CHAPTER 6

THE PUBLIC RESEARCH SYSTEM AND THE ISSUE OF DIRECTIONALITY: CONDITIONS, PROCEDURES AND POLICY IMPLICATIONS

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Abstract

This chapter addresses "directionality" in public research, focusing on guiding innovation to meet societal and industrial challenges. It contrasts research universities (RUs) and government research laboratories (GRLs), advocating tailored strategies for each to achieve targeted innovation outcomes. The analysis introduces directional adjustment costs (DAC) as key to understanding the trade-offs in redirecting research. It proposes two approaches: one that emphasises flexibility and low DAC, suitable for RUs, and another that involves more directive, higher DAC strategies for GRLs, aiming at precise technological advancements. The chapter suggests empowering RUs for broader societal impact whilst recommending a streamlined, accountable approach for GRLs to focus on specific goals. It calls for a strategic reassessment of how public research is directed, emphasising the importance of RUs in adapting to societal needs and the role of GRLs in achieving targeted innovations.

1. Introduction

One new buzzword in research and innovation (R&I) policy circles is 'directionalities'. Defined as a policy to encourage innovation in a specific direction, its application extends across multiple contexts, from addressing societal challenges (climate change, global health) to industrial policy issues (sectoral transition or modernisation, establishment of a new industry, strategic autonomy). While a certain rate of innovation may be found sufficient for sustaining productivity growth in the economy in general, it can be insufficient in certain domains where accelerating the production and application of knowledge is an imperative for particular reasons. In these circumstances, the policy goal is not merely to address market failure and incentivise R&I in the general economy, but to do so in a specific way within certain domains or in certain *directions*[1].

This chapter addresses the problem of 're-directing' public research. The public research sector is not homogenous; it is characterised by a diversity of institutions and incentive mechanisms and, therefore, the issue of re-directing public research needs to be contextually addressed in accordance with this heterogeneity. In particular, the public research sector includes two main models: the research university (RU) and the government research laboratory (GRL). These two models comprise different institutions and respond to different types of incentives. As such, the problem of directionality needs to be tackled using an alternate modality.

In the next section, some conceptual clarifications are discussed. In section 3, a framework to capture the abovementioned challenge of heterogeneity is then developed. Based on the main findings of the so-called 'new economics of science' (Dasgupta, 1988; Dasgupta and David, 1994; Stephan, 2010; Foray and Lissoni, 2010), the main features of the public research system in terms of governance, incentives and resource allocation principles are described and analysed. From this analysis, the two essential institutional pillars of the public research system are identified: RUs and GRLs. Section 4 goes on to discuss the concept of directional adjustment costs (DAC).

The fundamental message is that although the directions of public research can be influenced through a variety of policy instruments, this influence doesn't come without costs. In a research system where decentralised and bottom-up production decisions and freedom to experiment are not only the rules but an essential ingredient for R&I success, pushing people to shift their research or innovation agenda entails DAC. In designing and deploying programmes and instruments to generate directionalities, policymakers should not ignore these costs. Based on this premise, the identification of two institutional models and on the notion of DAC, the final section explores the different modes of management and governance of public research regarding directionalities.

1 In this sense, this paper is complementary to that of Teichgraeber and Van Reenen (2022), recently published as a working paper in the R&I Paper Series (European Commission). It deals with the policy toolbox available to sustain the rate of innovation in the general economy.

This critical review is informed by the new economics of scientific institutions developed by a few giants of the economics of science (Arrow, Nelson, Dasgupta and David, Stephan) and on national research policy experiences, particularly in the Western countries and within the EU. A modern public research system – which needs to be efficient and effective in supporting countries to meet their societal Grand Challenges – should include a large sector of research universities and a much smaller sector of government research laboratories. Reasons deal with i) the capacity of research universities – having appropriate levels of resources, autonomy and leadership – to 'spontaneously' shift their educational and research agenda towards areas of high societal relevance, and ii) the spillovers they generate through research, education and international flows of students in these relevant areas. Evidence shows that most European countries have not yet reached this stage.

2. Directionalities and missions: conceptual clarifications

'Directionalities' is closely related to another policy concept, 'mission', and the differences among them are not always clearly understood.

'Mission' is a large-scale R&I policy that focuses its support on a particular technological achievement or societal objective (Juhasz et al., 2023). Such support includes not only research but also technological development, as well as complementary programmes in terms of the formation of specific human capital and the provision of specialised services and infrastructures.

2.1 The initial policy model of 'mission'

The archetypical and iconic cases include the R&D programmes organised by the US Office of Scientific Research and Development during World War II (Gross and Sampat, 2021) and Kennedy's Apollo 'moonshot' (Mazucatto, 2022). Mission principles often involve:

- centralisation of the decision process, strong leadership, and a command and control type of governance;
- a public agency which plays multiple roles of coordinator, single buyer and main operator;
- a focus on applied research, development and deployment;
- a monopsony-oligopoly market structure which rules the relationships between one single buyer and a few large suppliers;
- an exceptional and unusual enrolment of scientists and engineers towards a clear and well-identified target.

Enrolling and mobilising researchers and laboratories to achieve a specific mission creates distortions, as the key principles of academic research – freedom to experiment and decentralised production decision – are broken, and the goal of maximising knowledge spillovers becomes secondary – e.g. can be sacrificed for a superior objective which is the achievement of the mission. While acknowledging the existence of spillovers generated by the Apollo programme, Bloom et al (2019, p.179) write: “Surely, the resources used in putting a man on the moon could have been directed more efficiently if the aim was solely to generate more innovation’’.

Any kind of causal identification of economic effect is obviously difficult, because any mission is a highly selected episode with no obvious counterfactual (Bloom et al., op.cit.). However, the very recent work by Kantor and Whalley (2023) on the economic effects of the Apollo programme shows both the reality of the economic effects and their limitations. They find local effects of NASA spending through a fiscal multiplier channel – an outcome that is not a strong point for this mission since it is of the same order of magnitude as the effects generated by any typical government expenditures. Furthermore, they cannot detect any local technology spillovers and productivity effects from mission contractors to neighbouring firms.

