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Innovation policy and directionality - a case for policy engineering

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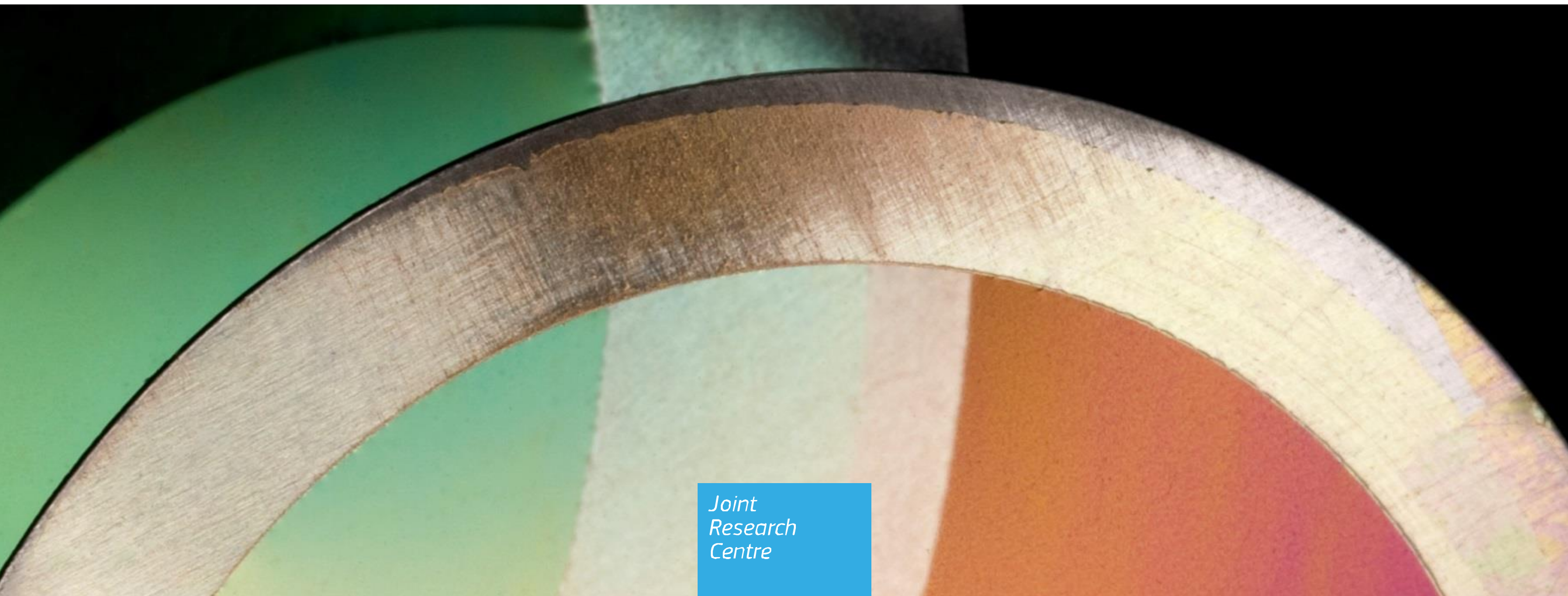

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Contents

Abstract

This paper deals with a series of 'innovation policy engineering problems' which are related to directionality, mission and transformative objectives. They involve the design of 'calls', the development of instruments to manage the tension between directionality and freedom to experiment, and the number of instruments to be deployed to support systemic transformations. These problems need to be identified and treated so that the innovation policy approaches which are currently deployed at regional level – such as smart specialization strategies and partnerships for regional innovation - can be effective in delivering directionality.

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1 Introduction

We are still missing serious works in the area of policy engineering. Mission-oriented innovation policy (Mazzucato, 2018, Foray, 2022, ESIR, 2018), partnerships for regional innovation (Pontikakis et al., 2022), smart specialisation strategies (Foray, 2023), targeted horizontal policies (Bergamini and Zachmann, 2020) are all important policy approaches which involve in principle some properties of directionality. These approaches make sense from a theoretical point of view and are based on a significant body of literature. However, we all know that a sound policy concept can have no impact because failures happen at the stage of concrete design and implementation. The area of policy engineering is about the way policy instruments and programs are designed and implemented in order to get what the policy concept 'promises' to deliver[1]. In the area of innovation policy, the devil is in details and there are many cases of very smart and theoretically-grounded policy concepts which just don't work in reality for one or another reason. Indeed, design and implementation of a policy is not just about a strong theory and the beauty of the concepts cannot substitute for serious works on policy design and implementation.

