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REGULAR ARTICLE

On sector-non-neutral innovation policy: towards new design principles

Dominique Foray[1]

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Abstract
The paper addresses the shift from a moderate innovation policy to a more radical one, aimed at radical transformations of existing structures, such as accelerating innovation to address grand societal challenges or to modernize a traditional sector. In this paper, we propose an analytical framework based on the identification of three constitutive rationales of policy intervention in the domain of innovation. This approach introduces the distinction between moderate and stronger modes of intervention. Stronger modes are characterised by a higher degree of intentionality, centralization and focus. The last part of the paper is devoted to certain principles of policy design under which the risks of such a shift can be minimized and positive effects can be maximized.

JEL Classification 025 · 031 · 038

Keywords Innovation policy · Non-neutral policy · Eclectic approach · Policy design

1 Introduction

This article begins with the assumption that certain innovation policy goals – such as accelerating innovation to address grand societal challenges or to modernize a traditional sector – imply a change in the degree and nature of innovation and research policies that have dominated the policy landscape in the past thirty years. These policies have been characterized by a moderate degree of interventions and *neutral* logics of resource allocation – in other words, such policies have deployed programs and instruments to support innovation without any pre-determination of the domains, sectors or technologies where these instruments should be used. Our assumption is

✉ Dominique Foray
dominique.foray@epfl.ch

[1] Chair of Economics and Management of Innovation, Institute of Technology and Public Policy, College of Management, EPFL, ODY station 5, 1015 Lausanne, Switzerland

that such types of innovation policy are insufficient in supporting more radical transformations, such as the modernization of an old industry or the acceleration of innovation to solve certain grand societal problems. It is thus necessary for policy to shift to a higher level of intervention, characterized by a higher degree of intentionality and prioritization. However, such a shift is full of risks. Adopting *non-neutral* logics of resource allocation, which implies preferential intervention, would result in much higher responsibilities for the government. Moreover, such a shift would open Pandora's box, with all of the ensuing problems that economists fear.

The current paper addresses this shift from a moderate innovation policy to a more radical policy, aimed at radical transformations of existing structures. Furthermore, it explains the conditions under which the risks of such a shift can be minimized, and positive effects can be maximized.

Our first section proposes an analytical framework based on the pragmatic use of market failure and other imperfections regarding R&D and innovation. This pragmatic or eclectic approach allows us to recognize the helpfulness of certain results of the economic analysis that are integrated within our framework, even if they stem from distinctive theoretical bodies. This allows us to identify three constitutive rationales of policy intervention in the domain of innovation. We can distinguish then in Section 2 between moderate and stronger modes of intervention based on the types of problems addressed (market failure, coordination needs, directionality). Sections 3 and 4 are devoted to certain principles of policy design that we consider as useful in minimizing the risks of a non-neutral innovation policy that is, a policy aimed at accelerating innovation in a particular field or technology.

2 An eclectic approach to building innovation policy rationales

We plead the case for a certain disconnection between the theoretical frameworks of the economics of innovation and innovation policy concepts that can be developed by economists. We thus resort to a certain form of eclecticism as supported by Kindleberger in his famous dialogue with Pasinetti. Eclecticism, he told us, is absolutely acceptable when it is not used at the theory level but at the applied economics level. It then becomes a source of richness, as it allows a combination of results originating from different theories without having to worry about the coherence of concepts at the theoretical level. Questions of innovation policy are by definition a case where eclecticism becomes an advantage. Each theory has produced important results for defining pertinent innovation policies. The notion of market failures originating from the general equilibrium theory is a good illustration of this, as is the crucial importance of institutions, their origin and their evolution that originates from the evolutionary theory or problems of lock-in and path-dependency that result from this hybrid combination of neoclassical microeconomics and the evolutionary theory. Each of these results is worthwhile for its intrinsic value with a view to elaborating an innovation policy and we must therefore examine their contribution to the understanding of certain innovation problems, without any obligation to take on board all the theory that goes with it that may be in contradiction with another theory that has produced other

interesting results. Thus the idea of eclecticism as a source of richness and the idea of a certain disconnection between theory and policy concept.

Winter does not write anything different when he acknowledges the interest and value of the neoclassical concept of market failure with the aim of elaborating an innovation policy. Of course, at a theoretical level, the concept of market failure is linked to the formal theory of general competitive equilibrium; it comprises the framework of optimizing actors, competition, general equilibrium and its counterpart, the theory of market failure.

But as Winter explains, his point here is not theoretical; rather, it is to recognize that the language and theory of market failure are valuable for building a strong case for innovation policy and communicating it to policymakers, as well as colleagues from other disciplines. The goal is then to impart a balanced perspective of market failure and use it for cases that can satisfy three criteria (Winter 2017):

- The mechanism generating the core market failure problem is relatively simple and transparent;
- The nature of the harm is fairly clear; and
- There is relevant experience with using non-market organizational arrangements to address the problem.

Then, based on these arguments – from Kindleberger to Winter – we can adopt a principle for the identification and selection of policy rationales that does not strongly depend upon theory but on the eclectic or pragmatic approach as described above. In so doing, we can assume that some standard market failures are important to consider because it is obvious that they satisfy these three criteria. This is the case, for instance, of so-called "knowledge spillovers" or positive knowledge externalities.[1]

Our framework for identifying policy rationales and subsequently building a typology of policy levels is thus not theoretically very ambitious. It is limited to: i) recognizing the helpfulness of certain results of the economic analysis that are useful for elaborating policy rationales and "relieving" them of their "theoretical weight" as it were in order to be able to use them without being restricted by the theories on which they are based, and ii) using a list of pragmatic criteria to select the "serious" policy rationales that can or must trigger an intervention in innovation policy.

