US (2014)



Source: PREF.

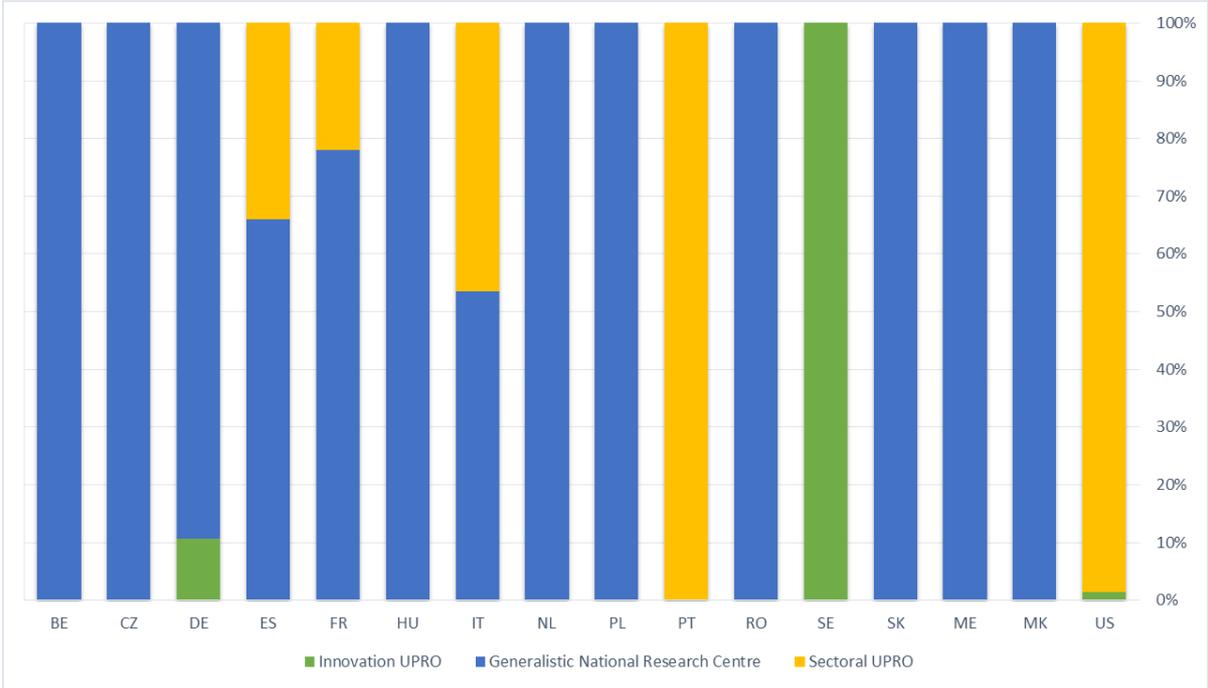
Note. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

Fig. 9.2 shows the funding streams per type of UPRO, as percentage of the total funding managed by all such actors, in 2014. The UPROs are classified as “government”, “innovation”, “sectoral”, or “generalist”. “Generalist” national research centres dominate the landscape in most countries where UPROs are present. These organisations are independent from the state in management of internal activities and selection of projects for funding, and typically have formal recognition of autonomy under law. As for RFOs, a key criterion of independence is that the UPRO retains the right to the final decision on selection and funding of projects. Generalist UPROs cover a broad range research fields, with funding mainly focused on basic and applied research, and with a strong connection to the academic community. In fact, the generalist UPRO could include academics in a form of mixed structures, at both decision-making and performer levels, (e.g. mixed committee membership, mixed research labs; see PREF Handbook).

Sectoral UPROs are the independent “sectoral” type, meaning organisations focusing on specific fields of sciences (e.g. INFN in Italy dealing with Nuclear Physics, or INRA in France dealing with Agricultural Research). Portugal and US are the countries where the most important UPROs in the area of public funding are sectoral. Finally, the independent “innovation” type of UPRO, which dominate in Sweden, have a mission and funding oriented towards innovation and creation of economic value, which can imply also allocation of a substantial amount of R&D funding.

A further type of UPRO is the Governmental one, which would encompass organisations performing activities under an instrumental relationship with the government and functional relationship with public administration; Governmental UPROs do not emerge as relevant actors in R&D funding in any country as to public R&D funding.

Figure 9.2 Funding streams managed by type of umbrella public research organisation (% , 2014)



Source: PREF.
 Note. Only countries where at least one UPRO is present were included.

Fig. 9.3a shows the funding streams by managing organisation as percentage of total GBARD (2014). In this case, the breakdown of RFOs is at the second level of

characterisation as defined in the PREF Handbook¹³. Among governmental RFOs, the most important role is played by national ministries of science and research, which have a prominent position in many countries. Among the independent RFOs, the most important type consists of the research councils, whose funding is mainly oriented towards basic and applied research, with a strong connection to academia. The figure also provides information on the relative importance of the funding streams managed by the RFOs compared to UPROs, allowing understanding of the level of heterogeneity of funding actors existing within and between countries. The data indicate that UPROs manage a relevant (or very relevant) amount of national public R&D funding in only a small number of countries, reaching levels of about 20% of total GBARD in the Czech Republic, Germany, Spain, France, Italy, Slovakia, and about 35% of GBARD in the USA.¹⁴

Second, research councils play a prominent role in Slovenia, (managing a percentage of 100% of GBARD), Portugal and Romania (70%), Israel (50%), Norway and UK (40%), Luxembourg (30%) Ireland, Poland and Switzerland (about 20% of GBARD).

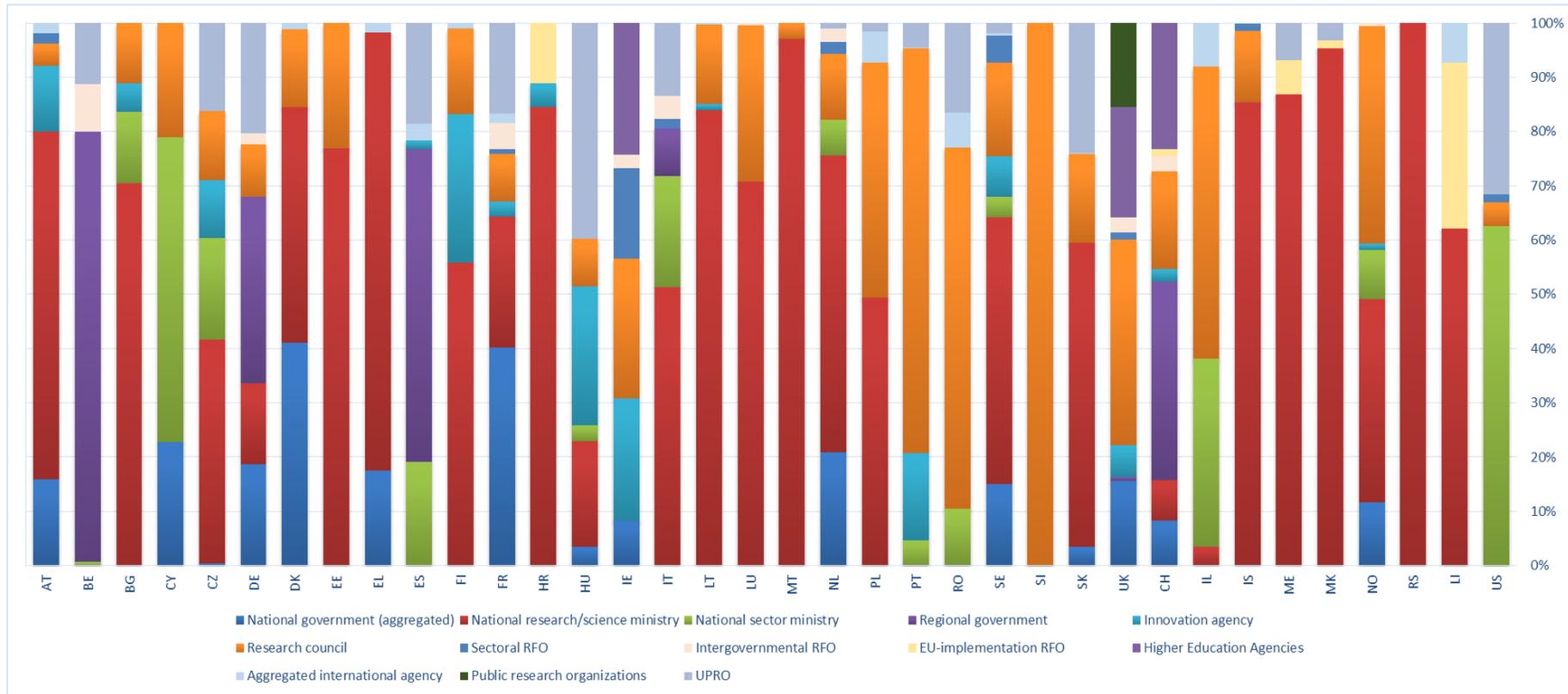
In the other countries state ministries (especially science/research) play the most important role, even in the presence of UPROs or research councils, such as occurs in France, Italy, Norway, Poland and Luxembourg. In countries with a federal structure (Germany, Switzerland) or strong decentralisation of state organisation (Belgium, Spain), the regions also play a strong role.

Figures 9.3b and 9.3c present further information on the funding streams managed respectively by governmental RFOs and independent RFOs, by category as percentage of total GBARD in 2014. We note that governmental RFOs manage all types of funding existing in a given country, while independent RFOs focus on project funding streams, with the exception of few countries where they also manage institutional funding streams allocated to PROs and HEIs.