In some cases, it is because there are intrinsic problems in the policy idea which makes it almost impossible to work in the real world[2]. In other cases, this is because not enough works have been done in the engineering of the concerned instruments so that there is a gap between how the instruments are actually performing and what the policy concept is supposed to do.

In this paper, I will deal with a series of 'innovation policy engineering problems' which are related to directionality, mission and transformative innovation policy. They involve the design of 'calls', the development of instruments to manage the tension between directionality and freedom to experiment, and the number of instruments to be deployed to support systemic transformations. These problems need to be identified and treated so that the policy approaches mentioned above can be effective in delivering directionality[3].

[1] Examples of such works on innovation policy engineering are given by papers on the design of grand innovation prizes (Murray et al., 2012) or of course on the design of patent.

[2] Think for instance of the patent buy out policy proposal by Kremer (1998) or the self-organized investment boards by Romer (1993).

[3] The ideas developed in this paper were first discussed within ESIR under the leadership of Luc Soete and Johan Stierna and then within the JRC expert group chaired by Luc Soete and Sylvia Schwaag Serger, as well as within the S3 CoP expert group of DG Regio chaired by Lena Tsipouri. A first academic argument was then presented in the Economics of Incomplete Plan paper (Foray, 2022). For recent developments on regional innovation policy involving directionality, see McCann and Soete (2020) and Schwaag-Serger, Soete and Stierna (2023).

2 Is it easy to influence direction? A preliminary discussion on directional adjustment costs in science and innovation

I will not challenge the various approaches mentioned above on their ability to really affect the direction of innovation. The question remains open and the economic literature is not converging on the question whether it is possible to design policies or strategies to affect the direction of technical change and innovation[4].

In the first place, it is always important to recall that bottom up principles and freedom to experiment are fundamental ingredients for research and innovation success. This means that policies cannot simply decree the "right" direction. And trying to obtaining 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 : "when scientists are free they are more efficient" (Azoulay et al., 2011). As a consequence, calls have grown for more flexible funding arrangements that leave more discretion to the scientists, because project-centered arrangements reduce incentives to be creative (Myers, 2019). Of course funding matters and the allocation of more funding to specific fields can change the course of science (see Gaulé and Murray, 2015 on malaria vaccine research funding) but empirical research shows that science is inelastic at least in the short run. Switching costs are high, in some cases so high that they are even detrimental to any direction changes.

Myers (2019) is probably the first scholar addressing 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. 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 and this can explain that grants allocated to proposals responding to targeted calls are bigger than grants allocated to proposals responding to non-directed call competitions.

Mancuso and Broström (2023) address similar issues and provide evidence based on an empirical study of targeted calls issued by the Swedish Foundation for Strategic Research. The evidence they produce have implications about 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 there is no difference between winners and non winners in the type of shift which is produced. There is therefore what they call an application effect (instead of a funding effect) which needs to be considered by funding agencies.

With a different approach, Foray and Cook (2007) address also the elasticity of science. They present a study of an extreme case of mission-oriented grant scheme: the research agency of the Department of Education in the US decided to push strongly quantitative research and experiments based on randomized clinical trials (RCTs). The goal of the agency was that RCTs-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 a discipline (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.

Scholars also warn about 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: 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" (Shankerman, 2009). Also there are strong complementarities among fields and these are hard to predict in advance. For both 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 provides caution and a longer range perspective than they otherwise take.