On this basis, we identify three constitutive rationales of policy intervention in the domain of innovation.

2.1 Standard market failures regarding R&D and innovation

In the domain of innovation, it is obvious that knowledge spillovers, as well as acute risk and moral hazard in financing R&D, and possibly also adoption

[1] On the contrary, the case of increasing returns to adoption leading to sub-optimal outcomes and lock-in is weaker in terms of using it to build a policy rationale. While the whole mechanism leading to potential inefficiencies (such as in the QWERTY case of Paul David) is correct, as Arrow (1995) writes, "it's hard to believe that you are losing a great deal. Well, it would be very interesting to see whether you could find an example where the result of this dynamic led to a great inefficiency .. the theory is pretty good, the empirical evidence may be by definition hard to come by, not just a practical question". The nature of the harm is rather unclear.

externalities, are cases of market failure that satisfy the three criteria. For instance, the whole geographically mediated patent citation literature has built an extensive base of evidence regarding the existence of knowledge spillovers (see, for instance and among many Jaffe 1989; Jaffe et al. 1993; Audrestch and Feldman 1996); the mechanism and effect of this market failure are clear, given that such spillovers are derived from the non-excludable and non-rival nature of knowledge. This creates a gap between private and social returns, resulting in systematic underinvestment in R&D, which is likely to be detrimental to innovation and productivity growth. Additionally, there is relevant experience in non-market organizational arrangements to address such a problem. This experience involves, for instance, the creation of private institutions by the economic agents themselves to capture the externalities and reduce the gap between social and private returns. This class of mechanisms is also labelled as "Coasean Institutions" – as Coase developed the idea that the existence of externalities induces the creation of institutions by the private agents themselves to correct them (instead of relying on the classical Pigou and Samuelson solutions).

Therefore, using the concept of knowledge spillovers as a strong case for market failure, policy goals involve increasing the appropriability of knowledge and innovation (for example, through the establishment of a patent system) or directly addressing R&D underinvestment (subsidies, tax credits, support of transfer of technology).

2.2 Coordination and collective action needs

Similar to these « standard market failures », one can identify coordination and collective action needs as a strong policy rationale (Elsner 2012). Here again, a pragmatic approach invites us to search for cases where the sources of failure are clear. They can come from the complementarity of investments (each needs the other to be profitable) or from the difficulty of small entities to join forces in order collectively to produce some industry-specific public goods. The negative effects of these failures are also easily identifiable. In many ecosystems of innovation and entrepreneurship, one important gap to be addressed by policies is the provision of complementary capabilities (or specific public inputs) upon which most small and medium companies can draw, even if they have not contributed to their production. Such complementary capabilities include specialized skills, R&D, specialized services for innovation, and so forth. As Suzanne Berger (2013) argues, based on numerous case studies in the US, Germany and China, the lack of such capabilities can be a real problem in many ecosystems, leading to the situation of firms *that are home alone*. The same kind of non-market organizational arrangement, as in the knowledge spillover case, can apply here to address coordination problems. They also stem from Coasean solutions, which again involve the creation of private institutions by the economic agents themselves in order to solve collective action problems resulting from the provision of specific public goods. In their article published in 1993, Weder and Grubel identify the importance of such a mechanism in the innovation systems of two countries (Japan and Switzerland). In a similar vein, Romer (1993) builds a model of specific public goods provision, based on a hybrid institutional arrangement that combines public intervention and a decentralized market process.

2.3 Directionality

The final type of problem that is important to consider could be called "directionality", a new term to describe an old and well-recognized problem (Chataway et al. 2017): innovation does not necessarily happen where it is socially desirable. To some degree, this is attributable to the failure of mechanisms that would otherwise properly gauge the intensity of each item forming the array of society's wants in the way that markets gauge the intensity of demand for the array of privately consumed commodities. This thereby generates price signals that stimulate profit-motivated efforts to satisfy those wants. A quite well-known example of such a failure is provided by observing that pharmaceutical companies respond to large market demand for new drugs to treat ulcers and hypertension, rather than investing R&D on improving the availability of drugs for victims of malaria and other tropical diseases that ravage poor countries (David and Foray 2002).

While a certain rate of innovation might be found to be sufficient in sustaining productivity growth in the economy in general, it can appear to be insufficient in some domains in which accelerating innovation is an imperative for certain reasons (climate change, health, modernization of an old industry, etc.). The policy goal then is not merely to address market failure and incentivize innovation in the general economy, but to do it in a specific way within certain domains or directions.

In 1962, a fundamental book edited by R.R. Nelson set up the research agenda of a new discipline for decades. This book (Nelson, 1962) was strongly empirical, alternating with case studies and statistical analyses, while also providing a few theoretical papers (including the famous paper by Arrow on innovation externalities and uncertainty) and putting evidence-based policy research very high on the agenda of the new discipline. The title of the book, "The rate and direction of inventive activities", was precisely an invitation to think of innovation policy in terms of this dichotomy: rate and direction. Some policies can address the rate of innovation within the entire economy, while others need to address both the rate and direction – or, more precisely, the rate in a certain direction of invention and innovation.