¹³ Also for RFOs the label 'Innovation' refers to the general mission of the agency (see the Handbook). The label therefore does not exclude that the agency can manage R&D funding instruments – those devoted to fund applied pre-competitive research (the 'D' of the R&D definition).

¹⁴ Data on US are collected at Federal level and refer to national RFOs and UPROs (See the Public Funding Country Profile for US).

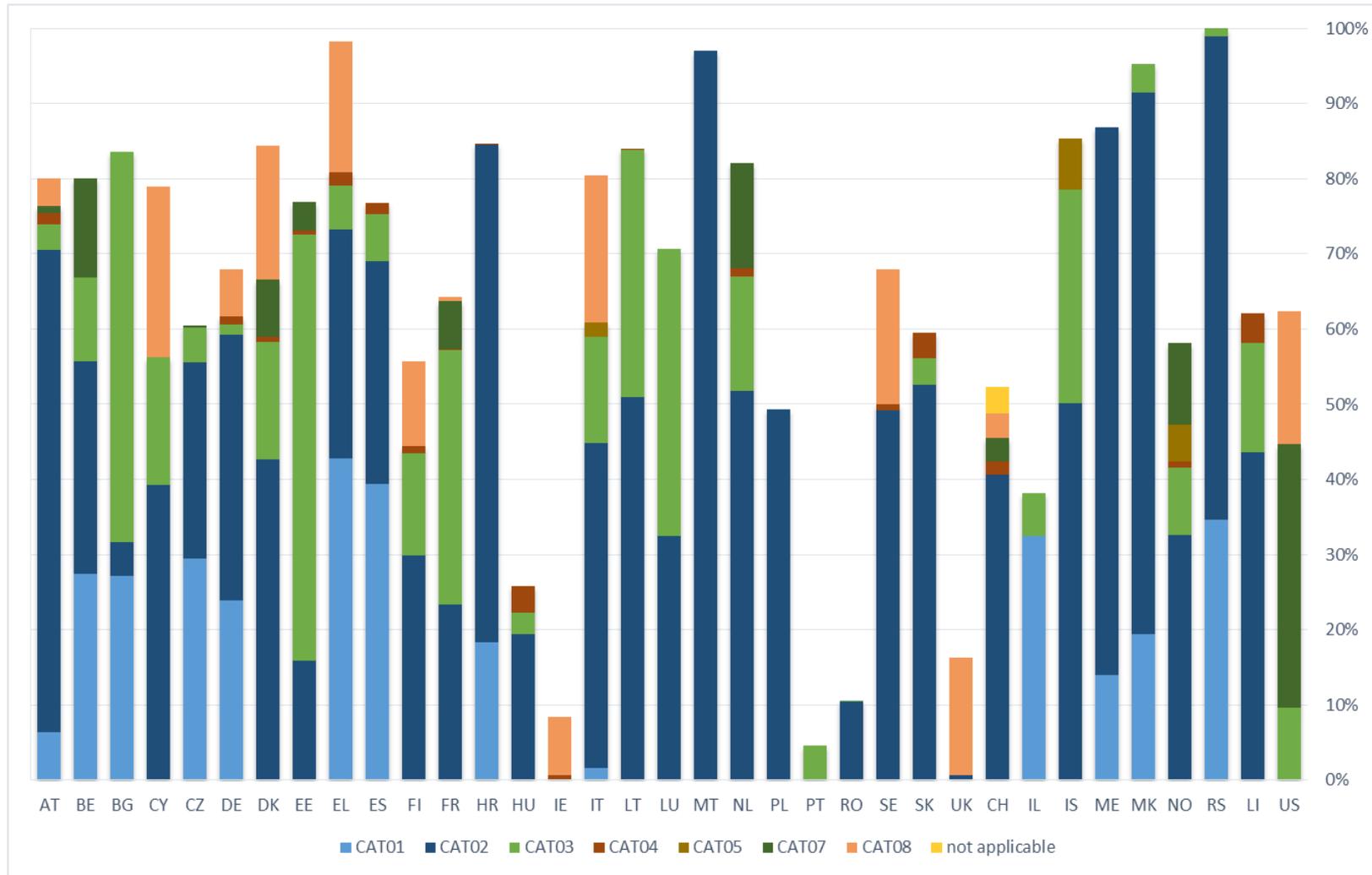
Figure 9.3a Funding streams by type of managing organisation (breakdown of RFOs at finer level of classification, 2014)



Source: PREF.

Note. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

Figure 9.3b Funding streams managed by governmental RFOs, by category as % of total GBARD (2014)

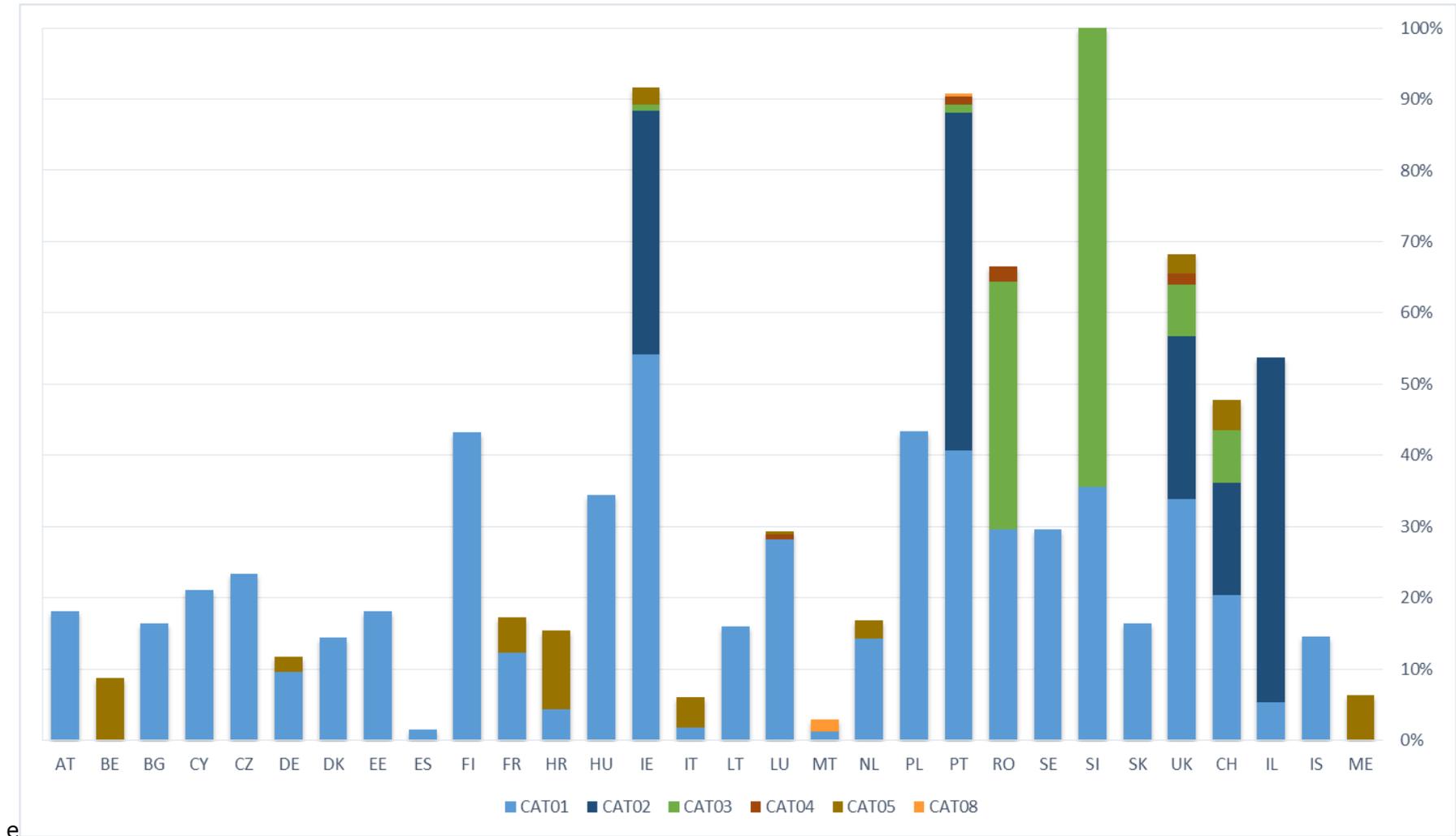


Source: PREF.

Note: CAT01=Funding to RFO; CAT02=Funding to HEIs; CAT03=Funding to PROs; CAT04=Funding to international performers; CAT05=Funding to international funding agencies; CAT06=Funding to UPROs; CAT07=Exchange funds; CAT08=Intra-mural R&D of the government.

