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Public funding of science:

An international comparison

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Samenvatting

Wereldwijd zijn centrale overheden belangrijke financiers van wetenschappelijk onderzoek. Hoe de overheid geld verdeelt over onderzoeksinstellingen, verschilt echter per land. In dit CPB Achtergronddocument brengen we de verschillende verdelingsmechanismen van publieke onderzoeksfinanciering in kaart voor zeven landen met een relatief hoge onderzoeksproductiviteit: Nederland, België (voornamelijk Vlaanderen), Duitsland, Zwitserland, Denemarken, het Verenigd Koninkrijk (VK) en de Verenigde Staten (VS). Voor deze landen schetsen we de belangrijkste kenmerken van de publieke onderzoeksbekostiging zoals die is waargenomen in 2011. Daarnaast onderzoeken we of er een relatie bestaat tussen de wijze waarop overheden onderzoek financieren en onderzoeksprestaties.

We onderscheiden drie manieren om als overheid wetenschap te financieren: (1) ex-post financiering, waarbij achteraf op basis van meetbare prestaties geld wordt uitgekeerd; (2) ex-ante financiering, waarbij van tevoren geld wordt verstrekt om bepaald onderzoek te gaan verrichten; en (3) vaste financiering, waarbij onderzoeksinstellingen financiering ontvangen onafhankelijk van onderzoeksprestaties. Per land wordt de totale publieke onderzoeks-financiering onderscheiden in deze drie financieringsvormen. Uit de analyse blijkt dat alle drie de financieringsvormen in zes van de zeven landen voorkomen. De verhouding verschilt echter behoorlijk. De VS kent al het publieke onderzoeksgeld toe op een ex-ante basis. België en het VK scoren ook hoog op de mate waarin ex-ante financiering een belangrijk allocatiemechanisme is. Denemarken, Duitsland en Zwitserland gebruiken vaste financiering voor het merendeel van de publieke onderzoeksmiddelen. Nederland is het enige land dat geen sterk dominante financieringsvorm kent.

Landen die meer middelen via ex-post financiering toekennen, besteden gemiddeld genomen minder publiek onderzoeksgeld per citatie en publicatie. Dit suggereert dat een grotere mate van ex-post financiering kan leiden tot een efficiëntere onderzoeksproductie. Een mogelijk nadeel van dit type financiering is dat sterke prikkels voor meetbare onderzoeksoutput ten koste kunnen gaan van niet-meetbare output. Wij vinden verder binnen onze steekproef geen relatie tussen de mate van ex-ante financiering en de onderzoeksoutput van een land. Wel lijkt een grotere mate van vaste financiering samen te hangen met een grotere onderzoeksproductie in termen van aantallen publicaties en citaties. Het ontbreken van financiële prikkels lijkt dus niet direct te leiden tot een lagere onderzoeksproductiviteit. Dit kan mogelijk worden verklaard doordat onderzoeksinstellingen intrinsiek gemotiveerd zijn en/of doordat zij zich laten leiden door reputatieoverwegingen. Het is van belang op te merken dat de resultaten van de analyses in dit achtergronddocument zicht bieden op de samenhang tussen type onderzoeksfinanciering en onderzoeksprestaties, maar niet als causale effecten kunnen worden geïnterpreteerd.

Summary

In most developed nations, central governments play an important role in funding science. How central governments allocate funds among public research institutes, however, varies by country. This CPB background document investigates the different allocation mechanisms of public research funding in a sample of seven countries that have a relatively high research productivity: the Netherlands, Belgium (focusing on Flanders), Germany, Switzerland, Denmark, the United Kingdom (UK) and the United States (US). For these countries, we outline the main features of public research funding as observed in 2011. We also explore whether there is a relationship between the way in which governments fund science and research performance.

We distinguish three ways for the government to fund science: (1) ex-post funding, in which money is paid in retrospect on the basis of measurable research performance; (2) ex-ante funding, in which money is provided in advance to pre-screened research projects; and (3) fixed funding, in which funding is allocated independent of research performance. In this document, we divide the total public research funding for each country into these three funding mechanisms. The analysis shows that all types of funding exist in six out of seven countries. However, the importance of each funding schema is quite different. The US allocate all public research money on an ex-ante basis. Belgium and the UK also score high on the extent to which ex-ante funding is an important allocation mechanism. Germany, Switzerland and Denmark use fixed funding to divide the majority of their public research funds. The Netherlands is the only country that has no dominant funding mechanism.

Countries that allocate more resources through ex-post funding spend, on average, less public research money per citation and publication. This suggests that a greater degree of ex- post funding may lead to a more efficient scientific production. A possible disadvantage of this type of funding is that strong incentives to provide measurable research output can be detrimental to immeasurable output. We find no relationship between the level of ex-ante funding and the scientific production or efficiency within our sample of countries. A higher degree of fixed funding seems to be associated with more research output in terms of the number of publications and citations. The lack of financial incentives does not appear to lead to lower research output. This can possibly be explained by the intrinsic motivation of research institutes and/or reputation concerns. Please note that the analyses in this background document provide insights into the relationship between the type of public funding and research performance, but cannot be interpreted as causal evidence for the effects of such funding mechanisms.

Preface

There seems to be consensus among politicians and policy-makers that there is value in science and that governments should play a role in funding science. The public funding of science can take place at different levels of government. In the Netherlands the central government funds about 40% of total R&D activities in the country. This amounts to roughly 0.7% of GDP that is being spent on public R&D activities by the national government. At the same time the European Union (EU) also spends considerable resources on science. For the period 2014-2020 the EU has pledged to spend a €70 billion budget on its new program for research and innovation, Horizon 2020.

It is therefore important to think about the most effective and efficient ways to spend this public money. This CPB background document wishes to contribute to the discussion on what funding allocation mechanisms exist and what are the advantages and disadvantages of these different mechanisms. In this study we describe how public funding for science is allocated in seven countries with a relatively high research performance: the Netherlands, Belgium (focusing on Flanders), Germany, Switzerland, Denmark, the United Kingdom and the United States. In this CPB background document we focus on national policies. It is also very useful to identify effective and efficient policy measures on other levels of government, e.g. European, regional and local (institute) levels. However this falls beyond the scope of this background document.

The authors of this report would like to thank the country reviewers for carefully reading our country reports and sharing their insights. We are also very grateful to the advisory board of this project that helped us focus. This board consisted of representatives of the Dutch Ministry of Education, Culture and Science, the Ministry of Economic Affairs, the Ministry of Finance, the Dutch Association of Universities, Netherlands Organization for Scientific Research (NWO), Center for Higher Education Policy Studies (CHEPS) and the Rathenau Institute. Within the CPB this report benefited from comments and suggestions by Roel van Elk, Daniel van Vuuren and Bas ter Weel.

This background document is part of a broader research agenda of CPB Netherlands Bureau for Economic Policy Analysis on science policy. Since April 2012 CPB does research on the economic benefits and downsides of certain science policy measures.

1 Introduction

This report presents an international comparison of how governments fund science. We define science here as the production of knowledge at public institutes such as universities and public research organizations (PROs). The report provides an overview of the characteristics of various funding schemes, focusing on the policy measures that federal governments take. Our aim is to lay out the various possibilities in terms of contracting between a government and research performing agencies and to provide some indication on whether it matters for research output which funding contract is chosen.

The choice of countries outside of the Netherlands - Belgium (Flanders), Germany, Switzerland, Denmark, the United Kingdom (UK) and the United States (US) - is made to select countries that are comparable in terms of population or that do better in terms of (certain measures of) scientific productivity. All seven countries formulate multiple goals for their science policy, as is common for many government policies. To produce world-leading research, to use new knowledge in society and to educate researchers are among the most commonly stated goals. These goals vary in their degree of measurability.[1] Whereas bibliometrics are accepted as indicators for the quantity and quality of research, such observable indicators are not available for knowledge utilization.

This report consists of two parts. The first part is a general chapter (Chapter 2) with a theoretical framework and summary statistics from the seven countries about science funding. Our theoretical framework uses notions from principal-agent models and contract theory and applies these to science policy. This theory says that the optimal contract between the government (principal) and the research institute (agent) depends on three elements: the degree to which the objectives of the government and the research institute differ, the degree to which research output can be monitored, and the degree of uncertainty in the production of new knowledge.

We distinguish three types of funding contracts based on the theoretical literature. In a research context these can be translated into three funding systems: ex-post funding, ex-ante funding, and fixed funding. These funding schemes differ in the degree to which they financially reward research performance and how autonomous research institutes are in deciding on subjects and research performers.

Ex-post funding gives research institutes strong monetary incentives to produce measurable research output. Research institutes enjoy a high degree of autonomy concerning the allocation of their budget but the government monitors performance ex-post. Alternatively, ex-ante funding provides weak monetary incentives to produce measurable research output. However, the government keeps control over the selection of research projects that receive funding. In this way, the most promising research ideas can be funded regardless of whether they result in

[1] Considering higher education, the multiplicity of goals becomes even larger when the education goal is also taken into account. This is certainly the case in those countries (such as the Netherlands) in which the funding contract between government and higher education institutes leaves considerable room to the institutes to shift funds from one task to another. Although important, we abstract away from the education tasks in this report. Many of the theoretical issues laid out in Chapter 2 will however also apply to the trade-off between education efforts (outputs harder to verify) and research efforts (outputs easier to verify).

research output that is easy to verify. The fixed funding contract is a combination of ex-post and ex-ante contract in which the contract specifies a fixed amount that is independent of research performance. Research institutes are autonomous in deciding about subjects and research performers without any monitoring of the government.

We try to draw conclusions about the relationship between different funding schemes and research performance in Chapter 2. In order to find evidence for our hypotheses, the main insights from the country studies are summarized into quantitative indicators and a ranking of the countries on each of the three funding schemes. It must be said that causal relationships between policies and outcomes such as the quantity and quality of publications are hard - if not impossible - to prove in this context. The reader should keep this in mind. Moreover, - for obvious reasons - this report lacks information about science output that is difficult to measure. We will focus on bibliometric outcomes such as publications and citations as this is the only verifiable output information available to us.

Our country studies show that, except for the US, all countries use a combination of the three research funding contracts. Although the elements of the funding mix are similar, the weights of each funding scheme vary substantially by country. Except for the Netherlands, there is a dominant allocation mechanism in each country. We define a dominant scheme as that contract through which more than 50 percent of public research funds are channeled to research institutes.

Our results show that funding schemes influence the amount of effort research performing institutes exert on the measurable versus immeasurable objectives of science. In particular, we find a positive relationship between the degree of ex-post funding and research efficiency. This is in line with our expectations. Research productivity is the highest in countries that fund most of its public research in a fixed funding scheme. This implies that reputational concerns and the associated signaling of research quality to others play an important role in producing scientific knowledge. The differences between the three allocation mechanisms are interesting for policy makers as it has implications for research productivity and efficiency. The incentives in each funding system sometimes reinforce but sometimes mitigate each other. This implies that a mix of funding systems, as is observed in the Netherlands, can be preferred to having a dominant funding system.

The second part of this report presents seven country studies which are based on desk research by various economists at CPB. The detailed country reports are included as separate chapters (Chapter 3 to Chapter 9). Each country chapter discusses the general and salient characteristics of each science system, focusing on public funding of R&D. These country studies have been externally reviewed by country experts. Of course, we take full responsibility for all remaining errors.

The remainder of this report consists of a literature overview (Chapter 10), an overview of the country reviewers (Chapter 11), an explanation of the calculations (Chapter 12) and a list of definitions (Chapter 13).

2 General chapter

This report presents a comparative analysis of public research funding in seven countries. Similar kinds of studies have been undertaken by Öquist and Benner (2012) and Dawson et al. (2009). Öquist and Benner analyze the relative decline of Swedish research that has a major international impact in comparison to Denmark, the Netherlands, and Norway. Dawson et al. (2009) indicate the specific characteristics of the Dutch research system and what the challenges are by comparing it to five other countries. Both studies give in-depth country studies that provide valuable insights into the research governance structures of each country and the differences between them. Rather than analyzing the governance structure of research systems, this report focuses on the relationship between research inputs (funding) and research outputs (bibliometrics).

The academic literature provides mixed results on the relationship between university funding and research output. Aghion et al. (2010) investigate how university governance affects research output as measured by patents and the Shanghai index. They find that autonomy and competition for research grants is positively correlated with output of European and American universities. Their causal analysis for American universities confirms this finding. The efficiency analyses for eight European countries by Auranen and Nieminen (2010) do not give such ambiguous outcomes. Countries with a more competitive funding environment appear to be more efficient in publication output but have not been able to increase their efficiency. At the same time, some less competitive countries are almost as efficient or have been able to increase their efficiency. Daraio et al. (2011) compare 488 European universities in terms of age, size and growth, diversity and differentiation. For most universities they also do not a find a clear pattern between funding and research output. Bolli and Somogyi (2011) distinguish public and private external funding at Swiss university departments. Their results indicate that both types of external funding improve publication productivity but technology transfer productivity only increases with private funding.

Our report also focuses on the relationship between research funding and research performance but has a broader scope than the effect of competitive funding at universities. We distinguish three types of public research funding at both universities and public research organizations (PROs) by using insights from principal-agent models and contract theory.

2.1 Notions from principal-agent models

The question that we like to answer in this subsection is the following: what does standard micro-economic theory tell us about which type of funding contract between government and research institutes is most suitable to maximize social welfare? The answer will help us to postulate hypotheses about the relationship between funding characteristics and research output indicators. These hypotheses are introduced in Chapter 2.2.

Governments value research. Most developed nations spend a considerable amount of money on research performed at public institutes. The so-called public R&D expenditure in our sample ranges between 0.53% of GDP in Belgium to 0.99% of GDP in the US in 2011. Governments spend this money and expect something in return. They would like to induce the production of new knowledge, they would like to stimulate the use of this knowledge in society and they also care for the development of research skills within the population. However, governments know little about how to do research, where to look for breakthroughs and how to disperse the newly found information. Those who specialize in research activities like universities and research institutes perform research on a daily basis and are hence much better at this. This situation resembles a management problem that is well-documented in the academic (economics) literature: the principal- agent problem (e.g. Grossman and Hart, 1986; Laffont and Tirole, 1991; Holmstrom and Milgrom, 1991; Tirole, 1994; Prendergast, 1999; Dewatripont, Jewitt, and Tirole, 1999 and 2000). We are certainly not the first to apply principal-agent theory to a science policy setting (e.g. Levitt, 1995; Van der Meulen, 1998; Huffman and Just, 2000; Fernández-Carro, 2007).

Theories about the principal-agent problem describe the situation in which the owner of a firm (principal) and the person actually managing the firm (agent) have different objectives. In a public research context the government is the principal and the research performing organization is the agent. In many, if not all, circumstances the objectives of principal and agent are not perfectly aligned. A classic example revolves around a car manufacturer and an assembly line worker that has to perform heavy duties. The manufacturer would like to maximize the number of cars produced, while the assembly line worker would like to minimize the effort he puts into his job. In terms of science one can think about the situation in which both the government and the research institute care about the quantity and quality of produced knowledge but in which the research institute cares less about how this knowledge is used in society because this does not enter university rankings.

Contract theory deals with the question how the principal can provide incentives in such a way that the agent will act in the best interest of the principal. In general, the best possible contract will depend on how the objectives differ, how strong the relationship is between inputs and outputs, and how well the principal can monitor output. Table 2.1 gives an overview of the different types of funding contracts and the circumstances under which these contracts are optimal. Consider the example of the assembly line worker. In this case the relationship between the effort exerted and the number of cars produced will be relatively high. The principal can perfectly observe the produced output and there is little uncertainty involved in the production process. The optimal contract would then be to pay the assembly line worker a piece rate, i.e. to pay him a fixed price for each car that he produces. This contract will induce him to produce the maximum quantity of output. Such a rewarding scheme has '*high-powered incentives*', as rewards increase strongly in the output delivered.

Table 2.1 Overview of optimal funding contracts

Type of contract	Degree to which objectives of the principal and agent differ	Degree of uncertainty in production process	Degree to which output can be monitored
High-powered incentives	high	low	high
Low-powered incentives	middle	high	low
No incentives	low	high	low

If we translate a contract with '*high-powered incentives*' to a contract between the government and a research organization this would be equivalent to paying the institute a fixed price ex-post for each piece of knowledge produced. As knowledge cannot be measured as such, an alternative would be to pay per published journal article, submitted patent or presentation given. Considering journal articles, the government would then induce the institute to produce as many papers as possible as long as the marginal reward for a paper is still larger than its cost price. This would be the optimal contract if the government would only care for the quantity and quality of knowledge produced, if the number of published articles is a good measure of knowledge production and if there would be a strong relationship between effort exerted and new knowledge.

However, the typical research environment does not resemble an assembly line. First, it is difficult to monitor the quantity and quality of the newly produced knowledge. Second, there is uncertainty in the production process. Sometimes a project succeeds by chance and sometimes, despite the hard work, nothing comes out of it. The alternative would be to design a contract with '*low-powered incentives'* in which there is no direct relationship between funding and output. Such an incentive scheme might be more appropriate because of the uncertainty in producing knowledge and the difficulty of monitoring research output. Under such a contract, the government decides ex-ante who will perform the research and/or what the budget for the research projects will be. A disadvantage of such contracts is that resources might be wasted as there are little incentives left to operate efficiently. Also, institutes might spend time and energy on objectives that do not match with the objectives of the government.

The degree to which moral hazard might be at play depends on the degree to which the objectives of the research institutes and the government differ. The government is not the only entity providing incentives to research performing agencies. Research institutes obviously care about the successes of their researchers. They care intrinsically about the outcomes of their research, but also because performing well adds to the reputation of the institute. A good reputation will for example help to secure funds from private parties and will help to attract researchers or students (in case of higher education institutes). These '*career concerns*' are also a central theme in principal-agent theory. Holmstrom (1999) was the first to show that even in the absence of incentives provided by a principle agents might still behave according to the principals best interest as they would like to signal that they are of the 'good sort'.

Monetary incentives might not be necessary if intrinsic motivation and reputational concerns are driving the behavior of research institutes. This will mitigate the moral hazard problems that can arise in a contract with '*low-powered incentives'*. We distinguish between two types of '*low-powered incentives'* contracts depending on the degree to which the objectives of the government and research institute differ. On the one hand, a '*low-powered incentives'* contract is preferred when the objectives are not perfectly aligned. The government decides to keep ex-ante control over who performs research and the budget for research projects. On the other hand, a contract without any incentives might be preferred in case the objectives of the government and research institutes are perfectly aligned, i.e. the *'no-incentive'* contract. There will then be no need for specifying details concerning who performs research and what research will be done. Research institutes will direct these funds to their best use and this aligns with the research interests of the government.

Most governments aim to achieve several goals by funding research performing organizations. Federal science policy is meant to produce research of high quality, quantity and relevance, to let society benefit from this knowledge and to educate research skills. This multiplicity of goals is common among government contracting areas. Think about international development policies that governments use to promote human development in other countries, to protect international security and to stimulate bilateral trade. The multitude of objectives imposes additional challenges to the relationship between principals and agents. Many economists have written about these '*multitask*' principal-agent problems (e.g. Holmstrom and Milgrom, 1991; Dewatripont et al., 1999 and 2000).

It is possible for a principal to induce an agent to do exactly what he would like in a *multitask* environment. However, an optimal contract can only be written when the output associated to every goal is as easy or difficult to measure and when the exact weight that the principal attaches to each goal is known. When the principal can observe all the different outcomes the optimal contract would include a payment formula of the weights times those outcomes. Circumstances are typically rather different when public research institutes are considered. Governments do not reveal the weights they attach to the various goals and there are also differences in the measurability of these goals.

It is hard to stipulate indicators that cover the entire spectrum of knowledge production and utilization. The quality and quantity of knowledge production seems to be the objectives that are easiest to monitor. Although bibliometric outcomes such as publications and citations are not a perfect measure of knowledge production, they are at least well-defined and quantifiable. Some of the other goals of science policy, like producing relevant research and disseminating knowledge to society, lack such commonly accepted output indicators. Recently, efforts have been undertaken to improve the measurability of for example knowledge utilization. Unfortunately no international nor national consensus has emerged regarding the validity of such indicators. Certainly, these indicators currently do not match the degree to which bibliometrics functions as a gold standard in measuring knowledge production.

In a *multitask* environment a contract with *high-powered incentives,* that rewards observed outcomes, will probably induce research institutes to exert most effort towards reaching those goals for which output can be measured. Under a contract that does not depend on observed output, i.e. with *low-powered incentives*, is it possible that relatively more time and energy will be spent on the goals that are more difficult to measure. Again, in this case there is the risk of moral hazard. When funds are distributed regardless of outputs research performing institutes will not always work towards the goals that society appreciates.

The reputation concern also has interesting implications for a *multitask* environment such as science policy. If one goal produces measurable outputs and another goal produces immeasurable outputs, a research institute is likely to put most effort in the goal that has most impact on its reputation. Given the fact that researcher institutes typically operate on an international job market, reputation concerns will matter in all seven countries in our analysis. It depends on the funding contract chosen how important these concerns will be.

It is interesting to provide some anecdotal evidence on the relationship between measurable and immeasurable outputs in science. Borjas and Doran (2013) published a recent working paper on the prestigious field medal winners in mathematics. They compared the winners of this prize to comparable, equally talented mathematicians. They found a productivity decline in terms of publications for the price winners. The authors show that the latter group in fact starts to work on less familiar problems for which it is harder to find a solution. Hence, when scientists have secured their financial and academic position by winning a prize, they start to put more effort in goals that produce outputs that are harder to monitor.

As already mentioned, one of the goals of publicly funding research institutes is thus that governments would like to promote relevant research. What is relevant research is a subjective matter. The demand for relevant research is certainly not monopolized by government. No doubt research institutes would also like to produce relevant research. Moreover, relevance is a selection criterion in many peer-review processes of scientific articles. However, government and research institutes can differ in the degree to which they consider research to be relevant to society. National governments will have national objectives in mind, whereas research institutes can both have a more regional or a more international focus. An example would be research about local languages or local biospheres.

In funding research activities a government can choose to steer towards certain research topics that it deems relevant. When the exact research topic preferences of the government are known, an optimal contract between the government and research institutes is relatively easy to determine. Governments should stipulate what type of research topics they require and only pay for outputs in these topics. This is when we assume that it can be monitored on what topics an institute performs research on. Clearly such steering on research topics will also generate efficiency losses. Governments will not be able to perfectly monitor which research institute is best able to perform research on which topic.

These notions on contract theory provide us with a set of potential contracts between the government and research performing organizations. The optimal contract will differ, depending on the goals and circumstances. Table 2.2 gives an overview of the main characteristics of the different types of funding contracts. The three types of funding contracts differ in four dimensions. Another dimension that is not included in Table 2.2 is the time period of funding. We do not observe differences in funding terms in the countries in our sample. Funding contracts concerning institutional funding generally last for one year, except for the UK where funding contracts based on evaluations last for six years, whereas project-based funding typically lasts for two to six years.

Table 2.2 Definition of funding contracts

Type of contract	Funding based on measurable outcomes	Control over the size of the budget of institute	Control over who performs research	Control over research subjects
Ex-post funding (High-powered incentives)	yes	no	no	no (theoretically possible)
Ex-ante funding (Low-powered incentives)	no	no	yes	both
Fixed funds (No incentives)	no	yes	no	no

The three types of funding contracts can be summarized as follows:

1. *Ex-post funding*: Government outsources control on who does the research and what research is done to the research performing organizations, but decides to monitor research efforts and research output closely. Government's assessment of outputs has consequences for funds. Although the government decides how to reward outcomes of research it does not directly control the size of each research institute's budget. This depends on the performance of each institute. Theoretically government funding can depend on research subjects but this is not observed. (*High-powered incentives*)
2. *Ex-ante funding*: Government decides to exert ex-ante control on who does research and what the budget for each research project will be. The funds can be allocated in open competition or to predefined research subjects. Funding does not directly depend on outputs. Selection can be based on excellence of the research institute and/or on the relevance of proposed research. The size of each research institute's budget depends on how successful it is in obtaining these ex-ante funds. From a welfare analysis point of view a disadvantage of ex-ante project funding is the efficiency loss associated to suboptimal allocations. (*Low-powered incentives*)
3. *Fixed funding*: Government decides the budget of each research institute regardless of how it performs on measurable research outcomes. It does not monitor output and leaves control to the research institute concerning the allocation of funds to fields of research and to specific research performers. This could be an optimal choice if monitoring is very costly and if the objective functions of the principal and agent do not differ a lot. (*No incentives*)

We know from our country analyses that in each country many different types of contracting exist. In almost all countries in our sample we observe mixed contract types on a national level. Moreover, it is not always clear where to position a certain policy measure. These nuances will be highlighted in the country reports by looking at the relative share of each funding option.

2.2 Hypotheses on funding schemes and research output

In this chapter we introduce the hypotheses that are formulated based on the notions from economic theory in the previous subsection. These hypotheses, of which we can only test five, are summarized in Table 2.3 and explained on the next page. In the table the three allocation mechanisms are related to research productivity and efficiency. Research productivity refers to the research output per thousand inhabitants or full-time equivalent. It can be divided in measurable output such as the quantity and quality of journal publications and citations and in immeasurable output such as the degree to which knowledge is utilized in society. Research efficiency is defined here as the extent to which public funds are well used for producing measurable outputs. In other words, a country that is more efficient in terms of science will produce the same amount of measurable scientific output against lower costs.

Table 2.3 Overview of hypotheses

	Research productivity		Efficiency
Type of funding	Measurable output	Immeasurable output	Measurable output
Ex-post funding	+ (testable)	-	+ (testable)
Ex-ante funding	- (testable)	+	- (testable)
Fixed funding	+ (testable)	-	?

As the hypotheses in Table 2.3 include the division between measurable and immeasurable outputs of research, testing all of these hypotheses will be impossible. Information about output that is difficult if not impossible to measure is obviously not included in this report. We can only check whether certain countries are better at producing measurable outputs; we cannot verify the reverse. From theory we thus formulate eight hypotheses of which we can only test five. For ex-post and ex-ante funding we formulate two testable hypotheses regarding the productivity and the efficiency of research output. We only have one testable hypothesis for the fixed funding contract as the theoretical predictions about efficiency are ambiguous.

In words, the hypotheses in Table 2.3 read as follows:

Hypotheses on ex-post funding

1. When the government mostly funds research institutes based on ex-post performance (ex-post funding), research institutes will spend a lot of effort on those goals that lead to measurable output. We expect that this effort will translate in a relatively high research productivity as measured by the quantity and quality of publications and citations. **This is testable hypothesis 1.**
2. Given that research institutes have limited resources, the incentives in the ex-post funding mechanisms are such that the immeasurable goals of science will receive relatively low levels of attention.
3. As the ex-post funding scheme rewards an efficient production of measurable outputs, the production of those outputs will be relatively cost efficient in such a scheme. We expect that the amount of public research funding spend per publication or citation will be relatively low. **This is testable hypothesis 2.**

Hypotheses on ex-ante funding

1. When the government tries to control the activities of research institutes by mostly funding certain projects beforehand (ex-ante funding), the measurable goals of research will receive relatively less attention than under other schemes. The most promising research ideas will be funded regardless whether they will result in easy to verify research output. We expect that this will translate in a relatively low research productivity as measured by the quantity and quality of publication and citations. **This is testable hypothesis 3.**
2. As the government can explicitly choose to fund those projects that promise to exert effort on immeasurable goals, these goals will receive relatively more attention in the ex-ante funding scheme then under the other schemes.
3. We expect the production of publications and citations to be relatively inefficient in schemes with ex-ante funding. This is because of moral hazard - the funds are already distributed which lowers incentives to produce measurable research output efficiently - and because of

the potential suboptimal allocation of resources - the government might not know who is the more efficient researcher. We expect that this will translate in a relatively high amount of total public research funding spend per publication or citation. **This is testable hypothesis 4.**

Hypotheses on fixed funding

1. When the government's funding scheme provides no direct incentives to research institutes to produce certain research output (fixed funds), it depends on the objective function of research performing organizations which goals receive most effort. Because of reputational concerns, it seems likely that most effort will be spent on measurable goals. Research institutes have an interest to signal their quality to attract researchers, students and eventually funding by focusing on producing measurable research output. We expect that this will translate in a relatively high research productivity as measured by the quantity and quality of publications and citations. **This is testable hypothesis 5.**
2. Given that research institutes have limited resources, the incentives in the fixed funding mechanism are such that the immeasurable goals of science will receive relatively low levels of attention. That is, compared to the ex-ante mechanism. Compared to the ex-post funding scheme we expect higher levels of effort exerted on the immeasurable goals as direct incentives to focus on the measurable goals only are absent
3. We cannot formulate a hypothesis considering efficiency when fixed funding is considered. Theoretically we expect two opposite effects. On the one hand, there are no direct financial consequences to bad research performance (moral hazard). On the other hand, research institutes have an incentive to produce measurable research output efficiently to signal their quality.

2.3 Conclusions on funding choices in 7 countries (input)

In this section we classify the funding schemes of science in the Netherlands, Belgium (Flanders), Germany, Switzerland, Denmark, the United Kingdom (UK) and the United States (US) into several funding categories. We present a synthesis of our findings from the country chapters and compare the funding schemes in the seven countries. Please note that we present a static picture of the science systems, mostly based on the year 2011. Therefore most numbers in this chapter represent the situation in 2011. If the year is different, it is explicitly mentioned. Chapter 12 provides detailed information about the sources of and where applicable the calculations used to obtain the numbers presented in this section.

Table 2.4 immediately presents our main findings on funding parameters. We have constructed three indicators, ex-post funding, ex-ante funding and fixed funding, such that they sum up to 100% of public R&D funding. Most countries make use of the same elements of funding policies, but apply these instruments in a different mix. It is interesting to see however that all countries, except for the Netherlands, allocate more than 50% of science funding through one of the three schemes. No country focuses on ex-post funding. Flanders, the UK and the US spend most science funds based on an ex-ante funding scheme, while Germany, Switzerland and Denmark seem to have a preference for fixed funding.

Table 2.4 Main funding of science parameters

	Ex-post funding	Ex-ante funding	Fixed funding	Main funding scheme
	% of total public R&D funds that is allocated on an ex-post performance base	% of total public R&D funds that is allocated on an ex-ante project base	% of total public R&D funds that is allocated on a permanent basis	(> 50% of funding)
Netherlands	23	28	49	Mixed
Flanders	22	61	17	Ex-ante
Germany	11	30	59	Fixed
Switzerland	9	25	66	Fixed
Denmark	1	31	68	Fixed
UK	27	64	9	Ex-ante
US	0	100	0	Ex-ante
Average	*13*	*48*	*38*	

NB. Details about sources and calculations can be found in Chapter 12.

In terms of science policy goals however we did not find large explicit differences. Table 2.5 summarizes the latter. The common science policy goals for the seven countries is producing world-class research and improving the utilization of this research in society. In Belgium and Denmark we also found explicit statements regarding the education of research skills. It could well be however that in the other five countries this is also a (more implicit) policy goal of funding science.

