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« *Evaluation des concours d'innovation du PIA (2010-2021), de la start-up à la PME innovante-Mission d'évaluation de politiques publiques pour le compte de l'ADEME et Bpifrance* »

A note on innovation policies

Philippe Laredo

23 Mars 2022

This note positions developments of and debates on innovation policies in a historical and wider context. It is complemented by a set of resources mostly produced by me and a set of colleagues with whom I very often work with.

Its ambition is to enable the reader to have a background to position the 'programmes' and 'activities' under evaluation.

It covers 4 dimensions: Initial definitions and key concepts mobilised, a simplified model for analysing components of a policy, a macro view of the evolution of policies since their creation as S&T or R&D policies at the beginning of the 1960s, and a discussion about factors to consider and challenges ahead. It concludes by discussing caveats linked to the evaluation of effects and impacts.

Part 1: Initial Definitions and Key Concepts

(Main source: handbook of Innovation policy impact, called the 'compendium')

Innovation policy

Public intervention to support the generation and diffusion of innovation, whereby an innovation is a new product, service, process or business model that is to be put in use, commercially or non-commercially.

It covers innovation the **generation**, its initial use (mostly through market introduction) and its **generalization** (whether called diffusion, uptake, adoption or replication).

Target groups: actors who generate innovation on the supply side, and actors that ask for it, absorb and use innovations from the demand side

Locus of policies

De facto most work on innovation policies focus on national states and their governments.

The relevant loci are then ministries and agencies explicitly responsible for the 'economy' and for 'innovation' with 2 caveats: (a) blurred delineation with S&T policy; (b) critical role of sectoral ministries (even if their interventions are not labelled innovation policy)¹.

However, this definition has been progressively blurred by the emergence of new policy actors: regions and in Europe, the European level. Most of the goals pursued have become de facto '**multi-level**' meaning that the 3 levels (plus more and more metropolitan areas) develop each 'innovation' policies, that co-exist on the field for actors, and which complementarities, in numerous cases, remain to be analysed.

Rationales for intervention

¹ This also applies at the European level between framework programmes and structural funds (the latter spending de facto more resources than the framework programme per se)

I present the 3 dominant ideal types. The reader should be aware that they are seldom mobilised alone, but in multifaceted combinations and incorporating strategic dimensions linked to other and/or wider policy objectives.

Market failure: the classical intervention. Key 'historical' sources: Arrow 1962, Nelson 1971 further expanded by Metcalfe (1995) or Metcalfe and Georghiou (1998). Rests on appropriation asymmetries and externalities of knowledge as information. Drives to suboptimal levels of knowledge and innovation generation. Objectives of public interventions: initially nurture the 'pool of knowledge' in which innovating actors can draw. More widely: support the cost of generating new knowledge (whoever are the actors: public or private) and favour intellectual property rights (that will enable innovating firms to capture the benefits of investments made).

System failure: It is based on 'innovation system' approaches. Such approaches focus on processes and the importance of interactions and complementarities between heterogeneous actors and the corresponding flows of knowledge. They further highlight learning as critical to dynamics. The central papers are linked to functions of an innovation system (Hekkert 2009 or Bergek 2008) and to the capacity to identify, diagnose and address 'policy problems' within the system (Edquist 2011, Borrás & Edquist 2013). Three main issues have been identified as a source for public interventions: dealing with legal, regulatory & financial conditions; dealing with inadequate capabilities; dealing with insufficient exchange, interaction & cooperation.

Addressing societal missions and challenges. This was one of the three core dimensions of S&T policies when formalized at OECD (Piganiol, 1963) alongside support to fundamental/academic research and to the development of a friendly environment for firms to innovate. For more than half a century 'mission-oriented policies' (the name given by the 1963 Piganiol report) have built the core of budgetary appropriations. These 'mission-oriented' approaches have been opposed by Ergas (1986) to 'diffusion-oriented' ones. 20 years later, this notion re-emerged as central under the terminology of societal challenges: first and foremost, around climate change and energy/ mobility, but also and more and more health issues (ageing, chronic diseases, and the successive crisis we have been through since the beginning of the 2000s). The notion of directional policies was coined (Weber 2012) with advocates for the rebirth of mission-oriented policies (Mazzucato, 2018).

De facto analysis of policies (see the wealth of OECD country evaluations) demonstrate that all S&T, R&D, STI or R&I policies (these terminologies have been present simultaneously for more than 3 decades now) are always a combination of the 3 macro initial dimensions underlined by Piganiol and of the 3 rationales.

Moving from rationales to roles

In a very recent paper (2020), Borrás and Edler propose, through the analysis of case studies, to add another dimension to the characterization of public interventions. They have identified 13 distinct roles that the Government intervention may play, and they show how each intervention studied is a specific combination of roles. Roles are both central to the implementation structures developed or mobilised for operating the public intervention, and for a multi-faceted analysis of its effects (whether expected or realized). Of course, this list remains preliminary and indicative, but as such the formalization of roles played for implementing a policy enables a clearer definition of the ways in which the higher-level policy objective has been 'translated' into action.

Below is the list of the 13 roles identified and a short definition associated to it.

The 13 roles played in implementing R&I policies

Observer: the state monitors the course of events, following up the developments and trends in the socio-technical system.

Warner: the state identifies potential risks to users, citizens and institutions; develops and communicates a warning narrative around those risks.

Mitigator: the state tries actively to reduce the negative effects that arises as a consequence of socio-technical change.

Opportunist: the state takes up the opportunity arising from socio-technical change, becoming itself an active beneficiary of the new social technical system for specific purposes.

Facilitator: the state actively seeks to make a process easier by supporting specific dynamics of other agents' change initiatives.

Lead-user: the state initiates market creation by acting as lead user and co-designer in order to find specific solutions to public needs.

Enabler of societal engagement: the state encourages actively the involvement of stakeholders in participatory processes to define direction of change.

Gatekeeper: the state actively controls access for change agents, opening up or closing down spaces for experimentation and transformation.

Promoter: the state acts as a champion, proponent and exponent of change in the sociotechnical system.

Moderator: the state acts as an arbitrator or negotiator between different social and political positions among agents regarding the direction of transformation of a sociotechnical system.

Initiator: the state identifies early on some opportunities, and pro-actively uses its own knowledge and resources to work in concrete ways for the transformation of the sociotechnical system.