Note. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

Figure 9.3c Funding streams managed by independent RFOs, by category as % of total GBARD (2014)

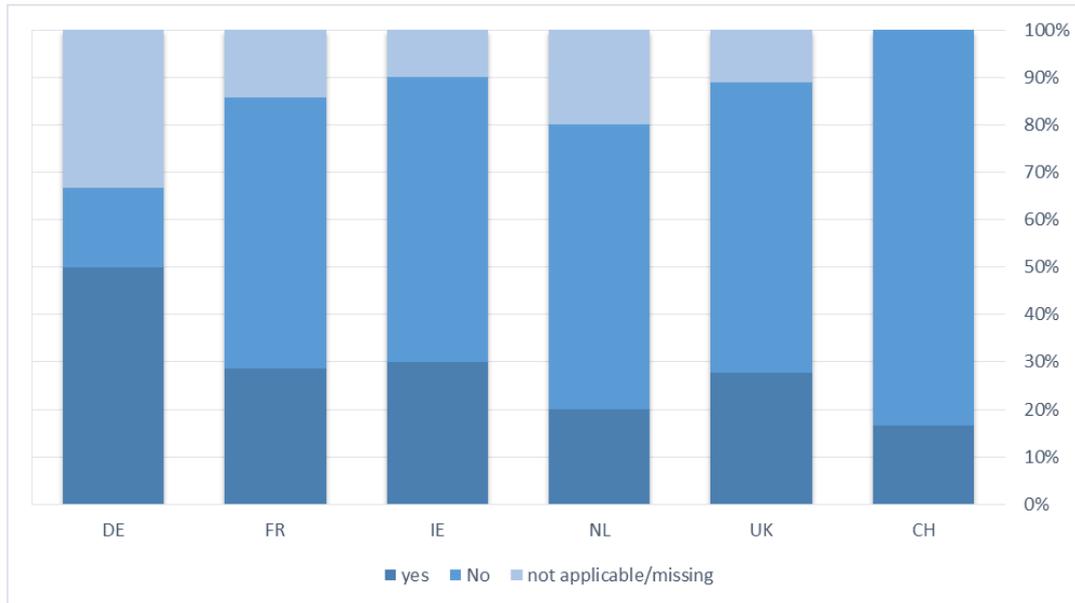


Source: PREF.

Note. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR. CAT01=Funding to RFO; CAT02=Funding to HEIs; CAT03=Funding to PROs; CAT04=Funding to international performers; CAT05=Funding to international funding agencies; CAT06=Funding to UPROs; CAT07=Exchange funds; CAT08=Intra-mural R&D of the government.

PREF data collection can also serve for investigation of other RFO organisational features data, which are able to provide some insights of further elements of differentiation of national R&D systems across European countries. Figure 9.4 shows that in a small number of countries, RFOs also play the role of performer.

Figure 9.4 Share of RFOs also serving as research performer, by country (% total RFO)



Source: PREF.

Note. Countries with reduced data collection not included. Only countries where at least 1 RFO with performer role appears were included.

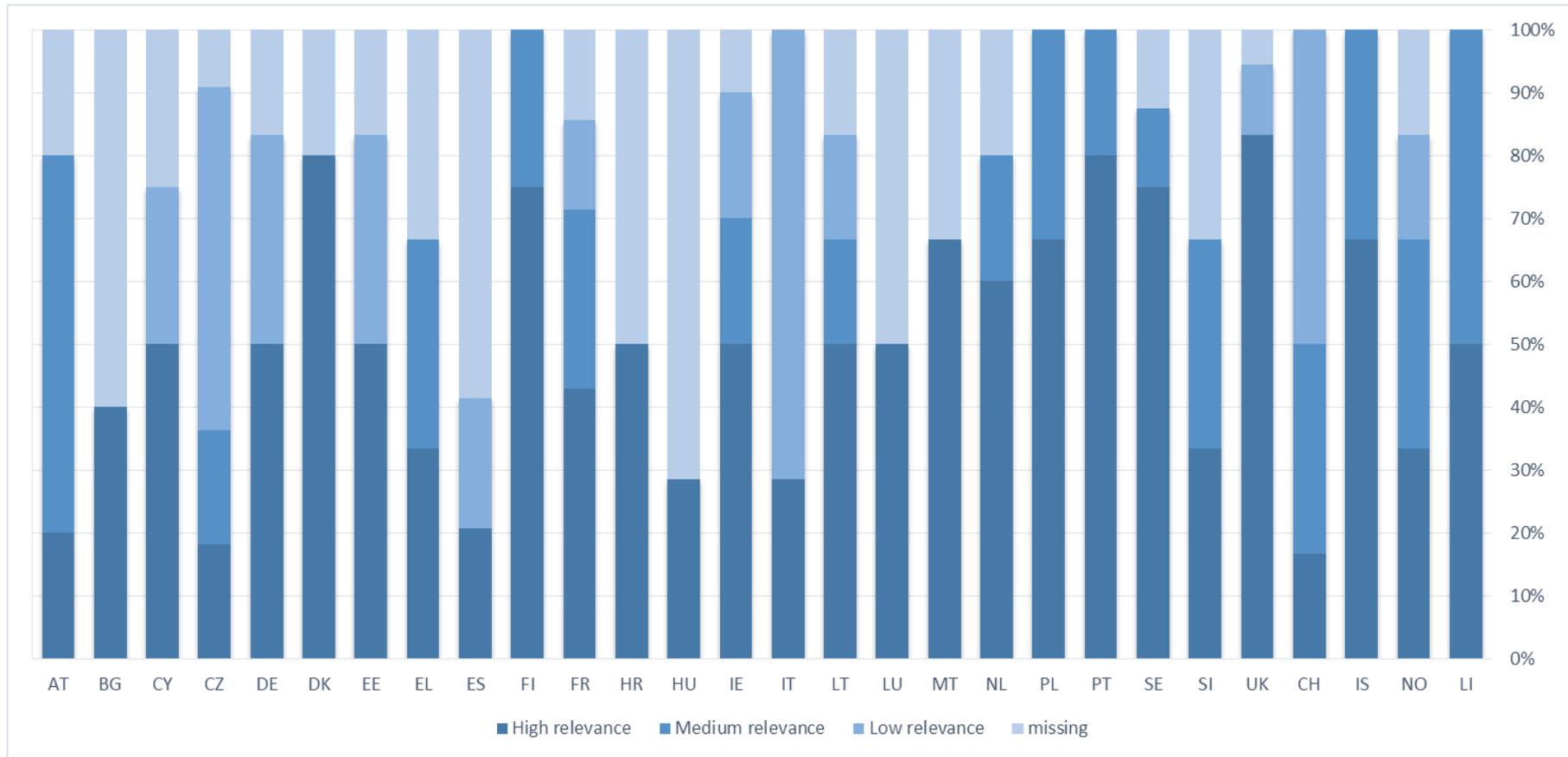
PREF data collection is also designed for investigation of the RFO or UPRO mission. The study established a set of scales (1=unimportant to 5=very important) for measurement of the relevance of different goals (see PREF Handbook). The current report focuses on two key missions or major goals of the funding organisation: scientific excellence and economic innovation. Scores of 5 and 4 are grouped as "high importance", score 3 is interpreted as "medium importance", and scores 2 and 1 as "low importance". Figures 9.5 and 9.6 show the share of RFOs by importance placed on two missions concerning improvement of research performance through public funding: those of "strengthening excellence" and "economic innovation".

Strengthening excellence is an objective whose importance is particularly high (more than 50% of the RFOs in the country) for RFOs in Denmark, Finland, Malta, the Netherlands, Poland, Portugal, Sweden, UK and Iceland. Excellence has low importance (less than 20% of the RFOs in the country) only in Czech Republic and Switzerland.

Innovation is also an important mission for RFOs in the countries covered by the PREF study. The highest percentages of organisations that consider innovation very relevant are in Iceland, Croatia, Bulgaria, Finland, Norway, and Luxembourg, where more than 50% of RFOs state this as a major goal. Countries where RFOs generally do not hold innovation as a very relevant goal (less than 20% consider innovation an important part of their mission) are Italy, Hungary, Czech Republic, Denmark and Portugal.

As to UPROs, excellence is always a very important part of the mission, no matter the home country. However, UPROs generally do not have innovation as a core mission. Exceptions are in Estonia and Sweden, where all organisations are innovation-oriented; Germany where Fraunhofer Gesellschaft is the most important UPRO, with innovation as a core objective; Portugal, where over half of UPROs in PREF data collection state an orientation towards innovation.