Because of these limitations, the economic or societal relevance of a mission is conditional to situations of proven crisis – where the speed for finding solutions becomes the main parameter and will justify strong coordination, top-down decisions and a focus on applied research and product development. As quoted in Gross and Sampat (2021), who document the US experience during WW2: ‘The time for basic research is before a crisis, and urgency meant that basic knowledge at hand had to be turned to good account’ (Conant, 1947). The point here is not so much to support fundamental research, but rather, applications.

Based on these conditions and principles, the metrics of success are clear and non-ambiguous. Missions are viewed as successful if they achieve the targets predefined by the government. Sometimes spillovers can be beneficial, sometimes they are insignificant. Always, they are a secondary objective.

2.2 Recent developments

Beyond this initial model, which was strongly related to defence and space ’missions’[2], conditions, procedures and challenges of mission-oriented public R&D policies have dramatically changed. The irruption of Grand Challenges such as adverse climate change, devastating diseases and many other formidable societal problems has triggered new policy issues and approaches (Foray et al., 2012; Mowery et al., 2010). This evolution is fundamentally characterised by the fact that numerous missions involve social and economic transformations, not only ‘simple’ technological and engineering objectives.

Consequently, the operational mode of such missions-oriented policy cannot be reduced to the mobilisation of an army of engineers and scientists distributed across a few organisations and conducted in some military fashion. Rather, the operational modes need to involve civil society (to transform consumption patterns and social practices) and the private markets (to fix dysfunctionalities and negative externalities). This is what the great Thomas Schelling observed already in 1996 in his work on global warming: ‘Decreasing emission has to be very decentralized, very participatory, and very regulatory.

2 Mowery (2012) has provided a survey of the mission aspect of defence R&D in the US, France and Great Britain, as well as a more general analysis of ‘mission-agency’ R&D programmes. In the same special issue of *Research Policy*, Wright (2012) and Andrews (2021) analyse an old mission policy in the US which was NOT related to defence or space, but deployed in the area of agriculture.

It requires affecting the way people heat and cool their homes, cook, collect firewood, drive cars, consume energy-intensive aluminium, and produce steam for electricity and industrial use. Methane abatement involves how farmers feed their cattle and aerate their rice paddies. Carbon abatement depends on policies that many governments are incapable of implementing'.

Schelling identified rather a social or societal problem, where some other experts formulated an engineering or scientific problem. There is probably a bit of truth in both camps, but what is certain is that the objectives and challenges of the new missions are not merely technological. While the initial 'Apollo' model was aimed at complex problems of engineering, the new missions are facing fundamental problems of transformation involving multiple dimensions – scientifical and technological indeed, but also economic, institutional and societal. These are also missions that create winners and losers. In this perspective, the analysis of such new missions requires further refinement and more emphasis on issues of building consensus or narratives about problems (Wanzenböck et al., 2020).

The concept of 'mission' as a structuring element of R&D policies at the EU level clearly illustrates such evolution (Mazzucato, 2019; Cavicchi et al., 2023). As described in section 2.1, the concept has a larger scope and is more ample than the initial concept. Beyond the identification of societal challenges and systemic transformations, this concept emphasises the strong participation of civil society and the need for cooperation and coordination between scientists and researchers based in the various national systems of EU R&I. Several objectives are, therefore, pursued simultaneously – this can be criticised[3], – but this also provides this specific pillar of Horizon 2020 some legitimacy thanks to its role in the perpetual development of the European project.

The COVID-19 pandemic allows the observation of another more market-based (or mixed) model of 'mission'. The issue of emergency and speed was clear, but the organisation of the mission was far more decentralised and spontaneous, while featuring a strong involvement of the private sector. This different institutional setup is likely a consequence of the fact that the concerned sector of pharmaceuticals is very different in terms of how it balances market and non-market institutions than the usual 'mission-oriented' sectors of space and military. The question here is whether a Manhattan Project or a 'man to the moon' Apollo-style mission would have been a superior solution to accelerate the discovery, development and manufacturing of COVID-19 vaccines. As explained by Cockburn and Stern (2010), such a solution would have come with a great drawback – the lack of diversity and freedom to experiment – which are the key engines of innovation in life science. The life science ecosystem has never worked under centralised/top-down principles: a single R&D surge seems to have never paid off in the pharmaceutical industry, and the success of the life science innovation system has been driven i) by intellectual freedom and scientific openness, and ii) by an intense and pervasive competition throughout the value chain in life science. The success of COVID-19 vaccines are, therefore, the outcome of a process of coordination and competition involving large companies, start-ups, universities and the public sector – all working within a very decentralised and bottom-up logic – an approach that is rather far from the old Apollo model.

3 According to Rodrik (2014), multiplicity of goals does not contribute to discipline. It becomes possible to justify any range of results after the fact, by highlighting the least problematic aspects of performance.

2.3 From 'mission' to 'directionality'

'Directionality' has a different meaning to 'mission', and refers to a set of micro-R&I policies which generate new incentive structures to achieve the 'right' direction in R&I[4]. The point is not so much to mobilise and enrol in a somewhat military way, but to influence and re-direct people who are, in principle, free in their production decisions. Here, market incentives matter. Principles of strong coordination, top-down decisions and a focus on applied research don't necessarily apply. In the following sections, the issue of introducing more directionalities in public research is thereby addressed.

3. Public research systems in the EU: concept and facts

3.1 A conceptual framework

Dasgupta and David (1994) and Dasgupta (1988) analyse the public research sector, dividing it into two different types of institutions: the first consists of the 'government'[5] engaging itself directly in the production of knowledge, while the second consists of 'private agents' undertaking research, who in turn are subsidised for their effort by the public pursue. While the first arrangement characterises the so-called GRL, the second characterises RUs.

The RU solution is a decentralised mechanism, in which knowledge production decisions are independently taken by members of a self-regulating profession (academic scientists), and whose work is subsidised by the government. The GRL arrangement is closer to a kind of 'command mode of planning', such that the decision of what to produce and how much to produce it is made by the government.