Guarantor: the state actively and directly secures operations against financial and/or security and safety risks.

Watchdog: the state actively ensures that individual agents in a sociotechnical system comply with particular collectively defined norms.

Some comments on roles: clearly promoting and facilitating roles are most often part of public interventions. It is often accompanied by anticipation capabilities based upon in-depth observation of the situation. More and more analysts have underlined the critical role of the state as lead-user (through all sorts of procurement activities). In 'directional policies' enabling social engagement, moderating and gatekeeping often become important features of public interventions.

Policy portfolios and policy mixes

The critical notion and observation is that policies and each of their macro-objectives (following Piganiol) have never been reduced to one instrument but de facto combine multiple instruments, building what we call a policy portfolio. Often this happens through cumulative addition over time without any discussion of the internal coherence (in space and in time) of the set of interventions. When it is pro-actively produced and structured, it becomes a policy-mix and this is an important dimension of both international discussions (see OECD 2010) or of academic work (Flanagan 2011, see Cunningham 2012 for a review).

Most observations made in OECD country evaluations highlight the richness of policy portfolios to support innovation. The review made in the Compendium 10 years ago (but the situation, following experts has not that changed) highlights the very limited number of pro-actively created policy mixes. In fact apart from the German High tech strategy (at the time still embryonic), the only elaborated examples found were with energy agencies in France and Sweden that highlight the importance of articulating supply and demand side tools along the innovation cycles specific to the different energy solutions supported.

A typical example of policy portfolio is linked with SME policies in France. Historically the 'aide à l'innovation' was created at ministerial level in 1968. It operated a move from the post WWII policy focused on industries with the creation of 'centres techniques'. It was later (1978) delegated to a dedicated agency and focused on smaller firms (ANVAR had been created earlier as an agency to support the transfer of knowledge from public research to industry; and sat beside another support for helping firms accessing the pond of existing knowledge). Over time the range of firms covered has enlarged from a narrow definition of manufacturing. This has been complemented since 1983/4 with an R&D tax credit (witnessing successive rounds of transformation), while structures to support 'transfer' have multiplied over time, from CRITT to new creations by the PIA (mostly SATT but in a way also IRT, ITE or IHU) building what multiple public reports have called the French 'Millefeuille'. And activities dealing with small firms have multiplied, in particular for dealing with start-up firms directly or indirectly (through support to venture capital funds and companies) and at all stages (from incubating to supporting growth, moving further down near market introduction or even generalization with supports to users). This was combined with specific supporting programmes for dedicated sectoral dimensions, in particular for energy-related or ICT related technologies (in the 1980s it was for the adoption of robotics or new materials). More recently the approach of 'filieres' (very fashionable in the 1980s as a de facto precursor of value chains) was rebirthed to organize public technological intervention, adding to the realm of potential supports for individual firms. And to be complete, one should mention in this list addressing firms and their projects the 'poles de compétitivité' that play an important role to access national project-based funding of firm (and inter-firm) projects.

It is thus important not to consider an instrument in isolation from other instruments that share the same or a similar macro-objective. But it is also important to highlight the combination of objectives in particular the combination of specific groups of industries, specific uses and given societal goals.

Policy instruments: 3 understandings of instruments (important reference: Van Nipsen, 2011)

Classical understanding: a policy instrument is seen as a policy mechanism for goal attainment. It is a top-down view based on the ability of government actors to identify a gap, understand its cause, design the appropriate instrument and implement it.

Modified understanding: It takes into account the context and process of the implementation of instruments as a major factor of success (meaning that 2 instruments with the same delivery structure might have very different impacts depending upon the context (actor landscape and capabilities, existence of other instruments, broader framework conditions, etc.)

Institutional approach to instruments (major ref: Lascoumes & Le Gales 2007): instruments are not neutral devices but quasi-institutions constructed with certain normative and causal ideas, collectively structured in given actor arenas, and undergoing a dynamic process of (re) definitions (of problems, roles, and ways of doing).

Borras and Edler (2014) show how relevant this latter approach has become for R&I policies, linked to the multiplication of available instruments. Recent work also highlights the old notion of 'national preferences' for certain instruments.

Policy instruments: A list of innovation policy instruments

The key reference used here is Edler and Georghiou (2007) taken as the central feature for organizing the 'compendium'.

A first central difference lies in the core actors they directly support: suppliers or users of innovation. A second central difference lies in the main goal they pursue or were originally conceived to address.

- A central goal (that has been for long the only one addressed in quantitative evaluations) has been to increase the R&D spend (in particular with direct support to firm R&D projects or tax incentives to reduce R&D costs)
- A second goal has often been to improve the Human resources of firms for innovating, either directly or indirectly. This has entailed policies for supporting training activities at the firm or professional level, facilitating access to technical services or expertise, and more and more developing entrepreneurial capabilities. And a number of analysts have developed broader views in which higher education as such becomes an important framework condition, in particular by developing professional curricula articulated to the environments in which they operate (whether 'local' or 'professional').
- A third goal has progressively gained in importance since the 1980s and the dominance of the system approach: nurturing collaborations and complementarities between (heterogeneous) actors at the industry/domain level, but also and more and more at the regional or local level.
- The 2000s are marked by two complementary foci (see EC Aho report as a landmark): reviving the role of demand in innovation diffusion, and rediscussing framework conditions (in particular IPR and regulation/standards).

The following is a list of frequently mobilised instruments to implement innovation policies. It does not capture instruments supporting the creation of public capabilities and the management of public research.

		Supply	Demand
1	Direct support for firm R&D & innovation	xxx	
2	Fiscal incentives for R&D	xxx	
3	Supporting HR capabilities	xxx	
4	Access to technical services & advice	xxx	
5	Policies to support collaboration	xxx	
6	Policies to support innovation networks	xxx	
7	Cluster policies	xxx	
8	Policies supporting demand for innovation		xxx
9	Public procurement of innovative solutions		xxx
10	Pre-commercial procurement	x	xxx
11	Innovation prizes	xx	xx
12	Standardisation & standards	xx	xx
13	Regulation	xx	xx

		Increase R&D spend	Increasing HR capabilities	Improve systemic capability	Enhance demand	Improve framework
1	Direct support for	xxx				

	firm R&D & innovation					
2	Fiscal incentives for R&D	xxx	x			
3	Supporting HR capabilities		xxx			
4	Access to technical services & advice		xxx			
5	Policies to support collaboration	x	x	xxx		
6	Policies to support innovation networks			xxx		
7	Cluster policies			xxx		
8	Policies supporting demand for innovation				xxx	
9	Public procurement of innovative solutions	xx			xxx	
10	Pre-commercial procurement	xx			xxx	
11	Innovation prizes	xx			xx	
12	Standardisation & standards				x	x
13	Regulation				x	x

The list is interesting not solely to position the instruments under evaluation, but also to actively think about the portfolio or mix in which they participate, and to characterize the portfolio they participate to, their relative importance, the potential complementarities (in space and time), but also the potential competitions or redundancies between prevailing instruments.