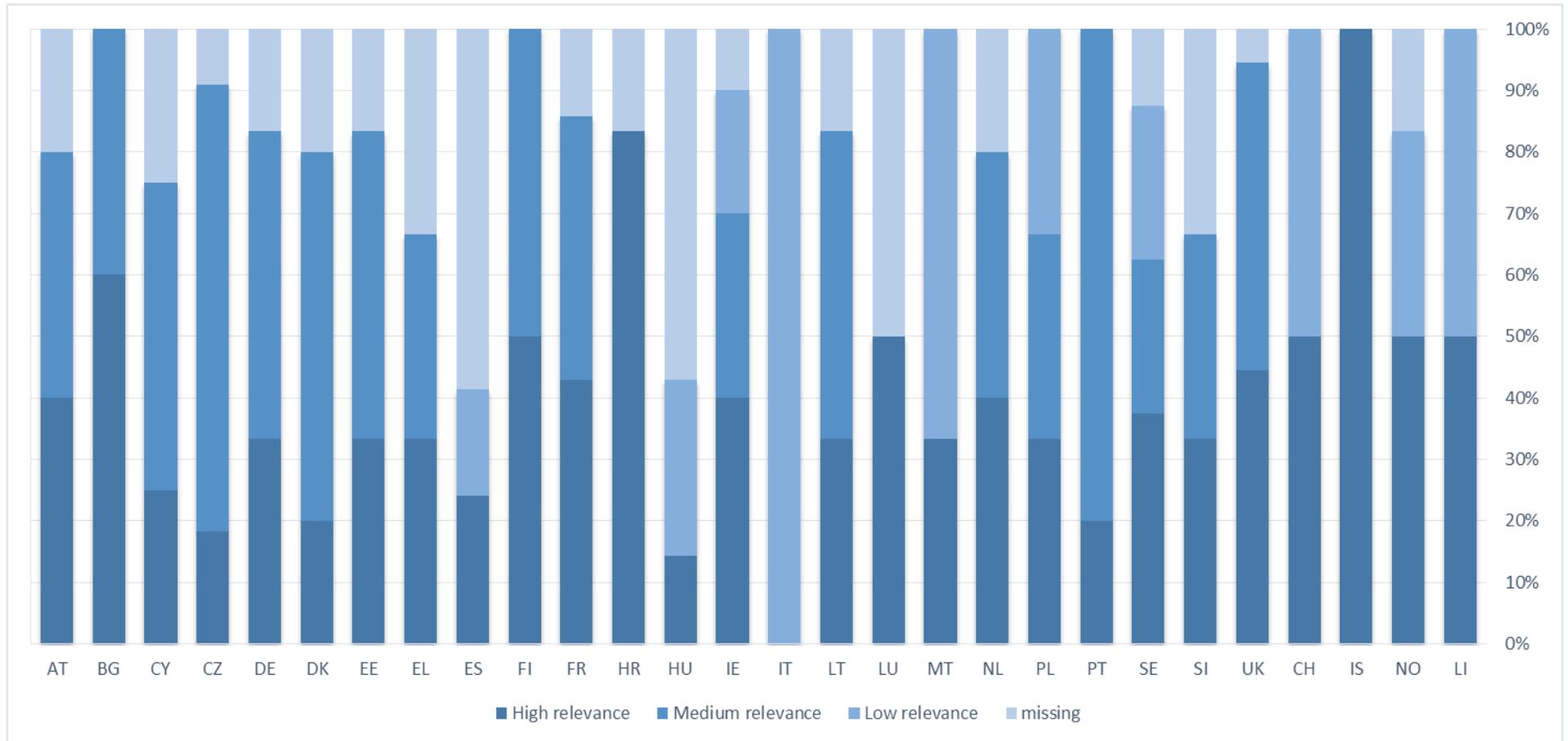
Figure 9.5 Share of RFOs by the mission=excellence (PREF countries)



Source: PREF.

Note. Countries with reduced data collection not included. Information not available for BE, RO, SK.

Figure 9.6 Share of RFOs by relevance of the mission=innovation (PREF countries)



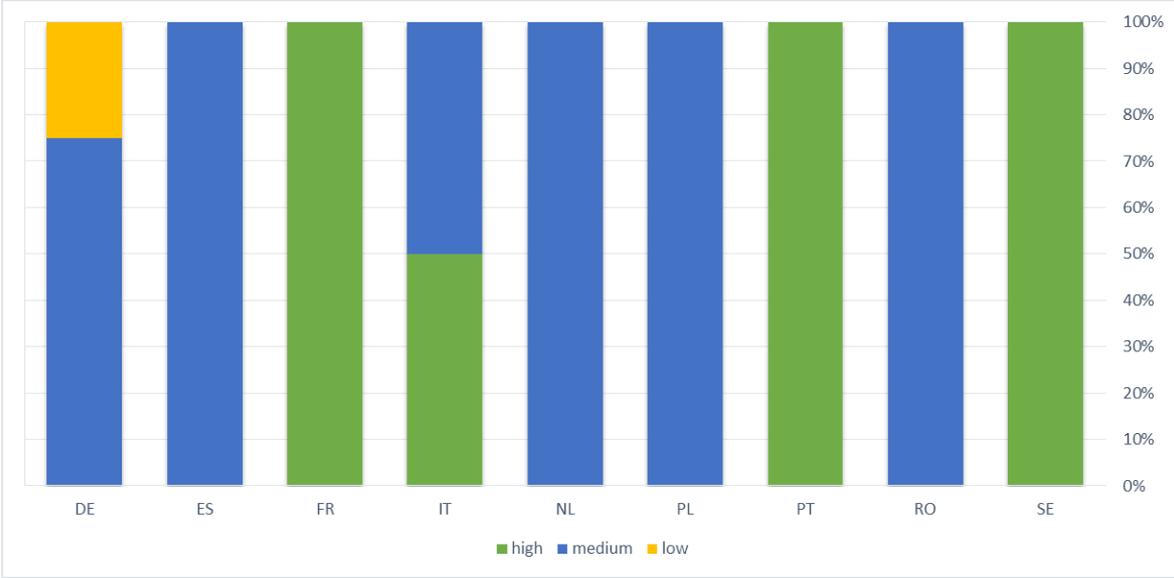
Source: PREF.

Note. Countries with reduced data collection not included. Information not available for BE, RO, SK.

The PREF data collection can also be used for characterisation of UPROs by level of organisational integration. The categories recognised are “high” organisational integration, for UPROs with centralised headquarters and important decision-making powers, such as those on researcher careers; “low”, for decentralised organisations without headquarters retaining power; “medium” where there is some centralisation but the labs maintain full autonomy under specific circumstances (see PREF Handbook).

From Figure 9.7, we can observe that there are very different configurations of UPROs among the countries. France, Portugal and Sweden have highly integrated UPROs, while Spain, the Netherlands, Poland and Romania (also Germany, with about 75% representation) have medium-integrated structures. The UPROs observed in Italy are half highly integrated and half medium integrated structures.

Figure 9.7 Share of UPRO by level of integration



Source: PREF.

Note. Countries with reduced data collection not included. Only countries where at least one UPRO is present were included. Information not available for BE, CZ, HU, SK.

10 Public research funding regimes in European countries

This section elaborates the evidence and findings discussed thus far, with the objective of identifying different public research funding regimes within the European countries. The main dimensions to be considered include:

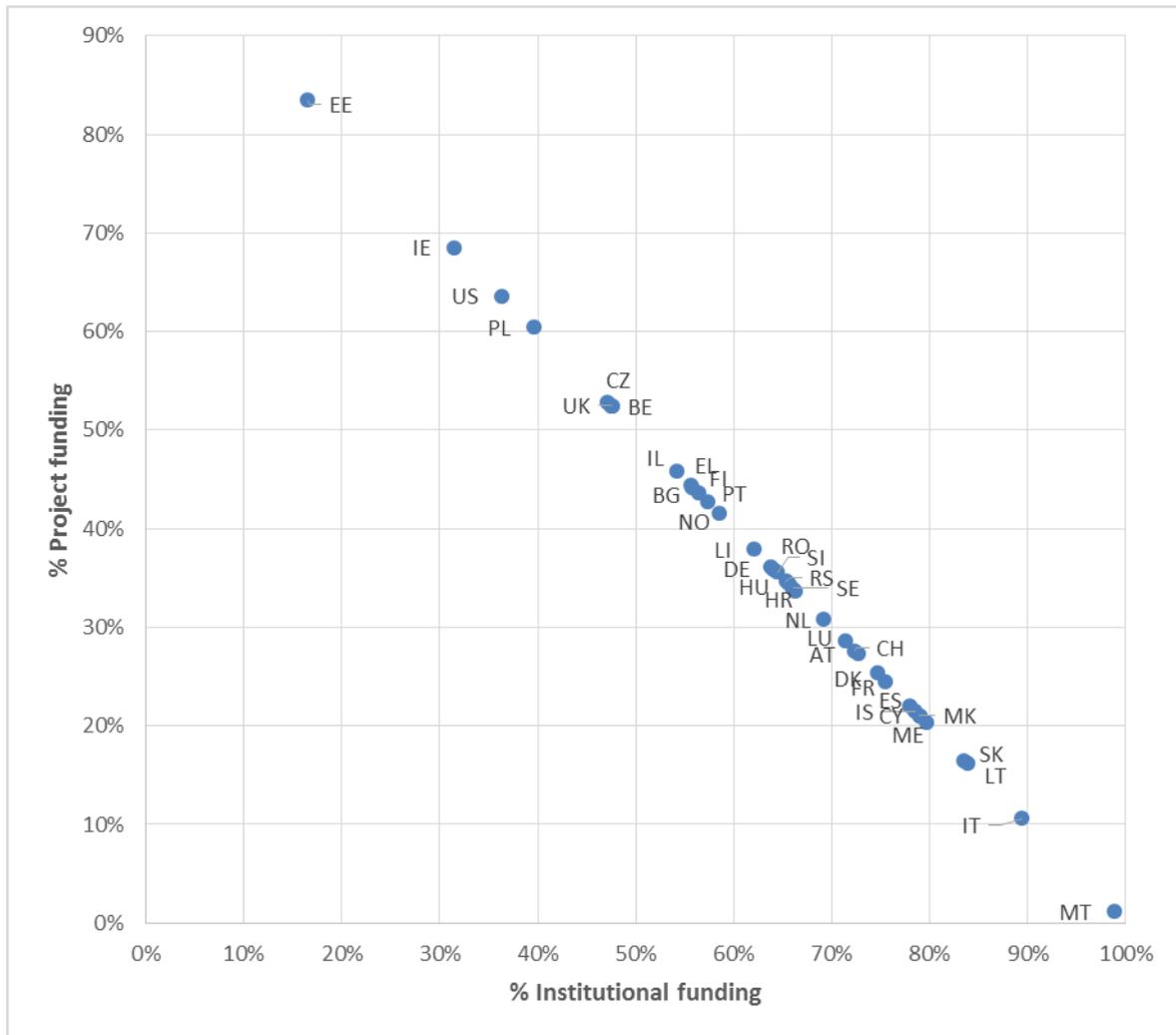
- Type of funding (project vs. institutional), to understand how countries are evolving the structure of public R&D funding allocation, increasing the amount of funding oriented towards targeted objectives.
- Implementation of performance based assessment in fourteen pilot countries. The purpose is to measure the extent to which European governments are using the core allocations of institutional funding to shift the research structure toward more competition.
- Characterisation of the coordination modes in European countries, by examining the types, organisation and mission of the research funding organisations.