[4] A complication to the debate among economists is that the concept of 'direction' – which was initially developed to capture a very specific feature of technical change (as involving a labour-saving and factor substitution logic) – is used nowadays in a much broader sense, which can create some confusion and ambiguity in policy discussions. For example, the policy discussion on AI is based on a rather narrow concept of direction (see e.g. Bresnahan, 2019) while the policy discussion on sustainability is based on a much broader concept. See WIPO (2022) for an update and policy-oriented discussion on the concept of *Direction of Innovation.*

In innovation, the case for a precautionary approach to directionality can be made as well: success always depends on decentralized decisions of potential innovators and customers, driven by socio-economic incentives. This makes it highly uncertain, unpredictable, difficult to plan and to organize. One of the giant of innovation economics and history – N. Rosenberg - made this point very clearly: “It is fundamental to the understanding of the nature of innovation to recognise that uncertainties are still at the heart of innovative activities. This implies a key principle for policy makers: preserving at all costs the freedom to experiment”. Freedom to experiment is a key principle, which will make innovation not always aligned to socially desirable directions. As a consequence, every policy maker should know the famous sentence of the same author (Rosenberg, 1992) “Innovation can’t be planned” Another perspective developed by innovation economists involves the measurement of directional adjustment costs of R&D (mostly in the energy sector). It appears again that these sorts of adjustment costs are very large because prior factor-specific investments differentially influence current productivity (respectively of the ‘dirty’ and the clean energy technologies) (Aghion et al., 2016).

These introductory remarks are made just to remind the fact that coining a new word such as directionality is not enough to see it working in practice. The opposite is the truth: science and innovation are very difficult to drive and there are some risks to try to do it. Hence, the important of science and innovation policy research in this area.

3 S3 directionality failures

In this section, I focus on the smart specialisation strategy case (S3) because this policy approach has attracted a lot of attention from policy makers, practitioners and economists, it has been implemented at large scale in the EU and has therefore produced a lot of information about real practices of policy design and implementation.

Anecdotal evidence about S3 shows that once a priority area has been established (which classically associates a sector (or a group of sectors) with a transformational goal) and then problems, gaps and opportunities have been properly identified through the entrepreneurial discovery process (EDP), the process stops often because of a lack of knowledge and command of the policy toolbox. The reality is that there is a large variety of instruments available; each of them is suitable to certain types of problems, gaps, opportunities. I experienced many cases of EDP in various regions where the process led to significant contributions of stakeholders in terms of the identification of problems and gaps which needs to be addressed in order to achieve the targeted transformation. But at some points, the process got stuck because of the lack of knowledge about the adequate policy responses. The policymakers present in the room provided poor support. Then the EDP turned into some kind of wish list with no concrete determination about the next policy step.

It is then rather disappointing to observe that in many cases the EDP failed in generating powerful roadmaps for driving transformations in a specific direction (such as pushing a certain industry (or a group of related industries) towards a sustainable trajectory of development). One could speak here of a policy mess because S3 has, by design, some directionality properties.

Indeed, any S3 process starts with the setting up of priorities which associate sectors and transformational goals. Through this prioritization phase, policy makers and stakeholders are able to provide a direction – e.g. a transformational goal – for the strategy. And in most cases of regional S3, these directions have some relevance with both green and digital agenda of the EU: the recent report by Prognos and CSIL (2023) highlights the fact that "with more than 700 out of 1018 (69%) priority areas of the 185 S3 in the EU, a majority of the priority areas have a connection to the topics of the green and digital transition" (ibid, p.65). So, in principle S3 can deliver directionality. But a nuance needs to be made to this statement – which is about the capacity of the policy makers and stakeholders to translate any priority area into a concrete roadmap including policy solutions which will deliver directionality in practice.

In many cases, the policy responses to the identified problems and gaps are reduced to calls for proposals in order to fund individual RTDI projects by consortia of research and firms. The Prognos & CSIL report (ibid) observes then that not only the diversity of instruments is not well exploited, but the one which is used (calls for R&D proposals) is in most cases poorly designed. Most calls which are designed throughout the S3 process are typically very broad. Gianelle et al. and Prognos & CSIL (ibid) highlight this problem – showing that, even in several cases, calls are addressing all priority areas together (the call is opened to projects addressing any of the existing priorities), instead of focusing on single priorities (Prognos & CSIL, p.174).

Once a priority has been established which has some directionality properties – such as establishing a circular economy for a group of industries or developing a resilient, digital and sustainable agriculture or innovating in medical devices to address specific health issues, it remains then for the S3 actors to drive the transformation through an appropriate use of the relevant policy instruments. Here the challenge of designing and using the right policy instruments comes.

