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Article (Published Version)

*Industrial and Corporate Change*, 2018, Vol. 27, No. 5, 833–850
doi: 10.1093/icc/dty028
Original article

OXFORD

# Elements of a Schumpeterian catalytic research and innovation policy

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## Abstract

In this article we take a fresh look at Research and Innovation (R&I hereinafter) policy and define a new notion: *Schumpeterian catalytic R&I policy*. Such policy style amends and enriches the new mission-oriented framework for innovation policy by assigning more weight to the microeconomic dimension of private actors' actions and by being more concerned with the temporary nature of interventions. We relate our argument to recent empirical trends in productivity dynamics and innovative activities. These suggest that an innovation slowdown is taking place and, consequently, that a renewed interest in the (re-)direction—rather than on the intensity of innovative activities—is key to the design of R&I policy capable to tackle current challenges. We use the evidence to build a schematic theoretical framework to inform policy design, and we outlined the defining features of our proposed policy style.

**JEL classification:** O38, O31

## 1. Introduction

In this article, we take a fresh look at Research and Innovation (R&I hereinafter) policy from an economics perspective and define a new notion: that of Schumpeterian catalytic R&I policy. We construct our contribution on three pillars: (i) the distinction between innovation intensity and innovation direction; (ii) the recent empirical evidence regarding productivity dynamics and innovative activities trends, suggesting that an "innovation slowdown" is taking place; (iii) the surging debate on innovation policy in the context of the Grand Societal Challenges and as a design within the so-called *new mission orientation*.

Our approach builds on insights derived from the discussion on the intensity versus direction of innovative change that recently reemerged in the academic debate (Mazzucato, 2016). Whereas the intensity problems of innovative activities have traditionally been at the core of the theoretical and political discussion, the direction dimension requires an extended theoretical analysis as well as further arguments for justifying policy intervention. We fulfill these requirements by drawing a schematic framework for R&I policy design between the intensity and the direction of innovation. We argue for a policy style different from "market fixing," a policy style that redirects and by this suggests certain new directions for innovation activities. In our proposal, to redirect innovative activities, state intervention can go so far to create new markets—and in this sense, we follow Mazzucato's argument in favor of an *entrepreneurial state* (Mazzucato, 2016), and we build on the building blocks of her recent conceptualization of mission-oriented innovation policy (Mazzucato, 2016). However, we amend the conceptual framework in two important dimensions, by stressing the (i) *Schumpeterian* and the (ii) *catalytic* nature of R&I policy, as we consider these features having not yet received adequate attention.

In our approach, first, private economic actors keep a role of protagonists on the innovation scene—our Schumpeterian element—whereas the state plays an experimenter's part with the aim to shed light on new opportunities and directions for innovative activities.

Our second conceptual amendment concerns the time dimension of policy intervention: we emphasize the *catalytic* nature of R&I policy. With catalytic we intend a type of intervention without which no interaction would take place (or would occur at a much slower pace), but that lasts only long enough to push the system toward a new path of development or structural equilibrium without exerting an everlasting pressure on preexisting dynamics. A catalytic policy should spark the flame of innovative activities, rather than being its permanent source. In a sense, a catalytic R&I policy oscillates: it should experiment the exploration of trajectories as long as new technological opportunities can be exploited by economic actors, and from that point on should return to intervene on the intensity dimension of innovation, until opportunities get fully exploited once again. In short, with *catalytic* we stress the temporary nature of state intervention.

Economic actors do not only act in given market structures and utilize given technologies; they strive to shape, conquer, and create their markets through innovation. Relatedly, a Schumpeterian catalytic R&I policy is one capable to maneuver the parallel necessities to influence both the intensity and the direction of innovative activities. In other words, to know when to intervene on the incentive to exploitation of given technological trajectories, and when to intervene easing the transition from an exploited technological trajectory to others, richer in opportunities (hence, on the incentive to exploration). Following Mazzucato and Robinson (2016), the issue can be framed as the search for a (dynamic and evolving) balance between the "orchestrating" and the "facilitating" role of policy, a continuous calibration of the weights to be assigned to these "shifting involvements" (Hirschman, 2002).