Table 2.5 Explicit national goals of science policy

	Producing world-class research	Utilization of research in society	Educating researchers
Netherlands	x	x	
Belgium (Flanders)	x	x	x
Germany	x	x	
Switzerland	x	x	
Denmark	x	x	x
UK	x	x	
US	x	x	

Many countries in our sample pledge to spend at least 3% of GDP on total R&D expenditures. In 2011 Germany, Switzerland and Denmark have managed to (approximately) achieve this goal. Table 2.6 shows that in terms of public R&D funding the US, Germany and Denmark do most at about 0.9% of GDP each year. The Belgian and UK governments spend considerably less in this context at 0.5% of GDP. In 2011, the Dutch government spent exactly the average amount in our sample.

There is no clear indication of public funds crowding out private funds for R&D in our sample. There are countries with a relative high percentage of public R&D funds and low percentage of private R&D funding (the Netherlands and UK) but also with the opposite pattern (Belgium and Switzerland). For three out of the seven countries a combination of high public and private R&D funding is observed (Germany, Denmark and the US).

Table 2.6 Government organization of science

	Total R&D expenditures as a % of GDP	Publicly funded R&D as a % of GDP (% of total R&D funding)	Privately funded R&D as a % of GDP (% of total R&D funding)
Netherlands	2.0	0.72 (36)	1.01 (50)
Belgium	2.2	0.52 (24)	1.33 (60)
Germany	2.9	0.86 (30)	1.90 (66)
Switzerland	2.9	0.66 (23)	1.96 (68)
Denmark	3.0	0.86 (29)	1.79 (60)
UK	1.8	0.54 (30)	0.82 (46)
US	2.7	0.89 (33)	1.60 (60)
Average	*2.5*	*0.72 (29)*	*1.49 (59)*

NB. The other sources of R&D funding are higher education, PNP, and foreign. Source: Eurostat, 2011. For Switzerland the most recent data is from 2008.

In the remainder of this section we present more detailed information on the three different funding systems. We present a final indicator for each funding system that ranges from 1 to 7. This final indicator is based on the quantitative indicators of each funding system which are also ranked from 1 to 7. The ranking of the individual elements are summed and the final ranking is based on this overall score.[2]

The funding indicators relevant to the ex-post funding contract are displayed in Table 2.7. The two quantitative indicators show the percentage of total public R&D funds that is allocated based on an ex-post performance. There is a distinction between performance that is related to research and education indicators and research only indicators. For example, roughly 23 percent of the public R&D funding in the Netherlands are allocated on the basis of the number of degrees (bachelor and master) and the number of PhD defenses. Whereas the number of degrees is an education measure, the number of PhD defenses is regarded as a research measure.

Table 2.7 Indicators of ex-post funding

	% of total public R&D funds that is allocated on an ex-post performance base (research and education)	% of total public R&D funds that is allocated on an ex-post performance base (research only)	Research monitoring with financial consequences	Ex-post classification
Netherlands	23	11	No	2
Flanders	22	17	In theory	2
Germany	11	11	No	4
Switzerland	9	9	No	5
Denmark	1	1	No	6
UK	27	27	Yes	1
US	0	0	No	7
Average	*13*	*11*		

NB. Details about sources and calculations can be found in the country chapters and Chapter 12.

[2] We also used an alternative approach based on a qualitative classification for each funding system (Low, Middle, High). This gives similar results. For example, countries which stay within one standard deviation of the average values in each table are regarded as average. When a country has an extremely low or high score on any of the indicators (so more than one standard deviation below or above the average) the country is classified as low or high, respectively.

For most countries the indicators for ex-post funding are based on a mix of different types of research performance. A quite common research indicator is the number of PhD defenses. Some other indicators include publications and citations (Flanders), external funding (Denmark Germany), and diversity of researchers (Flanders and Germany). The UK has a unique ex-post allocation mechanism, the Research Excellence Framework, in which experts assess the overall quality of research. These assessments have direct financial consequences. Although the other countries receive less funding if their research performance declines, their overall assessment of the quality of research does not have direct financial consequences.

The differences in general funding indicators that are related to the ex-ante project based contract are highlighted in Table 2.8. There are two important channels through which these funds are distributed: public research councils and public research organizations (PROs). Public research councils often select research projects by assessing the quality of research proposals whereas PROs often receive part of their public funding to carry out specific projects. Governments an also steer research subjects through these channels by predefining research fields in which proposals compete or focusing project funding in particular research fields.

The US clearly ranks first in the importance of ex-ante funding as all public funding is allocated on a project base. The UK and Flanders also allocate more than half of the public R&D budget through ex-ante funding contracts. Research councils play a prominent role in these three countries. Flanders allocates 57% of the total public R&D budget through research councils. These figures are substantial lower for the UK and the US but still above or at average. The other countries score below average in terms of the size of the ex-ante funding. Public research councils play a smaller role in their funding landscape but the role of PROs differs. Whereas Germany spends a substantial portion of its public R&D budget on national institutes, Switzerland and Denmark only spend a minor portion on these institutes.

Table 2.8 Indicators of ex-ante funding

				Indicators for steering on topics[4]		
	% of total public R&D funds that is allocated on an ex-ante project base[1]	% of total public R&D funds that is allocated through public research councils[2]	% of total public R&D funds that is allocated to PROs[3]	% of total public R&D funds that is allocated to physical sciences	% of total public R&D funds that is allocated to medical and life sciences	Ex-ante classification
Netherlands	28	17	22	47	28	5
Flanders	61	57*	19	58	22	2
Germany	30	13	41	64	18	4
Switzerland	25	20	3	45	29	7
Denmark	31	16	6	43	33	6
UK	64	33	23	41	23	3
US	100	26	36	38	52	1
Average	*48*	*26*	*21*	*48*	*29*	

[1] Details about sources and calculations can be found in Chapter 12.
[2] Details about the budget of the public research council can be found in the country reports.
[3] Eurostat, 2011. For Switzerland the most recent data is from 2008.
[4] Eurostat, 2012. For the US the data comes from the National Science Foundation, 2012.
* The public R&D funds for Belgium are divided between Flanders and Wallonia.

The German federal government mainly funds research at national research institutes as they can hardly influence research at universities which fall under the authority of the German states. This is different from the Danish research institutes that are integrated into the universities or the Swiss federal research institutes that are recognized as higher education institutes.

The importance of ex-ante funding is somewhat related to the degree of steering on research topics. For example, 52% of public R&D funding in the US is directed toward research in medical and life sciences. This is not surprising as the National Institute of Health distributes most of the federal funds in the US. Germany allocates 64% of its public R&D funding to physical sciences which can be explained by the important role of national research institutes which mainly focus on natural and technical sciences. We do not find a dominant research subject in terms of public R&D spending in countries that rank low on ex-ante funding.

Table 2.9 shows indicators that shed light on the fixed funding contract. Switzerland and Denmark use this type of contract most often: two out of every three Euros publicly spent on research is allocated on a permanent basis. On the other hand, Flanders, the UK and the US hardly or do not provide any funds without any incentives. The Netherlands and Germany rank between these two opposite groups of countries. The degree of no-incentive funding is positively related to the degree to which public funds are allocated towards higher education funds. Germany is the exception because the federal government focuses on funding national research institutes.

Table 2.9 Indicators of fixed funding

	% of total public R&D funds that is allocated on a permanent basis[1]	% of total public R&D funds that is allocated towards higher education institutes[2]	Fixed funds classification
Netherlands	49	72	3
Flanders	17	63	4
Germany	59	49	4
Switzerland	66	85	2
Denmark	68	87	1
UK	9	56	6
US	0	31	7
Average	*38*	*63*	

[1] Details about sources and calculations can be found in Chapter 12.
[2] Eurostat, 2011. For Switzerland the most recent data is from 2008.

As can be deduced from Tables 2.6 to 2.9 none of the countries in our sample have the exact same profile in terms of the main funding scheme and the classifications for ex-post funding, ex-ante funding and fixed funding. It seems that countries do make rather different choices when it comes to financing research activities at public institutes. This is remarkable as we did select a group of highly developed countries that share many characteristics. Whether the diversity in funding choices matters for research output will be the topic of Section 2.6.

2.4 Conclusions on research performance in 7 countries (output)

In this section we will classify the scientific output produced in the Netherlands, Belgium (here we use national statistics), Germany, Switzerland, Denmark, the UK and the US into several performance categories. Like in the funding subsection above, we present a static picture of the science systems, mostly based on the year 2011.

Table 2.10 presents information on measurable indicators of the quantity and quality of research production. In practice this means that Table 2.10 includes bibliometric outcomes - publications, citations and share of publications that are highly cited. Note that the classification that we derive about the productivity of research in each country is relative to the other countries in our sample, not relative to the average production worldwide. This is important to mention as we consider a group of well-performing countries. We have chosen to relate the bibliometric outcomes to the size of the population in each country, in order to be able to compare indicators across countries of different sizes. It turns out that Switzerland is the country that performs best, both in terms of quantity and quality of research. Germany is the negative outlier on the indicator for top 1% publications. Overall, Germany ranks lowest on scientific productivity. Like Switzerland, the Netherlands and Denmark score above average on all three indicators of knowledge production and rank second and third, respectively. Although the US has an above-average score on top 1% publications it has the lowest rank on publications and citations.

Table 2.10 Indicators of quantity and quality of knowledge production

	Publications per 1,000 inhabitants (1 fte researcher)[1]	Citations per 1,000 inhabitants (1 fte researcher)[1]	Top 1% publications (relative to expectations)[2]	Productivity classification
Netherlands	2.8 (0.9)	10.5 (3.3)	78	2
Belgium	2.4 (0.6)	8.1 (2.2)	54	4
Germany	1.8 (0.4)	5.3 (1.3)	31	7
Switzerland	4.4 (1.4)	18.1 (5.6)	112	1
Denmark	3.3 (0.5)	12.6 (1.9)	94	3
UK (England)	2.4 (0.6)	7.3 (1.8)	63	5
US	1.8 (0.4)	5.2 (1.1)	83	6
Average	*2.7 (0.7)*	*9.6 (2.5)*	*74*	

[1] Publications and citations are from 2011 from the website of Scimago (www.scimagojr.com). The number of inhabitants and 1 fte researchers are from Eurostat, 2011 or latest available.
[2] Top 1% publications is the number of publications belonging to the top 1% most cited publications in the relevant research area relative to the expected number of top 1% most cited publications. Data are for the period 2008-2011 and available on the Science, Technology & Innovation Indicators website (www.wti2.nl).

Table 2.11 presents measurable indicators of the efficiency of the research production process. Here we relate total public spending on R&D in 2009 to the quantity and quality of publications in 2011 (total number of publications and total number of citations respectively). Countries that spend a relatively large amount per unit of output have a low ranking on the efficiency scale. Two countries fall into this category: Germany and the US. There are three countries that share the number one position of the efficiency classification: the UK, Switzerland and Belgium.[3] These countries produce publications and citations most efficiently with the UK ranking first on publication efficiency and Switzerland ranking first on citation efficiency. The Netherlands and

[3] The relative position of countries does not change when total R&D spending is used as a denominator.

Denmark belong to the middle group in terms of efficiency and are closer to the most efficient countries than to the inefficient ones.

We are unable to show any indicators here that represent output for the goal ´utilization of knowledge in society´. We are aware of the recent efforts towards accountability in this area. However, we still believe that current indicators are unable to track effort and success in this area to a satisfactory degree. Note that university boards are faced with the same problem: how will they manage performance on this goal when it lacks clear performance indicators?

Table 2.11 Indicators of efficiency of knowledge production

	Total public R&D spending per publication (euros)	Total public R&D spending per citation (euros)	Efficiency classification
Netherlands	90,671	24,148	4
Belgium	66,598	19,473	1
Germany	140,510	46,826	6
Switzerland	68,286	16,640	1
Denmark	99,469	26,289	5
UK (England)	62,281	20,516	1
US	174,220	58,822	7
Average	*100,291*	*30,388*	

NB. Publications and citations are from 2011 from the Scimago website (www.scimagojr.com). These publications and citations are related to total public R&D spending in 2009 (Eurostat). Due to data availability, total public R&D spending in 2008 is used for Switzerland.

Table 2.12 deals with the science objective ’educating researchers’. It shows that PhD graduation rates differ widely between the seven countries, with Switzerland and Germany producing the most new research-oriented students. Belgium has the lowest PhD graduation rate, which may explain why Belgium has ´educating research talent´ as an explicit policy goal.

Table 2.12 Indicators of education of researchers

	PhD graduation rate	PhD graduation rate excluding foreigners	Education of researchers classification
Netherlands	1.8	1.2	6
Belgium	1.5	1.1	7
Germany	2.7	2.3	1
Switzerland	3.2	1.7	1
Denmark	2.2	1.7	3
UK (England)	2.4	1.3	4
US	1.7	1.3	5
Average	*2.2*	*1.5*	

Source: OECD, Education at a glance, 2011.

When summarizing Tables 2.10 to 2.12 it becomes clear that three countries receive an average rank on the measurable indicators for productivity, efficiency and education of researchers: the Netherlands, Denmark and the UK. Belgium has a relatively low PhD graduation rate, while the US has a relatively low measurable efficiency of science production. Germany has been classified as an underperformer in terms of productivity and efficiency, while Switzerland is seen as a highflyer in terms of productivity. It must be stressed here that we are discussing output measures that are relatively easy to observe and quantify. We cannot compare performances on other goals of science policy that are immeasurable.

2.5 Conclusions on relationships between in- and outputs

In this subsection we test our hypothesis about funding contracts and research output. First, we will present bulb charts that relate the three funding scheme indicators to three measures of performance on easy-to-observe goals. We show two measures of productivity - publication per 1,000 inhabitants and top 1% publications - and one measure of efficiency, total public R&D spending per citation. Looking at the productivity measures by researcher or by citation does not change the overall picture. We also obtain similar figures if we look at our efficiency measures in terms of publications. In these figures the diameter of each bulb represents the relative amount spent by each government on public R&D in terms of GDP. The figures will in certain instances highlight a possible positive or negative correlation between the intensity of a funding scheme and measurable performance. Second, we will draw conclusions regarding the five testable hypotheses posed in Chapter 2.2.

Figure 2.1 presents the relationships between our ex-post funding indicator and quantity, quality and efficiency of measurable scientific productivity. Surprisingly, there does not seem to be a clear relationship between the degree to which countries fund research based on measurable outputs and the extent to which those countries perform on those outputs. Only in terms of efficiency there seems to be a negative relationship between ex-post funding and the public funds being spent for each unit of output. This negative relationship implies that countries that allocate a larger proportion of their public R&D budget ex-post are more efficient in producing publications and citations.

Figure 2.2 presents similar graphs, but for the ex-ante funding indicator. As the US is an outlier for this type of science funding (at 100%) this puts a clear stamp on these figures. Besides the US, the UK and Flanders score high on ex-ante funding. These three countries do not do so well in terms of publication productivity. So, there seems to be a slight negative relationship between the degree to which a country funds research on an ex-ante project base and the quantity of scientific production. This relationship is less clear when considering quality and efficiency indicators. Germany can also be considered to be an outlier in terms of research performance. Among the group of countries that score relatively low on the ex-ante funding indicator, Germany has the lowest research productivity and lowest efficiency.

The last set of graphs, Figure 2.3, deals with the fixed funding indicator and its correlation with respect to the quantity, quality and efficiency of knowledge production indicators. Relatively the clearest relationship is presented in the first panel in Figure 2.3. It seems that a higher degree of fixed funding corresponds with a higher quantitative production of journal articles. Although Germany does not fit the story, the quality of journal articles is somewhat higher in those countries that focus on fixed funding. There does not seem to be a solid relationship between the fixed funding indicator and efficiency performance measure.

Figure 2.1 Percentage of ex-post funding in relationship to output indicators

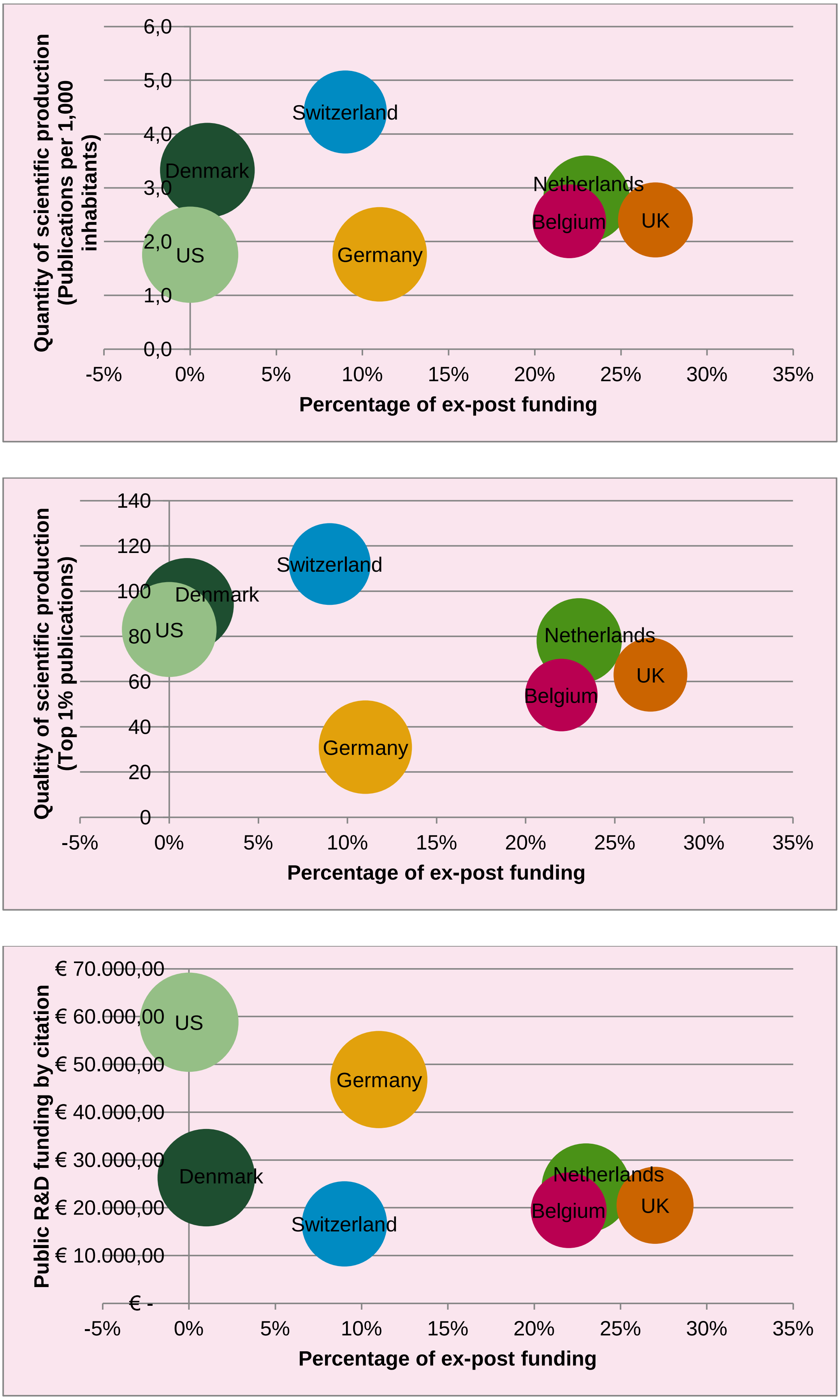


Figure 2.2 Percentage of ex-ante funding in relationship to output indicators

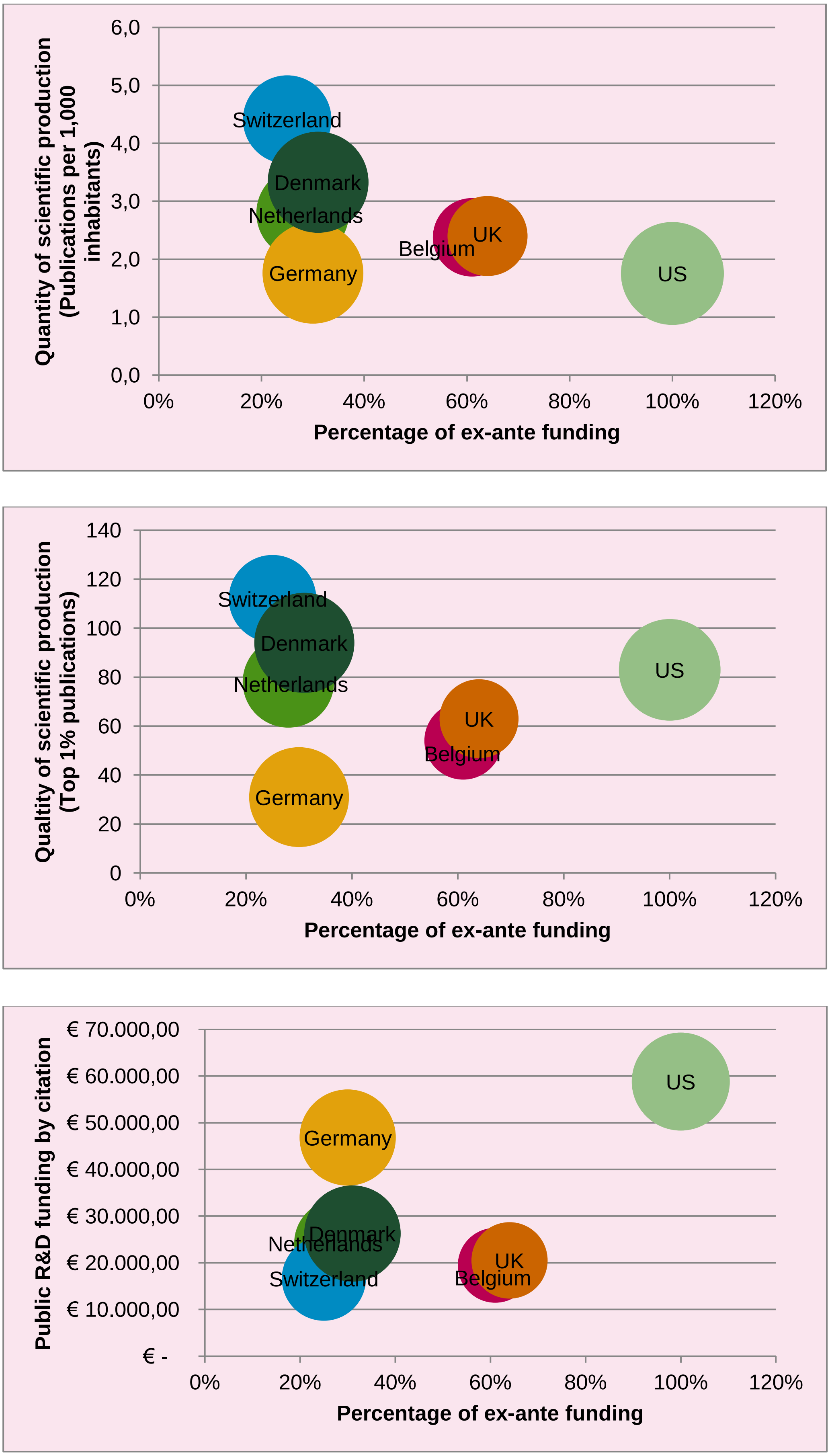
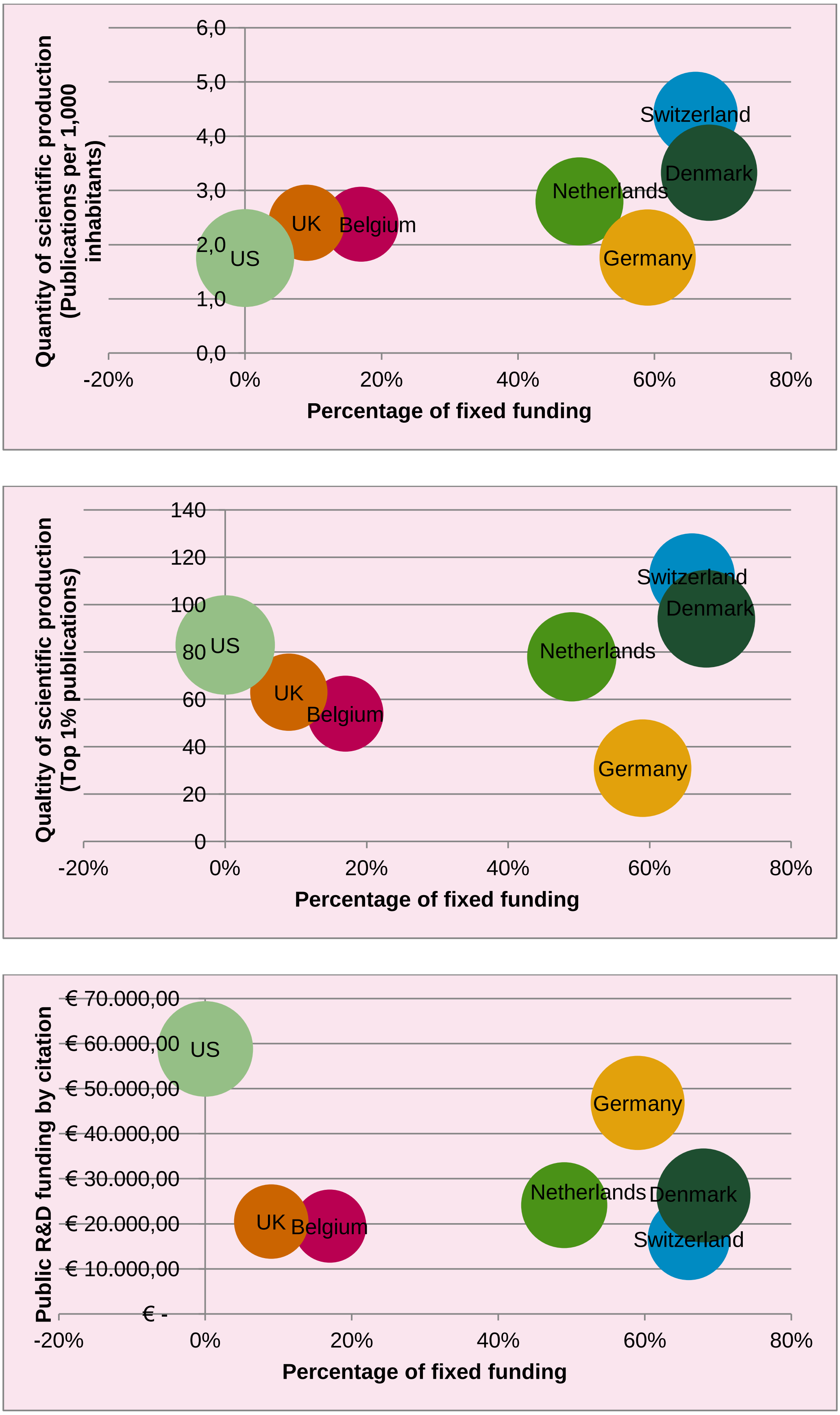


Figure 2.3 Percentage of fixed funding in relationship to output indicators



On this page, we will go by each of the testable hypotheses proposed in Chapter 2.2. Table 2.13 summarizes these findings.

Hypothesis 1: Is it true that countries that score high on the ex-post funding indicator focus on measurable outputs and hence have a relatively high research productivity as measured by the quantity and quality of publications and citations?

Not really. The country that applies ex-post financing the most is the UK, closely followed by the Netherlands and Belgium (Flanders). We do not observe that these countries do particularly well in terms of the quantity and quality of the publications.

Hypothesis 2: Is it true that countries that score high on the ex-post funding indicator produce measurable outputs more efficiently?

Yes. The amounts spent per publication and citation is lowest in the UK and Belgium. The efficiency of the scientific production process in the Netherlands is relatively lower. This could be explained by the emphasis in the Dutch ex-post science funding formula on performance in terms of higher education. This might generate efficiency incentives in the education arena, but not necessarily in the research area.

Hypothesis 3: Is it true that countries that spend a lot of funds on an ex-ante project base spend relatively low levels of effort on the measurable goals of science (as they exert relatively high levels on the immeasurable goals)? So do we observe that countries with a high degree of project funding have a relatively low research productivity as measured by the quantity and quality of publications and citations?

To some extent. Three countries score high on the ex-ante project indicator: the US in an extreme way, and the UK and Belgium (Flanders). These countries do not perform well in terms of the quantity of published journal articles. However, these countries perform on average when it concerns the quality of research. Overall, we do not observe a very high quantity and quality of research in the countries that mostly pay for research up front.

Hypothesis 4: Is it true that countries that score high on the ex-ante funding indicator produce measurable outputs less efficiently?

No. Although the US does not produce cited journal articles very efficiently, Belgium and the UK actually do well in terms of research efficiency. It must be noted that the latter two are also the two countries that have the highest score on the ex-post indicator. Therefore it is hard to draw conclusions on efficiency.

Hypothesis 5: Is it true that countries in which the government funds research largely on a fixed funding exhibit a relatively high research productivity as measured by the quantity and quality of publications and citations?

Yes. Switzerland and Denmark are the two countries with the highest percentage of fixed funds. In fact, these are also the countries that have the best performance on the quantity and quality of publications. The Netherlands follows close behind, both in terms of funding and in terms of quality of research. Thus, we do see a correlation between fixed funds and measurable research outputs. Germany however does not fit the story. The relatively large share of fixed funding to research institutes instead of to higher education institutes in Germany might explain this discrepancy.

Table 2.13 shows that out of our five testable hypotheses two are confirmed in our empirical analysis. First, countries that allocate more money through ex-post funding contracts are more efficient in producing publications and citations. Second, countries that often use fixed funding contracts have a higher measurable research productivity. Our analysis does not confirm the other three hypotheses. This does not imply that the opposite of our hypotheses holds, but rather that our sample does not display a specific pattern between these funding contracts and research performance.

Table 2.13 Conclusions about hypotheses

	Research productivity	Efficiency
Type of funding	Measurable output	Measurable output
Ex-post funding	Not confirmed	Confirmed (+)
Ex-ante funding	Not confirmed	Not confirmed
Fixed funding	Confirmed (+)	

2.6 Conclusion of general chapter and discussion

Although we must be careful in interpreting our partial and non-causal evidence, we conclude that our empirical findings are in line with two out of five testable hypotheses posed in Chapter 2.2. The analyses do not provide a clear pattern supporting or rejecting the other three hypotheses. It should be noted that comparisons are made within a group of countries whose scientific productivity is already high. Moreover, the reported productivity and efficiency measures only concern measurable research output such as the quantity and quality of publications and citations. This implies that we cannot verify any hypotheses concerning the immeasurable goals of science such as knowledge diffusion.