Part B A simplified model to characterise research and innovation policies

For a review see R6.1 a review course made for Manchester PhDs (2008 for the first edition used here), and a positioning analysis made for computer science analysts (Venice 2011, R6.2).

OECD has been at the core of the development of theories and frameworks underlying the framing of what was first called science and technical then technological policies, progressively incorporating innovation (STI policies or research and innovation policies) to be now often only termed as innovation policies.

The initial models were designed at OECD from its start (early 1960s) based upon a linear view of innovation. This entailed a focus on R&D expenditure (with the emergence of Frascati indicators) and a focus on 'market failure' and 'new industries' to tailor public interventions vis à vis firms.

The 1980s drove to a completely revised understanding of innovation processes around four critical dimensions: (i) the importance of tacit dimensions in the circulation of advanced knowledge and the multiplication of industry-university collaborations; (ii) the variety of technologies a new product incorporates which drives to a reconsideration of firm core competences and the transformation of suppliers in co-developers; (iii) the role of 'lead-users' in the effective shaping of new products or services. (iv) The three combined drive to the explosion of innovation networks, and of 'trial and error' processes and the importance of learning in innovation dynamics. For firms the consequence is a shift in innovation management focusing on projects.

This has nurtured multiple reflections about the relationship between innovation dynamics at the micro level and structuration and public intervention at the macro level. Evolutionary economics pushed the notion of 'system failures', driving economists and historians linked to OECD (Freeman 1987, Lundvall 1988 and 1992, Nelson 1993 and Edquist 1997) to propose the new conceptual framework: national systems of innovation. This concept has become prevalent in both academic and policy circles to discuss research and innovation policies.

For teaching purposes (PhD students in Manchester, engineers in Paris), I have built a simplified model (see R1, 2017) that is constituted of 4 poles

- Supporting invention with intellectual property as the first organized type of public intervention already in the 19th century,
- Market framing through regulation and standards, a mostly internationalized dimension and a growing one (see for instance REACH and chemical products)
- The wide range of policies to counteract market failures, and more recently system failures
- Supporting innovation in public goods, including science.

All this articulated around the organization of the system that builds a crucial dimension of its performance and relevance

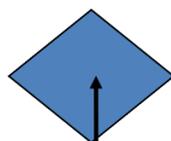
The resource mentioned (R1) captures historical developments of each of these poles and the recent trends.

Un modèle simplifié des justifications de l'intervention publique



Soutenir l'invention: la propriété intellectuelle

***Les défaillances
du marché et du
système***



***Le cadrage
des marchés***

Innover dans les biens publics
- Besoins régaliens : défense et sécurité
- Besoins des citoyens: santé, éducation,...
- La science comme bien public

***Le système et son organisation au coeur de la
pertinence et de la performance des politiques***

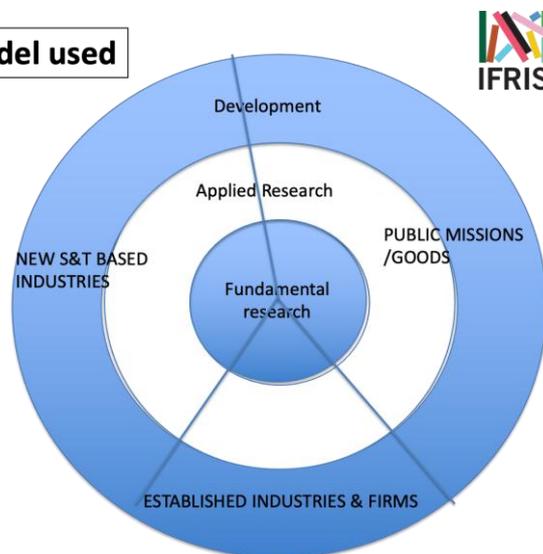
Part C- A macro view of the evolution of innovation policies over the last 50 years

This part proposes a simple view of the 3 main periods innovation policies have gone through, highlighting the preferred type of instrument for each period, considering that nearly all instruments have remained in existence and now co-exist.

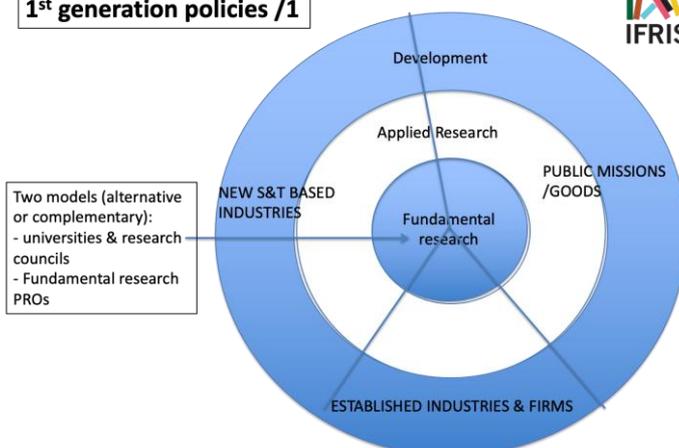
It is based upon two OECD critical sources: the recognition of the 3 types of over-arching goals proposed by Pigiainol, and the segmentation depending about the type of research activity conducted (here to simplify: fundamental, applied or development). In this model we distinguish between existing and new industries/technologies.

The four images below that sum them up, are taken from an extensive presentation made in 2017 in Vienna (resource R2). It is further explained in a book chapter in homage to Paloma Sanchez, a colleague who has been at the vanguard of work on intangibles in firms.