On this basis, our proposal of a Schumpeterian catalytic policy style is mission-oriented by design. However, as it primarily builds on private actors" innovation activities and it is constrained in time, it represents a novel typology of mission-oriented policy, enriching the conceptualization currently taking shape (Mazzucato, 2016).

As our focus is on the outline of a conceptual framework to rethink R&I policy, we spend the rest of the article at a rather general level of abstraction. This means that we do not deal with the literature on Innovation Systems—as we adopt a viewpoint microeconomic prevalently—nor will we discuss in details what are the current domains (e.g., the "grand/societal challenges") on which R&I policies should intervene. Recent contributions such as Weber and Rohracher (2012) already engaged in the exercise to build a bridge between the failures-inspired insights from Innovation Systems literature and the dynamic side of research, technology, and innovation (RTI) policy uncovered by the studies on transitions from a multilevel perspective (Schot and Geels, 2007). The framework derived there builds a comprehensive scheme to address static and dynamic failures in RTI policy design. Our aim in this article is different, as we provide a microeconomic-grounded discussion on the design principles affecting priorities and conduct of actions for R&I policy-making.

The article proceeds as follows: in Section 2, we review recent attempts to reread R&I policy from a viewpoint more consistent with real-world economic dynamics. In Section 3, first, we provide a microeconomic formalization of the intensity versus direction relationship. Second, we present some evidence supporting the idea that the direction of innovative activities, rather than their rate, is currently gaining momentum as a priority for policy-making. Third, we discuss the development of German R&I policy as an example to illustrate the swing between phases in which the prevalent focus of policy-makers has been on the intensity or on the direction of innovative activities. In Section 4, we outline the characteristics of the proposed catalytic approach to R&I policy, as opposed to similar approaches proposed recently in innovation economics. Section 5 concludes.

## 2. R&I policy: resurgence, critique, and new designs

### 2.1 Renewed interest

R&I policy is recently climbing the ranking of the most discussed topics in innovation economics (Christensen et al., 2016). The interest of economists on R&I policy and its practical relevance never really diminished over time—indeed, policy-makers are always "doomed to choose" (Hausmann and Rodrik, 2006). Current debates are just a new phase in the historical development of science, technology, and innovation policy discourse (Lundvall and Borrás, 2005). However, the path followed by the development of advanced economies in the recent years leads (i) to a renewed interest from policy-makers' side in understanding how to boost economic competitiveness and (ii) added additional emphasis to the need to design appropriate R&I interventions and to develop up-to-date tools.[1]

## 2.2 Empirical challenges

The main economic, technological, and societal reasons for that resurgence are several but can be summarized under four main headings: (i) the need to cope with the economic crisis of 2007/2008 and to rebuild destroyed capital structures; (ii) the competition with emerging economies that show a partly remarkable catching-up performance since the increasing globalization; (iii) the ongoing transformation of production and service processes, both in terms of automation and fragmentation; and (iv) the emergence of "grand challenges" imposing transformative pressures to whole societies (Foray et al., 2012).

## 2.3 Intensity of innovative activities

R&I policies are meant to help healing those malfunctions, coping with the various challenges, and taking advantage of as yet unaddressed opportunities. R&I policies toward the points (i) and (ii) above specifically address the *intensity* of innovation activities and attempt to raise them "towards previous levels" in the case of (i) and "relatively" for the catching-up countries in the case of (ii). Traditional R&I instruments in place are diffusion-oriented direct R&D subsidies, indirect subsidies for, e.g., research staff, or R&D tax credits, all of which are used in most advanced economies. They are designed to overcome weaknesses in the intensity of innovation activities caused by market and system failures; these failures, in turn, lead to low incentives to invest in innovation-oriented activities that accrue from asymmetric information, lack of sufficient financial means, neglect of spillovers, etc.