GRLs and RUs form what is commonly known as the public sector research. They are related by exchanges of knowledge, personnel and finances, and they recruit scientists on the same labour market. Yet it is important to maintain the distinction between these two forms of public research, because the economic incentives and resource allocation mechanisms are fundamentally different. In other words, each institution creates for their members a fair balance of advantages and constraints, but the balance is different.

In the RU system, individuals are free to pursue research targets of their own choice, although the system of grants provides funding agencies the opportunity to prioritise a few research areas (see below). In return for financing, individuals and institutions must provide educational services such

4 A complication to the debate among economists on directionalities is that the concept of 'direction' – which was initially developed to capture a very specific feature of technical change (involving a labour-saving and factor substitution logic) and gave rise to a huge literature devoted to the impact of factors endowment on the direction of technical change in the Hicks/Salter/Ahmad tradition – is used nowadays in a much broader sense, which can create some confusion and ambiguity in policy discussions. For example, the policy discussion on artificial intelligence is based on a rather narrow concept of direction (see e.g. Trajtenberg (2019) on human-enhancing innovation *vs.* human-replacing innovation), while the policy discussion on sustainability is based on a much broader concept of directionality.

5 Government' is a broad concept embracing any ministerial institutions and public agencies that fund and drive R&I policy in a country.

as teaching and supervision. **This is the fundamental 'social contract' between research universities and society**: individuals and teams are subsidised for their research activities and they are free to decide their research agenda but in exchange they teach.[6] Modern universities' scientists receive a fixed salary for their teaching and examination tasks, in addition to other rewards (promotion, grants and increased reputation) for successful research. Perhaps research projects fail, have little relevance to societal problems or even to the advancement of knowledge, but if the RU as a whole is educating a large quantity of students who then find 'good jobs', the RU and its members have fullfilled their contract with society.

By contrast, **the GRL system exhibits a very different 'social contract'**: there is no teaching obligation. Consequently, individual scientists and teams are not free as in RUs to decide their research activities; research is organised by the state in relation to targeted objectives. GRLs are, by design, well fitted to societal, strategic or policy support missions. They are dedicated to the advancement of applied knowledge in specific fields of societal or strategic interests, or committed to generating the evidence needed to inform data-driven policymaking.

These processes are frequently fast-paced and may not always align with the more extended research periods that academic researchers are accustomed to. This necessitates a balance between the sophistication and robustness of the analysis and the timeliness of the results. For these reasons, they are often under direct ministerial supervision (such as national space agencies, institutes of health or atomic energy organisations). A successful example is the Joint Research Centre (JRC) of the European Commission, which since 1998, acts as the internal research centre of the executive branch of the European Union 'to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle'. Over the past decade, JRC science for policy involved around 2 000 JRC scientists producing over 10 000 policy-support outputs, based on evidence from more than 8 000 peer-reviewed publications. As an example, JRC-backed EU energy legislation is expected save about 230 million tonnes of oil equivalent by 2030, translating to up to EUR 285 yearly savings for consumers on energy bills (Mitra A. et al., 2024).

Logically, principles of public accountability and conditionalities become very central in the management and governance of GRLs. Since the rationale for resource allocation to GRL cannot be based on education services and the training of a mass of students and is therefore only based on research and on what society can get from it, GRL must explain in great details what they are doing and how they are doing it. They must be transparent about their failures as their successes. They must also explain why they employ scientists in some specialised fields or disciplines, which seems rather far from the main 'mission' of the concerned GRL. It can be consistent with the research mission, but it needs to be explained to the public. Accountability helps legitimise the GRL's activities. The complement of accountability is resource conditionalities or discipline. Discipline requires clear objectives, measurable targets, close monitoring, proper evaluation, well-designed rules and professionalism (Rodrik, 2014; Mazzucato and Rodrik, 2023).

Historically, most countries that are now innovation leaders have experienced a slow shift from a system involving government laboratories and *teaching* universities as the main knowledge institutions to a system

6 The function of knowledge transfer and innovation is increasingly becoming fully part of the social contract between RUs and society.

characterised by the centrality of *research* universities – e.g. where both tasks of education and research are of equally high importance. Heavy reliance on GRLs can be seen as a legacy of the past: it was appropriate at a certain stage of economic development, when the main challenge for Western countries was to build a S&T infrastructure, and the fastest way to do so was to create these mission-oriented institutions[7]. However, as those countries become innovation leaders, the need for more resources in RUs is obvious. Indeed, RUs generate positive externalities in the form of both human capital and basic research that have the status of 'joint-products' (giving rise to economies of scope and internal spillovers: great scientists benefit from great students and vice versa). This explains the famous quotation by Arrow (1962, p.623): "The complementarity between teaching and research is, from the point of view of the economy, something of a lucky accident".

On the other hand, GRLs, by design, break the intimate relation between research and high education and only provide a small fraction of the total amount of positive externalities that RUs are able to provide[8]. Highlighting the double-externality argument, several economists thereby make a strong case for allocating most resources to RUs[9]. This is wonderfully explained by Zucker and Darby, two American economists:

The idea of research and technology organisations sounds very attractive, particularly in a small country that sees them as a vehicle to achieve a critical mass by concentrating the nation's best scientists in one place. In fact, we ourselves would like to have our research well funded until retirement and the opportunity to build a more permanent research group without the need to educate and train successive generations of graduate students and post doctoral fellows. Despite the personal attractions, ***we can also see how that situation might cool the entrepreneurial spirit as well as our impact on the most important objective of any knowledge institution: the generation of high quality human capital*** (Zucker and Darby, 1999; emphasis added).

Another very recent quotation is worth providing. This comes from Anne L'Huillier – a recent Nobel prize laureate in physics – who explained that she started as scientist at a French GRL (Commissariat à l'Energie Atomique or CEA) and at some point shifted to the University of Lund in Sweden, saying: « *Chercheur (au CEA), c'est formidable, on s'amuse bien, mais on se demande quand même ce que l'on fait pour l'humanité. L'enseignement c'est une récompense immédiate : on voit des jeunes gens s'éveiller devant soi, on nourrit leur enthousiasme* » (Le Monde, 4 décembre 2023). The statement accurately captures the positive impacts that teaching can have on the direction of research within RUs.