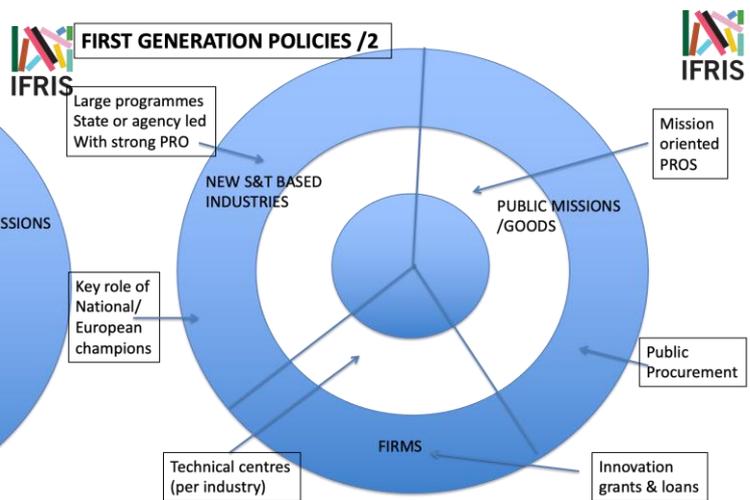
Simplified model used



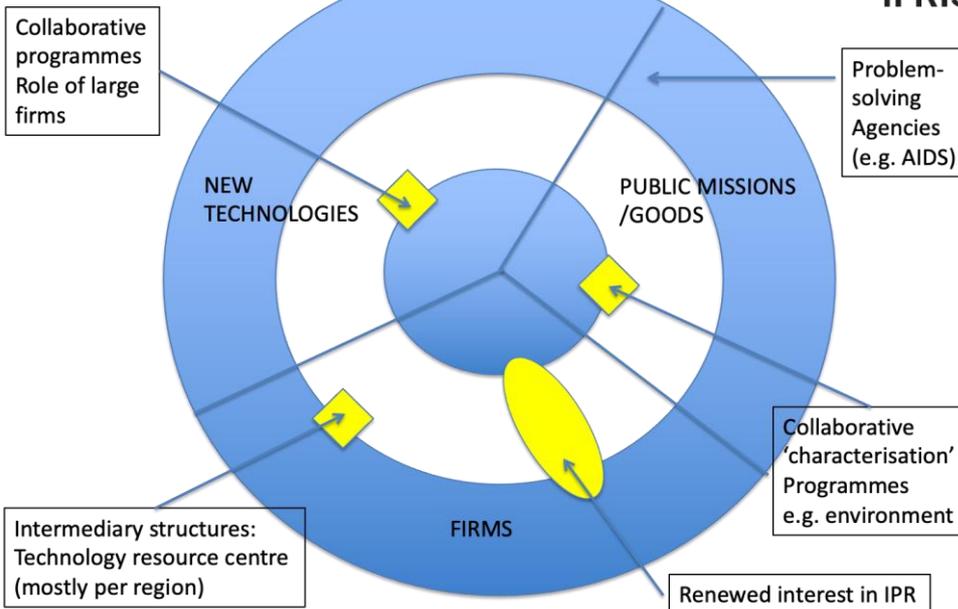
1st generation policies /1



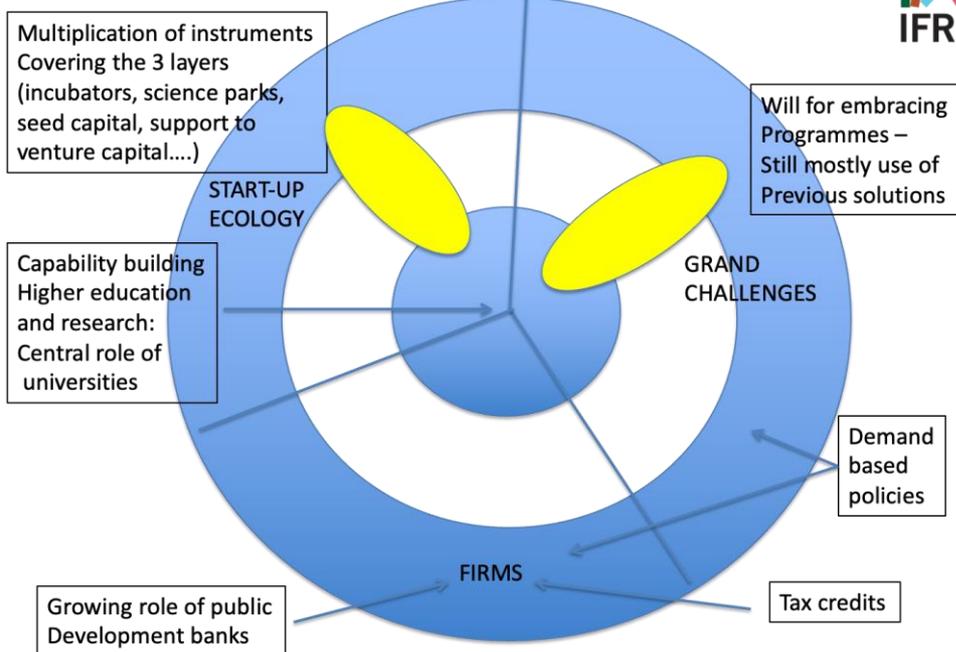
FIRST GENERATION POLICIES /2



2nd generation policies & national innovation systems



THIRD GENERATION POLICIES



A simplified account of moves observed

A1 - From supporting fundamental research to capabilities development

First generation policies following countries have adopted two models for supporting fundamental research: the construction of dedicated PROs (e.g., CNRS in France or Max Planck in Germany), or the creation of research councils for funding University research projects (e.g., the UK research councils or DFG in Germany). While most countries have focused on one model, some have combined both (as is shown here for Germany). This choice has remained stable for the different countries during the first two generations of policies observed and it is only during the third generation that a convergence took place. On one side, countries like the US recognized the importance of Federal Labs (especially for valorisation policies); On the other countries like France or Spain created funding agencies. This has driven to a central evolution shifting the focus from 'fundamental' research to academic research and training capabilities. Everywhere Universities have become central, and the object of multiple new types of policies (focused on their excellence materialized by the new tools for international ranking).