10.1 Project vs. institutional funding

Figure 10.1a plots the countries of the PREF study according to investment in project and institutional funding in 2014. Figure 10.1b presents the analogous data for 2008, the moment when most European countries began reforms providing for introduction and greater use of performance-based systems of allocation. The reforms mainly affected allocation of institutional funding to higher education institutions. The rationale behind these moves was generally linked to increasing and improving the use of performance-based and competitive public funding allocation as a means to improve levels of excellence in universities, as well as their capacities to contribute to wealth creation and national economic competitiveness (Jonkers and Zacharewicz, 2016).

The figures show that there is indeed a general increase of the importance of project funding in the countries of the PREF study. Between 2008 and 2014, the distance between countries was greatly reduced in terms of project funding. The figures also show a wide variation in the evolution of country systems over this period: some show strong growth in project funding (e.g. Ireland and Poland); others show a strong decrease (e.g. Romania), or no meaningful investment in the strategy (e.g. Malta). This wide variation demonstrates that project funding is a key indicator for mapping the changes in policy priorities for R&D funding and the volumes of resources thus mobilised.

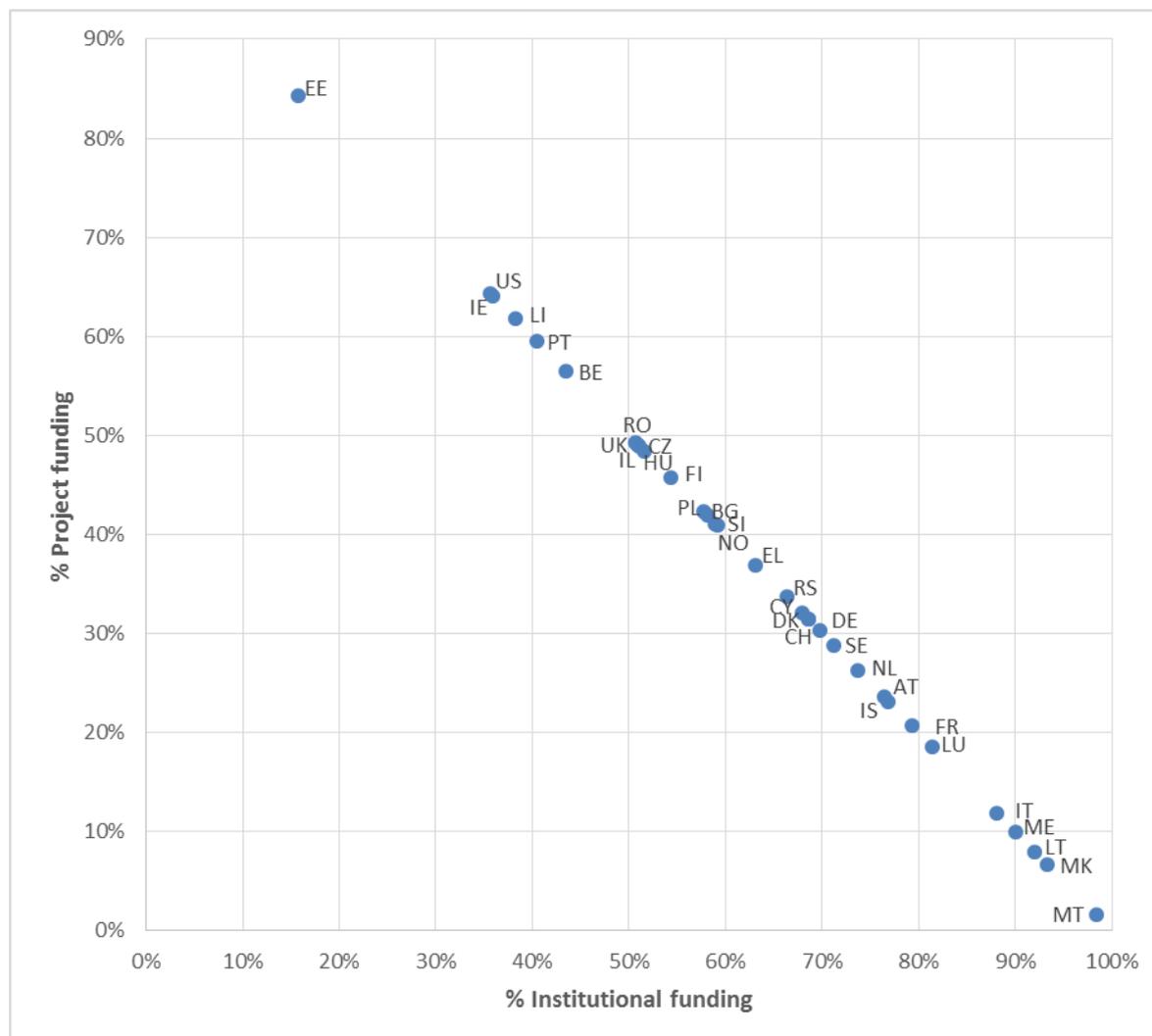
Figure 10.1a Project funding vs. institutional funding as % of total GBARD (2014)



Source: PREF.

Note. Reference year is 2013 for AT, ES, LT, UK.

Figure 10.1b Project funding vs. institutional funding as % of total GBARD (2008)



Source: PREF.

Note. Reference year is 2009 for IT; 2010 for CZ, RO, SI; 2011 for EE, FR.

Not included in this chart: ES, HR, SK.

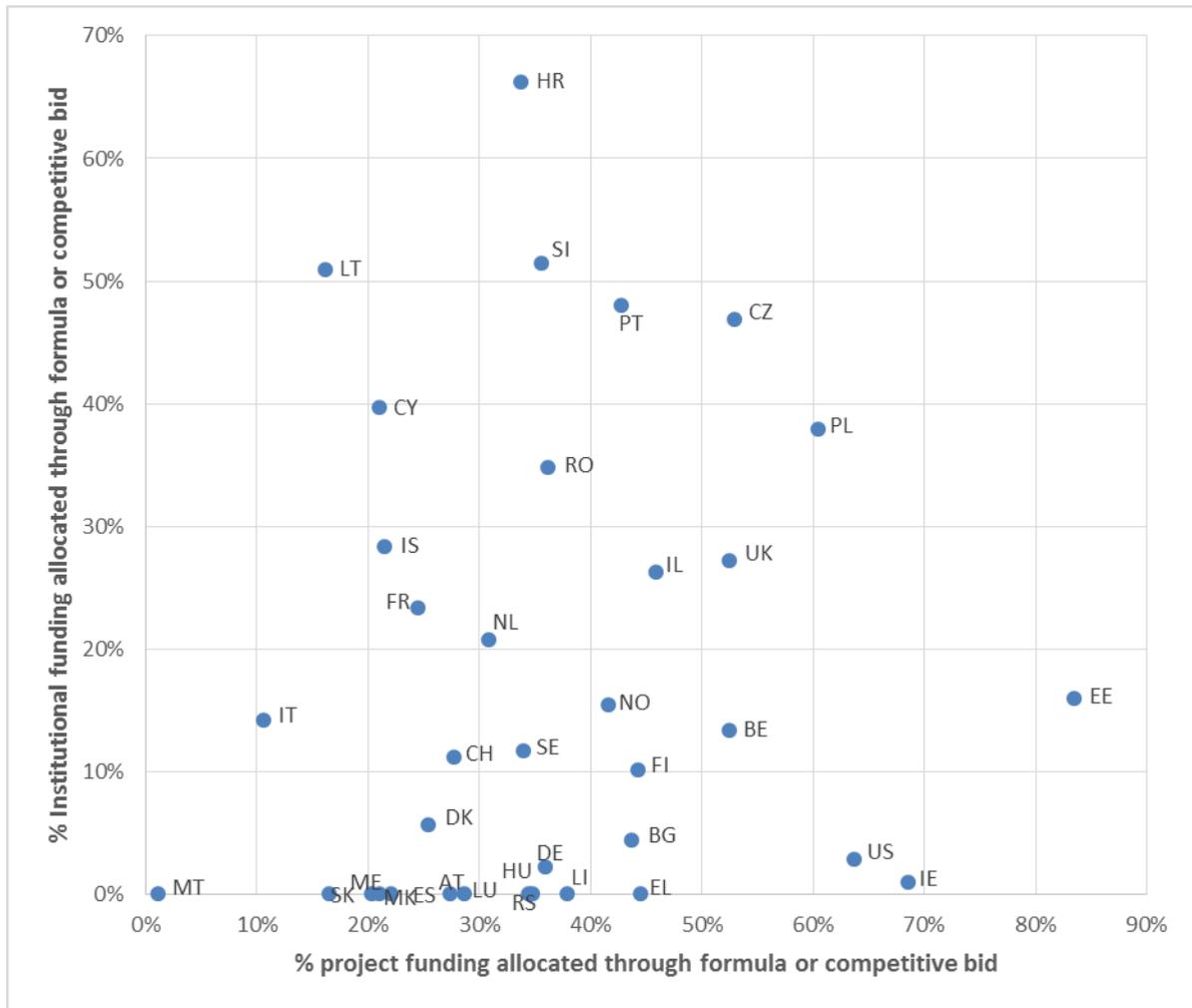
10.2 Performance based funding

The plots in Figures 10.2a, b and c are intended to assist in understanding how the different countries are progressing toward performance-based allocation in institutional funding, applying the PREF indicator based on allocation procedures, and the composite indicator based on performance-based funding (see Sections 6.1 and 6.2 in this Report).