4 Problems of policy design

I will discuss three problems of instrument's design when the innovation policy is supposed to provide directionality.

Designing calls to drive transformations in a certain direction

It is surprising that scholars and policy experts don't pay enough attention to the issue of designing calls for proposals. Indeed, issuing a call for projects is the most obvious and used policy instrument to deal with a range of problems and opportunities; and depending on whether the call is poorly designed or well done, the policy will deliver the desired outcome or not! We can argue rightly and repeatedly for more directionality and mission-driven innovation, if we don't work on how designing a call so as to get the desired transformations, nothing will happen!

From my recent interactions with regional policy makers and ERDF administrators and desk officers[5], it becomes clear that most calls are poorly designed and are typically very broad. However broad call can't deliver directionality! For instance, if a regional priority is, say, healthcare transformations, then the policy process will issue a call for projects in healthcare! This is very broad and it will work like trawling in the ocean: you cast a huge fishing net in the deep sea and you see what you will catch! You have no control on what you will catch! Through such broad calls, the policy process can't drive the desired transformations. The need is, thus, for much more specific calls which are tailored according to problems, gaps and opportunities.

Then, the next obvious question is why most calls are broad? Actually it seems that designing a call in the area of EU regional policy is a coordination problem between three classes of entities: regional policy makers, ERDF administrators and the industry/research partners. It then appears that all incentives are aligned towards broad calls: first, for regional politicians broad call means coffee for all; second, for ERDF administrators broad call increases the chance to spend the funds on time (which is an important KPI for them); and three, for industry & research partners broad call increases the chance to be relevant!

However such broad and poorly designed calls will not deliver what any mission oriented policy or S3 is looking for: addressing specific issues (knowledge, human capital, infrastructures, services, technologies and processes) to drive a transformation following a clear direction. We have here an interesting explanation about why S3 fails in many cases to deliver directionality, in spite of the fact that the S3 process explicitly involves prioritization: because the practice of broad call, albeit always used, is inconsistent with a S3 logic. And the PRI approach will fail equally in its capacity to influence the direction of innovation if the call design problem remains poorly investigated.

Moving to more specific calls is rising several design issues that needs to be addressed: how specific a call should be, at what granularity level, how to find a good trade-off between the fact that calls need to be specific and the fact that the number of potential applicants needs to be sufficient, etc.

Managing the tension between directionality and freedom to experiment

Inserting some directionality properties into a policy approach generates necessarily a tension between planning (which is the essence of a mission) and freedom to experiment (which is a central requirement for innovators, see below). This tension between mission and innovation or discipline and indiscipline creates challenges and issues for the design and implementation of the considered policy instruments. This tension calls for some modesty on the side of the policy process, since as already claimed: « innovation can't be planned » (Rosenberg, 1992).

The analysis of 'mission-oriented innovation policy' as an oxymoron emerged within the ESIR expert group (ESIR, 2018) and was further developed in Foray (2022): "a mission – in economists 'jargon - expresses an intentionality not directly linked with the economic incentives of private agents. It therefore imposes a discipline, and centralised priorities and decisions. It consists of goals, sub-goals, deliverables and targets. It is often conducted by an elite corps of scientists and engineers and a small number of dedicated companies. Innovation by definition eludes all this 'military' terminology" (ibid, p.124). Innovation fundamentally requires decentralized entrepreneurial search, freedom to experiment and strong autonomy from the Government. Here I am adhering to the reflections of authors as disparate as Phelps (2006) or Rosenberg (1992) who argue that innovation is essentially an economic discovery process: it is the validation of a new idea, new

[5] Last year, I was involved in a series of workshops organized by the Swedish national agency for regional development (Tillväxtverket) which gathered regional policy makers and ERDF officers.

product or service by the economy, consumers and companies. The uncertainty concerning consumer preferences, costs and potential profits make this validation extremely uncertain. The economic discovery and validation are essential since if they are not achieved, the new technology – even if it is green and exemplary from the environmental point of view (for example in the case of a mission concentrating on climate change) – will not be adopted. This makes innovation highly unpredictable, difficult to plan and to organize.

This is perhaps Rosenberg (1992) who wrote the most convincing argument on the potential clash between mission and innovation: "The notion that planning and centralization of decision-making are efficient is the opposite of the truth when there is a high degree of uncertainty and when goals and objectives cannot be clearly defined"[6].