Two notes on France:

- (a) ANR is a recent creation (2005) with a fast initial growth before a progressive marginalisation, making France rather unique in the European landscape (Lepori et al. 2007). But if one considers that CNRS is a 'unique' type of resource agency for joint labs located in universities, the French situation does not differ at all from other countries (see Theves and Laredo 2007).
- (b) The PIA is a typical feature of policies supporting 'excellent' universities with an important concentration of means over a long period of time on a limited number of universities. It is also quite similar to other initiatives in developing targeted mechanisms that enable a wider but focused coverage of universities (with labs of excellence, mid-size equipment and graduate schools).

A2 Existing industries: A progressive focus on SME and delegation to public development banks & tax credits

What has changed most between generations is the way to support the innovation ecology. In all the generations, policies have made a distinction between existing industries and 'new' developments: new high-tech industries in the first generation, new and advanced technologies in the second generation, start-up firms in the third (see point A3).

In the first generation, existing industries were mostly supported by industry based 'technical centres' and individual supports for R&D projects of firms. Technical centres have progressively lost importance (though most of them still exist) and have been complemented by multiple types of initiatives at the local/regional level broadly encapsulated in the terminology of technology resource centres. In parallel we have witnessed a permanent development of support to firm R&D projects over time but with a strong (if not exclusive) focus on SME. This development has gone along with a strong professionalization first through specialized agencies, and progressively the need to address

the survival and growth of firms has driven to incorporate them in public development banks that play a central role in a number of large countries (in particular Germany, Italy and France, see Laredo 2016 on this move with special reference to Italy, R4).

The second generation of policies added another smaller component for supporting SME to patent. It also included the emergence of tax credits that have become in many countries the most important financial tool to support innovation in third generation policies (France is an extreme example of this).

The 2000s have also witnessed a return of a pro-active role of procurement policies (public authorities represent 1/6th of total country buying on average) and more widely of demand-based policies (e.g., to support the adoption of renewable energies or lower domestic energy consumption products). This movement is still on-going and very articulated to the growing importance of 'societal challenges' (see section A4).

Finally societies (at a wider level than nations and states) are undergoing three major changes pushed by the central role of services, globalisation and the growing importance of users. We know quite well the first two but they are very few elaborations about the potential consequences of the third one that I have articulated (in a provisional way) around 5 developments: crowd sourcing, political consumption, social innovation, 'do it yourself' (including 3D printing and fablabs) and sharing economy. This has even driven me to ask whether 'we should throw the baby with the bath waters' (see R3, 2018 and R2 2017).

A3 From New industries to new technologies and to the start-up ecology

The second dimension of public policies for firm innovation is the one that has witnessed the most impressive changes: each generation has favoured another focus.

The first generation focused on creating new S&T based industries (aerospace, telecommunications, nuclear...). It was based on heavy funding organized in large programmes mostly under the aegis of dedicated agencies. Research and competence building were allocated to dedicated PROs, while support to development was concentrated on 'national' champions that progressively became European and/or world champions when countries were able to join their programmes as in aeronautics or space.

These large programmes have had a central importance in budgetary allocations until the mid 1990s where a shift progressively occurred that significantly reduced their financial role (more because of the increase of the overall budget for R&I than of a decrease in funds allocated).

The shift started with the emergence of the national innovation system approach and the emergence of a new generation of technologies (ICT, robotics, biotech and later nanotech). EU programmes have played a large role in this transformation, acting as frontrunners through a new type of instrument: collaborative programmes. Even though the range of actors has widened vastly, large firms have been de facto the structuring agents of these programmes.

Third generation policies have shifted focus probably following the dynamics initiated in the US in a very different context. Start-up firms were associated to breakthrough technologies

and the emergence of new markets in what we now label the digital economy & society, and to a lesser extent through the emergence of biotechnology (see below Part 4 on factors and search regimes). Whatever the explanation, within one decade the creation of new S&T-based firms has become a central preoccupation with a multiplication of policy instruments dealing with all aspects of creation, and growth (concours, incubators, seed capital, entrepreneurship policies, venture capital....).

Analyses made tend to highlight three profiles: (a) they are a critical resource in the development of a “Business to Research market” where large firms more and more delegate specialized R&D activities to start-up firms²; (b) they are ‘demonstrators’ of the relevance of new approaches and when doing so are bought by large firms in the search of new ways of addressing or complementing their markets³; and (c) and more and more: the GAFA have generated a myth of small firms becoming giants, with as a critical step, becoming ‘unicorns’ (this has even become a marker of the performance of a national system).

A4- From ‘sector-based’ mission-oriented policies to ‘societal challenges’ driven mission-oriented policies

First generation policies are associated with the systematic development in most countries of sector-based Public Research Organisations (PRO) to produce ‘applied research’: for agriculture, construction, transport, communication infrastructures, hygiene and health, etc not forgetting defence. And public procurement (following military practices) was the most important tool for incorporating new solutions faced by the corresponding department.

Second generation policies partly shifted to problem-solving agencies or programmes (AIDS being a typical case) while environmental issues generated a new type of collaborative ‘observation’ or ‘characterisation’ structures with long-term objectives mixing academic and applied research (some used the denomination strategic research to capture this evolution).

We are in the middle of a third generation focused on societal challenges and highlighted by UN ‘Societal Development Goals’. These interventions do not stop at the production of knowledge needed to address problems identified and aim at embracing the development and wide adoption of solutions. Solutions no longer appear as solely technological but incorporate critical social dimensions that no longer are linked with ‘acceptance’ policies but require the co-development with citizens concerned of potential solutions and their experimentation. OECD speaks of ***system innovations*** that require simultaneous transformations in products and services, infrastructures, values and norms, and user/consumer/citizens practices. Such system changes require new types of processes where experimentation becomes crucial, where the general use of solutions developed can follow very different pathways (diffusion of products being only one out of many) and where most require institutional changes at ‘higher level’ to be generalised. Geels (2002 for the seminal paper) has proposed a ***‘multi-layered’ approach*** combining niche, regime and landscape dimensions.

² This is often linked with the joint location and a quite large concentration in large or very specialized metropolitan areas

³ A large survey done in the mid 2000 on biotech start-ups showed that nearly all fast growing ones had been bought over by large pharma firms

These characteristics have pushed academics (cf. Mazzucato, 2018 report to the EC) to focus on a new type of mission, that translates at a managerial level the societal challenges keeping the focus of system innovations and of transdisciplinary research and development. Even if the term adopted send us back in history, discussions of the new missions focus on their objectives, coverage, design, and implementation. Foresight tools have been redefined to assist in this process. The re-evaluation conference to come in Vienna is exemplary of this move with over 2/3rds of the presentations dealing with ***transformative policies*** and ***new mission-oriented policies***.