2.4 Types of failure and problem and policy logic

We began this paper by offering a pragmatic vision of market failure because such a categorization forms the basis of the existing two policy logics. The first category of "standard market failures" (including essentially knowledge-positive externalities and risk and moral hazard in financing innovation) provides policymakers with the possibility to limit their actions to neutral interventions. Indeed, these market failures are generic and apply to any firm in an undifferentiated way. One could, of course, argue that, in some sectors, the knowledge base has a stronger tacit dimension that adds some characteristics of natural excludability to the knowledge and thereby limits the importance of knowledge spillovers; inversely, some sector capacities for reverse engineering are so strong that potential knowledge spillovers are very important. There are, indeed, sectoral variations in the potential importance of market failures across sectors, but economists recognize (in principle) the generality of these market failures in the economy – which opens the possibility of generalizing the application of policy instruments within the entire economy (R&D tax credits, R&D subsidies, patents).

This has positive implications in terms of administration and monitoring costs, as well as in terms of evaluating the effects of such a neutral treatment.

Conversely, coordination and directionality problems are mostly sector- or technology-specific by nature, and, therefore, imply non-neutral policies involving targeted interventions to fix these coordination or direction problems in certain ways.

3 Two levels of innovation policy intervention

From this very simple framework, one can infer two levels of innovation policy interventions and logics. A moderate level of innovation policy corresponds to neutral or horizontal programs that aim to increase the rate of innovation in the entire economy. We will see, however, that there is not a perfect match between neutral versus non neutral logic and moderate versus higher level of intervention. Some moderate interventions are indeed non-neutral.

Higher level of policy interventions are aimed at accelerating innovations *within certain targeted domains or technologies.* Such policies are essentially sector non-neutral and are characterized by a higher degree of intentionality, centralization and prioritization. This is the design of such policies that will be investigated in the last section.

3.1 Policy level 1 - moderate intervention

At the moderate level of intervention, the main characteristics are neutrality and the absence of preferential interventions in terms of the technology or sector, thus minimizing the risks of distortion and government failure. A *sector-neutral* (horizontal) policy addresses problems that are similar to those of any company and other innovation actors across sectors and fields. Such a moderate policy involves fixing generic market failure (such as knowledge spillovers), providing generic public goods and improving general framework conditions. This policy is neutral because the "allocation of help" is not based on any kind of technology or sector criteria. The only exception is size, since large companies have plenty of solutions to minimize standard market failure in the case of R&D and innovation (Cockburn 2004). In other words, small firms, as well as young innovative companies, may deserve specific support, but such support is not sector-specific.

Coordination problems are not usually solved at this level of moderate intervention. Indeed, problems of complementarity and coordination between investments and resources are mostly specific to particular sectors or technologies, and, as such, require non-neutral actions (i.e., actions targeted at specific sectors or technologies). Some generic coordination problems can be addressed at this level, such as the creation of a national bank for innovation. However, such interventions are actually less about solving coordination problems than improving the basic framework conditions or providing generic capacities.

A range of innovation policy instruments can be deployed at level 1, including R&D subsidies, R&D tax credits, funding for the transfer of technology and start-ups, and refundable loans, as well as an intellectual property rights system and adoption subsidies. What makes all of these instruments similar in nature, in spite

of the fact that they offer various mechanisms to fix market failure, is that there is no a priori determination of who, in which sectors, and for which technology, can benefit from them.

These instruments are neutral *by design,* which means that their beneficial properties (such as low administrative and monitoring costs) are conditional, in that they are used in a neutral manner. Thinking of an R&D tax credit and using it in a neutral manner make the phases of implementation, administration and monitoring of the instrument very easy and at low policy cost. If someone would now like to turn it into a non-neutral instrumental – for example, a *green* R&D tax credit – all of the dimensions of the policy would become much more difficult and costly.

Finally, even at such a level of moderate intervention, one can observe strong variations across countries in terms of the importance of such policies and the number of instruments used. This is due to the fact that market failures are not universal or free floating. The severity of the market failure depends on many parameters – relative specialization of the economy, the quality of institutions, cultures and values. One can observe huge variations among countries – for example, among France, Germany and Switzerland - in terms of the conception and implementation of a moderate innovation policy.

3.2 Subtelty – The case of non-neutral *and* moderate policy intervention

In reality, a policy aimed at encouraging innovation is never totally neutral.[2] For example, R&D tax credit – often considered as the panacea of neutral innovation policies – is actually an intervention *in favor* of companies doing research. Purely neutral policies would therefore more accurately be those that do not directly concern innovation but concern more generally generic capacities and institutions that form the innovation framework – human capital, functioning of the different factor and product markets, macroeconomic environment as well as the generic capacities and institutions that form the essential components of an innovation system (university, intellectual property, bank, etc.), even if the neutrality of each of these institutions – in other words, their general validity – is never absolute.