## 2.4 Direction of innovative activities

Contrariwise, policies oriented toward points (iii) and (iv) are meant to change the *direction* of innovative activities, toward automation and robotization in the case of (iii), and toward the grand challenges in the case of (iv). Such direction-oriented arguments are relatively new in the design of R&I policies. Directionality shows up in policy concepts such as smart specialization (Foray, 2013 and in this issue) and on recent reprises of innovative public procurement (Guerzoni and Raiteri, 2015). The former stresses the direction of innovation with the goal to channel specialization patterns at the regional level toward technological trajectories that are complementary and can build upon the general-purpose technology (namely, the enabling technological "core") that is prevalent in a given period. The latter focuses on directionality given its potential to create the critical masses of demand necessary to push a technology out of its niche and to acquire "generality" (Cantner and Vannuccini, 2017).

Furthermore, in combining the two dimensions of intensity and direction of innovative activities, the reopening of the Pandora's box of R&I policy fits quite nicely with the current interest in policy-mixes as a fruitful way to ease technological transition and support specific technology systems—in particular renewables and green technologies (Cantner et al., 2016).

In sum, endogenous and exogenous pressures on advanced economies push scholars and policy-makers to start rediscussing the rationale of R&I policy, its tools, and the mix and balance between them. Some of the challenges outline above can potentially be dealt with by resorting to standard interventions designed to affect the intensity of innovative activities. Others, instead, are more transformational in nature, and call for a rethinking of the specific direction and focus to be induced by policy interventions.

## 2.5 New designs of research and innovation policy

Given the discussion above, the current comeback of interest around R&I policy has induced a more profound debate on the theoretical premises of R&I policy. In general, R&I policy studies as a body of knowledge are criticized in its

1 In this respect, one of the most relevant arenas in which R&I policy is discussed is the European Union. There, the well-known European paradox (Dosi et al., 2006)—that is the relative incapacity of European excellent science sector to produce comparable industrial applications—has been tackled from different perspectives. First of all, R&I policy arguments have been used to identify weaknesses at the country level leading to an increasing innovation performance divide between states (Veugelers, 2016). Second, the room opened by the European multilevel governance has been used to invent and design new policy styles.

present form for two main reasons: the first relates to the very rationale of R&I policy (and industrial policy as well), namely, the correction of market failures (Mazzucato, 2016) and the objective to restore market forces. The second reason focuses on the narrower level of the conceptualization of the actors involved in R&I policy-making and the tools available to public interventions. In particular, the fact of having an atemporal approach to R&I policy and to consider policy-makers as passive recipient of scholarly prescriptions represents main dangers to which R&I studies are subject (Flanagan and Uyarra, 2016).

Limiting ourselves to the first issue, the general remark is that "fixes thinking"—namely, the view according to which correction of market and system failures[2] is enough to guarantee the desired level of innovative activities—assumes (i) an optimal benchmark as a reference point to inform public action and (ii) a well functioning of the market and the innovation system to always lead to desired outcomes. The role of policy in this context is only that of repairing failures with the aim to foster the rate of investment in innovation, by either reducing risk or increasing the returns of private action.

Innovation economists know from the very birth of the discipline that to guarantee perfect framework conditions is a goal doomed to fail, as knowledge production functions are not defined (Lundvall and Borrás, 2005) and innovative activities are rooted in uncertainty. As Mazzucato (2016) points out, a transformational or redirecting role for policy should instead be the one that matters for innovation and economic growth—one that creates markets rather than fixes them. A market creation approach implies that the policy-makers take direct actions, namely, to *create* markets, instead of limiting themselves to keep the economy on the track shortening the distance to the optimal benchmark, namely, to *cure* or *repair* markets. In this sense, the state has to turn from a *repair shop* into an *entrepreneurial state* (Mazzucato, 2015).