A striking phenomenon when policy mixes are being considered for these missions, is the variety of existing policy instruments that are remobilized in a new way, such as incorporating mission values and aspects to standards, targeting firm support to developments that feed in global solutions envisaged, etc.

Part 4- Factors to take into consideration

One important lesson of all evaluations of S&T or R&I policies has been to underline the importance of context. This has been highlighted in most of the OECD work (cf documents produced by the specialized committee at OECD, CSTP) and has been an important component of comparative analyses since the development of S&T policies (see Henriques and Larédo, 2013).

This has driven to numerous developments that consider policies from different angles. These are helpful to better shape and analyse public interventions/ policies to support actor innovation capabilities and the collective construction of such capabilities.

I propose in the following paragraphs, 4 complementary entry points that may enrich the debate on policies supporting SME innovation capabilities (it will probably be complemented in further versions).

A) Knowledge dimensions 1: not 'one size fits all' policy for different 'search regimes'

Bonaccorsi (2005 for the seminal paper) has proposed the notion of search regimes to discuss the differences in the characterization and dynamics of knowledge production. He considers 3 attributes in the definition of a search regime, and the core hypothesis is that different fields exhibit different attributes.

- The rate of Growth (WOS publications grow on average 1% per year, but it was 8% in genomics and 14% in nanotechnology in the period 2010-15) while we know from management, that markets become turbulent when, this rate exceeds 5%.
- The degree of convergence or divergence of the field (linked to the variety of high-level hypotheses that organize the field research agenda). He opposes high energy physics (with the standard theory) to molecular biology, where new knowledge multiplies rather than reduces the number of hypotheses made.
- And the importance and nature of complementarities needed. This third dimension has turned critical in the comparative analysis of different fields. Complementarities might be technical (e.g., organized around large facilities, based on technological platforms...), cognitive (i.e., the importance of inter / pluri/ multi-disciplinary research) or institutional (requiring university-industry or academic-clinical collaborative or joint work).

This has driven a set of colleagues to identify the core configurations associated to different fields over the last 70 years stylizing the dominant science, their dynamics, modes of production and coordination, their core industrial actors and industries (see R5).

What is important here for policies lies

- (a) in the role of anticipations and forms of alignments. In physics it works with early selection of a design and cumulative coordinated developments; in computer science and IT, what turned critical was linked to the adoption of standards (e.g., the semiconductor roadmap and its way to define the next five generations for each edition), while no such dimension does exist for molecular biology where the dynamics is supported by a competition between multiple paradigms.
- (b) In the role of infrastructures: Physics created the concept of large equipment (and big science) while IT deployment was linked to the telecom generic infrastructure

(creating the first generation was however critical in the overall dynamics) and progressively the internet / world-wide web. In molecular biology as in nanotechnology what is needed are technological platforms that can be accessed by most large labs and most regions/ metropolitan areas.

- (c) In the modes of coordination: large programmes for physics, technological and collaborative programmes for computer science and IT, networks and clusters for molecular biology and biotechnology, multi-actor poles and PPP for nanotechnology.
- (d) Key industrial players also widely differ between ‘national’ champions (those firms widely supported by their governments), large multi-national (and now global) firms, new-technology and start-up firms, and pre-existing incumbent large firms

All these have strong implications about the way a public intervention and its mix of instruments can be built, being both dependent of space and time (in the maturing cycle of fields).

R6, a presentation made about this approach, discusses implication on two critical dimensions for public interventions: supporting variety and exploration, market framing (as a selection and crystallization environment and process).

Table: Stylized search regimes. (Source: Larédo, 2006, updated 2010)

‘Dominant science’	Physics	Computer science / IT	Molecular biology	Nano ‘convergence’
Dynamics Crystallisation	Large objects or technical systems	Distributed IP (patent pools...) Strong industry-university relations	Science based / ‘individual’ IP (transfer / licences)	Hybridisation of ‘long distance’ disciplines
Trajectory	Early selection of a design / cumulative improvements	Adoption of standards and design tools	Competition between paradigms	(initially) based on previous trajectory of ‘central’ discipline
Critical infrastructures	Specific very large equipments	Generic infrastructures	No (limited) entry barriers	Technological Platforms + ‘interdisciplinary gatherings’
Modes of coordination	‘Large programme’ (product oriented)	Technological programmes	Networks & clusters (bottom-up)	Multi-actor poles (PPP): ‘Nanodistricts’
Main industrial actors	national champions (specialising in public infrastructures)	Multinational Firms (oriented toward mass markets). Specialised NTBF (B to B)	Start-up & venture capital in initial phases / (concentration around large established firms during diffusion)	Central role of ‘incumbents’ (global firms ‘B to B’ et ‘B to C’, ex start-up from previous waves)
Typical ‘industries’	Nuclear energy, Space, civil aeronautics, digital wired telecoms	Information technology, mobile telecom (GSM), internet-based firms	Biotechnologies	No specific industry (A support to R&D activities of most firms)

B) Proximities: relevant spaces for action as a new critical dimension for Research and innovation policies

I mentioned national systems of innovation as the core framework mobilised to discuss R&I policies for over 30 years. But it is important to know that there are 10 times more academic papers dealing with regional systems of innovation, and more and more work at the level of metropolitan areas.

This links with Marshall's classical work on industrial districts (see different versions of *Industry and Trade*). He considered that industrial districts where actors from the same industry gather, is an alternative to the integration into large vertically organized firms. This is because: (a) it enables to share competences and knowledge bases directly or indirectly (training, informal exchanges...); (b) it drives to specialization (both in the product value chain, and in products themselves); and (c) it offers a unique place for users to see the products of the industry and operate their selection. There has been ample work on districts (see the work on Italian districts) and clusters (see the seminal work by Porter, 1998) and cities and metropolitan areas (Jacobs 1969, see the important comparative paper by Beaudry 2009). Whatever the terminology clusters (poles de compétitivité in France) have become an important feature of policies, strongly highlighted at the European level by smart policies.