This means that neutrality as a policy principle is not always decisive for defining a "moderate level of intervention". We observe many cases of non-neutral *and* moderate interventions, such as those aimed at only supporting firms undertaking R&D (they are non-neutral), without an *ex ante* determination of sectors or technologies (they are moderate). In such case, the non-neutral and moderate policy is limited to influencing *the rate* of innovation, not the direction, and will focus on general categories - activities (R&D) or actors (SMEs) – regardless of their sectoral or technological affiliation. A non-neutral and moderate policy will create some kind of cross section in the innovation system to target a predefined category – SMEs, firms doing research. There is therefore a class of non-neutral policies that exclusively target the rate of innovation that are relatively easy to implement as they focus on the resolution of "standard" problems, the

[2] Rodrik (2007) argues: « *Horizontal interventions are a limiting case more than a clear-cut alternative to sectoral policies. In fact, very few interventions are truly horizontal. They almost necessarily favour some activities, even if the main goal was not to create such discrimination*".

category of actors targeted is simple to define, the policy instruments are relatively easy to use and the programme administration costs are relatively low.

3.3 Policy level 2 - higher degree of intervention

Now we can think of situations where the level of moderate intervention (whether neutral or non- neutral) is not sufficient because there is a directionality problem to be addressed by the policy. This is typically the case when the economic system – national or regional – needs to change more radically in order to move toward new fields, industries, and specializations. This is, of course, the case of the so-called grand challenges, such as climate change, implying the need to accelerate innovation in certain fields or domains. Another typical case is a high-tech strategy reflecting the importance for a country to develop capacities in terms of general-purpose technologies such as ICT because of the specific properties of such technologies in terms of potential spillovers to the entire economy (Trajtenberg 2002; Bresnahan 2010). A final case may simply involve the importance of radically transforming a traditional and mature industry through R&D and innovation. When one sector needs to change radically toward a new specialization or to address a large societal problem, this will not happen spontaneously, not even through some kind of moderate intervention. A moderate policy is not enough, and both *coordination* and *directionality* failures need to be fixed through specific and complex interventions that target one particular technology or one particular sector.

A significant difference *within* non-neutral policies between those that target simply a category of actors or activities (qualified as moderate intervention) and those that focus on certain technological or other objectives is that the latter inevitably have a *systemic character* (David 1993). They must indeed address questions of complementarities between different types of capacities, coordination between actors and between investments or the connection between innovation and diffusion. All these problems are only weakly addressed by a policy that focuses on only one particular category of agent or activity.[3]

A major contrast between level 1 and level 2 is a higher degree of intentionality, centralization of policy-making and commitment toward some kinds of new priorities. Level-2 policies are not sector-neutral. Their *raison d'être* is preferential intervention in targeted domains or sectors. This policy seeks to address specific problems for a specific technology or sector.

This is not a substitute for policy level 1, but rather an additional option that countries or regions are well advised to activate under certain conditions. Such conditions mainly deal with two questions: first, to what extent are coordination and directionality failures perceived as clear sources of potentially serious harm for innovations within a domain where innovations need to be accelerated? and second, what is the capacity of the government to establish a policy process for establishing innovation priorities and for developing an action plan that will minimize the risks and costs of possible failures?

The figure below summarizes the main findings of sections 1 and 2 (Fig. 1).

[3] Paul David (1993) distinguishes between the stage model of innovation policy (which tends to characterize the policies in the central sphere that focus on certain stages or certain actors of the innovation process) and the systems model of innovation policy that recognizes the importance of questions of complementarity, coordination and connection between innovation and diffusion and thus characterizes any policy aiming at accelerating innovation within a predetermined field or sector. More recently, such a system model of policy is also addressed by Elsner (2012).

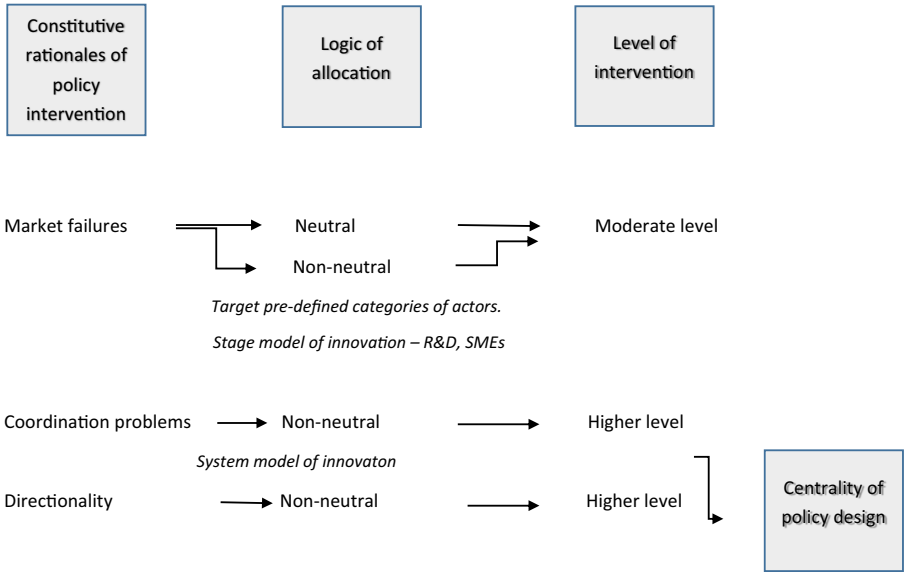

Fig. 1 Framework of analysis and the two levels of policy intervention

4 The centrality of policy design for level 2 – Type of intervention

Policies involving preferential interventions to accelerate innovations within certain domains or sectors have been seriously criticized. There are four main critical arguments that are important to consider. All of these sceptical views about these policies merit attention because they can contribute toward designing a policy process to minimize the problems identified below.[4]

The first kind of scepticism involves the classic concern about distortions: "*Although it is certainly true that not everything can be done at once, focusing on selected areas for large investments to the neglect of the rest of the economy is a highly questionable strategy"*. Krueger (2011) comments here on the works of Justin Yfu Lin, a great promoter of the new structural economics framework. She would have plausibly expressed the same objections to any kind of innovation policy involving preferential interventions. Ann Krueger is part of this large group of economists who theoretically recognize the existence of market failure (as a necessary counterpart to the formal theory of general competitive equilibrium), but strongly argue that these market failures are not sufficiently serious to warrant governmental intervention, and, in particular, preferential policies that discriminate across activities.