### 2.6 Justifications for directional R&I policies

The main justification for such kind of an enhanced role of public policy in innovation domain has two aspects, an economic one and an extra-economic one. The economic aspect is concerned with situations in which collective action is inhibited by inadequate economic incentives. This is due to high (switching or transformation) costs (e.g., lock-in situations), lack of the fundamental knowledge, and competences needed to change direction in an environment deeply rooted in strong uncertainty, and by the fact that knowledge itself has the character of a latent public good (Nelson, 1991). The extra-economic aspect goes somewhat deeper and is concerned with outcomes (instead of the mechanism) of market interaction and innovation system-related activities that are detrimental in the medium and long-run such as inequality, nonparticipation, and pauperization, or environment, climate, and energy resource-related maldevelopments (including the risk of mankind not to survive in the near future). These outcomes can be listed under the rubric of grand societal challenges. In such circumstances, the state and its entrepreneurial activities can substitute for the lacking collective action by taking herein the position of future generations, whose preferences should be duly considered to cope successfully with the aforementioned problems. In doing so, the state reveals (considerable) demand for proper solutions and by this creates markets which provide the necessary platform for private actors to get engaged.

### 2.7 Exploitation versus exploration

In fact, an R&I policy that goes beyond market failures and intervenes on a heterogeneous network of reactive actors should have a much wider scope. As in Mazzucato's (2016) framework, its aim is not anymore restricted to the creation of the condition capable to de-risk innovation projects or incentivize innovative endeavors. These tasks only affect the *exploitation* of existing technological opportunities. An R&I policy that claims a transformational role has instead the task to explore new trajectories and manage the costs the *exploration* entails. Such costs are indeed opportunity costs, as exploration is as appealing as the returns from exploitation of existing trajectories decrease. Such situation makes the idea of an R&I policy *à la* Mazzucato as an amended version of the mission-oriented framework: it reveals a preference of public policy for building "patient" capital rather than seeking for short-term financial gains. However, shifting the attention from the intensity to the direction of innovative activities requires a wary and temporary policy style that enriches that mission-oriented policy style, what we call a catalytic style. However, before

2 Market failures can be distinguished between allocation and coordination problems (Hausmann and Rodrik, 2006), can be more or less severe (e.g., markets can be affected by failures or may be nonexistent). System failures refer to problems of cooperation in innovation; one distinguishes intermediation, complementarity, and reciprocity problems.

outlining the characteristics of a catalytic R&I policy style, it is necessary to provide evidence of the suggested (and needed) shifting involvement of R&I policy away from intensity and toward direction.

On this conceptual background, the next section attempts to show that there are micro-based theoretical arguments empirical pattern of economic dynamics and issues of R&I policy development that make up the case for policy to extend its reach to the exploration of directions of innovative activities.

## 3. R&I policy between intensity and direction

The reasons for the change of focus of R&I policy over the years have certainly to do with the way in which societies identify and change their priorities. To rationalize that, we, first, conceptually discuss the dimensions of intensity and direction in innovation activities highlighting the role of technological opportunities. In a second step, we provide some evidence of the trends that justify about a required increasing focus on directional changes in innovation activities. A third step is devoted to the historical development of policy design toward a stage in which directional considerations are prominently taken into account.

### 3.1. Innovation between intensity and direction

In designing policy interventions in general and, in particular, when innovative activities are concerned, a central question to be addressed refers to the normative basis and, hence, the theoretical justification for the policies implemented. For the argument brought forward in this article, it is useful to spend few more lines to address a basic distinction in the economic analysis of innovation already mentioned above, namely, the analysis of innovation intensity and innovation direction. These two dimensions always coexisted in innovation studies: they have been addressed in the context of the factor-augmenting and factor-saving nature of technical change in the theory of localized technological change (Atkinson and Stiglitz, 1969), in Dosi's paradigm-trajectory approach (Dosi, 1982) and in the technology push versus demand pull debate (Mowery and Rosenberg, 1979). More from an historical and micro perspective, Rosenberg (1969) discussed how problem-solving activities and technological bottlenecks act as "focusing devices" affecting the direction of innovative activities. Nevertheless, the theoretical, empirical, and, therefore, the normative political discussion of innovation has been mainly concerned with the intensity of innovation activities.