Fig 10.2.a shows the positioning of the countries observed in terms of allocations using formula funding and competitive bid versus project funding, as percentages of total institutional funding.

The figure does not present a clear trend or a meaningful positioning of the countries, which generally have not engaged in formula allocation in a prominent or substantial manner, relative to total R&D funding allocated to institutions. This result confirms the difficulties in using the examination of allocation procedures (historical, negotiated, formula, competitive bid) to reveal the trends in research systems towards performance-based funding, arising because formula composition can be calculated with little reference to the outcome of the research activities.

Figure 10.2a Project funding and institutional funding allocated through formula/competitive bid (% of total funding, 2014)



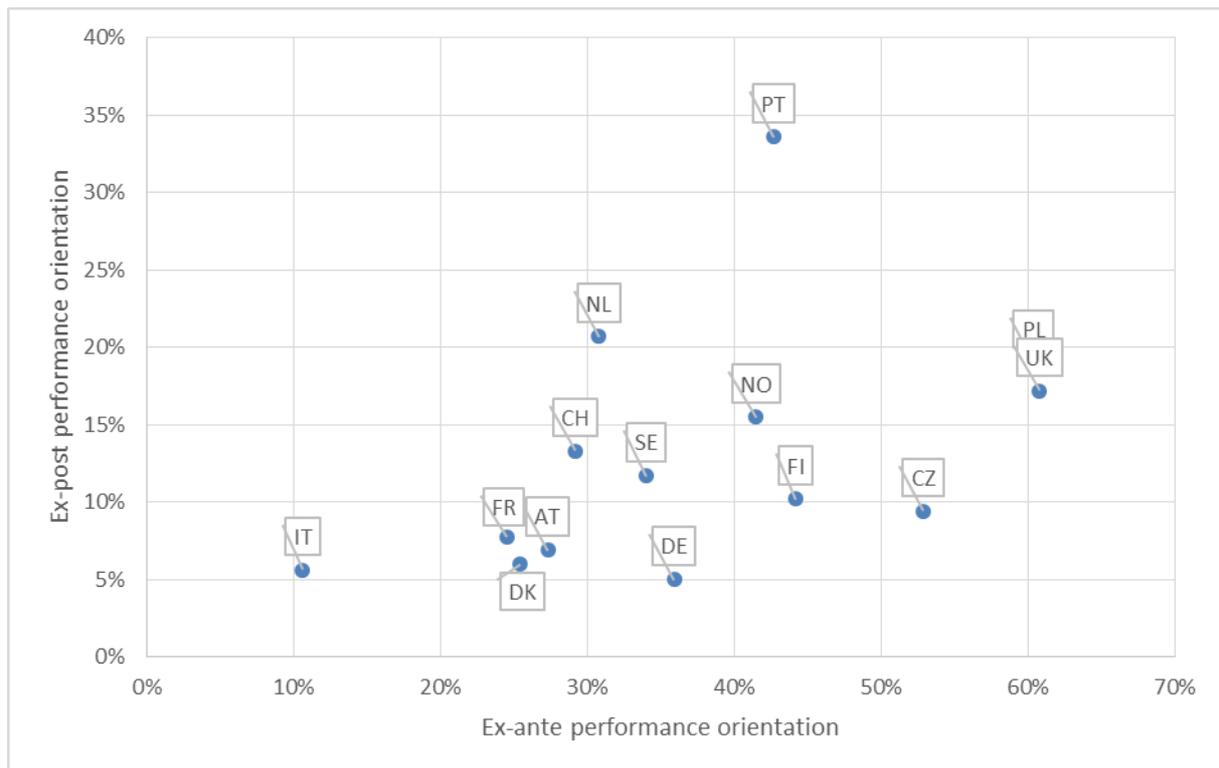
Source: PREF.

Note. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

Figure 10.2b plots the orientation towards ex-ante versus ex-post performance assessment in public RD funding in 14 countries as percentage of total funding, in 2014. The countries are those involved in the pilot study related to the second indicator on performance-based funding (see Section 6.2). The charting of these two dimensions clearly shows that most of the country systems employing similar types of balancing in funding allocation, choosing between the two orientations of performance assessment, with few countries showing a more important tendency toward ex-ante performance orientation (PL, UK, CZ).¹⁵ Also, it is interesting to note that some countries show a very high performance-based orientation of public R&D funding (either ex-ante or ex-post), namely UK, PL, PT, NO, FI, while Italy has the lowest performance-based orientation among the observed countries.

¹⁵ Ex-ante performance orientation refers to project funds, where allocation is based on ex-ante assessment of expected performance; ex-post performance orientation refers to allocation of institutional funds based on ex-post evaluation, including for example formulas based on research outputs, or allocation based on evaluation of other past performances (see Section 6.2).

Figure 10.2b Ex-ante vs. ex-post performance orientation of public R&D funding in 14 European countries (% of total funding, 2014)



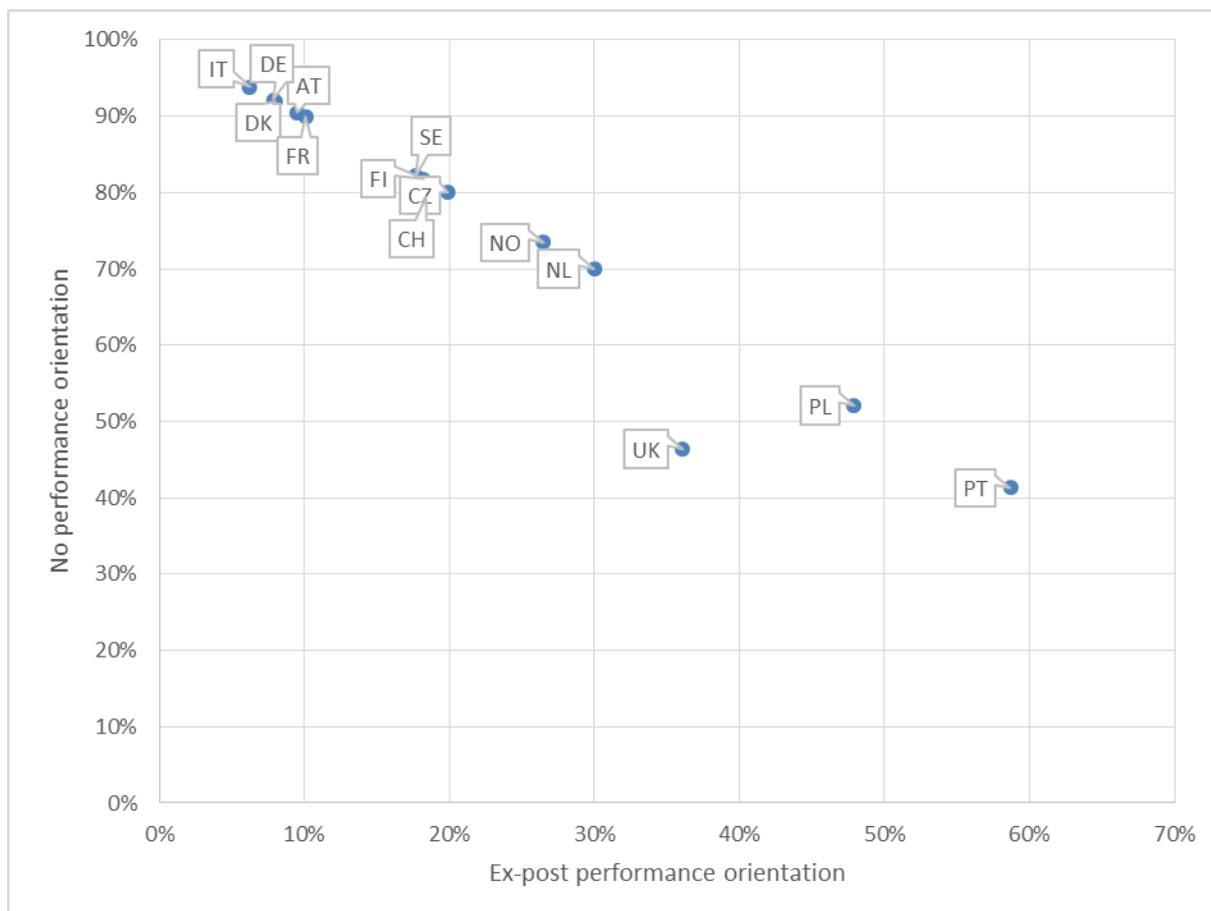
Source: PREF.

Note. Reference year is 2013 for AT, UK and 2015 for FR.