We find that all countries use a mix of the three funding schemes: ex-post, ex-ante, and fixed funding. Although the elements of this mix are similar, the importance of each funding scheme differs by country. The US allocates all public research money on an ex-ante basis. Belgium and the UK also score high on the extent to which ex-ante funding is an important allocation mechanism. Germany, Switzerland and Denmark use fixed funding to allocate the majority of their public research funds. The Netherlands is the only country that has no dominant form of funding. It is difficult if not impossible to draw conclusions regarding the optimal mix of the funding schemes. For example, the funding structure of Germany resembles that of Switzerland and Denmark but the latter clearly outperforms Germany with respect to measurable research productivity and efficiency. Other characteristics of the research landscape such as the integration of research and education at universities might explain this difference.

We find that the efficiency of knowledge production is the highest in countries that fund research to a high degree on an ex-post basis. This is in line with the expectations concerning *high-powered incentive* contracts. At the same time, we do not find evidence that countries that score high on the ex-ante indicator produce measurable research output less efficiently. Therefore, research efficiency cannot be contributed to a single funding scheme. Belgium and the UK are relatively efficient in producing research output and score high on the ex-post as well as the ex-ante funding indicator.

We provide suggestive evidence that the quantity and quality of bibliometric research output is higher in countries in which governments mainly provide fixed research funding. Despite the lack of monetary incentives in these *no-incentives* contracts, research institutes operating in a fixed funding scheme are more successful in the measurable goal of 'knowledge production'. A possible explanation is that reputational concerns mitigate the problem of moral hazard and give research institutes a strong incentive to exert research effort on measurable output. The ex-post funding scheme might then overemphasize the measurable research output by rewarding this performance.

It could then be argued that the advantage of fixed funding is that the immeasurable goals of science receive more attention. However, it is possible that the immeasurable or less measurable goals of science receive a level of effort below the optimum. If a research institute cannot prove it is achieving something in the area of utilization for example, it might choose not to put time and energy in it.

All in all, our results suggest that funding schemes can influence the research productivity and efficiency of research institutes. Our results are only suggestive and cannot be given a causal interpretation. Further research is necessary in the area of measurable versus immeasurable outputs of science, the optimal mix of funding schemes and on the causal relationship between funding parameters and performance measures.

3 The Netherlands

3.1 Introduction

3.1.1 Goal of national science policy

The Dutch government presents its science policy goals once every four years. The most recent strategic agenda, "Kwaliteit in Verscheidenheid", is from 2011 and presents the goals for education, research, and science policy.

The overall research and science policy goal is to be among the best knowledge economies worldwide. The strategic agenda presents two broad goals for research and science policy. First, research institutes need to focus on research excellence in selective research fields. The most important criteria for this research profiling are scientific quality and impact. The second goal is to optimize the utilization of knowledge (valorization). In other words, the government aims to increase the impact of research on the economy and on society by closer cooperation in the triple helix, i.e. universities, industries and government, and by targeted investments in the top sectors. This topsector policy refers to the nine leading sectors of the Dutch economy.[4]

3.1.2 Basic figures

Table 3.1 gives an overview of the R&D funding streams in the Netherlands in 2011. The upper panel shows that total Dutch R&D expenditures are 2.0% of GDP. This is below the 2.5% target that the Dutch government wants to reach in 2020.[5] The business sector is the most active R&D sector performing more than half of all R&D activities whereas the higher education sector is responsible for one-third of the R&D expenditures.

Table 3.1 R&D funding, the Netherlands, 2011

Source	Destination				
	Government	Higher education	Business	PNP	Total
Total	1,321.2	3,994.2	6,825.6	0	12,141.0
Percentage of GDP	0.2	0.7	1.1	0	2.0
		Percentage of funding			
Government	71.0	77.9	3.9	0	35.6
Higher education	2.5	0.0	0.1	0	0.3
Business	11.3	8.2	81.8	0	49.9
PNP	4.2	7.5	0.7	0	3.3
Foreign	11.0	6.4	13.5	0	10.9
Total	100.0	100.0	100.0	0	100.0

Note: The amounts are in millions of euro (current prices). R&D performed by the private non-profit (PNP) sector is included in the government sector since their contribution to R&D is very limited (less than 0.5% of GERD). [OECD, R&D Sources and Methods Database]. Source: Eurostat.

[4] The government identified nine top sectors which are Agro-food, Horticulture and propagating stock, High-tech materials and systems, Energy, Logistics, Creative industry, Life sciences, Chemicals, and Water. Every topsector has a Topconsortia Knowledge and Innovation (TKI) which consists of private companies, universities, research institutes, and government agencies. The TKIs handed in their research agendas and goals in 2011.

[5] The provisional figures for 2012 amount 12.9 billion euros, which is 2.2% of GDP.

The lower panel shows how the R&D expenditures of each sector are financed. For example, the R&D expenditures in the higher education sector are mainly publicly financed (77.9%) whereas the R&D expenditures in the business sector are mainly privately financed (81.8%). The lower panel also shows that almost half of total Dutch R&D funding is financed by the private sector.

Public funding amounts to 35.6% of total R&D funding which is roughly equal to 4.3 billion euros. Table 3.2 shows that the majority (72.1%) of this public funding goes to higher education and only a small part goes to the private sector (6.2%).

Table 3.2 Government funding by sector, the Netherlands, 2011

	Government	Higher education	Business	PNP	Total
Amount	938.3	3,110.9	265.6	0	4,314.8
Percentages	21.7	72.1	6.2	0	100

Note: The amounts are in millions of euro (current prices). Source: Eurostat.

Table 3.3 gives R&D input indicators for the seven countries that we examine in this project. In this section we focus on the Netherlands for which the information is given in bold in the table. Comparing the Netherlands to the other countries shows some interesting patterns.

The Netherlands scores on average with respect to public R&D spending as a percentage of GDP. A very large share of the Dutch public R&D budget goes to higher education whereas the share PROs is slightly above average. This implies that the business sector receives little public R&D funds as can also be seen from Table 3.2. The Netherlands is also the only country that has an above average score on these two aspects. For example, Denmark and Switzerland spent a larger fraction of their public R&D budget on higher education but spent only a very small fraction on PROs.

Table 3.3 Publicly funded R&D input indicators, the Netherlands

		Destination		Allocation Mechanism	
	% of GDP	PROs (%)	Higher Education (%)	Project-based (%)	Performance-based (%)
Netherlands	**0.72**	**22**	**72**	**26**	**25**
Belgium	0.52	19	63	60	23
Germany	0.86	41	49	31	11
Switzerland	0.66	3	85	25	9
Denmark	0.86	6	87	32	1
UK	0.54	23	56	62	28
US	0.89	36	31	100	0
Average	*0.72*	*21*	*63*	*48*	*14*

Note: All figures reflect the situation as in 2011 except for Switzerland (2008). The calculation of the allocation mechanism variables can be found in Chapter 12. Sources: Eurostat, Van Steen (2012), and country reports.

The Netherlands has, together with Switzerland, the lowest percentage of project-based public R&D funds. On the other hand, it ranks relatively high on performance-based allocation of public R&D funds. The UK is the only country that has a higher percentage of performance-based research funding. It is again interesting to compare the Netherlands with Denmark and Switzerland. They are similar in terms of their high education share in the public R&D budget but differ substantially in their use of performance-based funding. This implies that Danish and

Swiss universities mainly receive fixed funding whereas Dutch universities receive a relatively larger share on the basis of performance.

3.2 General information

3.2.1 Government funding of R&D

Table 3.4 gives an overview of the R&D expenditures for each Dutch ministry. The Ministry of Education, Culture and Science and the Ministry of Economic Affairs contribute most heavily to R&D, respectively 67.5% and 21.7% of the total public R&D budget.[6] Together they make up for almost 90% of total public R&D funding. It is therefore interesting to look more closely at how these two ministries allocate their R&D budget.

Table 3.4 R&D expenditures by ministry, the Netherlands, 2011

Department	Euros	Percentage
General Affairs	0.6	0.0
Foreign Affairs	80.9	1.6
Security and Justice	24.9	0.5
Interior and Kingdom Relations	16.8	0.3
Education, Culture and Science	3,357.4	67.5
Defense	70.2	1.4
Infrastructure and the Environment	116.7	2.3
Economic Affairs	1,081.30	21.7
Social Affairs and Employment	0.7	0.0
Health, Welfare and Sport	225.5	4.5
Total	4,975.1	100

Source: Rathenau Instituut, TOF-overzicht 2011-2017.

The largest part of the R&D budget of the Ministry of Education, Culture and Science is spent on the research component of higher education, roughly 75%, of which universities and medical centers receive 96%. Then, almost 20% of the R&D budget goes to intermediary organizations. The Netherlands Organization for Scientific Research (NWO), which is the Dutch research council, receives the majority of this funding (90%). The remaining 5% goes mainly to other smaller national and international research institutes. In contrast, the Ministry of Economic Affairs only spends a small part of its R&D budget on higher education and research councils (15%). The majority of their R&D budget is spent on non-university research organizations and the top sectors.

Another interesting difference is whether the public funds relate to institutional funding or project funding. Whereas 15% of the R&D budget of the Ministry of Education, Culture and Science is project funding, almost 75% of the R&D budget of the Ministry of Economic Affairs is spent on project funding. The main reason for this difference is that the Ministry of Education, Culture and Science mainly funds higher education institutes which receive institutional funding. The Ministry of Economic Affairs, on the other hand, mainly funds specific policy themes such as space, energy, and innovation-oriented activities which are based on project funding.

[6] This does not include funding for education purposes.

Another important part of the public funds for science have been allocated through the Economic Structure Enhancement Fund (FES). Since 1994 the government funds the FES by investing 40% of the natural gas revenues to this fund.[7] FES contributes to the knowledge economy by investing in infrastructure, education, and innovative projects. The budget for the period 1994-1998 and 1999-2003 were 113 and 211 million euros, respectively. In 2004, the Bsik-program started with a budget of 802 million euros.[8] In total, 67 project plans were submitted. In 2010, the government decided to phase out the FES funding by replacing it with increased fiscal facilities.

The Royal Netherlands Academy of Arts and Sciences (KNAW) evaluated the scientific quality of the projects, the Netherlands Bureau for Economic Policy Analysis (CPB) evaluated the societal and economic impact of the projects, and Senter evaluated the administrative and financial organization of the projects.[9] A commission advised the government on which projects to grant on the basis of these three evaluations. The government funded 37 Bsik-projects ranging between 6.5 and 95 million euros subsidies for projects of four to six years. All projects have been evaluated and monitored. In 2010, the government decided to no longer use the natural gas revenues to fund FES.

3.2.2 Intermediary organizations

There are three intermediary organizations that have an important role in allocating public research funding to universities and/or institutes. These are NWO, KNAW, and NL Agency. We will describe each of the three intermediary organizations in more detail below.

NWO

NWO is the national research council and consists of various organizational units: science divisions, foundations, institutes and temporary taskforces. It had a budget of 755 million euros in 2011 of which 596 million euros was spent on subsidies. These subsidies are competitively allocated to the best scientific talent and best research proposals in the Netherlands through NWO. The remainder of their budget goes to the NWO research institutes (97 million euros as basic funding), and management and other costs (62 million euros).

NWO receives its funding from all government ministries but mainly from the Ministry of Education, Culture, and Science. In total, NWO received 619 million euros from ministries.[10] In other words, 12% of the total public R&D budget goes to NWO. This funding consists of a structural contribution and a specific part for temporary programmes. Both types of funding are mainly earmarked for different funding instruments. Moreover, NWO has an internal allocation key for dividing these funds to the different science divisions.

Table 3.5 shows how the NWO funds are allocated over the different types of programmes and instruments. More than half of the funding can be attributed to one of the nine science division and one-fifth to the NOW institutes. The three largest funding instruments of NWO are talent, societal driven research themes, and the NWO institutes.

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[7] FES stands for Fonds Economische Structuurversterking.
[8] Bsik stands for Besluit Subsidies Investeringen Kennisinfrastructuur.
[9] Senter has become NL Agency in 2009.
[10] NWO received 585 million euros from the Ministry of Education, Culture and Science, 25 million euros from the Ministry of Economic Affairs, 9 million euros from other ministries, 87 million euros from others (private sector and public organizations), and 54 million euros from NWO resources.

Table 3.5 Allocation of NWO resources

Programmes		Instruments	
NWO institutes	154	Talent	195
Central programs	59	Free competition	86
Science divisions	415	Societal driven research themes	126
Earth and Life Sciences	*61*	Valorization	7
Chemical Sciences	*32*	Research infrastructure	82
Physical Sciences	*37*	NWO institutes	166
Humanities	*44*	*Institutional funding*	*97*
Social Sciences	*70*	*Project funding*	*59*
Physics	*46*	International cooperation	18
Technical Sciences	*58*	Other subsidies	27
Medical Sciences	*53*	Management and other costs	48
WOTRO Science for Global Development	*14*		
Foundations and Temporary Task Forces	87		
Total	755	Total	755

Source: NWO Annual Report 2011.

NWO offers several types of grants. These include grants for big facilities, grants for cooperation and exchange, individual grants, investment grants , open access grants, and programmatic grants. The programmatic grants are in line with the policy of top sectors which are the industries in which the Netherlands excels. The individual grants broadly fall into two categories: talent programmes and free competition. Table 3.6 gives an overview of the number of applications and number of awarded proposals by program type for the individual grants. The different programmes within the free competition refer to the different science division.

Table 3.6 Overview of submitted (S) and awarded (A) proposals, 2011

Talent programmes	S	A	Free competition	S	A
Veni	953	159	Earth and Life Sciences	227	51
Vici	95	31	Chemical Sciences	182	37
Mozaiek	38	19	Physical Sciences	235	48
Rubicon	693	85	Humanities	92	20
Graduate Programme	49	19	Social Sciences	236	24
Doctoral Grant for Teachers	126	36	Physics	132	36
PhDs in the Humanities	40	20	Technical Sciences	132	43
Stipendia	39	19	WOTRO Science for	8	4
Clinical Fellows	28	7	Global Development		
Other	12	5	Medical Sciences	50	9
Total	2073	400		1294	272

Note: In 2011, no Vidi grants were awarded. Source: NWO Annual Report 2011.

KNAW

The duties of the KNAW are defined by law. In short, it has to “serve as a learned society representing the full spectrum of scientific and scholarly disciplines, to act as a management body for national research institutes, to advise the Dutch government on matters related to scientific pursuit”.[11] The KNAW had a budget of 150 million euros in 2012.[12] The majority of this budget, around 75%, goes to the own research institutes.

[11] See website KNAW, www.knaw.nl
[12] www.wti2.nl

NL Agency
NL Agency is a division of the Dutch Ministry of Economic Affairs that carries out policy and subsidy programmes to support various business initiatives. These programmes focus on international entrepreneurship, sustainability, and innovation. NL Agency also includes the NL patent office. Only part of its budget, 280 million euros in 2010, concerns research and development.[13]

3.2.3 Research performing organizations

Higher education

There are two types of higher education in the Netherlands: research universities and universities of applied sciences. The Dutch government funds 18 research universities, eight medical centers, and 39 universities of applied sciences.

Research universities
The mission of research universities is three-fold: teaching, research, and utilization of knowledge. Table 3.7 gives an overview of the funding streams for 13 universities (the open university and the four theological universities are not included).

Table 3.7 Funding streams by university, the Netherlands

	First-stream funding				Second-stream funding		Third-stream funding		Total
	Institutional funding		Tuition fees		NOW funds		Other		
	euros	%	euros	%	euros	%	euros	%	euros
Erasmus Universiteit Rotterdam	236.7	50.1	78.6	16.6	20.9	4.4	135.9	28.8	472.1
Radboud Universiteit Nijmegen	264.9	59.6	29.7	6.7	54.2	12.2	95.4	21.5	444.2
Rijksuniversiteit Groningen	325.9	62.1	47.0	9.0	40.7	7.8	110.9	21.1	524.5
Technische Universiteit Delft	333.9	65.2	35.1	6.9	33.1	6.5	110.2	21.5	512.3
Technische Universiteit Eindhoven	185.4	62.0	14.9	5.0	24.0	8.0	74.6	25.0	298.9
Universiteit Leiden	283.3	58.6	36.4	7.5	55.8	11.5	107.8	22.3	483.3
Universiteit Maastricht	194.6	63.4	26.6	8.7	16.5	5.4	69.3	22.6	307.0
Universiteit Twente	189.9	65.4	17.2	5.9	21.0	7.2	62.4	21.5	290.5
Universiteit Utrecht	445.8	61.9	50.3	7.0	69.2	9.6	154.4	21.5	719.7
Universiteit van Amsterdam	372.4	70.7	58.5	11.1	48.6	9.2	47.2	9.0	526.7
Universiteit van Tilburg	104.6	58.2	21.8	12.1	9.4	5.2	43.8	24.4	179.6
Vrije Universiteit Amsterdam	284.1	68.5	39.5	9.5	34.9	8.4	56.1	13.5	414.6
Wageningen Universiteit	163.1	58.5	17.0	6.1	22.0	7.9	76.6	27.5	278.7
Total (average)	*3384.6*	*(62.1)*	*472.6*	*(8.7)*	*450.3*	*(8.3)*	*1145.3*	*(21.0)*	*5452.2*

Note: The numbers are in millions of euros. Source: DUO Staat van Baten en Lasten 2007-2011 and NWO Annual Report 2011.

It is common to distinguish three types of funding, the so-called first-, second-, and third-stream funding. The institutional funding together with the tuition fees forms the first-stream funding. Universities receive institutional funding for teaching, research, and knowledge utilization. This

[13] http://www.rathenau.nl/web-specials/de-nederlandse-wetenschap/financiering/intermediaire-organisaties.html

funding is allocated on the basis of measures of volume, prices, and historical considerations. The second-stream funding is allocated on a competitive basis through the national research council whereas the third-stream funding consists of other external funding such as EU-grants and private funding .

Universities receive institutional funding from the Ministry of Education, Culture and Science except for the Wageningen University who receives its funding from the Ministry of Economic Affairs. This funding consists of an education and a research part. The R&D expenditures presented by the OECD only include the research part of this institutional funding. However, universities can freely choose how to allocate this funding internally. In other words, this funding is not earmarked for education and research but the amounts are based on education and research specific parameters.

Table 3.8 Parameters of the first funding streams

Education	Research
Number of students and degrees (65%)	Number of degrees (15%)
Education provision (35%)	Number of PhD defenses (20%)
	Research schools (5%)
	Research provision (60%)

Note: The research provision includes strategic considerations. Source: Rijksbijdragebrieven 2012 and WHW 2008.

In total, universities and university medical centers received 3.8 billion euros from the government in 2012. This institutional funding is for 41% allocated based on education parameters and for 44% allocated based on research parameters. The remaining 15% goes to university medical centers.[14] Table 3.8 gives an overview of the funding parameters of the education and research part. The university-specific amounts for education and research are determined based on the following dimensions.[15]

- Education (1.6 billion euros in 2012)
  - *Number of students and degrees*
    The total amount allocated on the basis of number of students and degrees is 65% of the education part. The university-specific shares are equal to their shares of weighted enrollments and diplomas of bachelor and master students. The weights are 1, 1.5, and 3 for low, high (technical), and top (medical) studies, respectively for bachelor and master studies.
  - *Education provision*
    The remaining 35% of the education part is the education provision and consists of university-specific amounts and percentages. First, the government decides on amounts for each university which in total make up for around 7% of the education part. Second, the remaining part (28%) is distributed according to the university-specific percentages which are determined by the government.
- Research (1.7 billion euros in 2012)
  - *Diplomas*

[14] The public R&D figures only include the research component of university funding.
[15] The exact numbers and percentages that we use in this are from 2012.

The total amount for diplomas is 15% of the total research part. The university-specific shares are equal to their shares of weighted diplomas. The weights are 1, 1.5, and 3 for low, high (technical), and top (medical) studies, respectively and 1:2 for bachelor and master diplomas.

- *PhD defenses*
  Each university receives a bonus per PhD defense. In 2012, this bonus was equal to €93,408 per PhD defense. The number of PhD defenses make up for 20% of the institutional research funding.
- *Research schools*
  There is a distinction between research schools and top research schools. The total amount spent on research schools was 4.8% of the total research part whereas the total amount spent on top research schools was 1.6%. The government sets different university-specific percentages for both type of research schools.
- *Research provision*
  The remaining 60% consists of two parts: university-specific amounts and university-specific percentages. The majority of this item consists of strategic considerations (58% of the total research part) that are divided on the basis of the university-specific percentages. These percentages are based on historical considerations. The remaining 2% consists of university-specific amounts that are set by the government.

Applied universities
There are 39 applied universities affiliated to The Netherlands Association of Universities of Applied Sciences. In 2010, they received around 3.4 billion euros for education and research. Almost two-thirds of this budget is funded by the government and this institutional funding is mainly determined by the number of students and the number of degrees.[16] The remaining one-third consists of tuition fees and external funding of private companies and institutions.

Applied universities receive slightly more than 100 million euros for research purposes.[17] Half of this amount comes from direct governmental funding and the other half comes from RAAK-subsidies and private funding.[18] The applied universities introduced the position of lector in 2001 which are professors at applied universities. The research group is also referred to as a lectureship in which a group of researchers, including lecturers, work within a research centre to carry out applied research in relation to a particular theme. In 2010, there were 457 professors attached to applied universities. Most professors work part-time for the applied university and have some other employment in addition to this.[19]

From 2013 onward, 7% of the research part of the institutional funding will be based on performance contracts (123 million euros for research universities and 162 million euros for applied universities). Universities had to hand in proposals indicating how they are going to improve the quality of teaching, study success, profiling, and valorization. Around 70% of the

[16] The public funding of applied universities consists of an education component and design and development component. In total, 80% is based on the number of weighted students and degrees (weight of 1.28 for technical studies and 1.5 for medical studies), 10% is based on percentages per applied universities, and the remaining budget is allocated according to specific policies such as qualities, vulnerable studies, special provisions, and design and development.
[17] Het Nederlands wetenschapssysteem, institutioneel overzicht (april 2012).
[18] The RAAK (Regional Attention and Action for Knowledge Circulation) scheme is managed by the Foundation Innovation Alliance (SIA - Stichting Innovatie Alliantie) with funding from the Ministry of Education, Culture and Science.
[19] Facts and Figures: Applied Research by Universities of Applied Sciences. HBO-raad, April 2010.

amount tied to performance contracts will be redistributed among all universities while 30% will be allocated to only those universities that had a very good score on its proposal

Public research organizations

The research institutes are a small player in the field of academic research in the Netherlands. Table 3.1 shows that they contribute 10% to total R&D performance and receive 75% of their funds from the government. The research institutes vary substantially in their focus and the type of research they perform. In general, we can divide the research institutes into seven different categories:[20]

1. The research institutes of NWO and KNAW. Both organizations are also intermediary organizations as is already discussed in the previous paragraph.
2. Netherlands Organization for Applied Scientific Research (TNO).
3. Large Technological Institutes (GTIs).
4. Leading Technology Institutes (TTIs) and Leading Societal Institutes (MTIs).
5. Research universities of the Wageningen University and Research Centre (WUR).
6. Departmental institutes.
7. Other institutes.

NWO

NWO has nine research institutes that focus mainly on fundamental research in a wide range of research fields. The research institutes receive basic funding to cover personal and equipment costs and additional funding can be obtained by participation in NWO competitions and/or attracting other external funds. In 2011, the research institutes received 97 million euros as institutional funding and obtained 57 million euros through NWO competitions.[21]

KNAW

The KNAW has 18 research institutes which are organized around the following themes: Humanities and Social Sciences, Life Sciences, and Programming and Social Debate. The budget of KNAW was 150 million euros in 2012 and the majority of this budget is spent on scientific research while the remaining goes to the management, administration and opening up of collections by institutes. The institutes receive institutional funding which does not depend on past performance. Additional funding can be obtained by applying for grants and/or attracting other external funds.

TNO

TNO is a non-profit organization that focuses on applied research. Its mission is to make an important contribution to the competitiveness of companies and organizations, to the economy and to the quality of society as a whole. TNO concentrates on seven closely related themes that have a prominent place in the national and European innovation agenda.[22] TNO's consolidated revenue for 2012 was equal to 587 million euros of which a third (192 million euros) was institutional funding from the government.[23] This government funding includes basic funding

[20] A list of all research institutes can be found in Appendix 3A.
[21] NWO Annual Report 2011.
[22] The seven themes are: industrial innovation, healthy living, energy, mobility, built environment, information society, and defense, safety and security.
[23] TNO Annual Report 2012.

40% and demand-driven funding (60%).[24] Besides the institutional funding, the government spend close to 120 million euros on projects performed by TNO.

Other
The GTIs receive institutional funding from the government (104 million euros of basic and demand-driven funding in 2012) but the largest part of their budget comes from public (71 million euros) and private (152 million euros) demand for their products.[25] The TTIs started in 1997 and are public-private cooperations between knowledge institutes and firms that focus on areas that are considered to be important to the economy.[26] The MTIs started in 2006 and focus on important societal issues. Currently, there are ten TTIs and four MTIs. The research institutes of the WUR focus on agricultural research and are also part of the Foundation DLO (Dienst Landbouwkunding Onderzoek).

3.2.4 Monitoring

The Standard Evaluation Protocol 2009-2015 (SEP) describes the evaluation of scientific research in the Netherlands.[27] This includes the research at universities including the medical centres and the institutes of NWO and KNAW. The aim of the SEP is to provide common guidelines for the evaluation and improvement of research and research policy, based on expert assessments. In contrast to many other countries, the assessment does not have financial consequences in terms of amounts of public funding.

The evaluation of research includes a self-evaluation and an external review, including a site visit once every six years, and an internal mid-term review in between two external reviews. The external evaluation takes place at the two levels: the level of the institute (faculty or research school) and the level of research groups or programmes. The assessment regards the three vital tasks of research organizations, i.e. producing results for the academic community, producing results that are relevant for society, and educating and training the next generation of researchers. The assessment entails four main criteria, i.e. quality, productivity, relevance, and vitality and feasibility. The evaluation committee writes an evaluation report describing their main findings and also summarizing their overall assessment on five-point scale.

Research universities and applied universities only receive public funding for studies that are accredited.[28] The NVAO performs the accreditation for Dutch and Flemish bachelor and master studies. The indicators that are used for study programme assessment include the drop-out rates (first-year and overall), success rate, qualifications of teaching staff, student-teacher ratio, and education intensity. Moreover, the accreditation process includes the assessment of final theses and documents open for review.[29] Research schools that run PhD programmes are accredited by the Research School Accreditation Committee (ECOS[30]) from the Academy. The accreditation period is six years and research schools can apply for re-accreditation. The assessment of Research Master programmes is performed by both NVAO and the KNAW.

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[24] www.wti2.nl
[25] www.wti2.nl
[26] Technopolis evaluated the TTIs in 2005.
[27] This protocol has been developed by VSNU, NOW, and KNAW and it follows previous versions of SEP 1994, 1998, and 2003.
[28] Accreditation is also important for giving diplomas and degrees. A complete list of accredited studies can be found on the website of CROHO.
[29] See website http://www.nvao.net/panels
[30] Erkenningscommissie Onderzoekscholen

3.2.5 Research output

Table 3.9 gives an overview of R&D output and personnel indicator in the Netherlands. This table indicates that there are relatively few researchers in the Netherlands. The PhD graduation rate is also quite low, especially when foreign students are not considered. However, with relatively few researchers, the Netherlands perform above average with regard to publications and citations. This is both in terms of research output per 1,000 inhabitants as per 1fte researcher. Moreover, when we look more closely at the publication and citation productivity per 1 fte researcher, Switzerland is the only country that outperforms the Netherlands.

Table 3.9 R&D output and personnel indicators, the Netherlands

Country	# of researchers (fte) per 1,000 labor force	PhD graduation rate (excl. foreign students)	# of publications per 1,000 inhabitants (1 fte researcher)	# of citations per 1,000 inhabitants (1 fte researcher)
Netherlands	**6.1**	**1.8 (1.2)**	**2.8 (0.9)**	**10.5 (3.3)**
Belgium	8.3	1.5 (1.1)	2.4 (0.6)	8.1 (2.2)
Germany	7.9	2.7 (2.3)	1.8 (0.4)	5.3 (1.3)
Switzerland	5.4	3.2 (1.7)	4.4 (1.4)	18.1 (5.6)
Denmark	13.1	2.2 (1.7)	3.3 (0.5)	12.6 (1.9)
UK	8.3	2.4 (1.3)	2.4 (0.6)	7.3 (1.8)
US	9.1	1.7 (1.3)	1.8 (0.4)	5.2 (1.1)
Average	*8.3*	*2.2 (1.5)*	*2.7 (0.7)*	*9.6 (2.5)*

Note: All figures reflect the situation as in 2011, except for the number of researchers in Germany (2010), Switzerland (2008), and US (2007). Sources: OECD and Scimago. *The PhD graduation rate is measured as a percentage of the relevant age cohort.

3.3 Distinguishing features

An important aspect of the Dutch R&D system is that the share of total government funding of R&D is relatively large compared to the other countries. However, the government does not reach its goal of 2.5% of GDP which is mainly due to the relatively small R&D contribution from the private sector. In the other countries that are considered in this report the public share of the R&D budget is often substantially lower whereas the private share is substantially higher.

Another important feature is that the Dutch government spends a large amount of its R&D funds on higher education. The universities receive this funding for research as fixed funding and have a large degree of freedom with respect to the internal allocation of their budget. Moreover, more than half of this funding depends on strategic considerations which are mainly based on historical considerations.

The Dutch system has regular evaluation of research but there are no direct financial consequences of these evaluations.

Appendix 3A

This appendix gives an overview of the research institutes of the Public Research Organizations in the Netherlands

NWO
The nine research institutes of NWO are:

1. ASTRON, Netherlands Institute for Radio Astronomy
2. CWI, Centrum Wiskunde & Informatica
3. NIOZ Royal Netherlands Institute for Sea Research
4. NSCR, Netherlands Institute for the Study of Crime and Law Enforcement
5. SRON, Netherlands Institute for Space Research
6. FOM Institute Amolf
7. FOM Institute DIFFER (Dutch Institute for Fundamental Energy Research)
8. FOM Institute for Subatomic Physics Nikhef
9. NLeSC, Netherlands eScience Center (jointly with SURF)

Besides these research institutes, there is the foundation WOTRO Science for Global Development and some temporary taskforces (NGI, Netherlands Genomics Initiative NIHC, National Initiative Brain & Cognition, and NRO, Netherlands Initiative for Education Research).