There are, thus, two models of public research organisations and their respective efficiency is conditional to how the social contract is fulfilled: RU has a crucial high education function and involves norms of academic freedom for the research aspect of the activity; and GRL has a crucial research mission in certain areas of strategic relevance for a country and strong principles of command and control and public accountability regarding the research activities need to be applied.

7 GRLs are usually created as a public research entity, not as a funding agency. However, the model evolves in many cases – combining research performance and research funding.

8 We ignore in this discussion the classical spillover effects generated by any government expenditures that materialise in some kinds of expansions of the local economy and can vary according to an estimation of the multiplier effect. We don't consider these spillovers since they are not specific to research expenditures.

9 See, e.g. Aghion, Dewatripont et al., 2009, who develop rather similar arguments on the governance and performance of RUs. In a recent paper, MacLeod and Urquiola (2020) further provide a historical analysis of the emergence of the RU's institutional form in the US.

3.2 Academic freedom: a right for any scientist?

The fact that the two models of public research – while very easily identified in the real world – are not well understood in terms of their specific contracts they have with the society, generates great confusion in discussions about academic freedom. Of course, academic freedom as a principle of free decision by individuals or teams about research objectives and methodologies is not a right that any scientist can enjoy. Researchers in corporate R&D can't claim academic freedom. This is obvious. Less obvious but equally true is the case of scientists employed in GRLs. Thus, the claim that academic freedom is a principle that should apply to all scientists working in the GRL sector is nonsensical. Scientists employed in a GRL have to develop research activities that are consistent with the strategic goals and research agenda defined by GRL's management, which in turn has to report to the government. Of course, as in any 'good job' in industry and services, research jobs are characterised by high degrees of *autonomy* in the way the work is conducted. By definition, scientists who are highly qualified and have to undertake very complex tasks need to have a high level of autonomy. But this is not academic freedom, which has a larger scope and performative impact on the way academic researchers practice their profession.

3.3 Hybrid model of RU and GRL: does it work?

Any institution that is hybrid – taking some elements of each model – raises issues of efficiency.

The Centre National de la Recherche Scientifique (CNRS) in France is a typical example of an institution which is between the two models: it is not a RU because it is not a teaching institution, and it is not really a GRL because command and control governance and public accountability are rather loose and academic freedom dominates. CNRS scientists have no teaching obligations – they can teach of course, but such obligation is not part of the labour contract – but they fully benefit from academic freedom[10]. Subsequently, the fair balance between freedom and obligation is broken, and it is difficult to consider the incentive structures which are in place as efficient. CNRS was created to provide a small number of scientists with a professional research environment that the university was unable to offer – which was by this time a fine decision – but over time, it has become a very large organisation, covering all disciplines and employing about 11 400 scientists – which now makes it an institutional anomaly. What a country can afford at small scale (an elite group of scientists with no teaching obligation and full freedom to do research) becomes unaffordable as the researcher count increases. As written by Barba Navarett et al. (1998, p.8): *Institutions for the creation and transmission of knowledge emerge and evolve endogeneously. They change according to the type of knowledge they rule, the interests they serve and the return they generate…Yet, the dynamics of institutions has inherent market failures and it is not necessarily optimal in terms of social welfare. There are many cases where institutions have been negatively affected by vested interests both related to knowledge itself, or related more generally to the regulation of society*.

10 This institutional ambiguity or confusion is reflected in the way CNRS activities are captured in public research statistics. In the French statistical public research framework, the CNRS is considered a GRL. In Eurostat and OECD studies, it is categorised under higher education!.

In Aghion et al. (2009), other cases of institutional reforms are made, where the performance of public-sector research organisations is being adversely affected by the ''rent-protecting'' behaviour of agents with vested interests. These cases are especially strong when effective subunits are 'trapped' within a larger dysfunctional system, which is typically the case of CNRS.

3.4 The European public research landscape

As first-order policy guidance, two propositions can be derived from the framework presented above:

- First, because of the double externality feature of RUs, leading countries should try to keep the GRL sector as a small fraction of the whole public research system, giving to the RUs *la part du lion*;
- Second, the remaining small GRL sector should be subject to robust accountability and discipline principles so that the research which is undertaken is aligned with the national agenda dealing with various missions, and can deliver not only knowledge, but concrete solutions.

Let us now observe the current situation in the EU member countries. The table below provides an overview of the respective weight of RUs and GRLs in the national public R&D effort.

Table 6-1 Public funds allocated to Government Research Laboratories (GRLs) vs. Research Universities (RUs) *(billion EUR)*

Sector of performance Countries	Total (business, GRL, RU,..)	Total public research sector	GRL	%	RU	%
Germany	34	31	14	45%	17	55%
France	18	14.5	5.5	38%	9	62%
Denmark*	2.6	2.5	0.25	10%	2.2	90%
Austria	4	3.2	0.7	22%	2.5	78%
Italy	9	8	3	37.5%	5	62.5%
Sweden	4	3.7	0.7	19%	3	81%
Ireland	0.8	0.6	0.1	16.5%	0.5	83.5%
Belgium	3	2.5	0.7	28%	1.8	72%
Spain	6.4	5.5	2.3	42%	3.2	58%
Portugal	1.2	1	0.1	10%	0.9	90%
Netherlands**					-	
Finland	2	1.7	0.4	23.5%	1.3	76.5%
Greece	1.1	1	0.5	50%	0.5	50%
Czechia	1.5	1.3	0.6	46%	0.7	54%
Hungary	0.8	0.5	0.2	40%	0.3	60%
Poland	3	2.3	0.1	4%	2.2	96%
EU 27	100	87	31	35.5%	56	64%
Norway	3.7	3.2	0.9	28%	2.3	72%
Japan	21	19.5	11	56.5%	8.5	43.5%
South Korea	17	12.4	7	56.5%	5.4	43.5%
Switzerland	6	5.12	0.2	4%	5.1	96%
Turkey	2.6	2	0.4	20%	1.6	80%
USA	135.5	96.7	56.1	58%	40.6	42%

Source: Eurostat (2021).