Finally, 10.2c plots the different implementation of performance-based allocation of institutional funding in the fourteen countries of the pilot. Three groups of countries emerge, namely:

1. Those where a high percentage of institutional funding is still allocated with very limited performance-based orientation (IT, DE, AT, DK, FR);
2. Countries with performance-based orientation is now present in close to 20% of total institutional funding (SE, FI, CZ and CH);
3. Countries where the percentages of total of institutional funding with and without performance-based orientation are approximately balanced (UK, PL and PT).

Figure 10.2c Ex-post performance orientation as % of institutional funding vs. No performance orientation (% of institutional funding in 14 European countries, 2014)



Source: PREF.

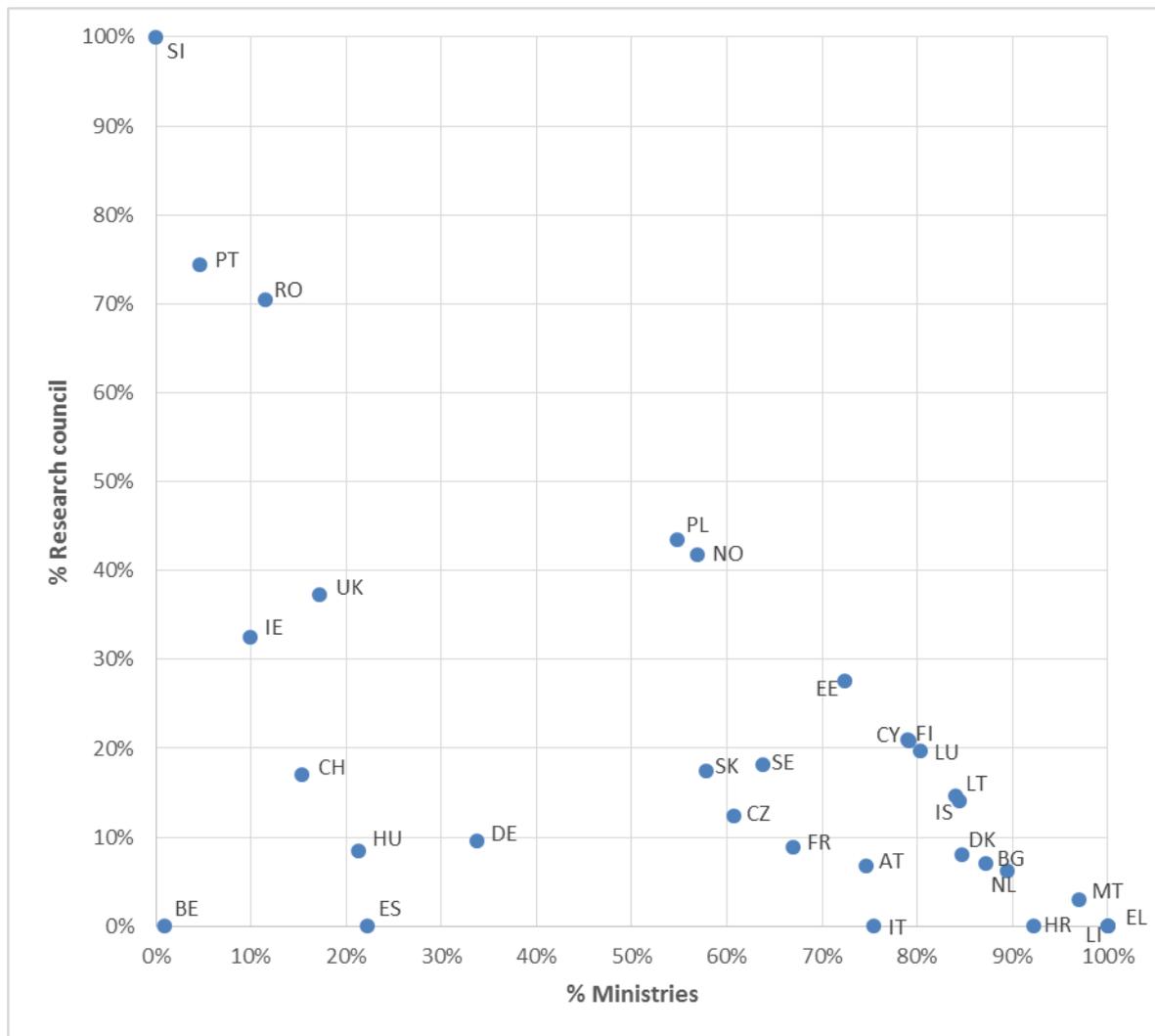
Note. Reference year is 2013 for AT, UK and 2015 for FR.

10.3 Managing agencies

The last two plots are devoted to understanding the positioning of the countries with respect to the most important types of government RFOs, namely ministries and research councils. Despite the fact that they are both governmental organisations, the position with respect to the state is very different. Research councils are in fact intermediaries with clear policy space between the decision makers and the beneficiaries, generally retaining substantial autonomy and room to manoeuvre in the design and management of funding instruments. Research councils generally assume a very prominent role in countries with a project-based characterisation, while ministries are more important in vertically-oriented countries.

Figures 10.3a and 10.3b present, respectively, the percentages of all R&D funding instruments managed by research councils and ministries, and the analogous plot referring only to percentages of project funding. The former figure reveals the important role in overall public R&D allocation held by ministries in a large group of countries. There are only a few exceptions (Slovenia, Portugal and Romania) where research councils largely manage the allocation.

Figure 10.3a Share of all funding instruments managed by ministries vs. by research councils, in different countries (% , 2014)

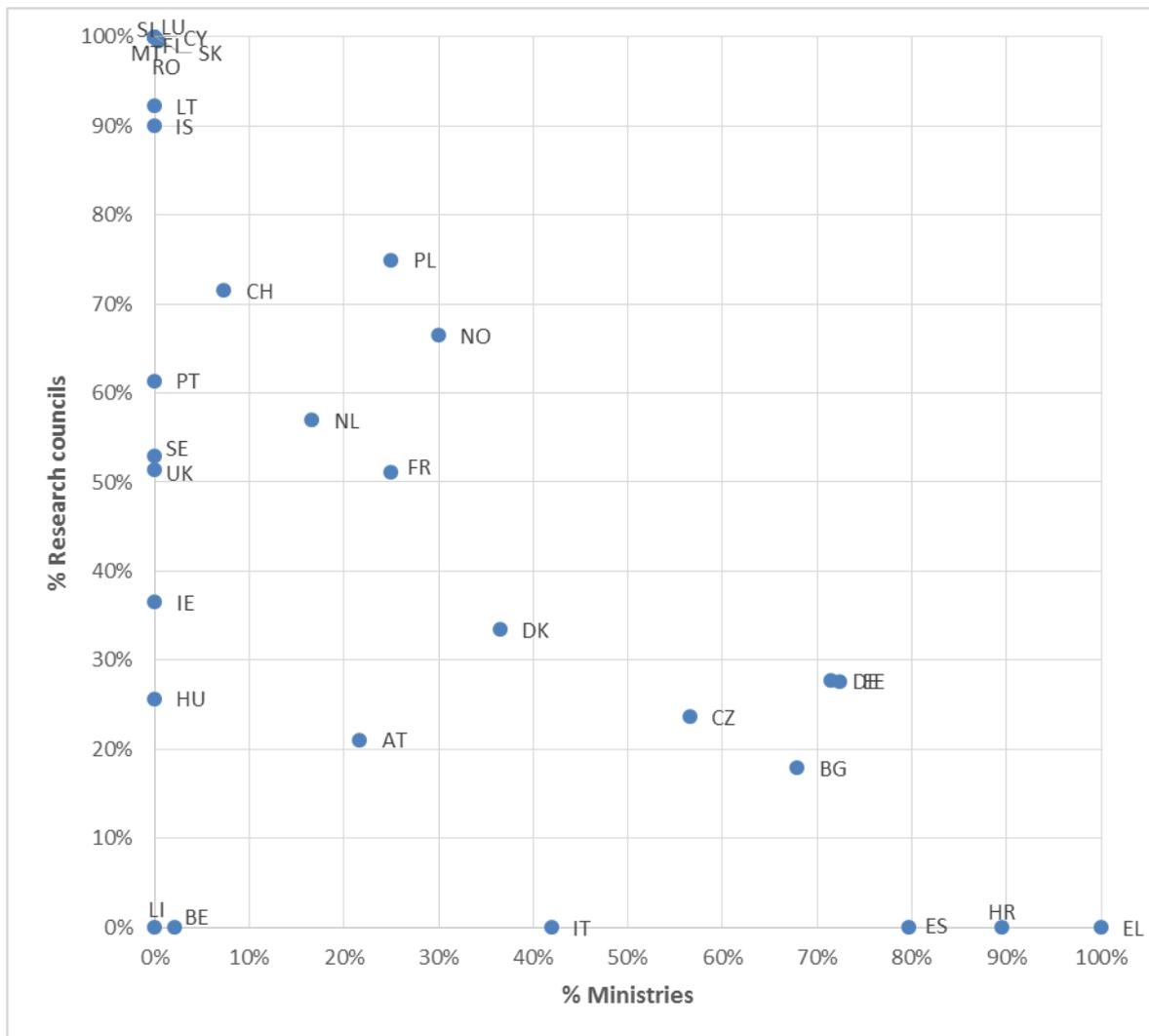


Source: PREF.