Very recently, however, a renewed discussion of innovation directions started. A first argument has been proposed in Acemoglu and coauthors' contributions on directed and skill-biased technical change (Acemoglu and Autor, 2011; Acemoglu, 2015). Second, the literature on disruptive innovations (Adner, 2002; Gans, 2016) addresses "directional" changes in consumer preferences and in the architectural dimension of innovations that can impair incumbent firms, as they focus on maintaining the innovation intensity and replicating the strategies that made them successful in the past. Third, recent studies in evolutionary economic geography focusing on path (and place) dependence, path creation and path renewal, and on the variety of diversification processes (Boschma et al., 2015) also emphasize the dimension of direction of change as vital to understand regional growth and development. Fourth, the same holds for the literature on strategic niche management and system transition (Schot and Geels, 2007), which is, however, more interested into the multilevel perspective on socio-technical systemic transformation than on the balance between intensity and direction of innovative activities. Further, the emergence of policy concepts readily implemented such as Industry 4.0 (Lasi et al., 2014) gave as well new momentum to the discussion around the directionality of technology and industry dynamics.

On this background, and to start with our theoretical discussion, we first address a broad body of literature in the economics of innovation that shows a rather focused interest in the *intensity* of innovation. Here, we provide a stylized representation of the "common" basic analytical framework underlying the ideal-typical study in innovation economics: given a well defined and in principal accessible technological or innovation opportunity $\omega$, to what degree are potentially innovative actors (entrepreneurs, firms, industries, regions, and countries) willing to invest resources $R$ into exploiting these opportunities to reap the reward $Y$, taking into account various contextual factors $F$ which influence $R$ as well as other determinants $X$ related to $Y$?

To apply a dynamic analysis to this question, all these "ingredients" need to be time indexed, allowing them to change over time and implying also inter-temporal causalities and relationships.

$$Y_t = f(R_t(\omega_t, F_t), X_t). \tag{1}$$

The "returns" $Y$ to innovative activities can be any kind of measurable performance indicator such as gross domestic product (GDP) or GDP growth, total factor productivity (TFP), profits, sales, market shares, patents, innovations, number of newly founded firms, cooperation projects, or likelihoods to survive or exit a given market. $X$ represents factors affecting $Y$ but which usually are independent of $R$. The opportunity $\omega$ represents the search space and potentials of innovative solutions. The innovation activities are guided and constrained by $\omega$ which therefore is one of the factors determining the level of $R$. Investment (effort) $R$ can be R&D expenditures, research employees, investments into and training of human capital, investment into high-tech capital, patents, scientific papers, number of new firms, etc. The contextual factors $F$ comprise dimensions such as industry structure, intellectual property rights (IPR) design as well as the institutional and political framework. The functional form $f$ is not to be considered a proper production function but a formal aggregation operator embodying the structural relationship that relates innovative activities to their determinants.

How is the opportunity $\omega$ treated in the different economic approaches dealing with innovation? First, common to all approaches is the assumption of the existence of one given opportunity that can be exploited. In general, where this opportunity comes from is not discussed; moreover, $\omega$ is a rather homogeneous set. Second, the opportunity $\omega$ is always meant to be a constraining factor; in this sense, it generally holds $\frac{\partial Y}{\partial R} > 0$ and $\frac{\partial^2 Y}{\partial R^2} < 0$, where the decline in marginal productivity of $R$ is driven as usual by a constraining factor, here $\omega$. Neoclassical approaches in *New Industrial Economics*, *Endogenous*, *and Schumpeterian Growth Theory* model such relationship between innovation costs and returns (e.g., production cost reductions and quality improved goods) straightforward as decreasing marginal returns to innovation costs. In *Neo-Schumpeterian and Evolutionary approaches*, an opportunity $\omega$ is modeled as a technological trajectory which constrains innovation activities in terms of the type of knowledge and its cumulativeness, and the specific competencies applicable and learning regime attached to it; decreasing returns are considered, as further technological advances become more difficult to achieve the more the opportunity $\omega$ gets exploited.