KNAW
The 18 research institutes of the KNAW are organized around the following themes:

- Humanities and Social Sciences: Data Archiving and Networked Services (DANS), Fryske Akademy (FA), Huygens ING, International Institute of Social History (IISH), Royal Netherlands Institute of Southeast Asian and Caribbean Studies (KITLV), Meertens Institute, NIOD Institute of War, Holocaust and Genocide Studies, Netherlands Interdisciplinary Demographic Institute (NIDI), and Netherlands Institute for Advanced Study in the Humanities and Social Sciences (NIAS).
- Life Sciences: Fungal Biodiversity Centre (CBS), Hubrecht Institute for Developmental Biology and Stem Cell Research, ICIN Netherlands Heart Institute (ICIN), Netherlands Institute for Neuroscience, Netherlands Institute of Ecology (NIOO), and Spinoza Centre for Neuroimaging.
- Programming & Social Debate: Rathenau Institute and Wadden Academy

Large Technological Institutes (GTIs)
- Deltares
- Energy Research Centre of the Netherlands (ECN)
- Maritime Research Institute Netherlands (MARIN)
- National Aerospace Laboratory (NLR)

Leading Technology Institutes (TTIs)
- Dutch Polymer Institute (DPI)

– Material innovation institute (M2i)
– Top Institute Food and Nutrition
– Top Institute Pharma
– Center for Translational Molecular Medicine (CTMM)
– TTI Green Genetics
– Center of Excellence for Sustainable Water Technology
– Topinstitute BioMedical Materials (BMM)
– Novay (formerly - Telematica Instituut) - ended in 2009
– Dutch Institute for Advanced Logistics (Dinalog)

Leading Societal Institutes (MTIs)
– Hague Institute for the Internalization of Law (HiiL)
– Netherlands Institute on Pensions, Aging and Retirement (Netspar)
– Platform 31 (previously NCIS - Netherlands Institute for City Innovation Studies)
– Top Institute for Evidence Based Education Research (TIER)

Wageningen University and Research Centre (WUR)
– Alterra
– Central Veterinary Institute
– Centre for Development Innovation
– Food & Biobased Research
– IMARES
– LEI
– Livestock Research
– Applied Plant Research
– Plant Research International
– RIKILT
– Wageningen UR Greenhouse Horticulture

Departmental institutes
The departmental institutes include among others WODC, NFI, RACM, ICN, RKD, PBL, KNMI, KiM, CBS, CPB, SCP, RIVM, etc.

Other institutes
Examples of other institutes are NIVEL, NIGZ, NKI, Clingendael, Verweij-Jonker Instituut, ASC, Research voor Beleid, EIM, NIGZ, NKI and NYFER.

4 Belgium (Flanders)

Please note that the input and output R&D indicators relate to Belgium whereas the allocation mechanisms are based on the situation in Flanders.

4.1 Introduction

4.1.1 Goal of national science policy

Science policy in Belgium is governed in a multi-level framework which involves the federal government and the autonomous regional and community governments. The involvement of the federal government is mainly restricted to fiscal measures and some federal policy competences such as defense, aerospace, nuclear energy and climate change. The different regions (Brussels-Capital, Flanders and Wallonia) are responsible for their innovation policy in a broad sense, whereas the communities are in charge of fundamental research in the broad sense. In this chapter we focus on Flanders because the total R&D expenditures in Flanders represent nearly two-thirds of the Belgian R&D expenditures.[31]

The science policy goals of the Flemish government are to become one of the top five EU knowledge regions and to meet the renewed EU2020 objective to spend 3% of its GDP on R&D by 2020.[32] The Flemish government emphasizes on innovation as a horizontal policy goal which takes place in all policy domains. Moreover, the government identified strategic domains and priorities. The key domains are transport-logistics-services, e-health services, biotech, healthcare, food, new materials, nanotech, ICT, and energy and environment. The strategic priorities in R&D are:

- Economic valorization of research and innovation with market and societal impact.
- Creative and innovative entrepreneurship.
- Economic clusters.
- Internationalization.
- Strengthening excellent and interdisciplinary basic research.
- More opportunities for research talent.
- Provision of top research infrastructure.
- Streamlined and output driven research policy.

4.1.2 Basic figures

Table 4.1 gives an overview of the R&D funding streams in Belgium in 2011. The total R&D expenditures are equal to 2.2% of GDP, in Flanders this is 2.4%. The upper panel shows that the business sector performs most R&D and it performs three times as much R&D as the sector higher education. The lower panel shows how the R&D expenditures are financed. For example,

[31] http://cordis.europa.eu/flanders/rd_en.html
[32] http://cordis.europa.eu/flanders/rd_en.html

the R&D expenditures in the sector higher education are mainly publicly financed (65.7%) whereas the R&D expenditures in the sector business are mainly privately financed (83.4%).

Table 4.1 R&D funding Belgium, 2011

Source	Destination				
	Government	Higher education	Business	PNP	Total
Total	658.6	1,825.5	5,613.4	73.6	8,1710.0
Percentage of GDP	0.2	0.5	1.5	0.0	2.2
	Percentage of funding				
Government	54.2	65.7	6.2	8.6	23.4
Higher education	0.0	12.8	0.0	0.6	2.9
Business	5.8	10.7	83.4	2.4	60.1
PNP	0.2	2.2	0.0	9.8	0.6
Foreign	39.8	8.6	10.4	78.6	13.0
Total	100.0	100.0	100.0	100.0	100.0

Note: The amounts are in millions of euro (current prices). Source: Eurostat.

Public funding amounts to 23.4% of total R&D funding which is approximately equal to 1.9 billion euros. Table 4.2 shows that the majority of this public funding goes to higher education whereas the remainder of the public R&D budget is equally split between the business and government sector.

Table 4.2 Government funding by sector, Belgium, 2011

	Government	Higher education	Business	PNP	Total
Amount	357.2	1,199.8	350.1	6.3	1,913.4
Percentages	18.7	62.7	18.3	0.3	100.0

Note: The amounts are in millions of euros (current prices). Source: Eurostat.

Table 4.3 gives R&D input indicators for the seven countries that we examine in this project. In this section we focus on Belgium for which the information is given in bold in the table.

The Belgian government has the lowest public R&D spending as a percentage of GDP. Interestingly, Belgium devotes a relatively high share of its public budget to the private sector. For example, the Netherlands, Germany, and Denmark spend less than 10% of their public on private R&D as the vast majority of these public funds go to higher education and PROs. Belgium only spends 82% of its public budget for R&D on these two research performing sectors. This percentage is more comparable to the UK and US that spend 82% and 75%, respectively, on these sectors. Belgium is also quite comparable to the UK and the US in terms of the degree of project-funding. It provides 60% of its public R&D budget on the basis of projects. Moreover, 23% of the public funds are allocated on the basis of performance indicators.

Table 4.3 Publicly funded R&D input indicators, Belgium

		Destination		Allocation Mechanism	
	% of GDP	PROs (%)	Higher Education (%)	Project-based (%)	Performance-based (%)
Netherlands	0.72	22	72	26	25
Belgium	**0.52**	**19**	**63**	**60**	**23**
Germany	0.86	41	49	31	11
Switzerland	0.66	3	85	25	9
Denmark	0.86	6	87	32	1
UK	0.54	23	56	62	28
US	0.89	36	31	100	0
Average	*0.72*	*21*	*63*	*48*	*14*

Note: All figures reflect the situation as in 2011 except for Switzerland (2008). The calculation of the allocation mechanism variables can be found in Chapter 12. Sources: Eurostat, Van Steen (2012), and country reports.

4.2 General information

4.2.1 Government funding of R&D

Table 4.4 gives an overview of the public Flemish R&D expenditures for each policy area. The Flemish government currently consists of nine ministers whereas the Flemish public administration is divided into 13 policy areas. The policy area Economy, Science and Innovation (EWI) and the policy area Education and Training (OV) have the largest budget for science policy making up for 72% and 21% of the total research budget, respectively. The other 11 policy areas make up for 7% of the total research budget. The table also distinguishes between research, education and support activities. The majority of the budget of the policy area EWI goes to research whereas the majority of the budget of the policy area OV goes to higher education.

Table 4.4 R&D expenditures by policy area, Flemish Community, 2013

Policy area	Euros	Research	Education	Support
Economy, Science and Innovation (EWI)	952.4	916.9	0.0	35.5
Education and Training (OV)	878.3	261.8	613.1	3.3
Environment, Nature and Energy (LNE)	38.2	20.4	0.6	17.8
Finance and Budget (FB)	30.9	30.4	0.0	0.0
Agriculture and Fisheries (LV)	22.5	17.9	1.4	4.6
Culture, Youth, Sport and Media (CJSM)	21.1	4.7	0.0	14.9
Town and Country Planning, Housing Policy and Innovative Heritage (RWO)	18.2	7.3		10.9
Welfare, Public Health and Family (WVG)	6.5	4.4	0.0	2.2
Mobility and Public Works (MOW)	4.3	2.0	0.0	2.4
Services for the General Government Policy (DAR)	2.8	2.7	0.0	0.1
Foreign Affairs (IV)	2.2	1.0	0.0	1.3
Adminstrative Affairs (BZ)	1.3	1.3	0.0	0.0
Work and Social Economy (WSE)	0.7	0.7	0.0	0.0
Total	1,979.3	1,271.5	615.2	92.7

Note: Amounts are in million of euros.
Note: Ranking departments gives the following list: 1) Innovation, Public Investment, Media, and Poverty Reduction (49%), 2) Education, Youth, Equal Opportunities and Brussels Affairs (44.4%), 3) Economy, Foreign Policy, Agriculture and Rural Policy (2.5%), 4) Environment, Nature and Culture (2.2%), 5) Public Governance, Local and Provincial Government, Civic Integration, Tourism and the Vlaamse Rand (1.0%), 6) Welfare, Public Health and Family (0.3%), 7) Finance, Budget, Work, Spatial Planning and Sport (0.2%), 8) Mobility and Public Works (0.2%), 9) Energy, Housing, Cities and Social Economy (0.1%).
Source: Speurgids 2013.

4.2.2 Intermediary organizations

There are three intermediary organizations in Flanders. The Research Foundation Flanders (FWO) is responsible for fundamental research at universities based on a competitive call. The government agency for Innovation by Science and Technology (IWT) is responsible for allocating funds to companies and research institutes and the Hercules Foundation responsible for funding medium- to large-sized and special research infrastructure. Besides these three intermediary organizations, the independent investment company PMV is the agency for risk capital, loans and mezzanine finance, and has a number of instruments specifically aimed at innovation policy.

FWO
FWO is an independent agency that supports fundamental research in all disciplines in Flanders. The FWO provides the necessary funding on the basis of an interuniversity selection with scientific excellence as the only criterion. FWO has a budget of almost 250 million euros of which 60% is funded by the Flemish government (including funding from the National Lottery). The federal government funds 12% of the FWO budget and focuses on specific subsidies for additional researchers, health, and fundamental research.

The allocation of FWO funds can be broadly divided into four categories. These are mandates (pre- and post-doctoral), individual grants and awards, research projects, and scientific contacts. Together these make up for slightly over 200 million euros in 2011 that are allocated in competition on the basis of different evaluation criteria.

IWT
IWT is the government agency for Innovation by Science and Technology. It supports innovation in Flanders by providing funding, advice, services, coordination, networking, and policy development. In 2011, its total budget was 304 million euros. IWT finances R&D projects and companies can apply for R&D funding throughout the year. There are three funding channels: R&D business support, SME programmes, and Sprint-projects. It also offers various types of subsidies and grant programmes to Flemish knowledge centres and researchers, including with business, and either thematic or specifically oriented. These are Strategic Basic Research (SBO), Innovation Platforms, VIS trajectories, Agricultural Research (LA), Doctoral specialty Grants (SB), Innovation Mandates (IM), Applied Biomedical Research (TBM), and transformational medical research (TGO). IWT evaluates the applications based on multiple criteria but attaches equal value to the quality and valorization of the research and/or development. Finally, IWT advices and funds collaborations that support innovations.

Table 4.5 gives an overview of the number of submitted and accepted proposals for different program types including the funding volume.

Table 4.5 Overview of submitted (S) and awarded (A) applications and total funding (F), 2011, IWT

	S	A	F
R&D Funding			
R&D Business Projects	170	102	Na
SME Programme	287	186	Na
Total	483	288	116.213
Basic Research			
Strategic Basic Research	70	15	36.674
Post-graduate Grants	661	201	32.587
Post-doctoral Research Fellowships	76	19	2.178
Applied Biomedical Research	45	8	5.415
Total	852	243	76.854
Collaborations			
Flemish Innovation-related Collaboration (VIS) and university interface services	50	15	20.570
Agricultural Research (LO)	47	10	10.122
TETRA Fund	70	23	8.298
Total	167	38	38.990

Note: Numbers are in millions of euros. Source: IWT Annual Report 2011.

Hercules Foundation

The Hercules Foundation is a structural funding instrument for investments in research infrastructure for fundamental and strategic research in all scientific disciplines.[33] There is a distinction between medium- and large-scale research investment initiatives. Hercules 1 and 2 belong to medium-scale projects with total funding costs between € 150,000 and € 600,000 and € 600,000 and € 1,500,000, respectively. Hercules 3 belongs to the large-scale projects with total funding costs above € 1,500,000.

Research universities and university of applied sciences can only apply for medium-sized subsidies. Each association (a network of research universities and applied universities) has drawing rights on the total available sum. These rights are based on past performance such as publications, spin-offs, and patents. Applications for large-scale research infrastructure must include strategic cooperation. Besides universities, the three Flemish postgraduate institutions and the four strategic research institutes can also submit proposals. There is double assessment of proposals. First, a commission called Hercules Science evaluates the scientific merit of the proposal. Second, a commission named Hercules Invest evaluates whether the proposals are sufficiently realistic from a budgetary-technical point of view.

Hercules subsidizes 70% of the costs and this percentage can increase up to 90% or 100% depending on the degree of cooperation between centres of knowledge and/or third parties. Hercules combines funding of two years for calls for medium- and large-scale research investment initiatives. Two-thirds of the funding is spent on medium-sized projects and one-third is spent on large-sized projects. The total budget for the years 2009-2010 was € 19.25 million.[34]

4.2.3 Research performing organizations

Besides the business sector, research is mainly performed by the universities and PROs. The universities of the Flemish community represent more than 85% of the Flemish scientific

[33] All information comes from the website www.herculesstichting.be
[34] The total budget for 2011-2012 was € 25 million.

(publication-)output.[35] Other institutes where research or data collection is conducted are the four strategic institutes of the Flemish community, the Flemish science institutes, the Innovation Platforms , various policy research centres, and other organizations such as ITMA (tropical medicine), VLIZ (marine science), NERF, MIP3, Center for Medical Innovation (CMI), i-Cleantech Vlaanderen, and Living Laboratories on Electric Vehicle, Social Innovation Factory and Care Innovation Space Flanders.[36]

Higher education

There are two types of higher education institutions in Belgium: universities and universities of applied sciences. There are six universities which are HUB-KUBrussel, Vrije Universiteit Brussel (VUB), Universiteit Antwerpen (UA), Katholieke Universiteit Leuven (KU Leuven), Universiteit Gent (UGent), Universiteit Hasselt (Uhasselt), transnational Universiteit Limburg (tUL). In addition, there exist 19 institutes of non-university higher education (university of applied sciences). Cooperation takes place in the framework of five associations (a university and one or more applied universities): Leuven, Gent, Antwerpen, Brussel, Limburg. There are also two theological institutions, four postgraduate training institutions, and five non-statutory registered institutions.

Universities

Universities receive their funding from the Department of Education and Training (OV) and from the Department of Economics, Science and Innovation (EWI). OV provides the institutional funding for universities whereas EWI provides the Special Research Funds (Bijzondere Onderzoeksfondsen - BOF) and Industrial Research Funds (Industrieel Onderzoeksfond - IOF) as well as funding from FWO. Table 4.6 gives an overview of the institutional funding stemming from the Flemish community for the six universities in 2013. This institutional funding comprises education (75%) and research (25%) funds.

Table 4.6 Institutional funding by Flemish university, 2013

University	euros
Katholieke Universiteit Brussel	1.150
Katholieke Universiteit Leuven	266.404
Universiteit Antwerpen	99.338
Universiteit Gent	236.028
Universiteit Hasselt	30.647
Vrije Universiteit Brussel	85.313

Note: Numbers are in millions of euros. Source: Speurgids 2013.

The Flemish university funding scheme for working payments is currently in a transition phase. The old system as in place until 2000 consisted of three components:[37]

- Teaching and teaching related research.
  This is a lump-sum which depends on three parts which are the number of academic courses, doctoral programmes, and teacher training courses, continuing studies, and General Practitioners programmes.
- Investments.

[35] Debackere and Veugelers, 2012, *Vlaams Indicatorenboek 2011*, www.ecoom.be
[36] Belgian Report on Science, Technology and Innovation (2010).
[37] This part is based on Dassen and Luijten-Lub (2007). Higher Education in Flanders. Country Report. CHEPS.

This is earmarked funding consisting of a fixed and variable part for which universities had to hand in investment plans for five years.

– Social facilities.
  This is earmarked funding consisting a fixed and variable amount for social facilities such as student housing or student restaurants.

In 2000, the funding mechanisms changed. The funding for teaching and teaching related research increased and did no longer depend on the number of students. From that year onwards, the total amount is yearly updated on the basis of an index of labor costs and consumer prices.

The new funding scheme focuses on quality and will be implemented in 2014. From 2008 onwards, the funding for each university is calculated on the basis of the new formula but universities still receive the same amount as in 2001 but yearly adjusted for inflation. The new funding scheme consists of four parts which are a fixed and variable component for both teaching and research. The total amount available for the variable component for teaching increases (decreases) with 2% if the generated financing points increase (decrease) with more than 2%.[38] This implies that the variable component for research changes in the same direction because there is a fixed between funding for teaching (45%) and research (55%). This also means that the total budget for the variable research component is dependent of the change in the variable teaching component and will be adjusted in the same direction. In practice, however, this will be a minor change as the fixed research component is the most substantial part of the research funding. Table 4.7 gives an overview of the funding parameters for each of these four parts that apply to research universities. We will discuss each of these four parts in more detail below.[39]

Table 4.7 University funding parameters, 2013

Type of funding	Fixed or variable component	Funding parameters
Education	Fixed	Number of enrolled study points (100%)
	Variable	Number of enrolled study points (25%)
		Number of obtained study points (25%)
		Number of obtained study points credit contract (25%)
		Number of degrees (25%)
Research	Fixed	Number of PhD graduates (50%)
		Number of publications (50%)
	Variable	Number of degrees (24%)
		Number of PhD graduates (40%)
		Publications and citations (30%)
		Diversity and mobility (6%)

Source: Decreet betreffende de financiering van de werking van de hogescholen en de universiteiten in Vlaanderen, 2008.

Teaching component

The total fixed teaching component is around 100 million euros and is distributed across research universities and applied universities. The percentage share of each university in the

[38] The variable component is based on financing points and will be explained in detail below Table 7. More information about this four different types of funding and the transition phase can be found in “De financiering van het hoger onderwijs in Vlaanderen” by Linda De Kock and Noël Vercruysse.

[39] The full details can be found in “Decreet betreffende de financiering van de werking van de hogescholen en de universiteiten in Vlaanderen”.

total number of enrolled study points (OSTP)[40] over all universities determines the university-specific share in the fixed teaching component. The OSTPs can be calculated as a five-year moving average and there is a weighting scheme for different number of OSTPs. This scheme implies that smaller universities receive a relatively larger share of the fixed teaching component.

The variable teaching component for universities is around 330 million euros. The division between research universities depends on financing points. These financing points depend on four elements which are the number of enrolled study points (OSTP), the number of obtained study points, the number of degrees, and the number of study points of students with a credit contract. The individual elements (study points and diplomas) are weighted by a factor 1.5 for students with a scholarship, a disability, or fulltime employment. Moreover, there is a weighting scheme ranging from 1 to 4.2 for different studies areas.

Research component
The fixed research component is 110 million euros. Only universities that have at least 65 PhD degrees in the last five years and at least 1,000 publications over the last ten years receive this component. The fixed research component is divided on the basis of university-specific percentages.[41] These percentages depend on two output measures which are the number of PhD graduates and number of publications. There is a different weighting scheme for both output measures with higher weights for lower output.

The variable research component is allocated to universities on the basis of university-specific percentages. The total amount available in 2011 was 187 million euros. The percentages are a weighted average of number of bachelor and master degrees, the number of PhD diplomas, the number of publications and citations, and a parameter concerning mobility and diversity (this includes the percentage of employees that received their PhD from another university, the percentage of employees that received their PhD from the same university but have been working somewhere else for at least three years during the last five years, and the percentage of female employees).

It should be noted that the allocation of funds as described in this section is in a transition phase. Currently, universities still receive minimum amounts of funding even if the funding rules would determine otherwise. The funding rules become binding from 2014 onwards.

Apart from funding from the Flemish Community, universities can also obtain support from the Programmatory Public Service for Science policy. One such scheme is the IUAP, which will after its current period be transferred to the Communities resulting the 6th state reform. This represents however a minor part of the total public support. Overall, Communities and Regions are responsible for over 80% of total public R&D expenditures (OECD, 2011).

BOF and IOF funding
Next to the institutional and FWO funding, universities receive BOF and IOF funding from the Department EWI. BOF includes basic funding, tenure track funding, and Methusalem funding.

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[40] Each student receives 140 study points at the start of his or her study. The number of study points for which a student enrolls is subtracted from the diploma contract whereas the number of study point that a student earns are added. So, a student looses the study points for the courses that he or she did not pass. The first 60 study points that a student obtains are added twice to the diploma contract.

[41] Except for the University of Ghent which receives a certain amount. This amount is deducted from the total amount available for the component research.

The BOF for basic funding focuses on fundamental research and is an interuniversity distributing mechanism providing universities with significant financial resources that can further be allocated to large and smaller research projects through internal selection based on peer-review of competitive project applications. The BOF-resources have been increased fivefold (from 21.1 million euros in 1995 to 102.1 million euros in 2002) in the period of 1995 to 2008.[42]

Before 2002, the allocation mechanisms or so-called BOF-key was based on three criteria: the share of master degrees over a time period of four years (35%), the share PhD graduations over a time period of four years (50%), and the share of resources that a university could claim (15%). From 2003 onwards, an additional criteria has been added which is the share in the total Flemish academic publication and citation output in the Science Citation Index over a time period of ten years. The original three criteria count for 90% and the bibliometric criteria for 10%. According to the update of the BOF-proposition in 2008, this 90/10 ratio is expected to grow into a 70/30 ratio in the coming years.[43]

The tenure track funding and Methusalem funding use the same allocation mechanism as BOF for basic research funding. Tenure track funding focuses on giving postdoctoral researcher the opportunity to start a tenure-track position whereas Methusalem funding is aimed at giving experienced Flemish researchers structural long-term funding to make them less dependent on project financing.

IOF funding aims to promote cooperation between associations and firms. These funds can be used for strategic basic research and/or applied scientific research that focus on economic relevant issues. The allocation mechanism of IOF funding among associations is based on performance indicators. From 2009 onwards these indicators are PhD graduations (15%), publications and citations (15%), revenues from industrial contracts (30%), revenues from Framework programme for Research and Technological Development and European Union contracts (10%), patents (15%), and spin-off companies (15%).[44] In 2013, the IOF-resources were 20 million euros.

Public research organizations

This section gives a short overview of the main PROs in Flanders. The research organizations can be divided into three categories: scientific institutes, postgraduate institutes, and strategic research institutes.

Flemish strategic research institutes

Apart from the universities, the four strategic research institutes are the main research actors. Each institute focuses on a specific research area:[45]

- Imec (Interuniversitair Mikro-Elektronika Centrum)
- VIB (Flanders Institute for Biotechnology)
- VITO (Flemish Institute for Technological Research)

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[42] www.ecoom.be
[43] Besluit van de Vlaamse Regering betreffende de financiering van de Bijzondere Onderzoeksfondsen in de Vlaamse Gemeenschap.
[44] Besluit van de Vlaamse regering betreffende de ondersteuning van de Industriële Onderzoeksfondsen en de interfaceactiviteiten van de associaties in de Vlaamse Gemeenschap.
[45] In 2010, two additional research centres were set up: Centre for Medical Innovation (CMI) and the Strategic Initiative on Materials (SIM).

- iMinds (ICT and broadband), previously known as IBBT (Interdisciplinair Instituut voor Breedbandtechnologie)

The institutes receive annual grants from the government that vary between 23 million euro and 45 million euro, or almost 150 million euro in total (2009). In return, the institutes must fulfill some performance targets and more generally strengthen the Flemish knowledge base with an emphasis on the commercialization of their research. They should also focus on cooperation with companies, knowledge centers and non-profit organizations on research projects.

Flemish scientific institutes
The scientific institutes are each managed by a department of the Flemish government that performs scientific research in the area of the corresponding policy domain.

- Research Institute for Nature and Forest (Instituut voor Natuur- en Bosonderzoek , INBO)
- Flemish Institute for Archaeological Heritage (Agentschap Onroerend Erfgoed)
- Royal Museum of Fine Arts Antwerp (Koninklijk Museum voor Schone Kunsten - Antwerpen, KMSKA)
- Institute for Agricultural and Fisheries Research (Instituut voor Landbouw- en visserijonderzoek, ILVO)

Flemish postgraduate institutions
These institutions are autonomous scientific institutes that have close relationships with Flemish universities.

- Vlerick Ghent Leuven Management School
- University of Antwerp Management School
- Prince Leopold Institute for Tropical Medicine

Innovation Platforms
The Innovation Platforms are thematically oriented initiatives in a variety of domains that are funded by IWT. These are: Flanders' DRIVE (automotive industry), Flanders' Food (innovative foods), SIM (Materials), Flanders InShape (product development and design), Flanders' Synergy (innovative labour), Flanders' PlasticVision (rubber and plastic converting), MIX (innovative media, previously MIC), FISCH (sustainable chemistry), Social Innovation Factory (social innovation; this is a living lab), DSP Valley (Digital Signal Processsing – Design Smart Products) , VIM (mobility), VIL (logistics), MIP3 (environment), FMTC (mechatronics).

Other institutes
- Flanders Marine Institute (VLIZ)
- Environment and Energy Technology Innovation Platform (MIP2)
- Neuro-Electronics Research Flanders (NERF)

4.2.4 Monitoring

In 1991, universities in Flanders implemented a new system of internal and external quality assurance in return for more autonomy. The institutions have full responsibility and ownership of the system of quality assurance. Although the decree for funding threatens to withdraw funding if the quality is insufficient, no exclusion measures have been taken so far.[46]

The teaching quality of the six Flemish research universities, 21 applied universities, and five associations have to be evaluated every other eight years. These external evaluations (visitaties) are organized by the VLUHR (Vlaamse Universiteiten en Hogescholenraad). The report is used for accreditation at the NVAO.

Research universities and university of applied sciences only receive public funding for studies that are accredited.[47] The NVAO performs the accreditation for Dutch and Flemish bachelor and master studies. The indicators that are used for study programme assessment include the drop-out rates (first-year and overall), success rate, qualifications of teaching staff, student-teacher ratio, and education intensity. Moreover, the accreditation process includes the assessment of final theses and documents open for review.[48]

4.2.5 Research output

Table 4.8 indicates that the number of researchers in Belgium is on average whereas the PhD graduation rate is low compared to the other countries, especially when foreign students are excluded. It also performs below average with regard to publication and citation productivity. Belgium is similar to the UK in terms of the quantity of research as measured by publication but produces higher quality as measured by citations. Only Germany and the US score lower on the publication and citation productivity whereas Switzerland has almost twice as research output than Belgium.

Table 4.8 R&D output and personnel indicators, Belgium

Country	# of researchers (fte) per 1,000 labor force	PhD graduation rate (excl. foreign students)	# of publications per 1,000 inhabitants (1 fte researcher)	# of citations per 1,000 inhabitants (1 fte researcher)
Netherlands	6.1	1.8 (1.2)	2.8 (0.9)	10.5 (3.3)
Belgium	**8.3**	**1.5 (1.1)**	**2.4 (0.6)**	**8.1 (2.2)**
Germany	7.9	2.7 (2.3)	1.8 (0.4)	5.3 (1.3)
Switzerland	5.4	3.2 (1.7)	4.4 (1.4)	18.1 (5.6)
Denmark	13.1	2.2 (1.7)	3.3 (0.5)	12.6 (1.9)
UK	8.3	2.4 (1.3)	2.4 (0.6)	7.3 (1.8)
US	9.1	1.7 (1.3)	1.8 (0.4)	5.2 (1.1)
Average	*8.3*	*2.2 (1.5)*	*2.7 (0.7)*	*9.6 (2.5)*

Note: All figures reflect the situation as in 2011, except for the number of researchers in Germany (2010), Switzerland (2008), and US (2007). Sources: OECD and Scimago. *The PhD graduation rate is measured as a percentage of the relevant age cohort.

4.3 Distinguishing features

An important aspect of the Belgian R&D system is that the government spends a relatively small percentage of GDP on R&D. The other countries considered in this report spend a higher percentage of GDP on public R&D. With respect to the division of the public budget for R&D, the Belgian government devotes a relatively high share to the private sector compared to the other continental European countries.

[46] Dassen en van Luiten-Lub (2007). Higher Education in Flanders. Country Report. CHEPS.
[47] Accreditation is also important for giving diplomas and degrees. A complete list of accredited studies can be found on the website of CROHO.
[48] See website http://www.nvao.net/panels

Another important feature is the heavy reliance on performance measures as parameters in the funding formula for universities. The share in the fixed amount depends on the number of PhD graduates and publications. Moreover, the share in the variable amount depends on the number of bachelor and master degrees, the number of PhD diplomas, the number of publications and citations, and a parameter concerning mobility and diversity. Belgium and the UK are the only countries considered in this report that place a large reliance on bibliometrics to decide on the amount of funding for universities. Belgium is also the only country that also has a bonus for the number of citations, mobility and diversity of its employees, and the number of spinoffs.

5 Germany

5.1 Introduction

5.1.1 Goal of national science policy

The *High-Tech Strategy 2020*, developed in 2006 and launched in 2010, defines the central goals of the German R&D policy. The overall goal of the *High-Tech Strategy 2020* is to make Germany a pioneering force in solving global challenges such as climate change or dwindling reserves of raw materials.

In order to achieve this goal, the federal government has defined *forward-looking projects*. These projects are meant to steer R&D and innovation policy towards a number of central missions. A few examples are 'a million electric vehicles in Germany by 2020', 'better health through an optimized diet', and 'making global knowledge digitally available and accessible'.

Other priorities of the High-Tech Strategy 2020 are to increase freedom for research and industry, support/attract domestic and foreign research talent, increase long-term participation of small- and medium-sized enterprises in R&D activities, and pushing the strategy forward by regular evaluations of the Industry-Science Research Alliance (a forum in which representatives from industry and science make proposals for innovation policies).

5.1.2 Basic figures

Table 5.1 shows which players perform academic research in Germany (upper panel) and how this research is funded (lower panel). Most of the R&D activities are concentrated within the business sector, amounting to 67.6% of the total R&D expenditures. Most of these expenditures are funded by the business sector itself. Other important players are the national universities and research institutes, which are mainly funded by the German government.