The second kind of scepticism deals with government capabilities to understand and fix coordination failures that are specific to each sector or technology. As aptly argued by Matsuyama (1997), "*Understanding the basic principles of coordination problems does not take one very far in the direction of useful, practical conclusions about how to*

[4] We do not mention here one classic policy problem because this problem is not specific to stronger modes of policy interventions. This problem regards project selection. The point is to minimize the risk of supporting projects that would have been undertaken anyway, turning the policy into a simple mechanism of funding transfers from the public to the private sector, without any additional effect. See Stiglitz and Wallsten (1999). This problem applies both to moderate and stronger modes of intervention.

construct technology policy. Understanding the basic problems, one is led to a new but not simpler set of questions: what activities in what firms are complementary and need to be coordinated, and in what way? An appropriate choice of policy tools requires a detailed understanding of the externalities and the innovative complementarities involved." This is obviously a relevant comment, but should it be taken as an argument to stop any policy intervention aimed at addressing specific capabilities and specific infrastructures in order to accelerate innovation within a specific domain (Aghion et al. 2009)?

The third sceptical view can be applied to any policy logic – non-neutral and neutral alike. However, the problem identified is likely to be amplified in the case of a policy involving preferential interventions. This is Romer's argument (Romer 2000): it is not enough to increase spending on R&D but what needs to be supported is the total quantity of inputs that go into R&D and this includes, in particular, human capital formation. Because the supply curve of specialized human capital is fixed in the short run, it is important to generate a correct sequencing of policy programs, addressing respectively the supply of specialized human capital and the demand for specialized R&D. Whereas this problem of equating human capital with an increase in the demand for R&D can be attenuated within the framework of a neutral policy by reallocating jobs between industrial sectors, it will be far more difficult if the increased demand for R&D caused by the policy concerns a specialized domain where innovations need to be accelerated.

The fourth sceptical view is well explained by Rodrik (2013): any pretext given to the government for setting innovation priorities and establishing strategic targets increases the risk that the entire policy will become a central planning exercise based on principal-agent governance, resulting in very poor information flows from the bottom up. However, to be fair, Rodrik is not using his argument against preferential intervention, but rather as a way to trigger the search for new policy designs.

Clearly, these four problems are relevant and deserve attention. However, economists can respond to them in two different ways. Some think that these problems are important, while the harm created by coordination and directionality failures are not so clear, which ultimately does not justify implementing a non-neutral policy. By contrast, other economists recognize the four problems mentioned above, but they also view coordination and directionality failures as clear sources of potentially serious harm for innovation within certain domains, and they emphasize how new principles of policy design can minimize or overcome these four problems.

To conclude this section, it is interesting to propose the following paradox: although mainstream economists and the international organizations that were strongly influenced by mainstream views have been sceptical and have recommended not to implement non-neutral policies, these policies have always been deployed by governments (in particular, those of large countries) under the old label of *mission-oriented policies* in domains such as aerospace, defense or agriculture (see Foray et al. 2012). In a sense, much of the mainstream economic discourse about economic policymaking has been radically out of step with reality. It has recommended that certain kinds of policy be avoided, but governments have not listened to such recommendations and instead have employed massively preferential intervention practices so as to establish new industries or develop new technologies. However, because of the mainstream intellectual taboo, very

little academic policy research has been undertaken on the kind of policy design necessary to deal with the four problems mentioned above – leaving a sort of *no-research land,* which has not helped governments improve their policy practices at this level of non-neutral intervention.

5 Toward a new design for a level-2 type policy

Responding to these sceptical arguments by formulating a policy design appropriate for the policy goal of accelerating innovation within a specific domain is crucially important. However, the literature addressing such a problem is not very well developed for the reasons mentioned above. There is work that provides certain indications indirectly by studying the historical cases of mission-oriented policies in different sectors or countries, from which certain good (and bad) practices can be deduced. These contributions range from the pioneering works of Freeman and Nelson on country-level case studies to several sectoral studies (Mazzucato 2011; Foray et al. 2012; Mowery and Simcoe 2002; Mowery 2012; Wright 2012; Anadon 2012; Henderson and Newell 2010; Jaffe 2011). There are also still a small number of studies that identify, from an econometric point-of-view, certain success factors of sectoral industrial policies – for example, the nature of competition in the targeted sector (Aghion 2016). Additionally, there are also studies dealing with the design of particular instruments that can possibly be used within the framework of mission-oriented policies (Kremer and Williams 2009; Murray et al. 2012). Finally, we must recognize a very significant contribution made by Rodrik and a few others (Sabel, Hausmann) who have gone furthest in the analysis of appropriate policy designs, as far as industrial policies in development economics are concerned. This section makes use of the literature, as well as our own observations, with respect to the design of smart specialization strategies within the framework of European regional policies to identify important design principles.[5]

Let's start with the following policy goal – accelerating innovation in domain X or sector Y. What needs to be done? What is the main *modus operandi* that a non-neutral innovation policy needs to follow? Faced with such a goal – accelerating innovation – the roadmap seems to be trivial: a public agency will look for projects in the targeted area; it will support the provision of complementary capabilities and the specific public inputs that are necessary to innovate, which small companies cannot produce and; it will help solve coordination problems. However, what does this mean more precisely in terms of the types and levels of intervention?