Note: The statistics above are based on Frascati classifications and definitions. It is obviously uneasy to separate teaching and research activities in the case of universities, as the same people (e.g. professors and other teaching personnel) are undertaking both tasks. The Frascati manual provides some guidance: all education and training of personnel are excluded from R&D. However, supervision of R&D projects for student qualification and performance of own R&D projects should be counted whenever possible as a part of R&D personnel and expenditure.

In column 2 (total = business, GRL, RUs and private non-profit), the numbers correspond to the total amount of public funding allocated to the full research system. In column 3 (total public research), the numbers correspond to the amount of public funding allocated to public research. Columns 4 to 7 shows the absolute public expenditures for GRL and RU respectively. The % are the share of funding allocated to RUs and GRLs as a % of the total amount allocated to public research (column 3).

* For Denmark – data source: 2019

** For the Netherlands – accounting issues.

The picture of national structures of the public research sector that emerges in Table 6-1 is one of enormous variance. Obviously it would not be very consistent to produce any normative rules against which one can measure how each country is fitting one unique best pattern. Initial conditions are different as well as the political and institutional structures, therefore diversity and heterogeneity among national models within the EU and beyond is perfectly understandable. However, as previously stated, a modern public research system should include a large RU system and a much smaller GRL sector. As a first approximation, a 70%-30% distribution could be roughly taken as a fairly sensible allocation principle. According to this principle, a few countries are clearly above this average of 70% share for their RU sector. Among the most prominent cases are Denmark, Sweden, Ireland, Poland, Austria, Portugal and Belgium within the EU, along with Switzerland, Norway and Turkey. In countries like Switzerland, Denmark or Poland, the GRL sector is, in quantitative terms, almost non-existent. It is also worth to note that EU average is at 64%. The countries that are systematically ranked very high in the various global innovation rankings such as Denmark, Sweden or Switzerland are those countries with the 'right' balance between RUs and GRLs[11].

France count numerous GRLs (26), including a few giants such as CEA (Commissariat à l'Energie Atomique), INSERM (Institut National de la Santé et de la Recherche Médicale) and CNRS. German GRLs include the Leibniz and Helmholtz networks of research centres, federal departments research centres, as well as the Fraunhofer (FhG) and the Max Planck (MPG) societies. FhG and MPG have clear 'special missions' (transfer of knowledge to industry in the first case, elite academic institution in the second case) which give them clear objectives, goals and metrics to measure performance. Both institutions are viewed as effective in undertaking these special missions (EFI, 2010).

France and Germany are the two European countries where the GRL aspect of the public research sector is rather high, followed by Italy and Spain; certainly too high according to the policy guidance as suggested above[12].

One question arising from Table 6-1 concerns the strategic and directionality capacities of countries that are characterised by a GRL sector, which is quantitatively negligible. What does it mean in regards to the capacity of these countries to conduct strategic R&I programmes? By design, in these countries, academic freedom is the general norm, and logically, the capacity of government to conduct strategic research is weakening. A recent policy discussion illustrates this point in Switzerland – a country that exhibits the highest share of public funding allocated to the RUs' sector: the executive manager of a platform ('the food centre'), established at the Ecole Polytechnique Fédérale de Lausanne (EPFL) to support research on the food transition, resigned while complaining about the fact that it was very hard to mobilise EPFL scientists to achieve food transition research objectives, and that he had no means to 're-direct' academic research towards the strategic topics of his centre. He concluded that, in a certain sense, 'academic freedom has perverse effects' – thereby conducting academic scientists to stay away from some research fields of strategic importance for the country[13].

11 The somewhat surprising numbers of the US case are due to two facts: firstly, the GRL sector is, indeed, very large; secondly, a significant part of the RU sector (including some of the best universities) is privately funded. Thus, the interpretation of the dominance of the GRL sector to explain R&I performance in the US case should be done in a very cautionary way.

12 It is also fair to say that countries characterised by a strong political and administrative culture of state centralisation and interventionism – such as France – have a natural tendency to develop a very robust and powerful GRL sector, which is then difficult to change.

13 Interview in the Swiss newspaper *Le Temps*, 08-01-2024.

The point is not to ask the countries with a very small GRL sector to change their model. It might, however, be more useful to consider how strategic research and directionalities can be better introduced in a system where RUs get the largest part of public resources. This point will be discussed below in section 5.

4. Directional adjustment costs

4.1 Freedom to experiment and autonomy as key ingredients of successful R&I

In the first place, it is always important to recall that bottom-up principles and freedom to experiment are fundamental ingredients for R&I success. This means that policies cannot simply decree the 'right' direction, and that trying to obtain it through the manipulation of incentives has a cost.

In science and fundamental research, academics are free to make their own production decisions. This is a fundamental principle. Empirical evidence shows that research grants awarded for projects (in predetermined areas) have a lower productivity than research grants awarded for people who are free to determine their research field, goal and method. In a path-breaking empirical study, Azoulay et al (2011) compare two groups of researchers. The scientists in the first group are supported by the Howard Hugues Medical Institute (HHMI), which gives the researchers great freedom to experiment and set their research agenda. The scientists in the second group are funded by the National Institutes for Health (NIH) and are subject to predefined deliverables; their degree of freedom and autonomy is therefore lower than for scientists belonging to the first group. They find that the scientists supported by HHMI produce high-impact articles at a higher rate than what is produced in the other group of similarly accomplished NIH-funded scientist. Here, it becomes clear that any R&I policy aiming at influencing directions comes with costs. Such costs have different origins.

4.2 Science inelasticity

Funding matters, and the allocation of more funding to specific fields can change the course of science. Gaulé and Murray (2011) take malaria research as a case study, and analyse the effect on an exogenous funding shock, which occurred due to NIH decisions to double of funding between 1999 and 2001, after a long period of steady but moderate growth. They find that the funding shock led to the entry of new people in the field of malaria research, and that scientists who entered during, or just after, the funding shock are significantly more productive than those who entered just before it.