Table 5.1 R&D funding, Germany, 2011

Source	Destination				
	Government	Higher education	Business	PNP	Total
Total	10,974.3	13,449.2	51,077.2	0	75,500.7
Percentage of GDP	0.4	0.5	2.0	0	2.9
	Percentage of funding				
Government	84.6	81.9	4.3	0	29.8
Higher education	0.0	0.0	0.0	0	0.0
Business	9.3	14.0	91.4	0	65.6
PNP	1.2	0.0	0.3	0	0.4
Foreign	4.9	4.1	4.0	0	4.2
Total	100.0	100.0	100.0	0	100.0

Note: The amounts are in millions of euro (current prices). R&D performed by the private non-profit (PNP) sector is included in the government sector since their contribution to R&D is very limited (less than 0.5% of GERD). [OECD, R&D Sources and Methods Database]. Source: Eurostat.

In total, the German government provides 29.8% of the total R&D funding within Germany, which amounts to 22.5 billion euros. All together, the German R&D expenditures sum up to 2.9% of GDP, which is well above the OECD average (2.4% in 2011) and close to the EU2020 target of 3%. The publicly funded R&D activities amount to 0.86% of GDP.

Table 5.2 summarizes how the public funding of R&D is distributed. We can observe that almost half of the public R&D budget goes to higher education, whereas most of the remainders go to PROs.

Table 5.2 Government funding by sector, Germany, 2011

	Government	Higher education	Business	PNP	Total
Amount	9,286.3	11,017.2	2,221.4	0	22,524.9
Percentages	41.2	48.9	9.9	0	100.0

Note: The amounts are in millions of euros (current prices). Source: Eurostat.

Below we will give a brief overview of some German R&D input indicators. Table 5.3 makes clear that PROs are relatively important in Germany. Relative to the other countries in our analysis, Germany allocates by far the largest share of public R&D funds to PROs. The share of the German public R&D budget that is project-based is similar to the Netherlands, Switzerland and Denmark. However, when we compare this to Belgium, the UK and the US, Germany spends relatively more public funding on institutional funding.

Table 5.3 Publicly funded R&D input indicators, Germany

		Destination		Allocation Mechanism	
	% of GDP	PROs (%)	Higher Education (%)	Project-based (%)	Performance-based (%)
Netherlands	0.72	22	72	26	25
Belgium	0.52	19	63	60	23
Germany	**0.86**	**41**	**49**	**31**	**11**
Switzerland	0.66	3	85	25	9
Denmark	0.86	6	87	32	1
UK	0.54	23	56	62	28
US	0.89	36	31	100	0
Average	*0.72*	*21*	*63*	*48*	*14*

Note: All figures reflect the situation as in 2011 except for Switzerland (2008). The calculation of the allocation mechanism variables can be found in Chapter 12. Sources: Eurostat, Van Steen (2012), and country reports.

5.2 General information

5.2.1 Government funding of R&D

Government funding in Germany is rather complex compared to other countries. This is due to the fact that the sixteen *Länder* are highly autonomous in matters of education policy. Therefore, the *Länder* mainly focus on education and research at the (applied) universities, whereas the federal government mainly funds PROs. In 2011, the federal government contributes 13,680 million euros to the total public R&D budget.[49]

[49] Source: BMBF, Bundesbericht Forschung und Innovation 2012, p. 418.

The distribution of the federal R&D budgets among the different ministries is summarized in Table 5.4. The *Bundesministerium für Bildung und Forschung* (BMBF) spends most, 56%, of the federal R&D budget. This budget is used to fund research of higher education and institutions that subsidize research. In order to allocate and make effective use of these public funds, the BMBF has developed numerous large funding programs. One of the most prominent examples is the *High-Tech Strategy 2020*. Instead of focusing on industries where Germany currently excels, the *High-Tech Strategy 2020* distinguishes five main research topics that are expected to be important in the future[50]:

1. Energy and climate.
2. Health and nutrition.
3. Mobility.
4. Safety.
5. Communication.

Table 5.4 R&D expenditures by policy area, Germany, 2013

Department	Euros	Percentage
Bundesministerium für Bildung und Forschung	7,649.8	55.9
Bundesministerium für Wirtschaft und Technologie	2,620.6	19.2
Bundesministerium der Verteidigung	972.4	7.1
Allgemeine Finanzverwaltung	877.0	6.4
Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz	516.0	3.8
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit	247.6	1.8
Bundesministerium für Verkehr, Bau und Stadtentwicklung	224.9	1.6
Auswärtiges Amt	179.0	1.3
Bundesministerium für Gesundheit	156.4	1.1
Bundeskanzleramt	85.6	0.6
Bundesministerium des Innern	47.8	0.3
Bundesministerium für Arbeit und Soziales	38.5	0.3
Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung	34.7	0.3
Bundesministerium für Familie, Senioren, Frauen und Jugend	25.0	0.2
Bundesministerium der Justiz	2.9	0.02
Bundesministerium der Finanzen	1.9	0.01
Total	13,680.1	100.0

Note: The amounts are in millions of euros. Source: BMBF, Bundesbericht Forschung und Innovation 2012, p. 418.

As discussed, the individual *Länder* are responsible for financing public research performed by the higher education sector. The BMBF, however, also has a mechanism through which to enhance the international appeal of German universities: the *Excellence Initiative.* The Initiative is organized by the BMBF, while the Deutsche Forschungsgemeinschaft and the Wissenschaftsrat are given responsibility for running the program. This program aims to promote cutting-edge and interdisciplinary research and to enhance the international appeal of German universities. Altogether the Excellence Initiative will distribute 2.7 billion euros over the years 2012-2017. The Initiative consists of three funding lines:

- Graduate schools to promote early career researchers.
- The creation of Clusters of Excellence that connect German universities with research institutes and business.
- The selection of 11 Universities of Excellence that are aimed to develop top-level university research and to enhance its international competitiveness.

[50] Source: BMBF, Ideas. Innovation. Prosperity. High-Tech Strategy 2020 for Germany, 2010.

The *Bundesministerium für Wirtschaft und Technologie* (BMWi) spends almost 20% of the federal R&D budget. The BMWi is important for connecting the world of science with business enterprises.

5.2.2 Intermediary organizations

Intermediary organizations help the German government with allocating the public R&D budgets. The three most important intermediary organizations are listed below.

Deutsche Forschungsgemeinschaft (DFG)
The German federal government provides about two-thirds of the DFG budget, whereas the *Länder* account for the remaining one-third. In 2011, the DFG had almost 2.5 billion euros (roughly 11% of total public R&D funding) to finance research. It mainly focuses on especially universities but also provides funding to PROs.[51] Another important characteristic of the DFG is its focus on basic research funding. Moreover, the DFG is completely independent in its decisions how to allocate the research funds.

The DFG is characterized by a bottom-up type of research funding, i.e. funding of investigator-initiated research. Another important aspect is that scientists are not restricted to particular research areas when applying for a DFG grant: "the core responsibility set out in the DFG's statutes is to promote all fields of science and the humanities in Germany."[52] Hence, the primary funding criterion is scientific quality.

Although the DFG is highly dependent on the researchers' ideas, this does not mean that the DFG works through bottom-up funding only. Priority programmes, Collaborative Research Centres and Research Units are examples of programs that enable the DFG to engage in strategic research.

Deutsche Akademische Austauschdienst (DAAD)
The funding of the DAAD (about 350 million euros on a yearly basis) is for 80% provided by the German government. The remaining 20% is accounted for by the European Union and private institutions. The main purpose of the DAAD is funding exchange programs for (PhD) students, researchers and technicians. Not only does it give German academics the opportunity to gain experience abroad, it also attracts foreign talent to Germany.

Alexander von Humboldt-Stiftung (AvH)
The AvH provides funding for (foreign) individual researchers. Its aim is to attract excellent researchers from abroad to come to Germany and do research together with German researchers. The yearly budget of the AvH amounts to approximately 100 million euros and is mainly funded by the German government.

See Appendix 5A for a brief overview of the available research funding programs.

5.2.3 Research performing organizations

Higher education

Throughout Germany there are about 400 higher education institutions, of which about 100 are universities and 200 are *Fachhochschulen* (universities of applied sciences). The remainder of the higher education institutions consists of colleges of art/film/music and other specialized

[51] Source: DFG annual report 2011, p. 208.
[52] Source: Strohschneider, P. (2013). 'Response-Mode Funding. Reflections on DFG funding policies.'

institutions that fit neither of these categories. Only two *Länder*, Bavaria and Niedersachsen, charge a tuition fee of maximum €1,000 per academic year. The other 14 *Länder* do not charge tuition fees.[53] Although each *Länder* has its own public funding policy, we give the reader a view of what the policy of a typical German *Länder* looks like.

Public R&D funds for higher education often take the form of institutional funding which they receive as a lump sum. As a consequence, the higher education institutions enjoy a high level of flexibility with regard to the internal allocation of the funds.[54] It is for this reason that it is difficult to distinguish between funding for research and teaching activities. We will therefore discuss the whole picture of German higher education funding.

Historically, the funds of the universities were determined by simply rolling-over the previous year's budget, possibly corrected for inflation (incremental-discretionary). During the past decade, *Länder* have introduced an indicator-based formula to determine the amount of public funding. Table 5.5 gives an overview of how the indicator-based part of public funding evolved over time. We observe an increase over time in the number of *Länder* that integrate an indicator-based formula into their funding program. Moreover, the individual shares increased as well for most *Länder*.

The indicator-based part of the annual budget consists of both a teaching and a research component. Typically, the research component carries more weight for universities than for *Fachhochschulen*, but the exact ratio varies by *Länder* (e.g. Berlin applies a 50/50 ratio for universities and a 80/20 ratio for *Fachhochschulen*).[55] The teaching component often consists of the number of students and graduations, whereas the research component is often distributed on the amount of external funding and the number of PhD graduations.[56] Appendix 5B gives an overview of how the indicator-based part of the institutional funding works for three specific *Länder*.

During the past years, the funding of higher education has increasingly turned towards indicator-based funding. On top of this, *Länder* started to implement state-wide pacts and individual target-agreements as a complementary steering instrument. An important thing to note about these target-agreements is that they are not directly linked to financial rewards and/or penalties.[57]

In summary, the *Länder*'s public funding typically consist of three possible procedures:

- Incremental-discretionary part
  This part is based on previous year's funding and corrected for inflation (non-competitive). When there is a serious need for investment, the institution can start negotiations with the state government. During the past years, the *Länder* have gradually moved away from this type of funding.

[53] Source: European Commission, National Student Fee & Support Systems 2011/2012, p. 12.
[54] Source: European Commission, Progress in higher education reform across Europe, p. 43.
[55] Source: Dominic Orr and Astrid Schwarzenberger, Higher Education Information System (HIS), Germany.
[56] Source: S. Lange, 2007. The impact of evaluation based funding on university research: Australia and Germany compared.
[57] Source: CHEPS, Quality-related funding, performance agreements and profiling in higher education.

Table 5.5 Shares of state grants allocated using formula for universities, 2000-2011

Länder	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Expenditures on higher education	# (%) Of universities in top 200	# (%) Of universities in top 500
Baden-Württemberg	14	14	21	20	20	20	20	25	30	30			2,553.7	3 (14%)	7 (32%)
Bayern	1.5	1.5	1.5	1.5	1.5	1.5	1.5						2,551.5	3 (25%)	6 (50%)
Berlin	-	-	6	10	15	15	20	25	30	30			1,193.9	0 (0%)	1 (25%)
Brandenburg	-	-	-	-	95	95	95						238.8	0 (0%)	0 (0%)
Bremen	-	-	-	5	5	10	10						235.4	0 (0%)	1 (50%)
Hamburg	-	-	5	5	5	85	85						639.0	1 (17%)	1 (17%)
Hessen	-	-	-	95									1,669.9	1 (17%)	4 (67%)
Mecklenburg-Vorpommern	-	-	1	1	2.5	2.5	4	4	6	8			363.2	0 (0%)	0 (0%)
Niedersachsen	-	-	-	-	-	3							1,653.8	1 (8%)	4 (31%)
Nordrhein-Westfalen	-	-	8	8	14	17	20	20	20	20	20	20	4,185.1	3 (14%)	8 (38%)
Rheinland-Pfalz	95	95	95	95	95	95	95						772.4	1 (17%)	1 (17%)
Saarland	-	-	-	-	-	-	-	-	-	-	-	5	212.0	0 (0%)	0 (0%)
Sachsen	-	-	-	-	-	1	1						1,097.2	0 (0%)	2 (100%)
Sachsen-Anhalt	-	-	-	-	-	-	-	-	-	-	-	5	444.6	0 (0%)	1 (13%)
Schleswig-Holstein	-	-	-	-	-	-	5						435.3	1 (33%)	1 (33%)
Thüringen	-	-	-	15	15	15	15	15	10	20	30	40	481.4	0 (0%)	1 (20%)

Note: University rankings are based on the Academic Ranking of World Universities (ARWU) 2013. The accompanying percentages reflect the share of top-ranked universities as a percentage of the total number of public universities in that particular *Länder* (this includes universities for art, music, etc.).
* Expenditures on higher education are based on the year 2009.
Source: Dominic Orr and Astrid Schwarzenberger, Higher Education Information System (HIS), Germany.
Source: BMBF, Bundesbericht Forschung und Innovation 2012, p. 444.
Source: Evaluation der leistungsbezogenen Mittelvergabe an die Hochschulen in Mecklenburg-Vorpommern, 2010.
Source: Evaluation der leistungsbezogenen Mittelvergabe an die Berliner Hochschulen, 2009.
Source: HIS, Bewertung der leistungsorientierten Mittelverteilung (LOM) im Hoch-schulbereich Sachsen-Anhalts, 2012.
Source: Die leistungsorientierte Mittelverteilung an den Hochschulen des Landes NRW, 2007-2010.
Source: HIS, Hochschulkennzahlensystem Niedersachsen, 2010.
Source: Ministerium für Wirtschaft und Wissenschaft, Ziel- und Leistungsvereinbarung III, 2011-2013.
Source: Thüringer Kultusministerium, Leistungs- und belastungsorientierte Verteilung und Zuweisung von Personalmitteln und Mitteln für Lehre und Forschung an die Hochschulen des Freistaats Thüringen, 2007.

- Contract- or mission-based part
  In order to achieve goals of the state government, like internationalization and gender equality, the state government can financially award well-performing institutions. This type of funding is generally non-competitive.
- Indicator-based part
  This funding procedure has become increasingly popular. This part typically exists of a teaching and a research component, whereas the research component is typically more important for universities than for *Fachhochschulen*.

The internal distribution of funds is often done by internal target agreements and an indicator-based part.[58]

Public research organizations

Below, we will discuss the four largest German PROs that receive public funding. Table 5.6 and 5.7 show the organizations' budget, source of funding and the amount of R&D expenditures by field of research (as a percentage of the total R&D budget).

The Helmholtz-Gemeinschaft mainly performs fundamental research and aims to solve future challenges of society. Therefore, the Helmholtz-Gemeinschaft concentrates its research activities on the fields of Energy, Earth and Environment, Health, Aeronautics, Space and Transport, Key Technologies plus Structure of Matter.

The Fraunhofer-Gesellschaft is the largest organization for applied research in Europe. It performs applied research for both public and private institutes. Compared to the other research organizations, the Fraunhofer-Gesellschaft receives little institutional funding.

The Max-Planck-Gesellschaft is an important player in the field of fundamental research. The Max-Planck-Gesellschaft focuses on a very broad set of research areas: Astronomy and Astrophysics, Biology and Medicine, Material and Technology, Environment and Climate plus Humanities.

The Leibniz-Gemeinschaft performs both fundamental and applied research. The research activities of the Leibniz institutes can be divided into five sections: Humanities and History of Education; Economics, Social Sciences, Regional Infrastructure Research; Life Sciences; Mathematics, Natural Sciences & Engineering; Environmental Science.

Table 5.6 Institutional funding of research organizations, Germany, 2008

Research organization	Type of research	Public funding		Private funding	Total budget
		Institutional	Project		
Helmholtz-Gemeinschaft	Fundamental	65% (9:1)	29%	6%	2,620
Fraunhofer-Gesellschaft	Applied	36% (9:1)	27%	37%	1,400
Max-Planck-Gesellschaft	Fundamental	81% (5:5)	15%	4%	1,110
Leibniz-Gemeinschaft	Fundamental and Applied	78% (5:5)	16%	6%	1,770

Note: The amounts are in millions of euros. The ratio of institutional funding received from the federal government and the *Länder* governments respectively is placed in parenthesis. Source: Bullinger, H. (2010, May). Fraunhofer within the German Research System. *Diversification through Innovation: Prospects for Growth.* Presentation at the Knowledge Economy Forum, Berlin.

[58] Source: Wolter, 2007. The Implementation of New Governance Structures in German Higher Education.

Table 5.7 R&D expenditures of research organizations by field of research, Germany, 2009

Research organization	Natural sciences	Technical sciences	Health sciences	Agricultural sciences	Social sciences and humanities
Helmholtz-Gemeinschaft	53%	34%	13%		
Fraunhofer-Gesellschaft	25%	71%	5%		
Max-Planck-Gesellschaft	84%		4%		12%
Leibniz-Gemeinschaft	68%		10%		22%

Note: The amounts are percentage of total expenditures. Source: BMBF, Bundesbericht Forschung und Innovation 2012.

The above mentioned PROs together with the DFG enjoy a high degree of financial planning security because of the Joint Initiative for Research and Innovation. This pact is designed to provide financial planning security for organizations that are jointly funded by the German federal government and the *Länder*. The first Joint Initiative for Research and Innovation was agreed on for the period 2005-2010. The pact that is currently in force (2011-2015) guarantees an annual funding increase of 5%.[59]

Beside these large research organizations, there are 38 federal research institutes that provide a scientific basis for government policy. These federal research institutes are funded directly by the German ministries. The total annual budget is about 850 million euros. Apart from the 38 federal institutes, the *Länder* provide funding for their own research institutes. In total, there are 130 research institutes that support the *Länder*.[60]

5.3 Other characteristics

5.3.1 Advisory organizations

Due to the complexity of the German R&D landscape, Germany has many advisory organizations at its disposal. Below, we will discuss the two most important advisory organizations:

Gemeinsame Wissenschaftskonferenz (GWK)
In Germany, both *Länder* and the federal government are important sources of public R&D. It is therefore of great importance that both governments cooperate closely on allocating resources. The GWK consists of the federal minister of Education and the minister of Finance, as well as their colleagues from the 16 different *Länder.* They meet every half a year to discuss matters concerning funding of research and innovation strategies.

Wissenschaftsrat
This council discusses developments regarding higher education and research at (applied) universities and gives advice for improvement in the future. Moreover, the council serves as a mediator between the government and the academic world.

[59] Source: BMBF website, 'Joint Initiative for Research and Innovation'. Accessed on: 16-1-2014. Accessible: http://www.bmbf.de/en/3215.php
[60] Source: AWT, 'Een onderzoek naar het Duitse wetenschapslandschap en R&D-beleid', p. 37.

5.3.2 Monitoring

Both the DFG and the Wissenschaftsrat evaluate publicly funded research in Germany. The evaluations are used to allocate public funds to its most effective use. These evaluations can be depicted as a 'shell' with three different layers[61]:

- Evaluation of individual researchers/groups
  Peer reviews are used to evaluate individual researchers and groups (e.g. bibliometrics). These evaluations take place ex-ante and are often labeled as 'science-internal evaluation'.
- Evaluation of programs
  These evaluations examine the impact of programs (are scientific, technological and economic goals reached?). They take place ex-post and are often labeled as 'science-external evaluation'.
- Evaluation of institutions
  The evaluation of institutions takes into account both the internal and external aspects of research.

Whereas the DFG predominantly evaluates individual researchers and individual research groups (first layer), the Wissenschaftsrat assesses the scientific impact of research programs and institutions (second and third layer).

5.3.3 Research output

Table 5.8 gives a brief overview of some important R&D output and personnel indicators. We can observe that Germany produces relatively many PhD graduates compared to the other countries in our analysis (especially when we exclude foreign students). It seems, however, that this relatively high PhD graduation rate is not directly translated into a relatively large amount of researchers per 1,000 labor force (7.9 is somewhat below the average). A possible explanation for this relatively low number of researchers is that within some disciplines (medicine, dentistry and law studies) German students obtain a PhD for other reasons than to pursue a career in research.[62]

Table 5.8 R&D output and personnel indicators, Germany

Country	# of researchers (fte) per 1,000 labor force	PhD graduation rate (excl. foreign students)	# of publications per 1,000 inhabitants (1 fte researcher)	# of citations per 1,000 inhabitants (1 fte researcher)
Netherlands	6.1	1.8 (1.2)	2.8 (0.9)	10.5 (3.3)
Belgium	8.3	1.5 (1.1)	2.4 (0.6)	8.1 (2.2)
Germany	**7.9**	**2.7 (2.3)**	**1.8 (0.4)**	**5.3 (1.3)**
Switzerland	5.4	3.2 (1.7)	4.4 (1.4)	18.1 (5.6)
Denmark	13.1	2.2 (1.7)	3.3 (0.5)	12.6 (1.9)
UK	8.3	2.4 (1.3)	2.4 (0.6)	7.3 (1.8)
US	9.1	1.7 (1.3)	1.8 (0.4)	5.2 (1.1)
Average	*8.3*	*2.2 (1.5)*	*2.7 (0.7)*	*9.6 (2.5)*

Note: All figures reflect the situation as in 2011, except for the number of researchers in Germany (2010), Switzerland (2008), and US (2007). Sources: OECD and Scimago. *The PhD graduation rate is measured as a percentage of the relevant age cohort.

[61] S. Kuhlmann, 2003. *Int. J. Technology Management.* 'Evaluation of research and innovation policies: a discussion of trends with examples from Germany', p. 134-136.
[62] Source: Adviesraad voor het Wetenschaps- en Technologiebeleid, 2012. 'Een onderzoek naar het Duitse wetenschapslandschap en R&D-beleid.

Lastly, with regard to the number of publications per 1,000 inhabitants and per 1 fte researcher, Germany performs worse than most of the peer countries. The only exception is the US whose publication productivity is similar to Germany. A similar pattern can be observed for the number of citations.

5.4 Distinguishing features

What distinguishes the German public R&D system from the other peer countries? First of all, Germany has a rather unique R&D system since it is organized in a multilevel structure where both the federal government and the regional authorities have competences in R&D policy. Another important aspect of the German R&D landscape is the large role of PROs (0.4% of GDP and 41% of public R&D funding). This is due to the fact that funding of higher education institutions fall under the authority of the *Länder*. Since the federal government has almost no influence on the R&D policy of universities, it has developed an R&D strategy that mainly focuses on PROs.

It must be noted that not all countries that are characterized by a high level of decentralization have developed a large role for PRO's. For example, in Switzerland there are ten universities that fall under the authority of the Cantons. However, instead of spending most of the federal R&D budget on PROs, the Swiss federal government mainly focuses its R&D policy on the so-called FIT Domain (an organization that comprises two federal universities and four research institutes) which is officially seen as a part of the higher education sector.

The drawback of a large PRO sector is the fact that many excellent researchers and top research projects are not located at the German universities. This weakens the research aspect of German universities and, consequently, weakens the position of German universities within the international university rankings.

Lastly, the vision of the German R&D policy does not focus on specific industries or technologies. Instead, the goal of the High-Tech Strategy 2020 is to make Germany a pioneering force in solving global challenges. These challenges are sufficiently broad which paves the way for interdisciplinary research and does not undermine the autonomy of the R&D performers.

Appendix 5A

Table 5A.1 Brief overview of available research funding programs in Germany as found in 2013

Program	Funded by	Target group	Support	Duration
Alexander von Humboldt Professorship	AvH	Senior researchers	3.5-5 million	5 years
Georg Forster Research Fellowship for Experienced Researchers	AvH	Senior researchers		6-18 months
Georg Forster Research Fellowship for Postdoctoral Researchers	AvH	Postdocs		6-24 months
Humboldt Research Award	AvH	Senior researchers	60.000	12 months
Humboldt Research Fellowship for Experienced Researchers	AvH	Senior researchers		6-18 months
Humboldt Research Fellowship for Postdoctoral Researchers	AvH	Postdocs		6-24 months
Sofja Kovalevskaja Award	AvH	Postdocs	1.65 million	5 years
Bilateral Exchange of Academics	DAAD	Senior researchers, Postdocs		0.5-3 months
RISE professional Summer internships with German companies	DAAD	Foreigners		2-6 months
Re-integration of German Scientists from Abroad	DAAD	PhD students, Senior researchers		
Re-invitation Program for Former Scholarship Holders	DAAD	Postdocs, Senior researchers		1-3 months
Research Grants for Doctoral Candidates and Young Academics and Scientists	DAAD	Graduates, PhD students, Postdocs	750-1000 per month	1 month to 3 years
Research Stays for University Academics and Scientists	DAAD	Postdocs, Senior researchers		1-3 months
University Summer Courses	DAAD	BSc and MSc students		>18 days
Research Grants	DFG	Postdocs, Senior researchers		
Scientific Networks	DFG	Early career researchers		Up to 3 years
Research Fellowships	DFG	Early career researchers		Up to 2 years
Emmy Noether Program	DFG	Postdocs		5 years
Heisenberg Program	DFG	Senior researchers		Up to 5 years
Reinhart Koselleck Projects	DFG	Outstanding researchers	0.5-1.25 million	5 years
Clinical Trials	DFG	Postdocs		3 years
Priority Programmes	DFG	All researchers who work at research institutions		6 years
Research Training Groups	DFG	Graduates, PhD students, Postdocs		4.5-9 years
Collaborative Research Centers	DFG	Research universities		Up to 12 years
DFG Research Centres	DFG	Research universities	5 million per year (average)	Up to 12 years
Research Units	DFG	Outstanding researchers		Up to 6 years
Graduate Schools	DFG	Graduates, PhD students, Postdocs		
Clusters of Excellence	DFG	Graduates, PhD students, Postdocs		
Grants to Support the Initiation of International Collaboration	DFG	Postdocs, Senior researchers		<3 months
Mercator Fellowship	DFG	Postdocs, Senior researchers		

Note: Amounts are in euros. For most programs, the amount of support is variable because it is dependent on the expenditures on travelling, consumables, workshops, alumni networks, etc. Sources: Research in Germany website, DFG website.

Appendix 5B

Table 5B.1 Nordrhein-Westfalen

Indicator-based part	Higher education institutions	Weight	Indicator
20%	Universities	50% teaching	50% graduates
		50% research	40% external funding 10% PhD
	Fachhochschulen	85% teaching	85% graduates
		15% research	15% external funding

Source: Die leistungsorientierte Mittelverteilung an den Hochschulen des Landes NRW, 2007-2010.

Table 5B.2 Baden-Württemberg

Indicator-based part	Higher education institutions	Weight	Indicator
30%	Universities	55% teaching	25% number of students 30% graduates
		45% research	35% external funding 10% PhD
	Fachhochschulen	80% teaching	40% number of students 40% graduates
		20% research	20% external funding

Source: Empfehlungen zur Gestaltung von Steuerungssystemen auf der Ebene Land/Hochschule.

Table 5B.3 Berlin

Indicator-based part	Higher education institutions	Weight	Indicator
30%	Universities	50% teaching	?
		45% research	45% external funding
		5% other	5% gender equality and internationalization
	Fachhochschulen	80% teaching	?
		15% research	15% external funding
		5% other	5% gender equality and internationalization

Source: IFQ, 2010. Leistungsorientierte Mittelvergabe und wissenschaftliche Nachwuchsforderung.

6 Switzerland

6.1 Introduction

6.1.1 Goal of national science policy

Switzerland is characterized by a relatively high degree of decentralization. This means that each canton (member state of the federal state of Switzerland) may pursue its own goals with regard to science policy. In this section we will however abstract away from the different cantonal policies and solely focus on the goals of science policy as set by the federal government.

In 2011, the Swiss federal government has established objectives with regard to research and innovation for 2013-2016. The overall objective is to "consolidate the high level of grant funding awarded on a competitive basis and further strengthen Switzerland's internationally competitive position". In brief, the Swiss government tries to achieve this by doing the following:[63]

- Increase the amount of project-based funding without cutting back on 'basic funding' since this is an important prerequisite for applying for project grants.
- Invest in strategically important research infrastructure.
- Maintain the level of international cooperation and networking with foreign countries and improve cooperation between research institutes and the private sector.
- Ensuring a top position in promising fields by targeted measures, while leaving enough room for unconventional research approaches.

6.1.2 Basic figures

Table 6.1 shows which players perform academic research in Switzerland (upper panel) and how this research is funded (lower panel). We can observe from Table 6.1 that more than two-thirds of all R&D activities are performed by the business sector. The R&D activities performed by both the government and higher education are mainly publicly funded. Compared with other OECD countries, Switzerland's higher education institutions play a very important role in performing public R&D, whereas the role of PROs is very limited.[64] The Swiss public funds for R&D amount 2,345.3 million euros (22.8% of total R&D funding in Switzerland). In total, Switzerland spends 2.9% of GDP on R&D, which is well above the OECD average (2.3% in 2008[65]) and close to the EU2020 target of 3%.

[63] Source: SERI website, 'Promotion of education, research and innovation for 2013-2016'
[64] Source: S. Nickel, Bilanz und Perspektiven der leistungsorientierten Mittelverteilung, 2008.
[65] Source: OECD, Science, Technology and Industry Outlook 2010.

Table 6.1 R&D funding, Switzerland, 2008

Source	Destination				
	Government	Higher education	Business	PNP	Total
Total	75.6	2,482.0	7,546.9	163.8	10,268.4
Percentage of GDP	0.0	0.7	2.1	0.1	2.9
	Percentage of funding				
Government	100.0	80.6	1.7	88.5	22.8
Higher education	0.0	9.4	0.1	0.0	2.3
Business	0.0	6.9	90.5	0.0	68.2
PNP	0.0	0.2	0.7	7.7	0.7
Foreign	0.0	2.9	7.0	3.8	6.0
Total	100.0	100.0	100.0	100.0	100.0

Note: The amounts are in millions of euro (current prices). Source: Eurostat.

Table 6.2 Government funding by sector, Switzerland, 2008

	Government	Higher education	Business	PNP	Total
Amount	75.6	2,000.1	124.7	144.9	2,345.3
Percentages	3.2	85.3	5.3	6.2	100.0

Note: The amounts are in millions of euros (current prices). Source: Eurostat.

Although Switzerland scores above average with respect to total R&D expenditures as a percentage of GDP (2.9%), they provide relatively few public R&D funds (0.7%). This implies that a large share of R&D activities is funded by the business sector. The large share of private R&D funding is related to the presence of large multinational companies with high research intensity.[66]

Table 6.3 Publicly funded R&D input indicators, Switzerland

		Destination		Allocation Mechanism	
	% of GDP	PROs (%)	Higher Education (%)	Project-based (%)	Performance-based (%)
Netherlands	0.72	22	72	26	25
Belgium	0.52	19	63	60	23
Germany	0.86	41	49	31	11
Switzerland	**0.66**	**3**	**85**	**25**	**9**
Denmark	0.86	6	87	32	1
UK	0.54	23	56	62	28
US	0.89	36	31	100	0
Average	*0.72*	*21*	*63*	*48*	*14*

Note: All figures reflect the situation as in 2011 except for Switzerland (2008). The calculation of the allocation mechanism variables can be found in Chapter 12. Sources: Eurostat, Van Steen (2012), and country reports.