Within this framework, the main focus is on the relationship between $Y$ on the one hand and $\omega$ in combination with $R$ and F on the other hand, something that can be summarized as $\partial Y/\partial \omega$, conditional on $R$ and $F$. This "indicator" can be interpreted as the intensity of innovation and change. The given and exploitable opportunity $\omega$ implies that the body of technological knowledge and competences required to successfully engage in innovation activities is rather well defined and given and develops over time in a cumulative way. This presumption can be easily identified in the dynamic models of Endogenous and Schumpeterian Growth Theory (Romer, 1986; Dinopoulos and Sener, 2007) but also, implicitly, in patent races within New Industrial Organization (Reinganum, 1989), and predominantly in the Neo-Schumpeterian and Evolutionary approaches, especially in Industrial Dynamics and Evolution (Cantner, 2011). The way this cumulative process works is rather mono-directional, governed by the size and shape of the technological opportunity $\omega$ and characterized by fundamental $\omega$-related domains of knowledge and competences, i.e., knowledge and competences required to exploit $\omega$. Actors aiming at exploiting $\omega$ share these domains and differ only by their degree of sophistication therein.

This conceptualization captures a specific way of learning (Arrow, 1962): current knowledge gets refined and extended and the specific increments of knowledge and competencies build up on each other. Knowledge and competencies are developed and enhanced but their very "core," consisting of fundamental principles and relationships, analytical tools and problem-solving methods (what we may call a paradigm, following Dosi, 1982) are not questioned. Innovation—understood in a very basic way as the generation of new knowledge and its economic application—is nothing else in this context than the enhancement, improvement, and development of the currently existent and applied body of knowledge. It is exploitation, rather than exploration.

In this kind of analysis, the direction of innovative activities does not play a specific role; it is simply implied in the shape of the opportunity $\omega$. Of course, sub-sets within one opportunity set can exist, so in practice there is never a neat distinction between pure intensity and pure direction of innovation. However, our point is to highlight conceptually the distinction between being active within a given trajectory and jumping to a different technological trajectory. In this sense, innovation decisions are not only a matter of "intensity" but also a matter of "direction," namely, choice between alternative opportunity sets. As an example, consider different energy technologies from fossil to renewables (and therein various variants). It is not only the decision on how much of R&D should be invested (intensity) but also into which (combination) of different energy technologies (directions). The same holds in the many cases featuring competing technologies that provide similar services (other examples can be those related to mobility, information and energy storage, and parallel trajectories for product development as the civil and military ones). In short, while established approaches to innovation study “serial” processes within the same opportunity $\omega$, the reality is instead that of “parallel” processes driven by a continuously renewed menu $\Omega$ of $m$ alternatives (directions), each one opening up a specific opportunity $\omega_i$ $(i = 1, \; \ldots m)$.

Incorporating alternative technological opportunities into the analysis extends the range of analytical questions—and the overall complexity—by allowing taking into account the dimension of the *direction of innovation and change*. Formally, we consider each of the alternative opportunities as a specific direction. Therefore, besides the conditions for the exploitation of given opportunities (incentives and competencies), the exploration and selection among alternative paths represent a yet underexplored but fundamental dimension of economic analysis. The issue of directionality—that is of exploration of alternative paths of technological development as opposed to a serial view of innovative activities—is not new, even within the established approached in innovation studies. In fact, Scherer (2011) recalls the discussion with Richard Nelson on the optimal choice (and mix) between pursuing single or parallel R&D projects in a context of uncertainty from an operation research viewpoint.

Applying the formalism introduce above to the problem of innovation directions, the conceptual framework now reads as follows:

$$Y_t = f(R_t(\Omega_t, F_t), X_t). \tag{2}$$

The important change is that here $m$ alternative opportunities in $\Omega_t = \{\omega_{1t}, \ldots, \; \omega_{mt}$ are considered. Hence, to engage in innovative activities actors have to take into account two dimensions, namely, the *direction* and the *intensity* of opportunities: $\frac{\partial Y}{\partial R}\frac{\partial R}{\partial \omega_i} <> \frac{\partial Y}{\partial R}\frac{\partial R}{\partial \omega_j}$.