Obviously, funding matters and can help to re-direct public research. But recent theoretical and empirical research shows also that science is inelastic, at least in the short run. This was initially highlighted by Paul Romer (2000), who showed clear implications on the complementarity between subsidising R&D and promoting the training of scientists and engineers to avoid any friction on the market for scientists. A few empirical papers go on to show that switching costs are high – in some cases so high that they are detrimental to any directional changes.

Myers (2019) is probably the first scholar to address the issue of switching costs through a systematic empirical analysis. He provides evidence based on an empirical study of targeted calls issued by the NIH. More precisely, he exploits the fact that the NIH quite regularly creates funds for one-time competitions, which request proposals on a predetermined topic (a specific disease or population, and/or methodologies). This funding mechanism is called 'Requests For Applications' (RFA). Designing and issuing multiple RFAs clearly show that the NIH believes it can steer researchers to certain topics and directions. Myers attempts to estimate how costly it is to operate this sort of migration of researchers towards determined topics. He finds that 'it is possible to induce scientists to shift their research focus, but incentivizing these redirections requires a substantial amount of funds'. Directional adjustments costs are high, which can explain that grants allocated to proposals responding to targeted calls are larger than grants allocated to proposals responding to non-directed call competitions.

Employing a different approach, Cook and Foray (2007) also address the elasticity of science. They present a study of an extreme case of a thematic grant scheme: the research agency of the Department of Education in the US decided to push strongly quantitative research and experiments based on randomised clinical trials (RCTs). The goal of the agency was that RCT-based approaches in education should increase from being <5 % of causal educational studies before 2002 to being 75 % just three years later. However, directional adjustment costs were so high within the field of educational research, where most researchers developed sociological analysis and case studies, that very few proposals were developed. The research agency was, thus, obliged to call for expertise from outside the field – contract research firms and researchers from public health.

4.3 The temptation of piloting science at a macro-level

If science is inelastic in the short term, policies can perhaps anticipate societal needs and plan structural changes in resource allocation among fields – providing more support to the fields which are critical for societal goals. Nathan Rosenberg (2009) documented and somewhat criticised the incredible increase of the NIH biomedical research expenditures that started around 1990, which led to the 2001 figure where federal R&D expenditures in US universities for life science counted for 58 % of the total of federal R&D expenditures in universities.

Drawing on such figures, scholars warn against the temptation of 'driving' science by piloting the system with frequent controlled variations in resource allocation among science domains: *The management of public science requires steady and balanced research budgets. First, research is an experimental, cumulative and interactive process, and it is very costly to adjust the level of effort over time. These large adjustment costs make multi-year funding horizons crucial. Second, there are strong complementarities among scientific fields, and these are hard to predict in advance* (Shankerman, 2009, p.125).

Paula Stephan (2012a) used the case of the 'NIH doubling' to warn against the idea that money is the answer to any problem – such as the problem of re-directing science towards socially desirable areas or objectives: *The doubling of the NIH budget from 1998 to 2003 triggered universities to hire more people and build more buildings, while scientists increased the number of grant's they submitted and the size of their labs. Now this biomedical machine needs increasing amounts of money to sustain itself, with calls for more funding* (p.31). And it seems likely that diminishing returns have set in (ibid.). Again, it is not easy and perhaps not without risk to make decisions about piloting and directing science towards specific areas – such as biomedical research in this case.

Lessons from all these works can be summarised as follows: in the short run, the efficiency of huge re-allocation of funding towards a specific scientific domain is limited, because only a subset of researchers have the right human capital to advance the knowledge frontier in the considered area. Moreover, the supply of adequate human capital both in terms of quality and quantity is very much inelastic in the short run. Human capital is not the only barrier: good research ideas may also be scarce. In a world of scarce ideas, increasing funding invariably leads to diminishing returns.

For these reasons, it is important to preserve a large measure of balance across fields, resisting any faddish focus on single scientific areas. This does not provide policy makers with detailed investment guidance – but it does provide caution and a longer range perspective than they may otherwise take.

5. Managing directionality in public research

We turn now to the specific issue of managing directionality in public research, taking into account the discussion thus far about the two different institutions that are ruled by different social contracts, and the existence of directional adjustment costs.

5.1 The Azoulay framework

Azoulay et al (2018) propose a framework to analyse how R&I can be 're-directed' according to strategic or societal goals. They use a two-dimensional table that deals with the source of idea generation (investigator initiation *vs.* mission-inspired solicitation) and the locus of control for project execution (investigator freedom *vs.* empowered programme staff). The two quadrants in the right column – where the source of idea generation is a thematic-inspired solicitation – are relevant for policies involving directionalities. In all these cases, a public agency or a foundation identifies a thematic priority's area, and issues a call for proposals within this area. The other dimension – locus of control – allows a clear distinction between the two logics of operation under the same directionality principle.

Table 6-2 Research management strategies

Idea generation Project execution	Investigator, scientist	Thematic-inspired solicitation
Investigator freedom	Competitive grant system	Directionality mode 1
Empowered programme staff	Venture capital	Directionality mode 2 (ARPA)

Source Azoulay et al. (2018) – modified

5.2 Mode 1: easy to implement, low cost… and low effect?

The first mode in Table 6-2 ('mode 1') is, in a sense, easy to implement: the agency predefines a priority area for R&I, issues a call and let researchers to explore freely this research area. Directional adjustment costs are thereby minimised because of large freedom and little oversight. It is easy to implement, but the capacity to drive a specific transformation or to achieve a specific (technological) solution is weak. This mode fits better the general objective of advancing any kind of knowledge within the considered specific area.

A good example is provided by Brodnik (2023), who presents the Vinnova's Challenge Driven Innovation Programme (CDI), in which directionality and flexibility are combined: *The program defines the overarching challenges that projects need to address, thereby providing long term orientation. At the same time the CDI leaves it up to the projects to define which solutions are required or which actors need to be involved thereby providing short term flexibility* (p.65).