Table 6.3 summarizes some important R&D input indicators. We can see that within the set of countries we analyze in this report, Belgium and the UK are the only countries that spend less on public R&D than Switzerland. Most of the public R&D budget is received by the higher education sector and only 3% of this budget goes to PROs. This figure is slightly misleading since the research institutes within the Federal Institutes of Technology (FIT) Domain are officially reckoned as higher education. Another interesting feature is that only 9% is allocated on the basis of performance indicators. Moreover, 25% is allocated on a project basis which is

[66] Source: European Commission, National report on joint and open programmes Switzerland.

lowest percentage among the seven countries. This implies that Switzerland spends most of its public R&D funding on institutional funding. These figures are comparable to the Danish system of allocation public research funds.

6.2 General information

6.2.1 Government funding of R&D

Switzerland consists of 26 cantons. Beside the R&D expenditures of the federal state, each canton can implement its own policy with regard to R&D. Table 6.4 further specifies the government's funding streams into funds from the federal government, cantonal governments and non-profit research organizations. The table shows that 61.4% of public funding came from the federal state, whereas 35.7% came from the cantonal governments.

Table 6.4 Public R&D funding, Switzerland, 2008

Source	Destination				
	Federal	PNP	Higher education	Business	Total
Total	75.6	157.5	2,006.6	177.0	2,416.7
Percentage of GDP	0.02	0.04	0.56	0.05	0.68
	Percentage of funding				
Federal	100	92.0	60.9	23.1	61.4
Cantonal			38.8	48.0	35.7
Non-profit		8.0	0.3	28.9	2.9
Total	100.0	100.0	100.0	100.0	100.0

Note: The amounts are in millions of euro (current prices). 2008 average exchange rate CHF/EUR: 0.630. Source: Bundesamt für Statistik, F+E der Schweiz 2008, Fortgesetzte Anstrengungen der Privatunternehmen und Hochschulen, and Eurostat.

Generally, government R&D funding agencies provide institutional funding, whereas the intermediary organizations focus on project funding. The intermediary organizations will be discussed in the next section. One of the main government R&D funding agencies is the *State Secretariat for Education, Research and Innovation* (SERI) and is part of the *Federal Department of Economic Affairs, Education and Research*. SERI was created in 2012 by merging SER (responsible for funding universities and research institutes) and OPET (responsible for funding vocational education and universities of applied sciences). Its main responsibilities are funding of the FIT Domain (two federal institutes of technology and four federal research institutes) and coordinating the cantonal universities.

We can subdivide the total amount of R&D expenditures into three forms of scientific research: fundamental research, applied research and experimental development. Table 6.5 shows in which R&D performing sectors these three types of research concentrate. We can observe that most of the fundamental R&D activities take place at higher education institutions. Although the business sector spends less than 10% of their R&D funds on fundamental research, they still contribute a substantial amount to the total amount of fundamental research (23.7%). Lastly, we observe that the business sector undertakes most of the applied research and experimental development activities.

Table 6.5 The importance of R&D types within the R&D performing sectors, Switzerland, 2008

Type of research	Government (% of total)	Higher education (% of total)	Business (% of total)	Total (% of total)
Fundamental research	210 (55%)	3120 (79%)	1035 (9%)	4365 (27%)
Applied research	155 (41%)	600 (15%)	4445 (37%)	5200 (32%)
Experimental development	15 (4%)	220 (6%)	6500 (54%)	6735 (41%)
Total	380 (100%)	3940 (100%)	11980 (100%)	16300 (100%)

Source: Bundesamt für Statistik, F+E der Schweiz 2008, Fortgesetzte Anstrengungen der Privatunternehmen und Hochschulen.

6.2.2 Intermediary organizations

Swiss National Science Foundation (SNSF)
The SNSF is completely funded by the federal government (SERI), but is also highly autonomous concerning its funding decisions. The SNSF consists of two main organs: the Foundation Council and the National Research Council (NRC). The Foundation Council is responsible for the general strategy, whereas the NRC decides which projects are to be funded. The main beneficiaries of the SNSF are the higher education institutions. In 2008, the SNSF budget amounted 416 million euros (660 million CHF) which is roughly equal to 18% of the total public R&D budget.[67] [68]

The SNSF is characterized by a bottom-up type of funding except for the Research Programs, which will be discussed in more detail below. This means that the research topics and scope are not pre-defined and that the main selection criteria are scientific quality and the applicants' track record. Although the project applications must be submitted within four research disciplines (including one for interdisciplinary research), the budget for each research discipline is not pre-defined.[69]

Below we will discuss two of the main funding Research Programs of the SNSF[70]:

- National Research Programs (NRPs)
  The National Research Programs aim at solving Switzerland's most pressing problems. Its topics are selected by the federal government. The duration of a typical NRP lasts 4-5 years and is funded with 3-17 million euros (5-20 million CHF).
- National Centers of Competence in Research (NCCRs)
  NCCRs promote long-term research projects that are of strategic importance. Since the establishment in 2001, 27 NCCRs have been launched. An NCCR has a maximum length of 12 years and is funded by the SNSF for the first four years, complemented by funds from universities and third-party funds. After four years, the NCCR can apply for an extension of the SNSF funding. The NCCRS are under the directorship of either a university or another research institute.

An interesting and relatively new (introduced in 2009) feature of the SNSF is the provision of overhead contributions to cover indirect research expenses (e.g. costs for infrastructure, maintenance and administration) incurred by research institutions for SNSF-approved projects. The SNSF overhead contribution beneficiary is the research institution (not individual

[67] 2008 average exchange rate CHF/ EUR: 0.630.
[68] Source: European Commission, National report on joint and open programmes Switzerland.
[69] Source: SNSF website.
[70] Source: SNSF website.

researchers) and the contribution is limited to a maximum of 20% of the project grant. The aim of this regulation is to strengthen competitively funded research.[71]

Since the introduction of the SNSF Overhead Regulation, the total amount of overhead contributions increased from 24.3 million euros in 2009 (36.7 million CHF, 5% of total SNSF budget) to 68.9 million euros in 2012 (82.0 million CHF, 10% of total SNSF budget).[72]

Swiss Innovation Agency (Commission for Technology and Innovation, CTI)
The CTI has the task to promote cooperation between higher education institutions and the private sector. Moreover, it provides assistance for the development of start-up companies. The private sector contributes at least 50% of the project costs and has the right to exploit the research outcomes.[73] The publicly funded budget of the CTI amounted to 55.4 million euros (88 million CHF) in 2008.[74] Whereas the SNSF mainly focuses on fundamental research, the CTI aims at promoting applied research.

6.2.3 Research performing organizations

Higher education

The higher education system consists of two federal institutes of technology (Zurich and Lausanne), ten cantonal universities and seven universities of applied sciences. The federal government takes complete responsibility for the funding of the institutes of technology. The funds for the cantonal universities and the universities of applied sciences are a shared responsibility of both the federal and the cantonal governments. The SNSF and CTI are the main providers of public project funding for the higher education institutions. The ratio between public institutional funding for R&D and public project funding within the higher education institutions is roughly equal to 80:20.[75]

Table 6.6 shows that the FIT in Zurich and Lausanne depend for 86.8% on federal funding. Most of the federal funding consists of institutional funding (72.6% of the total budget). The amount of institutional funding that is given to the FIT Domain is negotiated directly with the federal government and included in the four year research and higher education budget. The FIT Board allocates the budget among the two schools and four research institutes. This is based on historical considerations. Although the relationship between the federal government and the FIT Domain is ruled by contracts, there is no direct link between performance and the amount of institutional funding.[76] The FIT are highly autonomous with regard to how to spend the institutional funding.

Federal project funding (14.2% of the total budget) is distributed mainly through the SNSF and the CTI. The remainders of the budget come from tuition fees and private funding.

[71] Source: SNSF website.
[72] Source: SNSF Annual Report 2009 and Annual Report 2012.
[73] Source: European Commission, National report on joint and open programmes Switzerland.
[74] Source: OPET, Presentation by Dr. Ingrid Kissling-Näf, Swiss Innovation Promotion Agency CTI.
[75] Source: European Commission, National report on joint and open programs Switzerland.
[76] Source: Lepori, B. (2007). 'Diversity in the Swiss Higher Education System'. In Bonaccorsi, A. and Daraio, C. (Editors), 'Universities and Strategic Knowledge Creation: Specialization and Performance in Europe' (pp. 209-240).

Table 6.6 Sources of funding for higher education institutions, Switzerland, 2010/2012

	Institutes of technology*	Cantonal universities**
Total annual funding	1,885	3,303
	Source of funding	
Total federal funding	**86.8**	**25.7**
Direct federal funding	72.6	14.9
SNSF/CTI/EU	14.2	10.8
Cantonal funding		**66.1**
Direct cantonal funding		55.5
Inter-cantonal agreements		10.6
Third-party funding	**13.2**	**8.2**
Total	100	100

Note: The amounts are in millions of euros (current prices). The amounts of funding also include funding for teaching.
* Year: 2012. Source: Annual reports of ETH Zurich and EPFL. 2012 average exchange rate CHF/EUR: 0.830.
** Year: 2010. Source: Federal Department of Economic Affairs, 'Federal and Cantonal Funding in the Education, Research and Innovation Sector 2004-2016'. 2010 average exchange rate CHF/ EUR: 0.725.

The funding of cantonal universities is a shared responsibility of both the federal government and cantonal governments. Project funding from the federal government comes through the SNSF and the CTI (10.8%). The federal government provides additional direct funding as determined in the *Universitätsförderungsgesetz* (UFG). The UFG consists of three parts, of which the basic contributions are the most important[77]:

- Basic contributions
  The aggregate amount is determined in the four year research and higher education budget and is fixed. The distribution of this fixed amount among the cantonal universities is based on indicators: 70% is based on collected student tuition fees (60% for domestic students, 10% for foreign students). The remaining30% is based on research indicators (18.5% for SNSF projects, 1.5% of CTI projects, 5% for EU projects and 5% for private funding).
- Investment contributions
  When investments in buildings and research machinery amount more than, respectively, 1.9 million and 0.19 million euros (3 million and 0.3 million CHF), the cantonal university is eligible for federal funding (up to 30%).
- Additional project funding
  University cooperation projects and projects of national importance are qualified for additional federal funding. The federal government provides funding for up to 50% of the project costs. The remaining part must be financed by the private sector.

The cantonal universities mainly depend on funding from the cantons (66.1%). A special feature of the Swiss higher education funding system is the *Interkantonalen Universitätsvereinbarung* (IUV) which guarantees that students from all cantons can choose freely between the different Swiss universities. The canton from which the student originates pays, as defined in the IUV, a fixed amount to the university where the students chooses to study. These inter-cantonal funding agreements amount to 10.6% of the total budget. The larger part of cantonal funding consists of direct funding (55.5%) which is often contract-based and directly negotiated with the political authorities.[78] [79]

[77] Source: Finanzierungsmodelle universitärer Lehre: Internationale Beispiele, Erfahrungen und mögliche Strategien für Österreichs Universitäten, 2011.
[78] Source: A. Loprieno, Finanzierungsmodelle an Schweizer Universitäten, 2009.

FIT Domain's research organizations

Together with the FIT in Zurich and Lausanne, four federal research institutes form the Swiss FIT Domain. The FIT Domain is governed by the FIT Board. The FIT Domain's research institutions are often seen as higher education institutions because they are involved with teaching ans also cooperate closely with the federal institutes of technology. Below, we will elaborate on the four federal research institutes.

Paul Scherrer Institute (PSI)

The PSI focuses on natural sciences and engineering by means of both fundamental and applied research. Important research fields are matter and material, people and health, and energy and environment. The annual budget of PSI amounted 280 million euros (337.2 million CHF) in 2012, of which 73.8% was contributed by the federal government. The remainders of PSI's budget came from third-party funding.[80]

Swiss Federal Institute of Aquatic Science and Technology (EAWAG)

The research areas of EAWAG can be divided into three main areas: water for human welfare, water for the functioning of the ecosystem, and, lastly, how these topics form a conflict of interest. In 2012, EAWAG had a budget of 52 million euros (71.9 million CHF), of which 76.4% was funded by the federal government. 23.6% came from third-party funds.[81]

Swiss Federal Laboratories for Materials Science and Technology (EMPA)

EMPA focuses on applied research in the fields of nanostructured materials, natural resources and pollutants, sustainable built environment, health, and energy. EMPA's annual budget in 2012 amounted 132.8 million euros (159.8 million CHF). The federal government funded 61.2%, whereas third parties funded the remaining part.[82]

Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)

The research topics of the WSL are biodiversity, landscape development, management of natural hazards, sustainable use of natural resources, and forest ecosystems. The annual budget of WSL amounted 65 million euros (79.4 million CHF) in 2012. About 69.1% of the annual budget came directly from the federal government in the form of institutional funding, whereas 22.1% came in the form of project funding. The remaining 8.8% of the annual budget was collected from third-party sources.[83]

Public research organizations

Compared with other OECD countries, the role of PROs in Switzerland is very limited (not accounting for the private sector that performs in-house R&D activities). PROs account for only 3% of publicly funded R&D activities. Examples of PROs outside the private sector are the three federal agricultural research stations and the Swiss National Bank.

Agroscope is the umbrella organization for the three3 federal agricultural research stations: Agroscope Changins-Wädenswil (ACW), Agroscope Liebefeld-Posieux (ALP), and Agroscope

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[79] Source: Lepori, B. (2007). 'Diversity in the Swiss Higher Education System'. In Bonaccorsi, A. and Daraio, C. (Editors), 'Universities and Strategic Knowledge Creation: Specialization and Performance in Europe' (pp. 209-240).
[80] Source: PSI website.
[81] Source: EAWAG website.
[82] Source: EMPA website.
[83] Source: WSL website.

Reckenholz-Tänikon (ART). These research stations aim at developing an efficient agrarian sector.

6.3 Other characteristics

6.3.1 Advisory organizations

Swiss Science and Technology Council (SSTC)
The SSTC is the advisory body of the Federal Council (head of the Swiss government) with respect to education, research and innovation. It provides recommendations and evaluates the current policies.

Swiss Council for Educational Research (CORECHED)
Vocational education falls under the responsibility of the federal government. Switzerland has therefore succeeded in developing a national strategy for this kind of education. Since the higher education institutions fall under the responsibility of the different cantons, a nationwide strategy for universities (of applied sciences) is less self-evident. Due to this lack of central coordination, the CORECHED was created in 1991. This council analyzes and documents the state of the Swiss educational research landscape. Furthermore, it is responsible for coordinating educational research policies.

6.3.2 Monitoring

Since October 2001, the *Organ für die Akkreditierung und Qualitätssicherung der Schweizerischen Hochschulen* (OAQ) has been charged with assuring quality in teaching and research at Swiss higher education institutions. Only accredited universities will receive financial aid from the federal government and will be allowed to carry the title of 'university'.

The Swiss Science and Technology Council and the Swiss National Science Foundation are important organizations for evaluating science. The SSTC mainly evaluates independent research institutions and infrastructure organizations which receive federal funding, whereas the SNSF monitors scientific quality in large research initiatives (also those that are not directly funded by the SNSF).[84] [85]

6.3.3 Research output

Table 6.7 summarizes some of the main R&D output indicators. This table shows that Switzerland has the highest PhD graduation rate (mainly due to successfully attracting foreign doctoral candidates) but a relatively low number of researchers per 1,000 labor force. On the other hand, Switzerland is the most productive country in terms of publications and citations. The difference with Denmark, that is second-best in research productivity per 1,000 inhabitant, is 1.2 publications and 5.5 citations. The difference in terms of productivity per 1 fte researcher gives a slightly different picture. The Netherlands then becomes the second-ranked country with a difference of 0.5 publications and 2.3 citations.

[84] Source: SSTC website.
[85] Source: SNSF website.

Table 6.7 R&D output and personnel indicators, Switzerland

Country	# of researchers (fte) per 1,000 labor force	PhD graduation rate (excl. foreign students)	# of publications per 1,000 inhabitants (1 fte researcher)	# of citations per 1,000 inhabitants (1 fte researcher)
Netherlands	6.1	1.8 (1.2)	2.8 (0.9)	10.5 (3.3)
Belgium	8.3	1.5 (1.1)	2.4 (0.6)	8.1 (2.2)
Germany	7.9	2.7 (2.3)	1.8 (0.4)	5.3 (1.3)
Switzerland	**5.4**	**3.2 (1.7)**	**4.4 (1.4)**	**18.1 (5.6)**
Denmark	13.1	2.2 (1.7)	3.3 (0.5)	12.6 (1.9)
UK	8.3	2.4 (1.3)	2.4 (0.6)	7.3 (1.8)
US	9.1	1.7 (1.3)	1.8 (0.4)	5.2 (1.1)
Average	*8.3*	*2.2 (1.5)*	*2.7 (0.7)*	*9.6 (2.5)*

Note: All figures reflect the situation as in 2011, except for the number of researchers in Germany (2010), Switzerland (2008), and US (2007). Sources: OECD and Scimago. *The PhD graduation rate is measured as a percentage of the relevant age cohort.

6.4 Distinguishing features

Funding of higher education is complicated in Switzerland. It is organized in a multilevel structure which makes evaluating its funding policy difficult. The Swiss structure is even more complex than in Germany because of the differentiation between federal and cantonal universities. Furthermore, the cantons have agreed on the *Interkantonalen Universitätsvereinbarung* (IUV) which comprises an intercantonal financial compensation scheme. This is an aspect of university funding that we do not observe in the other countries in this analysis.

Institutional funding of higher education is in general determined by direct negotiations with the federal and/or cantonal government. The amount of funding is therefore highly dependent on the bargaining power of the university. Lepori (2007) points out that it is not by chance that universities from small cantons have a more differentiated source of income. Also, funding of higher education in Switzerland is, compared to other countries in this analysis, heavily determined on historical grounds, which ensures a less volatile funding stream.

An important aspect of the Swiss research system is the dominant position of the higher education sector. In our analysis, only Denmark spends a larger share of both GDP and public funding on the higher education sector. The Swiss higher education institutions spend about 56% of their total budget on R&D activities, whereas for the other countries in our analysis this figure does not exceed 40%.[86] Together with the relatively high PhD graduation rate, this illustrates the relative importance of R&D within the Swiss higher education sector.

Furthermore, the Swiss R&D landscape is characterized by a high degree of internationalization. Swiss multinational companies perform more R&D abroad than in Switzerland, which is an extraordinary figure compared to other countries.[87] This highly internationalized business sector, which spends about three times more on R&D than the public sector, is the reason that Switzerland spends almost 3% of its national income on R&D. This high degree of internationalization is also reflected by the large share of foreign PhD graduates (almost 50%).

[86] Source: OECD data.
[87] Source: OECD Statistics, Outward activity of multinationals - Share in national total (manufacturing).

7 Denmark

7.1 Introduction

7.1.1 Goal of national science policy

In 2006, the Danish government presented the Danish Globalization Strategy. This Strategy lists four main objectives aimed at increasing Denmark's international competitiveness: (1) world class educational system, (2) strong and innovative research, (3) more entrepreneurs, and (4) more innovation and change. The second objective is especially relevant when analyzing public R&D funding. The Danish government has developed several initiatives to achieve this second goal. We present the most important ones below:

- Institutional funding of universities must be related to the quality of research.
- University education is to be evaluated by an external accreditation institution.
- The number of PhD scholarships are to be doubled.
- Research councils must give priority to large investments in research infrastructure.
- A larger part of public funding is to be allotted to strategic (i.e. politically determined) research.
- 50% of public R&D funding must be competitive.
- Public R&D funding must amount to 1%, whereas private R&D funding must amount to 2% of GDP.

In 2010, the Danish government published the Denmark 2020 strategy.[88] The overall aim of this strategy is to be among the world's ten wealthiest countries by 2020. In order to achieve this target, the Danish government has developed nine goals. One of these goals is to have at least one Danish university to be in Europe's top ten and to improve the international ranking of all Danish universities. The Danish government has announced in 2010 to do the following:

- Develop high-quality education programs that match the needs of society.
- Maintain high level of ambition for research and innovation.
- Strengthen basic research (by increasing the support for Centers of Excellence).
- New matching fund (focus on cooperation between public and private institutions by rewarding public institutions that succeed in attracting private research funds).
- Internationalization of universities (by prioritizing funds for universities that participate in international partnerships and networks).

The ambitions from the 2006 Globalization Strategy as well as the Denmark 2020 Strategy are still present under the new Danish government which was installed in October 2011. However, the focus has changed towards a more strategic and coherent society view on the research, development and innovation policy areas, cf. the National Innovation Strategy from December 2012. A good example of this change of focus is the reorganization of the Ministry of Science, Technology and Innovation to a strengthened Ministry of Science, Innovation and Higher Education.

[88] Source: Source: Danmark 2020. Viden>Vækst>Velstand>Velfærd. http://www.stm.dk/publikationer/arbprog_10/index.htm#Regeringens_10_mål_for_2020

The Danish government's innovation strategy[89] focuses on three areas:

1. Innovation is to be driven by societal challenges.
2. More knowledge is to be translated to value.
3. Education has to increase the innovation capacity.

The innovation strategy contains 27 policy initiatives regarding research, innovation and education. It focuses on a better knowledge exchange between companies and knowledge institutions, across borders and between the public and private sector. The innovation strategy should be seen in connection with the government's other initiatives to secure growth and to future-proof the Danish economy. The strategy is part of the collective reform package presented by the government "Denmark at work – challenges for the Danish economy towards 2020".

7.1.2 Basic figures

In 2011, the Danish government spent 0.9% of GDP on R&D and the total R&D expenditures amounted to 3.0% of GDP. Hence, Denmark meets the objectives as defined in EU2020 almost perfectly (national R&D expenditures should amount to 3% of GDP, of which two-thirds ought to be privately funded).

Table 7.1 summarizes which sectors perform and fund R&D activities. Relative to other OECD countries, PROs play a marginal role within the Danish R&D landscape (2.2% of total R&D activities and 6.0% percent of public funding). Table 7.2 shows how the public R&D funds are divided among the different performers of R&D. We observe that the higher education institutions consume by far the largest part of public funding, whereas the remaining budget is almost equally divided between PROs and the business sector.

Table 7.1 R&D funding, Denmark, 2011

Source	Destination				
	Government	Higher education	Business	PNP	Total
Total	156.1	2,258.3	4,715.6	26.9	7,156.9
Percentage of GDP	0.1	0.9	2.0	0.0	3.0
	Percentage of funding				
Government	79.4	79.9	2.8	14.6	28.9
Higher education	0.0	0.0	0.0	0.0	0.0
Business	3.4	3.4	89.6	15.9	60.3
PNP	8.6	9.7	0.3	61.7	3.6
Foreign	8.6	7.0	7.3	7.8	7.2
Total	100.0	100.0	100.0	100.0	100.0

Note: The amounts are in millions of euro (current prices). Source: Eurostat.

[89] Source: Denmark – a nation of solutions. Available: http://fivu.dk/en/publications/2012/denmark-a-nation-of-solutions

Table 7.2 Government funding by sector, Denmark, 2011

	Government	Higher education	Business	PNP	Total
Amount	124.0	1,804.4	133.9	3.9	2,066.2
Percentages	6.0	87.3	6.5	0.2	100.0

Note: The amounts are in millions of euros (current prices). Source: Eurostat.

Below we will give a brief overview of some Danish R&D input indicators. We can see from Table 7.3 that Denmark spends 0.86% of GDP on public R&D funding, which is a large share compared to the other countries in this analysis. Almost all of this spending goes to the higher education section and only a small part goes to PROs. Switzerland is the only country that spends a smaller share of public R&D funding on PROs. This relatively low share is due to the fact that many research institutes have merged with the higher education sector. Furthermore, a third of the public funds are allocated on a project basis which is a relatively low share. In addition, only 1% is allocated through performance indicators. This implies that most of the Danish public R&D budget is allocated on historical considerations.

Table 7.3 Publicly funded R&D input indicators, Denmark

		Destination		Allocation Mechanism	
	% of GDP	PROs (%)	Higher Education (%)	Project-based (%)	Performance-based (%)
Netherlands	0.72	22	72	26	25
Belgium	0.52	19	63	60	23
Germany	0.86	41	49	31	11
Switzerland	**0.66**	**3**	**85**	**25**	**9**
Denmark	0.86	6	87	32	1
UK	0.54	23	56	62	28
US	0.89	36	31	100	0
Average	*0.72*	*21*	*63*	*48*	*14*

Note: All figures reflect the situation as in 2011 except for Switzerland (2008). The calculation of the allocation mechanism variables can be found in Chapter 12. Sources: Eurostat, Van Steen (2012), and country reports.

7.2 General information

7.2.1 Government funding of R&D

The Ministry of Science, Innovation and Higher Education is the administrative body of the Danish government that deals with PROs, universities, and high-technology business research. This government body distributes most of the public R&D funds and is also engaged in promoting cooperation between academic institutions and the business sector.

The Ministry of Business and Growth is engaged in promoting innovation at the business sector. This ministry is the second most relevant administrative body when it comes to public R&D funding, although far below the relevance of the Ministry of Science, Innovation and Higher Education. Most of the remaining ministries have a relatively minor R&D budget and have a special focus on their particular policy areas.

Table 7.4 shows us how the R&D-expenses within the public sector (both government and higher education) are distributed among the different fields of research. We can see from the table that more than one third of the expenses is spent on health sciences.

Table 7.4 R&D-expenses in the public sector by field by research, Denmark, 2011

Field of research	Amount	Percentage
Natural sciences	487.8	20.0
Technical sciences	329.4	13.5
Health sciences	854.3	35.0
Agricultural and veterinary sciences	164.6	6.8
Social sciences	418.4	17.2
Humanities	183.0	7.5
Total	2,437.5	100

Note: The amounts are in millions of euro (current prices). 2011 average exchange rate DKK/EUR: 0.134. Source: Statistics Denmark website.

7.2.2 Intermediary organizations

The funding landscape in Denmark will be changed in 2014. The most important change is that the three largest funding institutions will be merged into the Danish Innovation Fund. This new council will become the foundation for strategic research, advanced technology and innovation. The major purposes of each council are maintained in the amalgamated council but now with an aim of hindering overlap en being able to support more massively on targeted issues.

The councils that will be merged are the Danish Council for Strategic Research (DSF), the Danish National Advanced Technology Foundation (HTF) and the Danish Council for Technology and Innovation (RTI). Below we will describe the main funding elements of the DSF and HTF but do not provide any further details on RTI.

The following is a presentation of the council structure as it is observed in 2012.

Danish Council for Strategic Research(DSF)
This council promotes and funds research areas based on political thematic priorities (top-down principle). Examples of these fields of research are nanotechnology, food, and energy. Moreover, the Council promotes collaboration between public and private research institutions. In 2011, the DSF granted a total of 113.2 million euros (845 million DKK).

The Council has three different funding instruments at its disposal: research centers, research alliances, and research projects. All instruments are characterized by relatively large grants and relatively long durations. The grants are given after research quality judgment by peer review and expert panels. For more information, see Appendix 7A.

The Danish National Advanced Technology Foundation(HTF)
The HTF supports research based on collaborations between public and private institutions. This foundation is politically determined and has a special focus on promoting research and innovation and small and medium-sized enterprises. It provides public funding for up to 50% of the expected project costs. The remainders must be collected from private funds or financed by the participating firms.

Besides the three funding institutions mentioned above, there are two other important players. These are the Danish National Research Foundation and the Danish Council for Independent Research. They do not only provide research funds but the overall organization of Danish research is also under the auspices of the these two bodies. In 2014, the research performance in Denmark will be discussed following evaluations of the two bodies during 2014.

Danish National Research Foundation
The Danish National Research Foundation funds research activities that are initiated by the academic community. Between 2008 and 2012, it had on average an annual budget of about 54 million euros (400 million DKK).

The Centers of Excellence are the main funding mechanism. These centers may be established within all fields of research and there is no well defined formula for how it should be organized. The Danish National Research Foundation defines a Center of Excellence as follows: "units based at research institutions (the vast majority at universities) sharing a common idea or vision and an overall and clearly defined set of research objectives." The centers are based on the bottom-up principle and thus rely on the ideas of independent researchers. Funding is given for five years with a possibility for prolongation for another give years after a peered review. Hereafter, funding stops and the Centers need to rely on other sources of funding or merge into the university structures.

Other funding mechanisms of the Danish National Research Foundation mainly focus on promoting international collaboration. Examples are the Danish-Chinese research centers, Danish-Indian Collaboration Program, and Danish-French collaboration Program.

Danish Council for Independent Research
The Danish Council for Independent Research is split into five sub thematic areas and follows the bottom-up principle within each area. Table 7.5 gives an overview of the five different fields and their size in terms of monetary terms. It promotes and funds independent research based on the researchers' own ideas, i.e. the council does not focus on specific research fields that are selected by the government. In 2012, the research council granted a total of 168 million euros (1,253 million DKK). They received however more than seven times as much grant applications (in monetary terms). Table 7.5 shows how the research council's budget was distributed between the different fields of research. The single grants decisions are decided in the thematic research councils by peer reviews and expert panels.

Table 7.5 Grants of Danish Council for Independent Research by field of research, 2011

Field of research	Amount	Percentage
Natural sciences	36.6	22.7
Technical and production sciences	41.8	25.9
Health sciences	41.3	25.6
Social sciences	17.6	10.9
Humanities	24.0	14.9
Total	2,437.5	100

Note: The amounts are in millions of euro (current prices). 2011 average exchange rate DKK/EUR: 0.134. Source: Danish Council for Independent Research, Annual report 2011.

7.2.3 Research performing organizations

Higher education

The higher education system in Denmark consists of eight universities that focus both on education and research. Prior to 2007, there were 12 universities but this number was reduced to eight due to the University Act (2003) which resulted in a merging process between universities and government research institutes. The purpose of the merging process was more education, greater international impact of research, more innovation and collaboration with industry, the attraction of more research funding from the EU, and continued competence in the area of government commissioned research.[90]

Beside the research-performing universities, the Danish higher education system consists of multiple non-research performing universities and universities of applied sciences ('University Colleges'). Recently, some of these applied universities have merged with universities. The majority, however, has merged into regional multidisciplinary applied universities with separated locations. Although they have received a research mandate in recent years, they are not allowed to educate PhDs. They can apply for research grants, usually through knowledge centers, on the same conditions as university researchers. Knowledge centers carry out interdisciplinary development activities by cooperation between research universities and universities of applied sciences.[91] However, the contribution of the applied universities to research within the higher education system is marginal. Hence, in this report we will mainly focus on the eight traditional research-performing universities.