In Europe this has gone with an important political movement of decentralization in most centralized states (apart from UK, once account is taken of devolution). France is part of this movement that have progressively seen regions develop innovation-based development policies and higher education and research policies. Evaluations have even shown a reversal movement in the key instruments articulating national and regional activities (the CPER) where the source of the initiative has fully reversed from the central government to regional executives and their proposal capacity. And the movement of national policies towards procedural approaches (exemplary of poles de compétitivité or universités d'excellence) has reinforced the primacy of regions on the substantive definition of activities.

Recent work in geography has underlined the role of 'global cities' (see the multiple existing rankings, Chakravarty et al. 2021 for a review). In a recent work (Laurens et al., 2019 & 2021), we have demonstrated that the top 100 metropolitan areas represent 80% of total international patents showing the importance of Metropolitan areas in knowledge production. One decade ago (Laredo et al., 2010) we demonstrated a similar concentration for the emerging domain of nanosciences and technologies. Such concentrations which drive even large countries to count only a few poles, question policies based upon a wide geographical spreading of resources and call for complementing them by a place-based component even for policies targeting frontier knowledge.

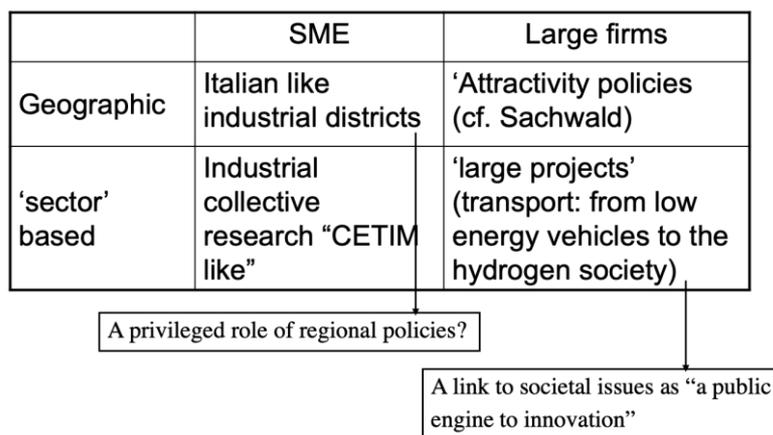
The core argument justifying such place-based policies lies in the role of proximity in the development of knowledge resources linked to the uncertainties of science in the making or frontier science, and in the corresponding absorptive capacity by firms. This is an important dimension to take into consideration whenever designing or analysing a policy. And the

central question becomes: *How important are proximities in the attainment of the goals pursued? And what type of proximities should be pursued?*

Here reference must be made to the seminal paper by Boschma (2005) on the other 4 types of proximities that can complement or substitute the advantages linked to geographical proximity: cognitive (linked to the belonging to a field or a specialty with its infrastructures of journals, conferences, workshops and the practice of joint research), organizational (mostly associated to the belonging of the same firm, with shared knowledge bases and important dimensions of cumulative learning; but also linked to lasting cooperation networks), social (linked to relations at the micro level through alumni associations, professional or family networks, see Granovetter on the strength of weak ties), and institutional (linked, following North, to values, ways of thinking and doing shared at the macro level mostly of countries).

Here follows a simplified elaboration to illustrate the type of proximity at play in the definition of policies (source: ENPC master course).

Employment and competitiveness of established industries: new “proximity policies”



C) Different policies for different types of innovation?

Innovation studies have long recognised the existence of different types of innovation. The classical differentiation in economics lied between incremental and radical innovations (see R7 on innovation types and actors, 2018)

Incremental innovation is based on existing competences and knowledge bases of firms. It is produced through established routines both in ways of doing and in relations between different services in firms. Most of the times it consists in adapting existing products to 'newly recognised' needs (a new market segment, a new geographical extension, a new function). These adaptations are mostly managed at business unit level while central labs focus on maintaining and deepening firm core competences in a cumulative way. Both

together represent 90% of industrial R&D. Most projects supported by public interventions are of this type.

Radical innovation breaks from this cumulative approach and introduces breaks either in the technologies mobilised or in the markets targeted. Abernathy (1985) has beautifully captured this in his synthesis article produced before his death, recognising 3 situations of radicalness:

- radical change in technology without changing markets (so called 'revolutionary' innovation): Dyson and the vacuum cleaner is a really spectacular case.
- radical change in accessing markets keeping the same technological environment (so-called 'organisational' innovations): For me the most striking example is Apple with both the ipod and iphone where what counted were itunes and a complete shift in the way to access music and the Appstore, also a complete revolution in the circulation of software for mobiles. New business models (mostly based on customer internet-based relations combined with a wealth of logistical innovations) makes of this type of innovation probably the dominant type of breakthrough innovation nowadays.
- Radical change in both technology and market use has been called by Abernathy 'architectural' innovation and is mostly labelled as breakthrough innovation today. His example remains the best example I know of. It articulates the development of the electric starter in cars with the opening of a completely new use: the use of cars by women. This generated two major transformations: a new technological paradigm with the progressive electrification of multiple functions in the car and a progressive shift in car architecture. And a complete redefinition of the market (where women buyers in the US nearly represented half of the total market within one decade).

That notion was pushed from the micro to the meso level by evolutionary economists speaking of technological paradigms (Dosi) and dominant designs (Tushman and Anderson). Dominant designs have been mobilised by science and innovation researchers to analyse the emergence and adoption of new technologies. They have identified two critical phases & dimensions:

- the role of 'protected spaces' or 'niches' to initiate a learning curve and enable initial moves from research to development. This corresponds to a fluid phase where concepts and designs multiply.
- The second phase is linked to the construction/ mobilisation of a selection environment that will enable the progressive emergence of a 'dominant design' that will structure the possibilities of development of the new technology. An example often taken to illustrate the emergence of a dominant design is the case of the GSM. Quite a few studies highlight the importance of 'market shaping activities' that are often linked to the transformation of regulations and standards, but also consider values that users/consumers integrate (the 'no palm oil' is a very visible example on products, or the label for sustainable fish which has gained a lot of traction).

Pushing more on the knowledge side, Stokes (1997) proposed a complementary approach to knowledge production, considering both understandings at stake (existing or new paradigm) and perspectives or not of new applications. He thus defined two quadrants (out of 4) that have been extensively used as references linked to new anticipated applications: the 'Edison'

quadrant where the application is new but based on existing knowledge (often assembled and integrated differently) and the 'Pasteur' quadrant that correspond to Abernathy architectural innovations where both the knowledge and the application are new. The labelling of this quadrant as Pasteur quadrant recalls something that is again at the core of today's issues: vaccines and the fight against 'pests'!