Another point can be made under mode 1 on managing directionality in public research. Mancuso and Broström (2023) provide evidence on the so-called application effect. They address the issue of re-directing public research and provide evidence based on an empirical study of targeted calls issued by the Swedish Foundation for Strategic Research. The evidence they produce has implications on how to structure and manage a call. Indeed, they find that both winners and non-winners of the targeted call (e.g. the entire group of applicants) shift their research agenda towards the topics of the call, and that there is no difference between winners and non-winners in the type of shift that is produced. There is therefore what they call an *application effect* (instead of a *funding effect*), which clearly applies to mode 1 of managing directionality, and therefore needs to be considered by funding agencies.

Finally, mode 1 raises two potential issues.

Firstly, a specific risk arising from this mode is duplication and inefficiency when multiple agencies identify similar priority areas and don't coordinate their calls. Let's assume a country has three funding agencies – one more oriented towards academic research, another focusing on transfer of technologies, and a third that is a body of the ministry of energy. They are all interested in supporting R&I in renewable energy. Given poor coordination between them and little oversight about research activities, the risk of duplication is significant. Such situations happen in many countries.

Secondly, because of a low level of programme management, monitoring and oversight, this type of programme is not the best mechanism to deliver concrete solutions.

To summarise: mode 1 is a way of minimising DAC, is rather effective in advancing knowledge within a certain priority area, but is not the best way to generate concrete solutions or applications and entails high risk of duplication.

5.2 Mode 2: ARPA

The second mode ('mode 2') emphasises command and control mechanisms, which may imply high directional costs. It is much more demanding on the agency side, because empowered and proactive programme managers will be deeply involved in the design and the execution of any programme that is targeted towards very specific and precisely defined goals. In this sense, this mode better fits the goals of developing, for instance, a specific technology, or solving a specific problem.

Insights from the US experiences show that such top-down and centralised mechanisms – if properly designed – can be very effective in boosting some technological domains and achieving specific innovation targets. This is the story of the US ARPA model and its featuring principles, such as general organisational flexibility, bottom-up programme design, discretion in project selection, and active project management – all these features relying on highly talented, independent and empowered programme staff. As analysed in Azoulay et al. (2018), the ARPA model showed that:

- it is possible to *efficiently organise R&I around technology-related missions or a set of overarching goals*;
- it proved to be particularly optimal for *technological areas where technology exists, is relatively unexplored, and has great potential for improvement*;
- it is also useful to solve *friction on markets for ideas and technologies* in sectors where the path from idea to impact is extraordinary difficult (such as in energy, due to many obstacles such as large amount of capital for demonstration and scale up, strong infrastructure inertia, etc.).

A typical ARPA process involves the following stages:

- the ARPA board selects a broad thematic area and hires a high-standing potential programme manager from academia, industry or elsewhere in government for a period of three to five years;
- the programme manager has about one to two years to identify the specific target, design the programme and build a network of partners;
- they then pitch the programme to ARPA leadership and, if successful, launch several projects, monitor execution and make decisions about funding increases, or cut within the remaining period.

The deployment of the ARPA mechanism across sectors – first in defence (DARPA), then in energy (ARPA-E) and health (ARPA-H) (perhaps soon, as recommended by Rodrik [2022]), and lastly in production and digital technologies (ARPA-W) – shows the popularity of this instrument in the US. Some ARPA-like experiences are arising in Europe – for instance, in the UK – as well as at the EU level[14]. In Switzerland, the Swiss Science Council (2023) has recommended the design and implementation of an ARPA mechanism within innovation funding agency InnoSuisse. In a recent paper published by the RTD Chief economist and staff (Cavicchi et al., 2023), the argument for reinforcing effective directionality goes in the same direction.

There is, therefore, a buzz around ARPA, and this is certainly well-deserved. However, policy makers need to comprehensively understand two points:

- First, a true ARPA schema (located in the bottom-right quadrant of Table 6-2) obviously entails high DAC – the cost for a scientist to adjust their research agenda to fit the mission – generated by a significant decrease of freedom to experiment and decentralised initiatives. This is clearly a sharper issue here than in the first logic (top-right quadrant of Table 6-2).
- Second, empowered staff and programme managers of high standing and reputation is a boundary condition that might be difficult to fulfil in Europe. The US culture of *va et vient* between the public and the private sector for high-calibre scientists and managers is a strength. Some wage flexibility within the public administration is also key to propose attractive packages to top managers or scientists coming from private companies or top universities for a temporary three to five-year position in the public sector to manage an ARPA programme.

Observations of national policies within the EU generally conclude that there are a lot of initiatives which can be associated to the first mode – but almost none according to the second one. Although some country's specific programmes could be viewed as between the two logics (such as in the Netherlands or the UK), the picture is clear: countries have numerous instruments to advance knowledge in some important mission areas under a mode 1 logic, and they don't have many programmes to operate under within that of mode 2.

5.3 Why (and how) can RUs respond spontaneously to directionality?

Returning to our conceptual framework highlighting the two models – RUs and GRLs – the viability of governance solutions become obvious, and it is possible to minimise DAC while developing a public research system highly responsive to societal goals and challenges. A short illustration is presented below.

Let's start with the RUs. In observing the evolution of educational programmes and teaching topics in any European university, one can only stress that these universities have experienced remarkable evolutions in their teaching domains and research fields – while not being obliged to do so by any kind of top-down planning decisions of the concerned national ministries. These universities are simply capable of responding positively to societal needs, as they are expressed by their students!

14 The Joint European Disruptive Initiative (JEDI) presents itself as the European ARPA.

Looking at the Ecole Polytechnique Fédérale de Lausanne (EPFL) – but most universities in the EU are experiencing the same process[15] – thousands of students are hoping to attend Bachelors and Masters programmes in critical areas such as sustainability, environment or artificial intelligence and data sciences. EPFL has enough resources and leadership to be able to respond to such needs through the creation of new programmes in these areas. For these programmes to be taught, the university therefore needs to hire new professors in the concerned expertise areas, whereby these scientists will conduct their research and produce scientific knowledge within these areas. Thus, no top-down planning (or 'directionality mode 1' in the Azoulay framework) is needed for universities to concentrate resources and focus education and research in areas of strategic importance for society. It is, rather, enough for a university to listen to its students and respond positively to their demand through a bottom-up, decentralised process which fully respect academic freedom and does not generate high directional adjustment costs.