Danish universities enjoy high financial autonomy because the institutional funding is not earmarked. Although funding of education and research is separated in Denmark, the universities are at least theoretically free to allocate the resources between education and research purposes. In practice, the flexibility and possibilities for cross subsidization are scarce.

The education part of public funding is based on a 'taximeter system'. This system is highly output-oriented since it links a high share of the amount of operational grant to the number of students who pass an exam. The tariff per passed exam varies substantially between different fields of education and is based on historical considerations.[92] Danish higher education institutions do not charge any tuition fees for nationals, Nordic and EU citizens. However, admission is not necessarily free but decided by budget and resource constraints.

The allocation of resources for research takes place through two channels. The first channel is through institutional funding. The Danish government allocates this funding directly to the universities. The level of institutional funding is calculated on an incremental basis and is therefore highly based on historical grounds (98% is based on previous year's budget). Each year, 2% of the research funding is retained and redistributed among the universities. Until 2010, the redistribution was based on a 50-40-10 ratio. That is, 50% was based on the level of educational funding, 40% was based on the amount of external research funding, and 10% was based on the number of PhD graduates.[93] In 2009, the Danish parliament agreed to include bibliometrics as a fourth indicator. Since 2010, this indicator has been introduced gradually at the expense of the weighting for external research funding. An evaluation of this change in research funding parameters took place in 2013.[94]

The second channel consists of external research funds. This includes project funding from the government as well as indirect government funding through research councils, subsidies from the EU, private funds and donations. According to CHEPS (2008), the competitive part of public research funding amounted to 40% of total public research funding for universities.

[90] Source: OECD, Public Research Institutions: Mapping Sector Trends, 2011.
[91] Source: E. de Weert & M. Soo, 2009. 'Research at Universities of Applied Sciences in Europe. Conditions, Achievements and Perspectives'.
[92] Source: OECD, 2006. 'Funding Systems and Their Effects on Higher Education Systems, Country Study - Denmark'.
[93] Source: OECD, 2006. 'Funding Systems and Their Effects on Higher Education Systems, Country Study - Denmark'.
[94] Source: K. Schmidt. 'University funding reforms in the Nordic countries'.

Public research organizations

The importance of Public PROs within the Danish R&D landscape has been substantially reduced since the University Act in 2003. This Act ensured a merging process between public universities and government research institutes. Due to this merging process, a considerable amount of the government R&D expenditures was shifted from the PROs to the higher education sector. Table 7.6 illustrates this structural change in the Danish R&D landscape between 1999 and 2011.

Table 7.6 R&D expenditures of different performers as a share of total R&D expenditures, Denmark, 1999-2011

Year	Government	Higher education	Business	PNP	Total
1999	15%	19%	65%	1%	100%
2011	2%	32%	66%	0%	100%

Source: Eurostat.

7.3 Other characteristics

7.3.1 Advisory organizations

Danish Research Coordination Committee
The aim of the Danish Research Coordination Committee is to promote coordination between research councils, intermediary organizations that fund R&D (see next section) and the performers of R&D in Denmark. This committee stopped its activities in 2010/2011.

Danish Council for Research Policy
The Danish Council for Research Policy includes both members from higher education institutions and the private sector. It advises the government and parliament on research at the general level. They evaluate Denmark's position in international research and provide advice with respect to research funding and major national and international research initiatives. Their present general recommendation is that decision makers follow the following signposts:

- The high international quality and level of Danish research is to be maintained and developed, and framework conditions should be designed with this in mind.
- The primary focus should be on the functionality and impact of the instruments used rather than on the organization of bodies and systems.
- The research and the results achieved are to create value in society.

7.3.2 Monitoring

As discussed, public funding of the education part of the Danish higher education sector is very much based on output indicators (taximeter system). The Danish Ministry of Education (before 2011) has acknowledged that the focus on output may have a negative effect on quality. To ensure quality the Ministry of Education has established the Danish Evaluation Institute (EVA). EVA is an independent body that evaluates the quality of higher education (universities of applied sciences). On top of this, external examiners play an important role in monitoring higher education.

At the universities, ACE Denmark is the accreditation institution where new educations are approved and where existing educations are evaluated. From 2014 and 2015 onwards, the accreditations system will change from individual education approval to institutional accreditation with re-accreditation of the institutions, i.e. universities, on a regular basis.

Evaluations of research programs on a regular basis are becoming a common feature in Denmark, after critique from the national parliament auditors (*statsrevisorerne*). The Danish government conducts now both more systemic evaluations and evaluations for specific fields of research in addition to the individual program evaluations. Examples are the evaluation of the Danish university sector in 2009 and the evaluation of PhD education in 2006.[95]

7.3.3 Research output

Table 7.7 shows that Denmark has substantially more researchers per 1,000 labor force than any other country in our analysis. The explanation for this large difference in number of researchers can be found in the fact that the Danish business sector employs about 8.1 researcher per 1,000 labor force. It is also interesting to see that this relatively high number of researchers does not correspond to a relatively high PhD graduation rate.

Denmark is among the most productive countries when it comes to publications and citations per 1,000 inhabitants. Only Switzerland performs better with respect to publications and citations per 1,000 inhabitants. Comparing the publications and citations per 1 fte researcher shows a different picture as Denmark then performs below average.

Table 7.7 R&D output and personnel indicators, Denmark

Country	# of researchers (fte) per 1,000 labor force	PhD graduation rate (excl. foreign students)	# of publications per 1,000 inhabitants (1 fte researcher)	# of citations per 1,000 inhabitants (1 fte researcher)
Netherlands	6.1	1.8 (1.2)	2.8 (0.9)	10.5 (3.3)
Belgium	8.3	1.5 (1.1)	2.4 (0.6)	8.1 (2.2)
Germany	7.9	2.7 (2.3)	1.8 (0.4)	5.3 (1.3)
Switzerland	5.4	3.2 (1.7)	4.4 (1.4)	18.1 (5.6)
Denmark	**13.1**	**2.2 (1.7)**	**3.3 (0.5)**	**12.6 (1.9)**
UK	8.3	2.4 (1.3)	2.4 (0.6)	7.3 (1.8)
US	9.1	1.7 (1.3)	1.8 (0.4)	5.2 (1.1)
Average	*8.3*	*2.2 (1.5)*	*2.7 (0.7)*	*9.6 (2.5)*

Note: All figures reflect the situation as in 2011, except for the number of researchers in Germany (2010), Switzerland (2008), and US (2007). Sources: OECD and Scimago. *The PhD graduation rate is measured as a percentage of the relevant age cohort..

7.4 Distinguishing features

The main distinguishing feature of Denmark is that almost all public research is performed by universities. According to Eurostat data, Switzerland has an equally small sector of PROs but it must be noted here that the Swiss federal research institutes are officially seen as higher education which makes direct comparisons difficult.

Similar to other Scandinavian countries, Denmark is characterized by a relatively large number of researchers. Besides providing tax deductions for R&D personnel, Denmark has also implemented measures aimed at improving employment in research.[96]

As discussed, Denmark does not excel with regard to the PhD graduation rate. Denmark has however created a stimulating environment for doctoral candidates. The Netherlands and

[95] Source: METRIS.
[96] Source: ERAWATCH, 2010. 'Research Inventory Report For: Overview across EU countries.

Denmark are the only European country that give doctoral candidates the status of employee which gives them rights with respect to healthcare, social security and pension.[97] Furthermore, Denmark tries to actively match the PhD training to industry needs.[98]

[97] Source: EUA, Doctoral Programmes in Europe's Universities: Achievements and Challenges.
[98] Source: ERAWATCH, 2010. 'Research Inventory Report For: Overview across EU countries.

Appendix 7A

Table 7A.1 Research funding programs in Denmark as found in 2011

Program	Funded by	Target group	Support	Duration
Individual postdoc grants	The Danish Council for Independent Research	PhD		
Sapere Aude DFF- Research Talent	The Danish Council for Independent Research	PhD	0.07 million	
Sapere Aude DFF- Starting Grant	The Danish Council for Independent Research	Young researchers	0.65 million	4 years
Sapere Aude DFF- Advanced Grant	The Danish Council for Independent Research	Elite researchers	1.1 million	5 years
Research Project 1	The Danish Council for Independent Research	Minimum requirement: completed a postdoc or assistant professorship	0.24 million	3 years
Research Project 2	The Danish Council for Independent Research	Research projects with several researchers	0.24 - 0.6 million	2-4 years
Centers of Excellence - Fundamental Research Centers	Danish National Research Foundation		2.6 - 8.0 million	5 years
Danish-Chinese Research Collaborations	Danish National Research Foundation		1.34 - 2.0 million	3 years
Projects	Danish National Advanced Technology Foundation		0.67 - 4.0 million	2-4 years
Platforms	Danish National Advanced Technology Foundation		4 - 20 million	3-5 years
Strategic Research Centers	The Danish Council for Strategic Research		>4 million	5-7 years
Strategic Research Alliances	The Danish Council for Strategic Research		2.0 - 2.68 million	5 years
Strategic Research Projects	The Danish Council for Strategic Research		1.34 million	3-5 years
Spir	The Danish Council for Strategic Research		8 million	5-7 years

Note: Amounts are in millions of euro. 2011 average DKK/EUR exchange rate: 0.134.
Sources:
http://www.science.ku.dk/funding/dff/open_calls/fsefall2013/
http://www.science.ku.dk/funding/gf/bevtyper/
http://www.science.ku.dk/funding/hoejtek/bevtyper/
http://www.science.ku.dk/funding/dsf/

8 United Kingdom

8.1 Introduction

8.1.1 Goal of national science policy

The Science and Innovation Investment Framework 2004-14 of the UK government lays out the main goals of UK science policy. Among the salient features is a desire to increase its knowledge intensity (R&D as a percentage of GDP) from 1.9% in 2004 to 2.5% by 2014 and to target support on key emerging technologies.[99] Promoting business R&D is seen as key to obtain this expenditure target. That is, the government aims to increase business investment in R&D as a share of GDP from 1.25% towards a goal of 1.7% over the course of the decade. The idea is to increase business engagement in UK science and to better assimilate new scientific knowledge into new technology. This seems to be different than the previous goal of the UK research system as an instrument of wealth creation and enhancing the quality of life presented in a key white paper "Realizing Our Potential" (OST Report[100], 1993).

More recently (in November 2011) Britain's Prime Minister David Cameron declared that deficit reduction was "line one, clause one and part one" of his government strategy and that "everything else was extra". This included raising the Value Added Tax (VAT) and also involved a reduction in public service spending by 25%. However, such was the 'importance' of spending for science that the science budget was ring-fenced till the financial year 2015-2016 to4.6 billion pounds.[101]

8.1.2 Basic figures

Table 8.1 provides a snapshot of the source and destination of UK research funds in 2011. We observe that 1.8% of UK's GDP goes to R&D activities of which about 64% is performed by the business sector, followed by the higher education sector which performs around 26% of all R&D activities. From Table 8.2, we can see that 55.7% of the public R&D budget goes to the higher education sector and about 19.3% of public funds go to businesses in the form of R&D subsidies.

The 2011 figures show that the UK has not kept up in its goal of increasing its total R&D expenditures to 2.5%. In fact, the total R&D expenditures as a percentage of GDP have been rather stable at 1.8% in recent years. This might be due to that fact that business R&D as a percentage of GDP - the channel that was thought to bring about this increase - has in fact decreased to 1.1% of GDP.

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[99] One of the indentified 'key technology' was research on graphene (crystalline from of carbon). This material is predicted to have major industrial applications after two professors at the University of Manchester won the 2010 Nobel Prize in Physics "for groundbreaking experiments regarding the two-dimensional material graphene".

[100] Office of Science and Technology (OST) was absorbed into Department for Innovation, Universities and Skills (DIUS) in 2007 which was later absorbed in 2009 by an overarching ministry Department for Business, Innovation & Skills (BIS) that coordinates both science and innovation policy.

[101] Other ring-fenced items include spending to Department of Food and Rural Affairs and National Health Service. It should be noted, however, that the inflation will erode the real value of the pound hence it is effectively a budget cut.

Table 8.1 R&D funding, United Kingdom, 2011

Source	Destination				
	Government	Higher education	Business	PNP	Total
Total	2,706.3	8,211.3	20,057.8	571.6	31,547.0
Percentage of GDP	0.2	0.5	1.1	0.0	1.8
	Percentage of funding				
Government	82.1	65.1	9.3	31.1	30.4
Higher education	0.6	4.1	0.0	2.7	1.2
Business	9.8	4.0	68.7	17.2	45.9
PNP	2.1	13.8	0.6	33.2	4.8
Foreign	5.4	13.0	21.4	15.8	17.7
Total	100.0	100.0	100.0	100.0	100.0

Note: The amounts are in millions of euro (current prices). Source: Eurostat.

Table 8.2 Government funding by sector, United Kingdom, 2011

	Government	Higher education	Business	PNP	Total
Amount	2,222.6	5,348.5	1,858.0	177.6	9,606.8
Percentages	23.1	55.7	19.3	1.8	100.0

Note: The amounts are in millions of euros (current prices). Source: Eurostat.

Table 8.3 gives a brief overview of some UK R&D input indicators. The percentage of GDP that is spent on public research funding is low compared to the other countries. In fact, Belgium is the only country that has a lower percentage. The table also shows that the importance of the higher education sector in terms of public research is slight below average whereas the importance of publicly funding PROs is slightly above average. Moreover, a relative high percentage of public R&D is allocated based through projects and performance indicators. In total, 90% of public R&D funding is allocated in such a way. These allocation figures are comparable to the figures of Belgium. This high percentage of ex-ante and ex-post funding imply that there is hardly any fixed funding in the UK research funding system. This chapter will shed more light on these numbers.

Table 8.3 Publicly funded R&D input indicators, United Kingdom

		Destination		Allocation Mechanism	
	% of GDP	PROs (%)	Higher Education (%)	Project-based (%)	Performance-based (%)
Netherlands	0.72	22	72	26	25
Belgium	0.52	19	63	60	23
Germany	0.86	41	49	31	11
Switzerland	0.66	3	85	25	9
Denmark	0.86	6	87	32	1
UK	**0.54**	**23**	**56**	**62**	**28**
US	0.89	36	31	100	0
Average	*0.72*	*21*	*63*	*48*	*14*

Note: All figures reflect the situation as in 2011 except for Switzerland (2008). The calculation of the allocation mechanism variables can be found in Chapter 12. Sources: Eurostat, Van Steen (2012), and country reports.

8.2 General Information

8.2.1 Government funding of R&D

In the UK, the ministry responsible for the disbursement of research funds is the Department of Business and Innovation and Skills (BIS). This ministry was formed after it absorbed the Department for Innovation, Universities and Skills (DIUS) and the Office of Science and technology (OST).in 2009. It forms an overarching ministry of Department for BIS that coordinates both science and innovation policy.[102]

There are two main channels through which government funds are distributed for science in the UK. The first are the UK-wide Research Councils that provide grants for specific projects as per applications by individual scientists, much like the National Science Foundation in the US and Netherlands Organization for Scientific Research (NWO) in the Netherlands. The second not-so-common method of allocating research funds are the county-side Funding Councils. This involves an evaluation of higher education institutes after which funding is distributed to top performing institutions. These evaluation are referred to as Research Assessment Exercise (RAE) or more recently, the Research Excellence Framework (REF). This results in granting institutional funding to higher education institutes to support research infrastructure and allows individual universities to conduct research of their own choosing.[103] This bimodal funding through peer review of individual grants by Research Councils and a research evaluation of individual universities by Funding Councils is termed the "Dual Support System" in the UK.

Table 8.4 gives the breakdown of government research funding. The Research Councils received 33% of total government research funds in 2011 whereas the Funding Councils received 23% of the total government R&D budget. Additionally, around 24% of research funds goes into civil government departments or research institutes and 13% is spent on defense research. Over the last decades, the shares of these categories in public R&D funding has varied. Funding to Research Councils and Funding Councils has increased over the past decade, though more sharply for the Research Councils. On the other hand, funding to Civil Departments has largely remained stable and R&D spending on defense has decreased.

Table 8.4 Research funding of United Kingdom government

	2011	% Of total
Research Councils	3286	33
Funding Councils	2259	23
Civil Departments	2389	24
Defense	1306	13
EU R&D budget	629	6
Grand Total	9868	100

Note: The amounts are in millions of pounds. Some research councils and government departments have merged.
Source: Office of National Statistics (ONS) R&D Survey 2012.

[102] Unlike other European Countries, the Department of Education in the UK focuses on early education and is "responsible for education and children's services" (gov.uk).
[103] This funding also enables the higher education institutes to undertake research commissioned by the private sector, government , charities, the European Union and other international bodies.

8.2.2 Intermediary organizations

Research councils

The Research Councils receive the majority of government R&D funding in the UK. Hence, it is important to outline where exactly these funds go. There are seven research councils in the UK which the federal government itself administers. Table 8.5 provides a break-down of those funds by research council.

Table 8.5 Break-down of Research Council funds

	2011	% Of total
Engineering and Physical Sciences Research Council	854	26
Medical Research Council	672	20
Science & Technology Facilities Council	542	16
Biotechnology and Biological Sciences Research Council	488	15
Natural Environment Research Council	417	13
Economic and Social Research Council	180	5
Arts & Humanities Research Council	99	3

Note: The amounts are in millions of pounds.

The Engineering and Physical Sciences Research Council (EPSRC) receives most funding. In 2011 the EPSRC received 0.85 billion pounds, i.e. 26% of all Research Council funds. This is followed by funding to the Medical Research Council (MRC) that receives about 20% of the research council funds. The Science & Technology Facilities Council[104] (STFC) and Biotechnology and Biological Sciences Research Council (BBSRC) each receive around 15% of the research council funds.

The Research Council money flows into the higher education sector through the process of peer review. The Research Councils administer the peer review process and have various "themes". These themes are decided on by the academics in the Research Council. EPSRC themes include research on digital technology, energy and engineering. The BBSRC, on the other hand, prioritizes food security, biotechnology and aging studies. Hence, funds are funneled to the thematic areas chosen by the respective Research Councils.

Figure 1 gives the funding rates by number and value according to the themes of the largest research council (EPSRC). In this period, EPSRC considered 1938 research grant proposals through peer review and provided funding for 803 proposals. This is a funding rate of 41% in terms of the number of proposals. This amounted to a total demand for research grants of 818 million pounds, with granted funding of 377 and a funding rate by value of 46%. The highest success rates of grant applications are within the theme " Research Infrastructure" and "Global Uncertainties". The latter revolves around topics such as cyber security, technologies on terrorism prevention and threats to infrastructure.

[104] The STFC carries out research on "particle physics, nuclear physics, space science and astronomy".

Table 8.6 Funding rates at the Engineering and Physical Sciences Research Council, 2011

	Funding rate by number of proposals	Funding rate by value of proposals
Challenge programme		
Digital Economy	53%	42%
Energy	65%	60%
Global Uncertainties	83%	82%
Healthcare Technologies	54%	51%
Living with Environmental Change	na	na
Manufacturing the Future	57%	60%
Capability programme		
Engineering	27%	31%
Information and Communications Technologies	37%	42%
Mathematical Sciences	53%	47%
Non Theme Specific	29%	30%
Physical Sciences	42%	50%
Research Infrastructure	93%	93%

Source: http://www.epsrc.ac.uk/SiteCollectionDocuments/funding/FundingRates1112.pdf

Funding Councils and the specifics of the Research Assessment Exercises (RAEs)

The RAEs have been carried out approximately once every five years since 1986. The aim is to assess the quality of research and produce “quality profiles” for each submission of research activity made by research institutions (RAE, 2008). However, upon a review of the RAE exercise in 2003, a six year cycle was proposed and implemented. The RAE is carried out jointly by the Higher Education Funding Council for England (HEFCE), the Scottish Funding Council (SFC), the Higher Education Funding Council for Wales (HEFCW) and the Department for Employment and Learning, Northern Ireland (DEL). The four funding councils collaborate in running the UK-wide RAE (now REF) but the budgets they spend are separate and the way the results of the REF are used to allocate funding differs from council to council.

Each activity is ranked on a scale ranging from “world leading” (4*) to “no research contribution” (0, unclassified).[105] According to the latest RAE in 2008 around 54% of UK universities and higher education colleges was either ranked “world leading” or “internationally excellent” (see Table 8A.1 in Appendix 8A). The assessment was performed by 67 panels of experts corresponding to 67 subject areas, called units of assessments (UOAs). Examples of such areas are Economics and Econometrics (UOA-24) and Cancer Studies (UOA-2). Each submission to the Funding Council includes information on “research activity, including about research active staff and their published research outputs, the research environment in which they operated and indicators of esteem conferred on those staff as individuals or groups” (RAE Report, 2008). The submissions were consequently evaluated and the assessments determined how much funds a Funding Council would transfer to the research institution.

The RAE assessment itself is subject to review. For example, a report in 2001 highlighted the distortive mechanisms in the evaluation process. An increase in resources for the administration of those performing the RAE was urged, to take a more careful and transparent review and panel selection. Moreover, it was also recommended that performance indicators should only be used as secondary measures. Most recently, the RAEs were renamed to Research Excellence Framework (REF). The changes are to be implemented in the next assessment cycle of 2014. The most salient changes are twofold. First, there will be a shift in focus from university

[105] In the latest RAE 2008 a four point scale was used, while earlier RAEs had a five or larger point scale.

publication quality to an assessment of research that has wide ranging societal benefits. In assessing the overall quality of research, a 65% weight will be given to "originality, significance and rigor" and a 20% weight will be given to "reach or impact", while a 15% weight will be given to the environment. Secondly, the units of assessment by the Funding Councils will reduce substantially from 67 in 2008 to 36 subject areas in 2014.[106]

8.2.3 Research performing organizations

In the UK, public research is mainly performed by the higher education sector which comprises of 159 universities and colleges of which around 115 are considered research universities. This together with the intramural research capabilities of government departments and the centers maintained by the Research Councils forms the UK science base.

Table 8.7 presents a breakdown of Funding Council funds according to the purpose of dispatch for 2011-2012 for England. This is the disclosure by universities themselves of the use of Funding Council money. The largest amount, i.e. 3.9 billion pounds, is spent on teaching and research of which the majority is spent on teaching. Only 0.28 billion pounds is used for capital and infrastructure investments.

Table 8.7 Break-down of funds at Higher Education Funding Council of England

Funds allocated to	Amount
Teaching	2,300
Research	1,600
Knowledge exchange	160
Capital grants	280
Special funding	149

Note: Amounts are in millions of pounds. Source: HEFCE Report 2012.

To evaluate how individual universities distribute their funds, Table 8.8 displays the top five higher education institutions in England receiving most funding (and hence the universities that received the best overall evaluations in the latest RAE 2008). The University of Oxford received the largest funding of approximately 170 million pounds of which around 79% went to research and 21% to teaching.[107] Although there is variation in this research-education ratio, the top performing universities show a general pattern of spending a larger proportion of funding to research. Generally, the research funding as a proportion of total funding decreases as total funding to the university decreases. This might be explained by the large emphasis on research quality in the RAE evaluations (See Table 8A.1 in Appendix 8A to this country for assessment criteria).

[106] More information of the units of assessment can be found here: http://www.ref.ac.uk/panels/unitsofassessment/
[107] The remaining 2% goes to other projects such as "Knowledge Exchange" that aims to facilitate flow of knowledge in public and private sectors (not shown on Table 4).

Table 8.8 Council Funding usage by purpose

Rank	University	Teaching (%)	Research (%)
1	University of Oxford	21	79
2	University College London	30	70
3	University of Cambridge	22	78
4	University of Manchester	39	61
5	Imperial College London	28	72

Note: Exact amounts can be seen in Table 8A.2 in Appendix 8A to this chapter. Source: HEFCE Report 2012.

8.2.4 Monitoring

The recent innovation strategy document released in December 2011 by the UK government pledges to monitor research funds on a biannual basis. The evaluation is to be based on research output indicators, the EU's Innovation Union Scorecard, the number of small- and medium-sized enterprises (SMEs) claiming R&D tax credits, and the internationalization of research. For example, "monitoring the proportion of UK research outputs that have an international coauthor, the quality of these collaborations, and the volume of R&D investment leveraged from abroad" (BIS, 2011, p .89).

Apart from this the RAE or REF too acts as a monitoring device.

8.2.5 Research output

Table 8.9 documents and compares some science output measures for the UK to those in the other countries in our sample. The UK employs more than eight researchers per 1,000 member of the labor force which is exactly the average. The PhD graduation is rate is above average and shows a high degree of internationalization at the higher education sector. The difference between the total PhD graduation rate (2.4) and the PhD graduation for natives (1.3) is considerable. Only Switzerland has a slightly larger differences between those two graduation rates.

Table 8.9 R&D output and personnel indicators, United Kingdom

Country	# of researchers (fte) per 1,000 labor force	PhD graduation rate (excl. foreign students)	# of publications per 1,000 inhabitants (1 fte researcher)	# of citations per 1,000 inhabitants (1 fte researcher)
Netherlands	6.1	1.8 (1.2)	2.8 (0.9)	10.5 (3.3)
Belgium	8.3	1.5 (1.1)	2.4 (0.6)	8.1 (2.2)
Germany	7.9	2.7 (2.3)	1.8 (0.4)	5.3 (1.3)
Switzerland	5.4	3.2 (1.7)	4.4 (1.4)	18.1 (5.6)
Denmark	13.1	2.2 (1.7)	3.3 (0.5)	12.6 (1.9)
UK	**8.3**	**2.4 (1.3)**	**2.4 (0.6)**	**7.3 (1.8)**
US	9.1	1.7 (1.3)	1.8 (0.4)	5.2 (1.1)
Average	*8.3*	*2.2 (1.5)*	*2.7 (0.7)*	*9.6 (2.5)*

Note: All figures reflect the situation as in 2011, except for the number of researchers in Germany (2010), Switzerland (2008), and US (2007). Sources: OECD and Scimago. *The PhD graduation rate is measured as a percentage of the relevant age cohort.

The UK produces around 2.4 scientific articles per 1,000 inhabitants each year. This is a close to average score in our sample of countries. The number of citations, however, are below average. The US and Germany score lower on these productivity outcomes whereas the other countries are equally or more productive in producing publication and citations.

8.3 Distinguishing features

The UK science system is characterized by the Dual Support System. This involves funding of research through project peer-review of individual projects via the Research Councils and the evaluation of research output of faculties or research groups through Funding Councils. An important point to note is that Research Councils are administered by the UK government. However, Funding Councils funds are devolved to the respective counties of Scotland, Wales, England and Northern Ireland. Moreover, the government actively monitors the research performance of its science system by evaluating research output and internationalization. Another salient feature of the UK R&D system is the overarching Ministry of BIS that is responsible for managing both science and innovation policy.

Appendix 8A

Table 8A.1 Research Assessment Exercise 2008[108]

Scale	Definition	Overall % at this quality level
4*	Quality that is world-leading in terms of originality, significance and rigor.	17
3*	Quality that is internationally excellent in terms of originality, significance and rigor but which nonetheless falls short of the highest standards of excellence.	37
2*	Quality that is recognized internationally in terms of originality, significance and rigor.	33
1*	Quality that is recognized nationally in terms of originality, significance and rigor.	11
(0) Unclassified	Quality that falls below the standard of nationally recognized work. Or work which does not meet the published definition of research for the purposes of this assessment.	2

Source: RAE (2008).

Table 8A.2 Council funding usage by purpose

Rank	Universities	Teaching	Research	Total
1	University of Oxford	33,603.0	133,828.5	170,281.2
2	University College London	51,320.0	115,874.1	170,043.7
3	University of Cambridge	35,898.0	122,510.1	161,257.9
4	University of Manchester	57,395.5	83,893.7	144,139.2
5	Imperial College London	40,973.4	98,400.3	142,222.7

Note: Amounts are in millions of pounds.

[108] Funding Council support for research (Quality Related or QR funding) is distributed on the basis of the excellence of individual departments in higher education institutions, using the results of the Research Assessment Exercise (RAE).

9 United States

9.1 Introduction

9.1.1 Goal of national science policy

The goal of US science policy is to "fund investigative activities in promising and strategic frontiers of research." The long term goal includes total R&D expenditures that amount up to 3% of GDP. More short-term goals are presented with the budget documents every year in the form of a President's Memo to the heads of research agencies. For example, the 2013 memorandum communicated the following explicit goal to the heads of the research agencies:

"We look to scientific innovation to promote sustainable economic growth and job creation, improve the health of all Americans, move us toward a clean energy future, address global climate change, manage competing demands on environmental resources, and ensure the security of the Nation." Moreover, applied but high risk research and "quantifiable" measures of research output are preferred. For example, it is stated: "Within research portfolios, Federal agencies are encouraged to identify and pursue clearly defined 'Grand Challenges'.[109] Agencies should describe the targeted outcomes of research and development (R&D) programs using meaningful, measurable, quantitative metrics where possible and describe how they plan to evaluate the success of those programs."[110]

9.1.2 Basic figures

Table 9.1 provides a snapshot of the source and destination of US R&D funds in 2011. We see that 2.7% of US's GDP goes to R&D activities of which two-thirds is performed by businesses, followed by 15% in the higher education sector, and 12% in the government sector. The remainders are performed by the private non-profit sector.

Public funding amounts to 33.4% of total R&D funding which is roughly equal to 99.6 billion euros (0.9% of GDP). Table 9.2 shows that 36.4% of public funding goes to PROs and that 30.7% is allocated to the higher education sector. A relatively large share is allocated to the business sector (28.3%).

[109] Grand Challenges are defined as ambitious goals that require advances in science, technology and innovation to achieve, and to support high-risk, high-return research. These are laid out in "President's Strategy for American Innovation". This involves research on nanotechnology, climate change and clean energy. More generally, the Present Strategy for American Innovation is a general framework that emphases that the US Administration focus of science policy on "people, ideas and infrastructure".
[110] Source: Office of Management and Budget (2012). 'Memorandum for the Heads of Executive Departments and Agencies: Science and Technology Priorities for the FY 2014 Budget'.

Table 9.1 R&D funding, United States, 2011

Source	Destination				
	Government	Higher education	Business	PNP	Total
Total	36,237.1	45,331.9	203,867.8	12,834.0	298,270.8
Percentage of GDP	0.3	0.4	1.8	0.1	2.7
	Percentage of funding				
Government	100.0	67.4	13.8	35.7	33.4
Higher education	0.0	19.8	0.0	0.0	3.0
Business	0.0	5.0	86.2	7.1	60.0
PNP	0.0	7.8	0.0	57.2	3.6
Foreign	0.0	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0

Note: The amounts are in millions of euro (current prices). Source: Eurostat.

Table 9.2 Government funding by sector, United States, 2011

	Government	Higher education	Business	PNP	Total
Amount	36,237.0	30,561.8	28,214.1	4,585.5	99,598.4
Percentages	36.4	30.7	28.3	4.6	100.0

Note: The amounts are in millions of euros (current prices). Source: Eurostat.