But if innovation can't be planned, how directionality can be generated? Can we design policy instruments which can help to manage this tension and solve the oxymoron? Let's open the innovation policy toolbox[7].

In this toolbox, one can find neutral instrument such as the patent system or R&D tax credit; neutral means that they can't be used to influence the direction of innovation. They have no directionality effect as they are applied in all invention domains[8].

However, many of the standard innovation policy instruments can be used non-neutrally. In other words, they can generate incentives for a particular domain or direction and can be sufficiently well specified in order to avoid any abusive exploitation of the tool outside the mission domain. However, this specification of the tool will logically increase its design and monitoring cost[9].

Using policy tools in a non-neutral way means that the policy tool will help to attract resources and concentrate research and innovation forces in some pre-determined fields or sectors corresponding to the mission or transformation goal. Such direction can come at the expense of the freedom of the innovator. However, as said in footnote 6, freedom to experiment is a key ingredient of innovation success (Rosenberg, 1992). It is, therefore, important to differentiate policy instruments according to the way they can promote flexibility and freedom to potential innovators as searching for solutions, even if they are used in a non-neutral way (i.e. they have some directionality effects). Different tools can offer larger or smaller scope for freedom to experiment and give more or less leeway to potential innovators for their innovation decisions. It is, therefore, important to evaluate and compare various innovation policy instruments in their capacities to find a good balance between directionality and freedom to experiment.

The historical example of the prize offered by the British Government to find a solution to the Longitude problem is highly instructive (Kremer and Williams, 2010). While the prize committee expected astronomers and mathematicians to develop a solution, the invention was actually developed by a clockmaker. This shows that an ex ante prize which specifies solutions and not methodologies promotes freedom to enter (the competition) and to experiment. A prize focusing on methodologies or, as an alternative mechanism, an R&D subsidy schema (which would have only accepted proposals by reputed astronomers and mathematicians) would have missed the clockmaker. Policymakers need to use tools that offer the best balance between mission and targets on the one hand and freedom to experiment on the other.

Innovation policy tools can be roughly subdivided into two categories (Kremer and Williams, 2010; Kyle, 2020): push programs and pull programs.

1. Under a **push logic**, the instrument addresses essentially the cost of innovation activities. This includes the direct provision of research through government labs, directed grants and subsidies to R&D; R&D tax credits; subsidies to transfer of technologies or to support innovation adoption.

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[6] Quotation from ESIR (2018)

[7] Recent works by Bloom et al. (2019) and Teichgraeber and Van Reenen discuss a number of innovation policy tools -emphasizing those which can be subject to causal evaluation – tax incentives for R&D, patent boxes, Governement research grants, human capital supply, intellectual property, programs to support small firms. Kremer and Williams (2008 and 2010) add to the toolkit the instruments which can be used for solving grand challenges: prizes, advanced market commitments.

[8] Both instruments are not perfectly neutral since they create bias in favour of firms doing R&D or firms inventing something. But the expression neutral instruments means at least that the beneficial properties of the instrument (such as low administrative and monitoring costs) are conditional in that they are used in a neutral way (e.g. they are not used to support preferential interventions). Using them for preferential interventions in specific fields would greatly increase all these costs. For instance, if someone would like to turn an R&D tax credit into a non-neutral instrument – for example a green R&D tax credit – all of the dimensions of the policy would become much more difficult and costly (Foray, 2019).

[9] For instance, it is possible to design a program of R&D subsidies corresponding to specific objectives identified by a mission but this will imply a detailed control of the alignment of the projects to the mission and their subsequent execution in accordance with the mission's objectives (Foray, Mowery and Nelson, 2012).

2. Under a **pull logic**, the instrument addresses essentially the reward for a successful activity. The most important pull policy is patent protection but in many sectors and circumstances ex ante prizes and advanced market commitments are gaining in importance. Public procurement for innovation can also be considered as a pull instrument.

As in the case of the marine chronometer, pull instruments seem to have an advantage against the push instruments when directionality matters. They create a better balance between directionality and freedom to experiment.