The only boundary condition is the level of resources, leadership and autonomy the university can enjoy to be able to transform its educational offer – and subsequently, its research agenda – to adapt the supply of teaching and knowledge to students' values, aspiration and needs, with the students being always the best 'messengers of society' for a university. Concretely, EPFL has created a dozen new programmes during the last ten years in the areas of sustainability and artificial intelligence, and has recruited more than 50 new professors to meet the new teaching needs[16].

Conditional to a sufficient level of resources, autonomy and leadership, an RU is well positioned to concentrate assets and activities in areas of high societal relevance. A question arising from this claim, however, is whether most of the research programmes labelled as 'directionality mode 1' are necessary. Perhaps the resources spent for these programmes would be used more efficiently if they were transferred directly to RUs, to increase their capacities to respond to their students' needs, and to build the relevant teaching and research programmes. They just need to know their students, listen to them, and respond to their new values and aspirations. When an RU is doing that, it becomes naturally and logically a key asset to help society overcome the Grand Challenges.

With a strong and powerful RU sector, many programmes located in the top-right quadrant of table 6-2 become redundant. The strategic goal of concentrating resources on thematic areas while preserving academic freedom can be almost entirely fulfilled by RUs at lower cost[17] and higher social returns because of the double-positive externality.

The same cannot be said regarding the capacities of RUs to manage and execute spontaneously ARPA-like programmes as per mode 2. These programmes, which are targeting very specific and concrete goals within a short period of time, are not easily executed in a spontaneous way within the RU system. High levels of coordination, oversight and monitoring, and high DAC require specific management and governance mechanisms, and hence specific agencies and instruments. By design, the GRL sector should always be a key resource in any country willing to deploy an ARPA-like policy.

15 EPFL is part of the Eurotech Alliance – including DTU, TUM, TU/e, Technion and Ecole Polytechnique Paris – which are all powerful higher education and R&I institutions. Of course, this is just an example of the many European universities that exemplify the model presented here.

16 Source: General Secretariat at EPFL.

17 There is no administrative cost to manage a mode 1 programme, and DACs are minimised given the newly recruited scientists match the fields of high societal relevance.

5.4 Research universities and the ‘triple spillover’ in the context of Grand Challenges

When Grand Challenges matter, powerful and autonomous RUs are well prepared to concentrate resources and focus research in areas of critical concern, and can thereby generate spillovers in terms of knowledge and human capital in the relevant areas of societal priorities. Empowering RUs to make them capable of responding to student demands by creating new programmes and recruiting new professors to teach in these programmes and conduct research in the corresponding areas is a priority.

In fact, when Grand Challenges matter, RUs generate a third type of spillover through international student flows. A vibrant campus of any European RU is a powerful mechanism for raising awareness and communicating a new narrative – for instance on climate change, sustainability, etc. – to students arriving from countries outside of Europe. By way of utopic example, a student coming from outside of Europe to make a chemical engineering degree may return in her home country four years later to launch a start-up in *green* biochemistry. However, the spillover mechanism is not about imposing some kind of green propaganda or teaching the doxa. It is just as much about student’s socialisation within a great campus – through the coffee-shops, the student associations and the social events – as it is via the offer of relevant educational programmes[18].

RUs are, therefore, a precious asset for countries that are today under pressure to address various Grand Challenges. Because of this pressure, countries should allocate more resources to their RUs, which clearly need to have enough capacities, leadership and strategic autonomy to be able to re-direct teaching and research agendas in a decentralised and bottom-up fashion, and to maximise the triple-positive externality in the considered areas of societal relevance.

Regarding the GRL sector, a more administrative logic should apply. According to principles of planning and control, GRLs serve specific or ‘special’ missions which are determined by the government or its agencies. The problem here is one of how the tension between job autonomy (as distinct from academic freedom) and discipline is managed, how well the predetermined research objectives are met, and thus, how the key principles of public accountability and discipline apply.

18 Empirical evidence on the third spillover effect is missing, although a research project is currently in progress, titled ‘Are student flows a source of knowledge spillovers for green technologies?’ (Marino, M.).

6. Conclusion

This critical review was developed as a reminder of the fact that coining a new word such as 'directionality' in the area of innovation and research is not enough to see it working in practice. The opposite is the truth: science and innovation is very difficult to drive, and there are some risks involved in trying to do it. The importance of the emerging science and innovation policy research domain therefore becomes clear.

Overarchingly, this chapter discussed the issue of 'directionality' in relation to the public research system. It was also demonstrated that RUs are better suited to i) concentrating resources on strategic areas which matter for society (purely by responding in terms of teaching and hiring to student's needs and demands), and ii) producing a triple-spillover (education, research and rising awareness) in relation to these strategic areas. Conversely, a relatively small, transparent, and accountable GRL sector was held to be effective in responding to urgent technological policy needs, as well as to inform the fast paces demands of data-driven policy making.

Because of the great properties of the RU sector, the way countries are managing strategic research needs to be critically evaluated. According to the Azoulay framework as modelled through table 6-2, one mode of managing strategic research is easy to implement and minimises directional adjustment costs, but is likely to have a weak impact on the mission identified. In countries where the RU sector is operating well in terms of resources, leadership and autonomy, such programmes are in many cases superfluous. The other *modus operandi* – often identified with the ARPA US policy – is much harder to operationalise, and entails high directional adjustment costs. However, its potential impact is likely to be much higher when the foci of research objectives are about fast and rather precise technological achievements. Nevertheless, it is not easily managed in a system where academic freedom and decentralised decisions are the rules.

A set of recommendations for European countries could therefore be:

- to develop, improve and empower the RU sector;
- to keep the GRL sector as a small fraction of the public research funding, and reform it under strong principles of public accountability and discipline;
- to implement an ARPA agency when and where it is needed to improve the strategic arm of the government.

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