Types of innovations



Disruption in	Use/market NO	Use/market YES
Technology NO	Cumulative / incremental innovation	Organisational innovation & new business models
Technology YES	'revolutionary' innovation* (in technology and/or ways of producing the same good)	'Architectural' innovation*

* Other terms: radical or breakthrough innovations

Key Ref: Abernathy and Clark (1985)

Stokes Quadrants

	New understanding NO	New understanding YES
New applications YES	EDISON quadrant	PASTEUR quadrant
New applications NO		BOHR quadrant

Incremental innovations, cumulative knowledge, stabilised networks

These considerations have a strong resonance with the last 20 years of policies. In France we tried to design an agency for large breakthrough projects that failed facing dominant EC rules because they relied quasi exclusively on selected large firms (often one only) that would become champion of the new innovation, thus breaking competition rules. It was easier to support breakthrough innovations when they are pushed by start-up firms that have very limited chance to disrupt the overall landscape (and when in a position to do so, will most probably be bought by an incumbent large firm through traditional market rules). This was even easier to promote when using procedural approaches, leaving substantive matters to mediating actors (such as venture capital funds).

D) Knowledge dimensions 2: how important are the different types of knowledge mobilised

We have underlined the importance of national and innovation systems approaches as a basis to ground innovation policies. There has been a third approach to systems based upon economic sectors (seminal paper on sectoral systems of innovation: Malerba 2002). This in part grew out of the work done by Stankiewicz on 'design spaces' (2000). He opposed two types of design spaces: synthetic and analytic design spaces

- Synthetic design spaces are born in domains/sectors where knowledge is accumulated within firms, largely linked to accumulated experience ('learning by doing') and firm internal knowledge on what works or not, and how to do it. This concerns most industries where the 'engineering' experience prevails.
- Analytical design spaces rely on the development of scientific activities, require strong university-industry linkages, depend highly on the patents that protect the new knowledge produced, and often drive to a wealth of start-up firms that demonstrate (or not) the value of the new concept ... and end-up mostly in

acquisitions (before or after IPO). Biotechnology was the core example selected to illustrate this new path (further demonstrated by Rothaermel 2007).

Asheim (2011) added a third type of knowledge: symbolic knowledge that is well illustrated worldwide by the rankings that evaluate the value of brands. Brands do not only 'guarantee' the qualities of products⁴, they also incorporate societal values (e.g., no work by children, or no impact on primary forests) and personify individuals' positioning in society. They often are considered as the core asset of large and global firms. They instil a number of non-functional aspects to the design of new products and processes.

Industries and firms widely differ in the balance of the 3 types of knowledge, and my guess is that it is an important factor to define the type of instruments needed in a policy-mix (even when dealing with support to SMEs).

Part 5 – caveats and words of caution when considering impacts and more widely for evaluation purposes (preliminary)

In 2012 we were asked by INRA, after a full review of existing methods, to develop a new approach for measuring impacts of research. The ASIRPA approach has proven quite successful, being institutionalised with INRAE and source of multiple academic articles. See R8 for the first article reviewing the literature that supports the approach developed.

Four aspects strongly resonate for the present evaluation.

- a) Impacts observed are highly concentrated on a limited number of projects: typically 80% of what is measured comes from 10% of projects.
Rather than measuring all projects the same way, it might be more fruitful to identify those with strong impact and develop specific metrics for understanding more in depth what explains this⁵. Similarly, I do not know of evaluations that have specifically targeted the eventual negative effects for the other projects and firms (so as to better design criteria for selection of future programmes)
- b) They are direct and indirect effects: the BETA approach developed in the 1980s was focused on indirect effects that firms benefit from projects e.g., new knowledge capabilities, new HR, new collaborative capabilities. An even more important dimension for small firms is learning about organisational aspects and ways of doing R&D and incorporating it as an intrinsic dimension of their activities. Others have spoken of 'behavioural additionality' to characterise these aspects.
- c) R&I activities nearly all start before the official start of projects and end far after the project official end date. This drives to consider effects that span over a longer time frame and incorporate other that supported activities ('project fallacy'). How to consider the role of the support granted in this overall R&I process is a critical issue for understanding what is measured. The ASIRPA method looks at the role and contribution of INRAE research to innovation networks and impacts. It would be

⁴ Think of the debate on generic drugs and the role of fake products on the internet or on markets in less developed countries.

⁵ Reference should be made of the extensive work done on these aspects by colleagues in the frame of ADEME evaluations.

interesting to try and develop (even on an exploratory level) an approach to address this critical issue (that probably introduce tremendous biases in all measures produced)

- d) The ways through which the impact is generated is seldom internal to the firm, rarely linear or ballistic, goes through phases and should differentiate 'initial' situations of use from 'generalised' use by targeted audiences. This is why impact pathways have become widely used in multiple evaluations and heavily discussed in academic circles as a major dimension for understanding dynamics of effects and impacts.

One core caveat about the measure of impacts.

'Winners and losers': not a zero-sum game, but..."

Innovations mostly enable firms to gain market shares in existing markets. This means that other firms lose their positions and this drives to job losses. It is useless to measure gains at the national level not considering activities that have been discarded. Of course, the policy discourse most often focuses on export gains or of replacing imports (one of the oldest public interventions since the mid 1900, following List). But this is seldom the case and the jobs won in Toulouse resonate with the jobs lost around Lille! Remember: 'what is good for General Motors may not be good for the US'. Of course, one may consider that if the innovation had not taken place in France, then it would have in other countries and the replacement effect (i.e., jobs lost) would be the same. The question is how to develop models and approaches that help to deal with these aspects not only at the micro but also at the meso level.

The situation may differ with breakthrough innovation, as it aims to be a change agent. For a long time, it was classical to say that prime movers were seldom the winners in new markets and that early followers with a better market or service definition largely benefitted (e.g., Google). But this seems less and less the case and now we consider that there is clearly a lasting advantage for prime movers. But this holds as long as prime movers remain autonomous firms (thus may be the focus on unicorns), but this may not be the case when firms are bought (Phil Cooke has spoken for biotech firms of 'decapitation', with all the advantages of growth going elsewhere than in the places of initial development).