The theoretical argument is that when policies need to affect both the level of innovator's effort and the direction of innovation, while preserving freedom to experiment, pull instruments such as an ex ante prize will make a better job to fix a particularly significant market failure. This market failure involves the fact that research and other innovation inputs only produce knowledge with uncertainty. As observed by Bryan and Williams (2021), in many business contexts, uncertainty does not harm economic efficiency as long as risks can be suitably hedged. But Arrow (1962) noted that the uncertainty of research and innovation is combined with the fact that the principal cannot observe the effort of the agents. This means that innovation involves uncertainty which cannot be fully hedged because success depends on unobservable effort by inventors. This market failure is particularly significant for mission innovation where the supported inventors not only are expected to allocate the appropriate level of effort to innovation but also to allocate it in the right direction or domain. Then the design of efficient policy instruments raises new questions. How to get the appropriate level of effort in the right domain from potential innovators if the latter cannot be observed and monitored?

Some instruments following the pull approach increase the rewards for developing specific knowledge and products by committing to reward successful innovations conditional on their development and diffusion. It becomes clear that in the context of an innovation policy – where:

- An appropriate level of efforts in a certain mission's area is required;
- The freedom to experiment is preserved as an essential condition of success; and
- The market failure of unhedged uncertainty is highly significant;

these pull mechanisms seem to be very adequate. Mechanisms such as advanced market commitment or grand prizes, involving ex ante technical specifications and metrics of ex post use, identify targets and achievements and set up a reward conditional on the production of the specified output and perhaps on its impact (diffusion). Such instruments are likely to solve the three problems of direction, freedom to experiment and unhedged uncertainty by combining incentives and coercion. Public procurement for innovation is a policy instrument which displays the same beneficial properties in such policy contexts where directionality is needed, freedom to experiment remains key and the market failure of unhedged uncertainty is massive[10].

Of course, a lot of issues need to be addressed for designing a fully operational instrument which is supposed to strongly incentivize potential innovators to commit resources to innovation in a certain area, while keeping the reward conditional on success. For example, Kremer and Williams (2010) suggest that the schema should guarantee all firms (not only the winner) partial reimbursement for R&D sunk costs as they achieve milestones. The partial reimbursement ensures that firms have "skin in the game", in spite of high probability of not winning the race.

<u>How many instruments?</u>

Finally, how can we be sure that supporting the execution of a roadmap to achieve a systemic transformation will not result in a piling up of useless instruments that are poorly coordinated and ultimately costly? Respecting the S3 principle regarding the correct definition of a transformational roadmap for a priority – that involves supporting not only breakthrough innovations but also actions to solve coordination problems of many sorts – is likely to produce an over-elaborate policy. The same will be true for PRI – as a policy approach which is supposed to involve many instruments. Then the question is: how many? Do we deploy too many programs or not enough? A policy design principle is essential here. It is the one known as the *Tinbergen*

[10] Public procurement for innovation displays other interesting properties as an adoption mechanism: government and other public agencies can act as "lead customers", making large purchases of a new technology or product at an early stage in its development. Such lead customer generating substantial early purchases can generate several benefits for the whole industry: economies of scale in production, learning effects and reduction in production costs and prices, improvement in product quality, learning in use, etc. Collectively, these benefits can accelerate improvement in price/performance ratios, supporting broader adoption by non-government users, etc.

assignment theorem that provides at least first-order guidance on the number of instruments or programmes that need to be deployed according to the goals or targets (Tinbergen, 1967)[11]. The number of externalities or market failures should determine the number of instruments. Take for instance the case of the mission of the digital transformation of agriculture as a condition for its sustainability. The EDP has produced a transformational roadmap according to which there is a need for instruments to support research and start-ups, because of knowledge externalities as well as capital market imperfections, and instruments to support technology adoption and skill formation in the agricultural sector because of adoption and network externalities as well as training externalities. Coordination failures can happen at the interface between the high-tech and traditional sectors as well as between SMEs and research. Again, different instruments would be needed to fix this (for example a platform of specialised services to support transfer of technologies). All in all, the execution of the transformational roadmap in this special case should therefore involve a certain (but not uncontrolled) number of instruments to be implemented in a coordinated way.

[11] The idea of applying the Tinbergen assignment theorem to innovation and industrial policy was suggested by Paul David in a personal memo to OECD DSTI in 1994.