Table 9.3 gives a brief overview of some R&D input indicators for the US, in comparison to those from the other countries in our sample. The US seems a relative outlier within these seven countries. First, the US government spends both in absolute and relative terms most funds on public R&D (0.89%). Second, the percentage of public funds that goes to PROs is second highest and the percentage of public funds that is spent at the higher education sector is lowest. Interestingly, the US allocates the smallest share of public R&D funds to the public sector (PROs and higher education). More specifically, about 33% of all public R&D funds are received by the business and private non-profit sector. The US allocates its entire public R&D funds on a project basis. It is, therefore, the only country in this report that does not have a mix of different funding allocation mechanisms.

Table 9.3 Publicly funded R&D input indicators, United States

		Destination		Allocation Mechanism	
	% of GDP	PROs (%)	Higher Education (%)	Project-based (%)	Performance-based (%)
Netherlands	0.72	22	72	26	25
Belgium	0.52	19	63	60	23
Germany	0.86	41	49	31	11
Switzerland	0.66	3	85	25	9
Denmark	0.86	6	87	32	1
UK	0.54	23	56	62	28
US	**0.89**	**36**	**31**	**100**	**0**
Average	*0.72*	*21*	*63*	*48*	*14*

Note: All figures reflect the situation as in 2011 except for Switzerland (2008). The calculation of the allocation mechanism variables can be found in Chapter 12. Sources: Eurostat, Van Steen (2012), and country reports.

9.2 General information

9.2.1 Government funding of R&D

Since World War II, the amount of public spending on research in the US has depended on the economic and (geo-)political conditions.[111] Recently, science in the US has benefited from two anti-cyclical policy measures. First, the commitment to double the National Institute of Health budget from 1998 to 2002 raised the overall science budget in a period of economic crisis. However, one should note that this commitment to raise this budget was made before the economic recession. Second, a large increase in science spending over the 2009-2019 period was part of the American Recovery and Reinvestment Act 2009 (ARRA). A detailed breakdown of ARRA funds for science can be found in Table 9.4.

Table 9.4 Break-down of ARRA funds

Amount of ARRA funds	Government
US$ 10.4 billion	National Institute of Health
US$ 3 billion	National Science Foundation
US$ 2 billion	Department of Energy
US$ 1 billion	National Aeronautics and Space Administration (NASA)
US$ 1.5 billion	Others[112]

Source: United States Government (2013).

Over 90% of the federal R&D budget is allocated through five federal agencies. Table 9.5 shows how the federal R&D funds are distributed among the most important institutions. We can see from Table 9.5 that almost 55% of all federal R&D funds are transferred to the Department of Defence (DOD). Together, the Department of Health and Human Services (HHS) and DOD spend more than 75%of the federal R&D budget.

Table 9.5 Federal R&D budget by agency, United States, 2011

Agency	Amount	% Of total	Mission
Department of Defense	56.9	54.8	Defense
Department of Health and Human Services	22.4	21.6	Health
National Institutes of Health	21.5	20.7	
Other HHS institutes	0.9	0.9	
Department of Energy	7.7	7.4	Energy
NASA	6.5	6.3	Aerospace
National Science Foundation	4.0	3.8	Basic science
Other institutions	6.3	6.1	Other

Note: The mounts are in billions of euros. 2011 average exchange rate USD/EUR: 0.7188.
Source: AAAS Report XXXVII, Research and Development FY 2013, Table I-1 'FY 2013 Budget by Agency'.

The amount of public funding the US spends on defense-related R&D is extraordinarily high relative to the other countries in this analysis. Whereas the US spends around 57% of the

[111] Source: Stephan, P. (2012). 'How Economics Shapes Science'. Location: Massachusetts.
[112] "Others" include smaller allocations. For example, US$ 230 million to NOAA operations research facilities and US$ 140 million to United States Geological Survey.

federal R&D budget on defense R&D, the UK does only 17% and the other countries no more than 4%.[113]

The federal funding for R&D is complemented by state programs to stimulate R&D activities. State level funding has, however, not been substantial. Most of these programs have a focus on collaboration among triple helix actors.[114]

9.2.2 Intermediary organizations

Unlike other countries in this analysis, institutional funding is not a major feature of the US public research system. Instead, the US distributes almost all public research funding on a competitive basis. Hence, we can practically consider each of the above discussed US agencies as intermediary organizations since they all provide research grants on a competitive basis and the funding relationships are directly between the agency and the recipient. However, for sake of comparison with the other countries in this analysis, we will only consider those agencies that conduct relatively much extramural research as an intermediary organization. Furthermore, we abstract from departments and agencies that are predominantly focused on funding business R&D since this is outside the scope of this analysis. This basically leaves us with the National Institutes of Health (NIH) and the National Science Foundation (NSF) which are also the largest and most prominent ones. Around 60% of all research funds pass through the peer review process of these two research councils. They are in many ways comparable with research councils that exist in other countries (e.g. DFG in Germany, NWO in the Netherlands, SNSF in Switzerland, etc.).

National Institutes of Health(NIH)

The NIH budget was about 21.5 billion euros in 2011. Table 9.6 presents an overview of the funding mechanisms of the NIH. Only 11% of the NIH budget is spend on intramural research (own laboratories).[115] Most of this intramural research takes place on the NIH campus in Bethesda, Maryland. The largest part of the NIH budget is spent on extramural research grants, of which most of these grants are noncompeting continuation grants. These grants are received by more than 300,000 researchers at more than 2,500 universities and research institutions.

Table 9.6 NIH funding mechanism, 2011

Agency	Amount	% Of total
Research grants	15.3	71
Research Project Grants	11.8	55
Noncompeting	8.5	39
Competing	2.7	13
Other	0.6	3
Research Centers	2.2	10
Other Research	1.3	6
Training	0.6	3
R&D Contracts	2.1	10
Intramural Research	2.4	11
Other	1.1	5

Note: The mounts are in billions of euros. 2011 average exchange rate USD/EUR: 0.7188.
Source: NIH website. 'NIH Data Book'. Accessed on: December 12, 2013. Accessible: http://report.nih.gov/nihdatabook/index.aspx

113 Source: OECD Science, Technology and Industry Outlook 2012.
114 Source: European Commission (2006). 'Private Sector Interaction in the Decision Making Processes of Public Research Policies. Country Profile: United States.'
115 Source: NIH website. 'NIH Budget'. Accessed on: December 12, 2013. Accessible: http://www.nih.gov/about/budget.htm

The most popular NIH grant is the R01 grant - also called the 'bread and butter' of university investigators - which constitutes about 60% of the total grant awards. The average R01 grant amounted about 300,000 dollars in 2011 and has, in general, a duration of three to five years. The success rate of the R01 grant has declined over the years from 30% in 2002 to 18% in 2011.[116] Overall, the average NIH grant size amounted about 1.34 million dollars in 2011. The average grant size in constant terms has been decreased substantially relative to ten years earlier (-25%).[117]

Table 9.7 gives an overview of the distribution of NIH funds by type of performer. The largest part of NIH funds is received by universities and colleges, followed by the government. Grant applications that are submitted to the NIH are evaluated by means of peer review. The peer review process consists of two levels. The first level - conducted by a Scientific Review Group (SRG) consisting mainly of non-federal experts on the relevant research area - is an assessment of scientific and technical merit. The outcome of the first level review is then provided to the NIH component with funding authority: the NIH Institutes and Centers (IC). The second level of review is conducted by one of the 27 ICs that each have their own research agenda. The core values of NIH peer review consist of expert assessment, transparency, impartiality, fairness, confidentiality, integrity, and efficiency.[118]

Table 9.7 Distribution of NIH funds by type of performer, 2011

Type of performer	Percentage
Government	32
Higher Education	60
Business	7
Foreign	1

Source: National Science Foundation/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development: FYs 2010-12.

NIH grants only cover the direct costs of a research project, i.e. those costs that can be specifically identified with a particular research project. Indirect costs like maintenance, depreciation and administration are not covered 'directly' by the NIH grants. These indirect costs, typically referred to as Facilities and Administrative (F&A) costs, are however indirectly provided to the research institute by means of an institution specific pre-negotiated F&A rate. Each research institution must negotiate with the HHS Division of Cost Allocation over the height of this rate.

National Science Foundation (NSF)
The 2011 R&D budget of the NSF amounted to about 4.0 billion euros.[119] The NSF focuses primarily on funding of fundamental research. Table 9.8 presents an overview of the distribution of NSF funds by different types of performers. The higher education sector is by far the largest recipient of NSF funding. In contrast to the other US departments and agencies that receive R&D budgets, the NSF does not perform intramural research.

[116] Source: NIH report 2013.
[117] Source: NIH website. 'NIH Data Book'. Accessed on: December 12, 2013. Accessible: http://report.nih.gov/nihdatabook/index.aspx
[118] Source: NIH (2013). 'NIH Peer Review: Grants and Cooperative Agreements'.
[119] The total 2011 NSF budget amounted about 5.0 billion euros. However, about 1.0 billion euros were spend on education and human resources.

Table 9.8 Distribution of NSF funds by type of performer, 2011

Type of performer	Percentage
Government	12
Higher Education	81
Business	6
Foreign	1

Source: National Science Foundation/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development: FYs 2010-12.

The NSF describes itself as "the only federal agency whose mission includes support for all fields of fundamental science and engineering, except for medical sciences." A detailed overview of the NSF funding allocation by field of research is presented in the Table 9.9. In 2011, the average annualized NSF grant size was 156,200 euros and had an average duration of 2.9 years. The success rate of grant applications was 22%.[120]

Table 9.9 Distribution of NSF funds by field of research, 2011

Field of research	Amount	% Of total
Biological Sciences	511	13
Computer & Information Science & Engineering	457	11
Engineering	548	14
Geosciences	636	16
Mathematical & Physical Sciences	940	24
Social, Behavioral & Economic Sciences	178	4
Other Programs	728	18
Cyberinfrastructure	151	4
International Science & Engineering	35	1
Polar Programs	355	9
Other	188	5

Note: The mounts are in millions of euros. 2011 average exchange rate USD/EUR: 0.7188.
Source: NSF (2011). 'Full-year Appropriations Bill Passed, NSF Funded at $6.8 Billion for FY 2011'. Accessed on December 13, 2013. Accessible: http://www.nsf.gov/about/congress/112/highlights/cu11_0523.jsp

NSF grant applications are processed by means of peer review. After submission of the research proposal, the proposal is assigned to one of the appropriate NSF programs (roughly comparable to the fields of research in Table 9.9). If the proposal meets the NSF requirements, the proposal will be reviewed by one NSF Program Officer and three to ten experts on the relevant research area from outside the NSF. The two main funding criteria are intellectual merit and (broader) impact. The integration of research and teaching plays a prominent role within the NSF peer review process.[121]

The NSF also provides funding to cover indirect costs. Organizations must annually submit proposals for updating the F&A rate. The F&A rate must then be negotiated with the Cost Analysis and Audit Resolution staff (CAAR).[122]

9.2.3 Research performing organizations

US public R&D funds are very equally divided among the players in the triple helix - government (36.4%), higher education (30.7%) and business (28.3%). This is a rather unique characteristic of the US R&D landscape since the other countries in this analysis allocate the majority of public R&D funds to higher education. Also, the share of US public R&D funds that is allocated to the

[120] Source: NSF (2013). 'NSF Funding Profile'. *NSF FY 2013 - Budget Request to Congress*.
[121] Source: NSF (2004). 'NSF Proposal Processing and Review'. *NSF Grant Proposal Guide.*
[122] Source: NSF website. 'Indirect Cost Rates'.

business sector exceeds the equivalent shares of other countries substantially. This section will primarily focus on the higher education and government sector as performers of public research.

Higher education

There are over 4,000 higher education institutions in the US, but only 207 universities are classified as research universities (high to very high research activity) by the Carnegie Classification of Institutions of Higher Education. Among these research universities, the distribution of federal funds for research is highly skewed with only 100 universities receiving around 80% of government funds.[123]

Table 9.10 gives a break-down of all funding streams coming into American higher education institutions by its source. The federal government provides the majority of these public R&D funds. We see that the state and local governments finance 7% of all research funds coming into higher education, almost the same as industry. Moreover, 20% of all funding is self-generated by the respective institutes.

Table 9.10 Break-down of university funds, United States, 2009

Source of funding	Percentage
Federal government	59
State and local government	7
Industry	6
Self-generated	20
Other sources	8

Source: National Science Board (2012). 'Science and Engineering Indicators 2012'. Accessed on: December 19, 2014. Accessible: http://www.nsf.gov/statistics/seind12/pdf/seind12.pdf

R&D funding that comes from the federal government is primarily allocated through competitive peer review. As shown in Table 9.11, universities receive their public funding mainly from the NIH (and vice versa most of the NIH R&D budget goes to higher education (59%)). As discussed earlier, the NIH focuses primarily on funding health-related research. Another important funding source is the NSF, which funds all sorts of basic research apart from health. 78% of the NSF budget is allocated to the higher education sector. Also the Department of Defense contributes a substantial amount to R&D funding of the higher education sector. However, the other way around, the higher education sector receives only a very small share of the total DOD R&D budget (3%).

Table 9.11 Higher education public R&D funding by US agencies, 2009

US agency	Percentage
Department of Defense	9
Department of Energy	3
Department of Health and Human Services	66
National Institutes of Health	64
Other HHS institutes	2
NASA	2
National Science Foundation	14
Other agencies	6

Source: National Science Foundation/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development: FYs 2010-12.

[123] Source: European Commission (2006). 'Private Sector Interaction in the Decision Making Processes of Public Research Policies. Country Profile: United States'.

The state and local governments contribute 7% of total research funds to higher education institutions. There is considerable heterogeneity among states however. Appendix 9A shows the funding flows for the top 20 academic institutions.

Public research organizations

PROs play an important role within the US R&D landscape as they perform about 12% of all US R&D activities and receive 36.4% of all public R&D funds. PROs can be distinguished roughly into federal laboratories under the control of a federal agency (government intramural R&D) and federally funded R&D centers (FFRDCs). These FFRDCs conduct research for the US government but are administered by either industry, university or private non-profit organization. There were 30 FFRDCs during October 2011.

As shown in Table 9.12, the Department of Energy provides most of the public R&D funds to FFRDCs (58%), whereas the Department of Defense provides most of the public funds to federal laboratories (government intramural R&D). The federal laboratories compete amongst themselves for R&D funding from their respective federal agency.

Table 9.12 Public funds to federal laboratories and FFRDC's by federal agencies, United States, 2011

Agency	Federal laboratories	FFRDCs
Department of Defense	61.1	23.6
Department of Health and Human Services (HHS)	16.9	6.7
National Institutes of Health	15.1	6.7
Other HHS institutes	1.8	0.0
Department of Energy	2.7	57.6
NASA	3.2	8.3
National Science Foundation	0.5	1.4
Other institutions	15.6	2.4
Total amount	23,337.1	7,395.2

Note: The mounts are in millions of euros. 2011 average exchange rate USD/EUR: 0.7188.
Source: National Science Foundation/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development: FYs 2010-12.

9.3 Other characteristics

9.3.1 Funding by non-profit organizations

An interesting feature of research funding in the US is the role of non-profit organizations (NGOs). Although exact figures are unavailable, it is reasoned that over 10% of total research funds within universities are provided by NGOs (Stephan, 2012).

The largest NGO is the Bill and Melinda Gates Foundation with a total endowment funds of 38 billion dollars. The foundation gave away 3.4 billion dollars in grants for the year 2012 from which at least 1 billion dollar was for research (Gates Foundation, 2013). Other smaller non-profit organizations focus on specific areas. For example, the American Cancer Foundation, the American Heart Association, and the Ellison Medical Foundation which focuses on ageing studies. The Howard Hughes Medical Institute (HHMI) is regarded as the NGO with the most impact. Its endowment fund was valued close to 16 billion dollars in 2013 of which 3.5% goes to biomedical researcher each year. The recent financial crisis has greatly hurt most endowment funds which has resulted in smaller grant sizes or sometimes complete liquidation of an NGO.

9.3.2 Advisory organizations

An important advisory organizations in the US is the National Science Board. Besides the responsibility with regard to NSF policies, the Board provides an independent advise to the US President and Congress about science and engineering.

The National Academies consist of three non-profit organizations that provide advice with regard to their respective field of research (science, engineering and medicine). The National Research Council is the working arm of the National Academies with regard to providing advice and informing the general public.

9.3.3 Monitoring

There is no direct monitoring of research activities at research performing organizations in the US. However, as the majority of research funds is allocated on a project basis the peer review process serves as a monitoring device.

Intermediary institutions such as NSF and NIH are required to describe the targeted outcomes of R&D programs using quantitative metrics where possible and describe how they plan to evaluate the success of those programs. This involves presenting annual reports on the outcomes of research activities that involved public funds. The NIH and NSF present these annual reports to Congress. In addition, a review of NSF is done periodically by the Committee of Visitors (COV) that aims to assess the "integrity and efficiency" of the decisions processes. Each COV consists of five to twenty external experts from science and education who provide assessments on the "people, ideas, and tools" used in grant allocations.[124] The COV report and response by the directorate of NSF are then assessed by the Advisory Committees (ACs) with experts from academia, industry, government and the public sector. The ACs also advice on the priorities and program effectiveness of the grant allocations.

Moreover, it is important to note that the congress monitors US funds indirectly. For example, NIH is provided appropriations by institute, not to NIH as a whole. So, if congress is unsatisfied with the performance of a certain institute or has a particular interest in a specific research field (e.g. cancer research), they have the power to increase or decrease institute budgets accordingly. This, in turn, has an impact on the mix of funds going to various research fields.

9.3.4 Research output

Table 9.13 shows that the number of people - 9.1 per 1,000 members of the labor force - that are employed as researchers is considerable. Apart from Switzerland, the US has the highest degree of researchers in its labor force. The total PhD graduation rate is relatively low in the US.

The US and Germany have very similar research productivity as measures by number of publications and citations. They both produce around 1.8 (0.4) scientific articles and have slight more than 5 (1) citations per 1,000 inhabitants (1fte researcher) in 2011. These productivity figures are the lowest among the seven countries.

[124] Source: NSF (2003). 'National Science Foundation Strategic Plan FY 2003 – 2008', pp. 28. Accessed on: December 18, 2013. Accessible: http://www.nsf.gov/pubs/2004/nsf04201/FY2003-2008.pdf

Table 9.13 R&D output and personnel indicators, United States

Country	# of researchers (fte) per 1,000 labor force	PhD graduation rate (excl. foreign students)	# of publications per 1,000 inhabitants (1 fte researcher)	# of citations per 1,000 inhabitants (1 fte researcher)
Netherlands	6.1	1.8 (1.2)	2.8 (0.9)	10.5 (3.3)
Belgium	8.3	1.5 (1.1)	2.4 (0.6)	8.1 (2.2)
Germany	7.9	2.7 (2.3)	1.8 (0.4)	5.3 (1.3)
Switzerland	5.4	3.2 (1.7)	4.4 (1.4)	18.1 (5.6)
Denmark	13.1	2.2 (1.7)	3.3 (0.5)	12.6 (1.9)
UK	8.3	2.4 (1.3)	2.4 (0.6)	7.3 (1.8)
US	**9.1**	**1.7 (1.3)**	**1.8 (0.4)**	**5.2 (1.1)**
Average	*8.3*	*2.2 (1.5)*	*2.7 (0.7)*	*9.6 (2.5)*

Note: All figures reflect the situation as in 2011, except for the number of researchers in Germany (2010), Switzerland (2008), and US (2007). Sources: OECD and Scimago. *The PhD graduation rate is measured as a percentage of the relevant age cohort.

9.4 Distinguishing features

The US public R&D system is largely characterized by their funding through peer review. In general, the US provides no institutional funding to research organizations. To compensate for overhead costs, research organizations receive a pre-negotiated F&A rate on top of their project-based funding. Whether or not the research organization receives this compensation for overhead costs is completely dependent on whether the organization attracts project funding. This makes the US funding system one that does not give any financial guarantees for research to higher education institutes and PROs.

Another important aspect of the US R&D system is the extraordinary large focus on defense-related R&D. According to the OECD, there are only 3 OECD countries that spend more than 10% of their total public R&D budget on defense-related activities: South-Korea (16.3%), UK (16.9%), and the US (57.3%).[125] The majority of the DOD's R&D budget is contracted out to the business sector.

Another, important aspect of the US funding system is the relatively strong degree of steering in terms of research fields. US Congress first decides on allocating the federal R&D budget to the different agencies (Table 9.4 shows broadly their main focus), after which the federal agencies further allocate the budget towards different fields of research. The NIH, for example, has 27 institutes and centers, each with their own research agenda. Congress can tweak these agendas as the allocation of funds are administered by institutes which are in turn distributed along different research subjects.

[125] Source: OECD Science, Technology and Industry Outlook 2012.

Appendix 9A

Table 9A.1 Top 20 Academic institutions in R&D expenditures, by sources of funds, 2008

Rank by amount of funds	All sources	Federal government	State/local government	Industry	Academic institutions	All other sources
1. The John Hopkins University (private)	1,681	1,425	7	39	87	123
2. University of California - San Francisco (public)	885	473	287	46	158	180
3. University of Wisconsin - Madison (public)	882	474	37	21	270	79
4. University of Michigan, all campuses (public)	876	593	5	41	193	45
5. University of California - Los Angeles (public)	871	472	23	47	186	144
6. University of California - San Diego (public)	842	491	31	50	141	129
7. Duke University (private)	767	451	19	152	91	53
8. University of Washington (public)	765	614	11	74	41	25
9. University of Pennsylvania (private)	708	482	17	51	61	97
10. Ohio State University, all campuses (public)	703	335	99	128	103	38
Total, top ten	8,980	5,810	277	649	1,331	913
11. Pennsylvania State University, all campuses (public)	701	407	68	99	126	2
12. Stanford University (private)	688	509	14	60	53	52
13. University of Minnesota, all campuses (public)	683	364	62	29	123	104
14. Massachusetts Institute of Technology (private)	660	495	1	87	11	66
15. Cornell University, all campuses (private)	654	359	75	26	123	71
16. University of California - Davis (public)	643	269	56	34	215	69
17. University of Pittsburgh, all campuses (public)	596	456	15	12	83	29
18. University of California - Berkeley (public)	592	249	44	42	168	89
19. University of Florida (public)	584	231	111	32	175	35
20. Texas A&M University (public)	582	246	124	43	157	12
Total, top 20	15,363	9,395	847	1,113	2,565	1,442
Total, all institutions	51,909	31,231	3,418	2,870	10,435	3,954

Note: All amounts are in millions of current dollars. Source: National Science Foundation, Division of Resources Statistics, Academic Research and Development Expenditures, FY 2008.

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12 Calculations for ex-post, ex-ante and fixed funding

Van Steen (2012) is the most important source for classifying total public R&D funding into ex-post, ex-ante and fixed funding. Van Steen provides detailed data about the amounts of project funding and institutional funding for, among other countries, the Netherlands, Belgium, Germany, Switzerland and Denmark. Since Van Steen does not provide data for the UK and US, we used other sources (see Table 12.2). Table 12.1 shows how we calculated the variables for the countries excluding the UK and US.

Table 12.1 Calculations for the Netherlands, Flanders, Germany, Switzerland and Denmark

Variable	Value	Source	Year
Percentage of public funds that goes to research at:			
Government	A	Eurostat	2011
Higher education	B	Eurostat	2011
Business	C	Eurostat	2011
Private non-profit	D	Eurostat	2011
Percentage of public funds that goes to research that is project-based at:			
Government	E	Van Steen (2012)	2008
Higher education	F	Van Steen (2012)	2008
Business	G	Van Steen (2012)	2008
Private non-profit	H	Van Steen (2012)	2008
Percentage of public funds that goes to research that is institutional funding at:			
Government	I	Van Steen (2012)	2008
Higher education	J	Van Steen (2012)	2008
Business	K	Van Steen (2012)	2008
Private non-profit	L	Van Steen (2012)	2008
Percentage of higher education institutional funding that is based on performance indicators	M	Based on own estimation (see country reports)	Most recent information
Percentage of higher education institutional funding that is based on research-performance[1] indicators.	N	Based on own estimation (see country reports)	Most recent information
Percentage of *ex-post* public R&D funding (based on research and education performance)	B*J*M		
Percentage of *ex-post* public R&D funding (based on research performance)	B*J*N		
Percentage of *ex-ante* public R&D funding	A*E + B*F + C*G + D*H		
Percentage of *fixed* public R&D funding[2]	A*I + B*J*(100%-M) + C*K + D*L		

NB. (B*J*M) + (A*E + B*F + C*G + D*H) + (A*I + B*J*(100%-M) + C*K + D*L) = 100%.
Note: For Switzerland: Eurostat data for 2011 was not available so 2008 data was used instead (most recent available).
Note: For Denmark: Van Steen (2012) figures for Denmark were 'incomplete' because an amount of 3520 million DKK (about 30% of total public funding) was not classified into one of the three sectors of performance. It is, however, known that this unclassified amount of public R&D funding is project-based. We used the Van Steen figures of institutional funding together with Eurostat data for aggregate public R&D funding per sector of performance to calculate the amounts of project-based funding.
[1] Examples of research-performance indicators are the amount of external funding, publications, citations, PhD graduates, etc. This means that for example bachelor/master graduates and student enrollments are excluded.
[2] Here we assume that institutional funding to PROs, business and private non-profit depends on historical considerations.

Table 12.2 Calculations for United Kingdom and United States

Variable	Estimate	Source/argumentation
United Kingdom		
Percentage of public R&D funds that is project-based (institutional funding):		
Government	61% (39%)	Source: Office for National Statistics (2008). 'Table 1: R&D performed in the UK in each sector according to source of funding, 2008'. *UK gross domestic expenditure on research and development 2008.* When estimating this value we assumed that all R&D funding coming from Research Councils is ex-ante funding (also those funds that are allocated directly to research institutes of the research council) and that all R&D funding from the government to PROs is institutional funding.
Higher education	52% (48%	Source: Office for National Statistics (2008). 'Table 1: R&D performed in the UK in each sector according to source of funding, 2008'. *UK gross domestic expenditure on research and development 2008.* Here we assume that all public funding, except the funds coming from HE Funding Councils, is ex-ante funding.
Business	100% (0%)	From the data of Van Steen (2012) we observe that, in general, public R&D funding to the business sector is 100% project-based (ex-ante funding).
Private non-profit	100% (0%)	From the data of Van Steen (2012) we observe that, in most cases, public R&D funding to the private non-profit sector is project-based (ex-ante funding).
United States		
Percentage of public funds that is project-based (institutional funding):	100% (0%)	Sources: Erawatch website. Page: United States - Research Funders. Accessed on: December 17, 2013. Available: http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/us/country?section=ResearchFunders&subsection=GovernmentAndRegionalAuthorities OECD (2002). 'Steering and Funding of Research Institutions. Country Report: United States' According to Erawatch, the US provides, in general, no institutional funding to the higher education and private non-profit sector. Given this information and the figures of other countries [Van Steen, 2012], we also assume that the business sector receives no institutional funding. According to the OECD, federally funded public research institutions compete among themselves for intramural research from their respective US department. Although the US provides, in general, no institutional funding, they do provide compensation for overhead costs (the so-called F&A rate). Whether an institution actually receives this compensation is however completely dependent on whether or not the institution attracts project-based funding (ex-ante funding).

The calculations for the UK and US are very similar to the calculation as discussed above, apart from the fact that we lack data about sector specific amounts of project funding and institutional funding. Therefore, we made an estimation for these figures (values E to L in Table 12.1). Table 12.2 shows the estimates and argumentation/source behind the estimates. The reader must keep in mind that the figures for the UK and US may be less accurate since they are based on more varying sources, estimations and assumptions.

13 List of definitions

This list of definitions is inspired by the Frascati Manual.

1) Basic definitions

Research and experimental development (R&D): R&D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. The term R&D covers three activities: basic research, applied research and experimental development. Education and training are excluded when measuring R&D.

Basic research: Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

Applied research: Original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.

Experimental development: Systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

Public R&D: R&D activities undertaken by either the government (e.g. Public Research Organizations)or higher education institutions.

Publicly funded R&D: R&D activities that are funded by the government.

2) Institutional classification

Business enterprise sector: All firms, organizations and institutions whose primary activity is the market production of goods or services (other than higher education) for sale to the general public at an economically significant price. This sector includes public enterprises.

Government sector: All departments, offices and other bodies which furnish, but normally do not sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and the economic and social policy of the community. Public enterprises are included in the business enterprise sector.

Private non-profit sector: Non-market, private non-profit institutions serving households (i.e. the general public). For some countries in our analysis, Eurostat has included this sector in the government sector because the magnitude of this sector is very limited.

Higher education sector: All universities, colleges of technology and other institutions of post-secondary education, whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating under the direct control of or administered by or associated with higher education institutions.

Abroad: All institutions and individuals located outside the political borders of a country, except vehicles, ships, aircraft and space satellites operated by domestic entities and testing grounds acquired by such entities. It also includes all international organizations (except business enterprises), including facilities and operations within the country's borders.

3) Sources of funding for public R&D performers (government and higher education)

Institutional funding: Regimes where research funds are allocated directly to institutions according to historical considerations (discretionary-incremental funding), performance indicators (formula-based funding) or budget negotiations between actors (contract-based funding). Institutional funding is non-competitive and may contain both a teaching and a research part. In our analysis we particularly focus on the research part.

Discretionary-incremental funding: Institutional funding that is based on historical considerations. This involves most often the institution's previous year's budget, adjusted for inflation. This grant can be allocated as a line-item budget or as a block grant, and the latter is associated with more autonomy.

Contract-based funding: A flexible form of institutional funding which is used as a steering instrument by the government to reach consensus between the government and the research organization about future policy and goals. The duration of these contracts typically cover more than one year. The ultimate achievement of these goals may or may not be measured.
Also: mission-based funding

Recurrent institutional funding: This is the sum of both discretionary-incremental funding and contract-based funding. This type of institutional funding is relatively stable and not directly related to performance-indicators.

Formula-based institutional funding: Institutional funding based on performance indicators. These performance indicators can be demand oriented (the amount of students, amount of external funding) and output oriented (passed exams, (PhD) graduates, publications, citations, etc.). The formula-based part of institutional funding can sometimes distinguish between teaching and research related indicators.

Project-based funding: Regimes where scientists obtain project funds from external sources (either public or private) competitively. Public competitive funds are often distributed through intermediary research funding organizations such as research councils or research agencies.

Performance-based funding: This comprises both project-based funding and formula-based institutional funding. Compared to recurrent institutional funding, this type of funding is relatively more volatile.

4) Other definitions

Research institute: An establishment established for doing research.

Intermediary organizations: Organizations that mediate between public research organizations and the government. They aim to coordinate the allocation of research funding and may (but not necessarily) coordinate research agendas. In our analysis, we exclude intermediary organizations with an annual budget less than 100 million euro.

Public research organization (PRO): A research institute that operates under the direct control of or administered by or associated with the government.

PhD graduation rate: The number of PhD graduates as a percentage of the relevant age cohort.

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