[5] - Based on a seminal policy paper (Foray et al. 2009), the Smart Specialization Strategies (S3) approach was integrated into the reformed cohesion policy of the European Union for 2014–2020. Member States and regions have developed over 120 S3 s, establishing priorities for research and innovation investments for the 2014–2020 period. Throughout this period, more than EUR 40 billion (and more than EUR 65 billion including national co-financing) allocated to regions through the European Regional Development Fund will fund these priorities. The impact of the S3 concept has been significant in terms of the design and implementation of regional smart specialization strategies. This large-scale European experience provides a unique case study of a new type of industrial policy particularly oriented towards the modernization of industrial sectors (Foray 2015).

5.1 Granularity level and the concept of transformative activity

In cases of preferential intervention to accelerate innovations in a targeted field, the right level at which a policy action plan needs to be deployed is one of intermediate granularity, finer grained than sectors, but coarser than individual entities. This point is strongly made by Rodrik (2004): the new "non-neutral innovation policies" are not about prioritizing a sector, but rather focus on the activity that aims to transform a sector or establish a new one. Such activities have scale or agglomeration economies. They exhibit the characteristics of coordination failures, and thus, would fail to develop in the absence of support.

Transformative activity is a key concept. It is neither an individual project nor a sector as a whole, but rather a collection of innovation capacities and actions that have been "extracted "as it were from an existing structure or several structures, to which extra-regional capacities can be added, that are oriented toward a certain direction of change (to address a grand challenge or modernize a traditional sector).

A transformative activity concentrates the actions needed – R&D projects, partnerships, a supply of new specific public goods – to explore a new area of opportunity. The basic operational mode is not necessarily a collaborative project, but rather the search for coordination and links between the entities and projects concerned, which will facilitate spillovers, economies of scope and scale and the supply of specific public goods and infrastructures to the domain in question. As such, a transformative activity can serve as a catalyst for collective action by firms, suppliers and research partners.

5.2 Policy design principles

These principles should guide processes of building and developing a transforming activity, while minimizing all risks mentioned in Section 3.

5.2.1 Securing specialized human capital supply as demand for specific R&D increases

This principle is formulated to directly resolve Romer's problem – spending more on formal R&D may end up inflating wages of R&D personnel and not producing more innovation – and thus focuses on the correct sequencing of the policy: the formation of specialized human capital and capabilities should precede, or at least occur at the same time as, the programs aimed at increasing the demand for R&D in the specialized domain in question.

5.2.2 Coupling innovation and diffusion

Given that the objective of an activity is to modernize a traditional sector or accelerate an innovation to address a grand challenge, constructing a transformative activity should avoid a systematic allocative bias in favor of high-tech innovations, even if these innovations are related to the traditional sector or to the grand challenge. Policies aimed at promoting rocket science and high-tech entrepreneurship will hardly have an impact on traditional sectors or potential user sectors unless another complementary, i.e., "adoption-oriented" policy, is designed and implemented.

The point is to develop an integrated vision of a transformative activity that must not focus only on the *high-tech* dimension of the structural change sought. The activity must also integrate actions that allow the adoption of high technology by the sector that will be a potential user. Let us take the example of modernizing some segments of the agrifood sector. The transformative activity concerning a certain number of scientific innovation projects for agriculture must also include actions (adoption, training, management) that will facilitate the adoption of high technology by the traditional sector. The point here is to involve the agrifood sector as a huge reservoir of potential adopters of these new technologies. The goal is therefore twofold: to encourage young innovative firms by equipping their ecosystem with all of the necessary capabilities AND to address the innovative complementarities between the high-tech industry and traditional sectors. The latter goal involves addressing human capital and capability problems, fixing adoption externalities, dealing with coordination failures and providing specific public goods; in other words, it will address many barriers and obstacles to innovation diffusion in a traditional sector. If this is not done, the activity will remain limited to start-ups, and it will lose its truly transformative nature.

5.2.3 Deploying different instruments and the Tinbergen assignment theorem

By aiming to accelerate innovation to address a grand challenge or modernize an industry through the development of "activities", policymakers might think of a long list of instruments to intervene on the supply side (science, technologies, human capital, R&D), on the demand side (procurement, adoption, prices and tax), and on specific issues such as entrepreneurship, competition or finance. In a sense, there is no limit to the number of instruments! All components of the innovation system in the targeted area need, in principle, some support from fundamental science to technologies, R&D, skills and diffusion. Henderson and Newell (2010) build a framework of policy instruments to accelerate innovation in energy, which includes a long list of *to-do* items from a policy point-of-view. Yet, how can we be sure that supporting the development of all these capacities will not result in many useless instruments that are poorly coordinated and ultimately costly? Taking care of everything is likely to produce an over-elaborate policy. However, omitting some important policy actions can be detrimental, given that the final performance of the system is likely to be determined by the 'weakest link'.