Note. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

When the focus is narrowed to project funding only, the positioning of a number of countries changes: in this type of funding, ministries play very little or no role, and in a number of countries research councils become important (UK, IE, SE, PT, CH, NL) or very important (SI, LU, RO, FI, CY, LT, SK, IS). The countries where ministries still play a central role include those where the national model remains strongly centralised on public funding allocation, such as in Greece, Croatia and Italy. Spain is also included in this group, though this indication is less confident, because in Spain it was not possible to break down project funding coming from regional governments. Still, it is quite surprising that there remain countries where public R&D project funding is mainly managed by the ministries, despite the creation of a specific funding organisations intended to play a prominent role in this type of allocation. Thus, while it is true that there is a tendency toward strengthening national system along project-based modes of coordination, the process is far from homogeneous among countries, and a large variety of coordination modes can still be observed.

Figure 10.3b Share of project funding instruments managed by ministries vs. by research councils in different countries (% , 2014)



Source: PREF.

Note. Reference year is 2013 for AT, ES, LT, UK and 2015 for FR.

11 Conclusions and recommendations

The aim of the current report is to analyse the characteristics and evolution of national public R&D funding in the 40 countries of the PREF study, from 2000 to 2014, in terms of percentage of project versus institutional funding, main allocation mechanisms of public funding for R&S, objectives of research funded, and convergence around research themes and topics identified in FP7 and Horizon 2020.

The analysis refers to the following issues:

- Funding intensity of the countries;
- Characteristics of public R&D funding by types of allocation criteria and funding mechanisms;
- Proxy of competitiveness of institutional public funding;
- National-level engagement in R&D on Key Enabling Technologies (KETs) and Societal Grand Challenges (SGCs) priorities;
- Characteristics of the organisational system for managing national public R&D funding.

National public R&D funding (GBARD) shows growth in volume between 2000 and 2014, although with different rates between countries. The differences between countries in public funding of R&D remain very high even when GBARD is measured as percentage of general government expenditures. A number of countries, both from western and eastern areas of Europe show significant decreases of GBARD as percentage of general government expenditures; however, given the imbalanced situation in the starting levels of public funding, mobilised in 2000, the decreases observed are likely to produce very different effects, with the worst occurring in eastern countries.

Project funding, inferring allocation on a competitive basis, to a group or individual for research activity limited in scope, budget and time, is visible in all European countries in 2014 and in almost all the non-European ones examined. However, the level of this type of funding generally remains low in comparison to institutional public funding, with very few exceptions. Examining project funding as percentage of total GBARD, the PREF data confirms the general tendency of European countries towards increasing the share of project funding, although progress is very differentiated and in some countries, remains stationary.

As to institutional funding, thus the funding attributed to PROs and HEIs for operations, allocation based on performance-based mechanisms can derive from different procedures, namely formula funding or competitive bid, while non-performance based funding follows historical patterns with adaptations and/or negotiated procedures between funder and performers. In examination from this point of view, the presence of a performance orientation in institutional funding appears generally very low, and indeed cannot be detected in most European countries.

The PREF study also tested a different approach to detecting performance-based funding in a pilot study of fourteen countries. The aim was to develop a composite indicator of performance-based funding, taking into account both allocation procedures and allocation criteria – the importance of input criteria and output criteria for determining the level of funding, in ex-ante (project funding) and ex-post (institutional funding) allocation. The results of the pilot methodology are promising in terms of capability of measuring performance-based orientation of all public funding, and specifically public institutional funding. Applying the indicator, a general orientation emerges in which countries with fairly low levels of project funding (e.g. Austria, Italy) have increased the competitiveness of public funding allocation by introducing output-oriented allocation criteria for institutional funding. Some limitations of the proposed indicators, of which the most important are the hidden mechanisms affecting the R&D allocation of public funding in the different national contexts, and the scoring based on experts' assessment. Thus,

the PREF exercise confirms the need to handle the data on performance-based funding carefully.

Analysis of the engagement in KETs and SGCs priorities through public R&D funding proved difficult and the data presented in the report must be used with caution. However, it is interesting to note that in the cases where reliable data are available, the differences in shares of funding orientated towards KETs and SGCs priorities appear very high: a small number of countries in western areas of Europe, with strong public funding investment in R&D, account for the largest values of funding both in absolute terms and as percentage of national budgets. This evidence is a further signal of the imbalance between countries in terms of public R&D investment, which for a variety of reasons could become worse over the coming years. The low levels of national public funding oriented toward KETs and SGCs might in fact become a further constraint to participation in EU programs such as Horizon 2020.

The PREF data confirm the role of ministries as the organisations managing the institutional segment of national public R&D funding, in most national systems. Research councils emerge in several countries as organisations dominating the management of project funding, while ministries remain lead managers for this type of allocation in very few countries. Thus, the different role of project funding also implies consequences in the organization features of European countries.

Summing up, the picture provided by the PREF data confirm the heterogeneity of the European countries, although some convergences in allocation of public funding emerge. First and foremost, there is a drift toward improvement of the performance-based funding system, based on both project funding and institutional funding. However, the European landscape is characterised by strong imbalances in the intensity of national public R&D funding mobilised, unequal alignment with the priority of project funding, and diverging capacities to attract resources from EU funding programs: all factors that are likely to negatively affect the desired moves towards integration within the European Research Area.

Recommendations

The main recommendations arising from the PREF study can be summarized as follows:

- Data show a drift toward elaborated performance-based funding systems. This observed trend calls for more precise and developed indicators aimed to deepen the knowledge of project funding and institutional competitive funding mechanisms through the European landscape of public funding for R&D.
- To improve the approach tested by PREF in order to detect performance-based funding through the use of a composite indicator taking into account both allocation procedures and allocation criteria – the importance of input criteria and output criteria. The results of the pilot methodology are promising in terms of capability of measuring performance-based orientation of all public funding, but needs further development.
- The characterization of the project funding instruments as to the objectives, conditions for eligibility, and evaluation criteria, is extremely useful to compare patterns of changes of R&D strategies in different countries. A further work on qualitative indicators is advisable.
- The organizational characteristics of the funding organizations prove to be key information to understand the coordination modes of public R&D funding. More detailed indicators can be developed to identify the level of autonomy and the type of relationship with the government.

Moreover, following the PREF workshop held in the JRC premises of Brussels on February 2017 the 24th, the Commission and the experts addressed additional comments and suggestions aimed at improving the project. These comments, summarized below, also complement the observations emerging from the study and described above.

Main recommendations concerning the PREF methodology are:

- Explore the possibility to link PREF data with metrics of various sources in order to allow correlations between funding allocations and funding intensity to emerge.
- Exploit additional sources to allow further breakdown of funding allocation data (e.g. by fields, by NABS).
- Improve indicators to address performance-based funding systems investigation.
- Develop further indicators to characterize the project funding instruments with respect to both allocation procedures and allocation criteria.
- Improve the prevision and comparability of the UPRO definition across European countries, mapping the organizational configuration of R&D performers.
- Check more accurately the different national contexts to see whether there are specific instruments under 5% fitting with the Handbook exceptions.

Some comments also regarded the characteristics of the PREF database and the possible developments that could improve its use, could broaden the types of investigations it might support and provide additional information on the public funding for R&D phenomena. The link of the PREF database with other databases (e.g. ETER¹⁶ database) was mentioned in order to develop further measures related to PREF data as well as the possibility to develop additional qualitative indicators, in particular with respect to the RFOs, their role, missions and the role in the scientific and political context across countries investigated.

Finally, based on the PREF results, some policy considerations were addressed which highlighted that PREF data would allow for further research and discussion with very relevant policy impact. Main considerations emerging from the discussion are the following:

- The future role of research funding organizations, in particular of research councils: what is the optimal development of funding for these councils?
- The issue of increasing competition: what can be considered as the optimal level when distributing public funding?
- The equity question emerging from PREF data: how to address it? What level of concentration of funding at the system level would be the desirable one?

As concluding remark from the PREF exercise, the need to be very careful when using data about funding; in fact, despite the fact that data can be useful for policy discussion, further details and improvements need to be considered to fully understand determinants and dynamics affecting public funding.

¹⁶ ETER (European Tertiary Education Register) is a project promoted by the Directorate General for Education and Culture of the European Commission, in cooperation with the Directorate General for Research and Innovation and EUROSTAT. <https://www.eter-project.com/>

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13 List of abbreviations

BE	Business Enterprise sector
BERD	Gross Business Expenditures for R&D
EC	European Commission
ERA	European Research Area
ESA	European Space Agency
ESF	European Science Foundation
EU	European Union
EUFP	European Union Framework Programme
FI	Funding Instrument
FM2015	Frascati manual, 2015 edition
FORD	Field of R&D
FP7	Framework Programme Seven
FS	Funding stream
GBARD	Government Budget Allocations for R&D
GERD	Gross Domestic Expenditures for R&D
GOV	Government sector
GUF	General University Funds
HEI	Higher Education Institution
JOREP	Joint and Open Research Programs project
KETs	Key Enabling Technologies
NABS	Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets by Socio-Economic Objective
NACE	Statistical Classification of Economic Activities in the European Community
NESTI	OECD Working Party of National Experts on Science and Technology Indicators
NSA	National Statistical Authorities
OECD	Organisation for Economic Co-Operation and Development
PNP	Private Non-for-Profit sector
PREF	Public Research Funding study
PRO	Public Research Organisation
R&D	Research and Development
RFO	Research Funding Organisation
S&T	Science and Technology
SGCs	Societal Grand Challenges
UPRO	Umbrella Public Research Organisation

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Annex D4.1 PREF Handbook for data Collection and Indicators Production

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