5 Conclusion

There are interesting and useful works to be done in this area of innovation policy engineering, particularly as the principle of directionality becomes central in the policy agenda. This should be an area of particular relevance for the JRC whose works are at the interface between academic research and policy practices. If this work is not done, the consequences are highly predictable: great concepts – very little effect.

References

Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R. and Van Reenen, J. (2016), Carbon tax, path dependency, and directed technical change: evidence from the auto industry, Journal of Political Economy, 124(1)

Arrow, K. (1962), Economic welfare and the allocation of resources for invention, in RR Nelson (ed.), The rate and direction of inventive activity : economic and social factors, Princeton University Press, 609-666

Azoulay, P., Graff Zivin, J. and Manso, G. (2011), Incentives and creativity: evidence from academic life sciences, RAND Journal of Economics, 42(3)

Bergamini, E. and Zachmann, G. (2020), Understanding the European Union's regional potential in low-carbon technologies, Working Paper 07/2020, Bruegel

Bloom N, Van Reenen J and Williams H (2019), A toolkit to promote innovation, Journal of Economic Perspectives, 33(3), pp.163-184

Bresnahan, T. (2019), Artificial Intelligence technologies and Aggregate Growth Prospects. Available: https://web.stanford.edu/~tbres/AI_Technologies_in_use.pdf

Bryan, K. and Williams, H. (2021), Innovation: market failures and public policies, NBER w. p. 29173.

ESIR, (2018), Memo II – Implementing EU missions, ESIR expert group, European Commission

Foray, D. (2019), On sector non-neutral innovation policy: towards new principles, Journal of Evolutionary Economics, vol.29

Foray, D. (2022), The economics of incomplete plan – on conditions, procedures and design of future mission-oriented innovation policies, Review of Public Economics, 243.

Foray, D. (2023), Smart specialization strategy, in Cantner, Fornahl and Kuhlmann eds., The New Role of the State for Transformative Innovation, forthcoming

Foray, D., Mowery, D and Nelson, R. (2012), Public R&D and social challenges: what lessons from mission R&D programs?, Research Policy, 41(10)

Foray, D and Cook, T. (2007), Building the capacity to experiment in schools : a case study of the Institute of Educational Sciences in the US Department of Education, Economics of Innovation and New Technology, vol.16(5)

Kremer, M. (1998), Patent buyouts: a mechanism for encouraging innovation, Quarterly Journal of Economics, 113(4): 1137-1167.

Kremer M. and Williams H. (2010), Incentivizing Innovation: Adding to the Tool Kit, Innovation Policy and the Economy, vol 10

McCann P. and Soete, L. (2020), Place-based innovation for sustainability, European Commission, JRC

Mancuso, R. and Broström, A. (2023), Do mission-oriented grant schemes shape the direction of science?, draft

Mazucatto, M. (2018), Mission-oriented research and innovation in the European Union – a problem-solving approach to fuel innovation led growth, European Commission, Brussels

Murray F, Stern S, Camphell G and MacCormack A (2012), Grand Innovation Prizes: a theoretical, normative and empirical evaluation, Research Policy, 41 (10)

Myers, K. (2019), The elasticity of science, draft

Phelps, E. (2006), Further steps to a theory of innovation and growth – on the path begun by Knight, Hayek and Polanyi, ASSA 2006 Conference Paper

Pontikakis, D. et al. (2022), Partnerships for Regional Innovation – Playbook, EUR 31064 EN, European Commission

Romer, P. (1993), Implementing a national technology strategy with self-organizing industry investment boards, Brookings Papers- Microeconomics, 2: 345-399.

Rosenberg, N. (1992), Economic experiments, Industrial and Corporate Change, 1(1)

Schankerman, M. (2010), Comment, in Foray ed., The new economics of technology policy, Edward & Elgar

Schwaag-Serger, S., Soete, L., and Stierna, J. (2023), The Square: Putting place-based innovation policy for sustainability at the centre of policy making, European Commission, JRC

Teichgraeber A. and Van Reenen J. (2022), A policy toolkit to increase research and innovation in the EU, R&I Paper Series, 2022/02, European Commission

WIPO, (2022), The Direction of Innovation, Geneva