A design principle is essential here, known as the Tinbergen assignment theorem (Tinbergen 1967), which provides at least first-order guidance on the "number "of instruments or programs that need to be deployed, according to the goals or targets. The number of externalities or market failures should determine the number of instruments (Jaffe et al. 2004). If we take the case of environmental and energy innovation policy, there is a need for instruments to support R&D and start-ups (because of the knowledge externalities, as well as capital market imperfections) and instruments to support technology adoption and training programs in various sectors (because of adoption and network externalities, as well as training externalities). Coordination failures can happen at the interface between technology producers and potential users, which would also need to be fixed through other instruments (for example, a platform of specialized services to support the transfer of technologies and the provision of complementary capabilities). Last, but not least, the environmental externality needs to be addressed

through some kind of carbon tax or other instrument to price emissions. All in all, such a policy should therefore involve approximately five or six instruments to implement in a coordinated way. Moreover, because the sceptical argument of Matsuyama is pertinent (see Section 3)– how can the government manage such complexity? – the latter must choose and determine a small number of structural objectives to be supported. "Doomed to choose "Hausmann and Rodrik (2006) tell us so!

An interesting lesson can be derived from this example for economists engaged in innovation policy research and analysis. To obtain this sort of first-order guidance about the deployment of different instruments (number of potential failures), one needs more than an abstract understanding of innovation externalities. In Acemoglu et al.'s (2009) famous paper on environmental and innovation policies, the authors tend to highlight the need for coupling R&D subsidies with carbon prices; however, they simply forget the other problems and market failures that are likely to impede innovation within the targeted domain. In particular, they do not recognize the existence of adoption externalities that need to be fixed if we do not want to see public resources allocated to research – turning into some knowledge that will never be used in the industry. This means that the value of pragmatically using the notion of market failure (as argued in Section 1) is conditional on an accurate and detailed understanding of the conditions and procedures of innovation within the domain considered. This is only possible when economists learn and gather the facts about the technologies and innovation themselves. This effort is necessary for the economics of innovation policy to go beyond a very abstract level, and to avoid producing very limited evidence and knowledge for the practical design and implementation of an innovation policy.

5.2.4 Recognizing the experimental nature of the policy

Non-neutral innovation policies aimed at accelerating innovation to address a grand challenge or to modernize an industry are necessarily experimental. The actions undertaken to achieve these objectives are by definition experiments; some will work, while others will not. We can clearly see the difference in relation to a neutral policy applying a relatively well-managed instrument, the "treatment effect "of which is known – for example, an R&D tax credit available to all companies involved in R&D. We see that the political risk in this case is low. In view of past experiments and well-managed evaluation methods, we can surmise that this policy will be effective in most contexts (i.e., it will lead to an increase in research efforts). It is, of course, a case appreciated by politicians and policymakers! In the case of a non-neutral policy, where the objective is the acceleration of innovation within a certain sector, the experiment is much riskier, and the set of programs and actions is a gamble! These risks imply certain design principles.

The first principle involves the centrality of *entrepreneurial discovery*, as a consequence of the fact that one cannot apply a principal-agent logic of governance here, which supposes that the government has sufficient information to construct a plan and to provide the incentives necessary for firms to carry it out. As concrete R&D activities and coordination actions advance (projects, partnerships, platforms, training), successes, failures and surprises will happen. The centrality of entrepreneurial discovery in developing an activity stems from the fact that there is initially no complete knowledge regarding how the process of accelerating innovation in a certain specific

domain will unfold. According to Sabel (2004), "*What if, as I and many others assume, there are no principals … with the robust and panoramic knowledge needed for this directive role?"* (p.3). We talk about entrepreneurial discovery (Kirzner 1997), as this term comprises a crucial surprise dimension regarding the real possibilities of development and the structural effect offered by transformative activities. Integrating the entrepreneurial discovery concept into an industrial policy design was first achieved by Hausmann and Rodrik (2002); although Hirschman (1967) earlier proposed the concept of "a voyage of discovery" as an essential component of non-neutral development policy. This represents an essential step forward in enabling non-neutral innovation policies to avoid the tragedy of centralized planning, in other words, reconciling the logic of strategic choice and priorities with the logic of decentralized and entrepreneurial information and initiatives.

Second, *the flexibility of the policy* is a requirement. Whatever is learned, thanks to the entrepreneurial discovery, must exert a retroactive effect on the characteristics of the programs within each transformative activity, and also on the activities themselves to modify or possibly discontinue. Moreover, new combinations can emerge at any time and must be integrated in the form of new priorities. The flexibility of the strategy imposes *control and evaluation* mechanisms that are essential for conducting the strategy. Monitoring is a key element: projects need to be measured in order to understand performance, the degree of progress, the direction and magnitude of change, and in order to indicate that some issues warrant further investigation. One key feature of such indicators is to provide an up-to-the-minute barometer of the activity that can be used for immediate feedback and adjustment of the policy (Feldman et al. 2014).[6]

Third is the *maximization of spillovers*. The social value of the process of entrepreneurial discovery is that it informs the entire system about new opportunities, potential successes and failures; i.e., what are the directions of R&D and innovation that are likely to generate the desirable structural changes? The maximization of informational spillovers created by the discovery phase is a key design principle that distinguishes entrepreneurial discoveries supported by a public policy, as is the case here, from those made privately within firms, which tend not to disseminate such information.

When the entrepreneurial discovery process is supported by a public policy, it is critical that the informational value of the process be maximized. The companies that are supported in joining the entrepreneurial discovery process must accept and conform to these rules of information and audit. This creates a design issue: the reward for entrepreneurial discovery should be structured in a way that maximizes spillovers to other participants and potential entrants in the transformative activity (Rodrik 2004; Foray et al. 2009).

5.2.5 The general nature of the policy design

This policy, based on such design principles, is neither purely bottom-up (because, at some point, priorities are chosen by the government) nor totally top-down (because a few

[6] Rammer's recent works provide a good basis for the development of subsidy mechanisms for R&D projects, allowing certain flexibility in the allocation of resources: instead of one single financing decision, made at the start of the project, Rammer elaborates a multiple and sequential decision model that allows unsuccessful projects to be interrupted sooner and to allocate more financing to successful projects (Rammer and Klingebiel 2012).

design principles, such as the entrepreneurial discovery process, introduce a strong bottom-up component). It is rather an intermediate process aimed at enhancing entrepreneurial coordination within a framework (priority areas) structured by the government.

6 Conclusion

For a long time, governments have developed and implemented non-neutral policies to accelerate innovation in various domains, which is viewed as strategic, or in various industries that need more dynamism, modernization or diversification. These non-neutral policies are necessary because the problems they address – coordination and directionality problems – require specific and preferential interventions. Therefore, they imply a determination of the domain(s), where a set of actions aimed at accelerating innovations will be undertaken.

A certain kind of «economist's fundamentalism» has tried for a long time to discourage governments from using this type of non-neutral approach. As a result, very few academic policy studies dealing with the design of these policies have been carried out. Thus, governments have been "left to themselves", so to speak, in designing and implementing their mission-oriented policies. As a consequence of creating such a "no research land", most non-neutral policies from long ago have turned out to be very much central planning exercises, resulting in very poor information flows from the bottom up, as well as programs to support national champions, while totally ignoring issues as important as self-discovery, flexibility and spillovers.[7]

Under the triple inspiration of i) historical works on mission-oriented policies (notably done by Nelson, Rosenberg, Freeman and Mowery, among many others); ii) the contributions of Rodrik, Hausmann or Sabel on industrial policy and development economics; and finally iii) the micro-economic analysis of the design of specific policy instruments used in a non-neutral way (such as prizes), academic policy research has been developed. This research has also progressed through a confrontation between theory and practice, as in the case of smart specialization regional policy in the European Union.

The increased knowledge base on non-neutral innovation policies resulting from all of these works and contributions now allow us to identify a few policy design principles that can help provide governments with strategic capacities for prioritization and focus, *which are nurtured* by decentralized information and entrepreneurial activities.

Among these design principles, we have discussed the following:

- The granularity level – between sectors and individual projects – which corresponds to a collection of capacities, actors and instruments, structured and coordinated toward a certain direction of structural change in a specific area or technology.
- The consideration of the complementarities between specialized human capital and demand for specific R&D should help to focus on the correct sequencing of the

[7] - Although a few notable successes should be highlighted. See, for instance, National Research Council (1999) and Mowery and Simcoe (2002) on the success of the US innovation policy in computer, telecommunication and Internet.

policy and to avoid the inefficient outcome of inflating wages of R&D personnel while not producing more innovation.
- The coupling between innovation and adoption, which implies a policy supporting not only the high-tech industry and entrepreneurship, but also human capital formation, management capabilities and technology adoption in potential user sectors.
- The Tinbergen rule, which provides first-order guidance regarding the number and variety of instruments or programs to be deployed in the considered policy case, given the number of market failures or externalities that impede the considered structural change. This rule is only relevant if sufficient empirical knowledge of the targeted field or technology allows for an accurate identification of the main failures and limitations.
- Finally, the view of such a policy, as essentially experimental by nature, imposes a logic of entrepreneurial discovery instead of a principal-agent governance logic as an essential mechanism generating information about programs and activities in progress. This, in turn, plays a crucial role in the principles of flexibility, monitoring and maximizing informational spillovers, which are produced by the entrepreneurial discovery process.

Last, but not least, and by definition, for any level 2 type of innovation policy intervention, choices matter! What should be done, in what kinds of domains, and for what kind of objective?

John Enos wrote very pertinently that it is useful and productive for countries to put more effort into discovering and choosing priority areas for R&D and innovation (Enos 1995). One key reason for devoting more effort to specifying what is and what is not likely to be fruitful priority areas is that the knowledge and experience acquired from discovering and choosing the right directions for R&D and innovation can be valuable in carrying out subsequent stages of product/process/market design, production and distribution.

Therefore, the idea is that the process by which priorities and transformative activities can be identified is not a process by which resources must be economized or accelerated at all costs. Neither is it a process that should be "confiscated "by the government, which would proceed to the selection of priorities in isolation from the most important innovation actors (firms and universities). Rather, it is the process of learning about the capacities and opportunities specific to the economy that is useful and productive. As such, it lies at the very heart of any non-neutral innovation policy.

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