Some qualifications seem appropriate at this point: first, assuming an $S$-shaped relationship between $Y$ and the different $\omega_i$ (implying $\frac{\partial Y}{\partial R} > 0$ and $\frac{\partial^2 Y}{\partial R^2} <> 0$) leads to a sequence of switching decisions: since a new opportunity $\omega_j$ has to be learned, the returns to $R$ will first be rather low, and therefore, the switch from an older opportunity $\omega_i$ to the new $\omega_j$ will only take place when a certain degree of exploitation of $\omega_i$ has been accomplished. Second, switching costs need to be taken into account which relate to the depreciation and obsolescence of knowledge and competences relevant for $\omega_i$ and the building up of new knowledge and competences for $\omega_j$. These costs can be responsible of severe lock-in effects preventing or postponing a switch from the old to the new opportunity. Third, costs related to higher degrees of uncertainty characterizing a new opportunity $\omega_j$ compared to the (quite well known) old opportunity $\omega_i$ are also to be considered. Fourth, within $\Omega_t$, over time the different $\omega_m$ might take value of 0, they may come up and disappear again.

Equation (2) describes a minimum economic framework accounting for both intensity and direction of innovative activities. The size of $\Omega_t$, its dynamics, and the structural relationship among $\omega_j$ determine a mapping of the distribution of returns to innovative activities over which R&I policy can intervene. From this basic description many issues worth to be studied descend, including the choice and selection of innovation paths given their history-dependent and potentially inflexible nature (Cantner and Vannuccini, 2017), the switching and transition between innovation directions, and the modalities of generation and creation of new opportunities.

### 3.2. Some empirical evidence on intensity and direction

The theoretical discussion on innovation intensity and direction just mentioned should be complemented by some empirical support. With technological opportunities at the core of the intensity–directionality discussion in the previous section, in the following we attempt to identify empirical patterns that can be related to their exploitation/exploration. A satisfactory comparative account of innovation intensity and innovation direction identifying also situations of switching between the two dimensions is not available yet. However, at least with respect to innovation intensity, there is some evidence of exploited (or rather concentrated) opportunities combined with declining marginal rewards.

As shown in Cantner (2017), one observes a worldwide rather uniform tendency of declining productivity changes—more pronounced when using labor productivity than when calculating total factor productivity. This tendency holds on the macroeconomic level but also on the sectoral and industry level. A possible interpretation suggests more and more exploited technological opportunities being over time responsible for same level of effort leading to less and lesser returns or, in other words, that ideas are “getting harder to find” (Bloom et al., 2017). This interpretation goes in line with the suggested trend of “secular stagnation” (or, at least, one interpretation of the phenomenon, the one “supply driven,” as opposed to the “demand driven”) pushing down the innovative and productive potential of advanced economies (Lindsey, 2015). Decreasing market dynamism and productivity slowdown might be not the consequence of mismeasurements (Syverson, 2017), but the signal that established innovation trajectories show signs of exploited potential.

The argument here is that the decline in (labor) productivity growth is caused by the degree of exploitation of innovation opportunities: the established paradigm(s) is (are) exhausted with an alternative one not yet at the horizon, or just at the outset. Indications for this trend are, e.g., an increase in innovation costs on the one hand and a decline in innovation activities, innovation incentives, and in new (high-tech) firm founding on the other. If this holds true, then innovation activities responsible for productivity changes should align with that development and show over time a slowdown in intensity, collectively for all actors and individually.

Starting with research productivity, a rough proxy we use is the ratio between the number of patents and business expenditures on research and development. Figure 1 shows this indicator for selected OECD countries for the period 2003 to 2012. In general, a declining development takes place, indicating that the efficiency of business R&D expenditures has been decreasing over time. Despite the remarkable spread of research efficiency, the declining trend applies to all of the selected countries, and it goes hand in hand with an internationally increasing number of patents over time. This pattern provides illustrative support to the idea that a common "data generating process" lies behind it—namely, the fact that technological potentials are getting exploited, increasing the marginal difficulty of innovating, and hence raising the cost of any further step of opportunities' exploitation. Alternatively, the possibility of an "innovation slowdown" is corroborated by the approach taken by Bloom et al. (2017) that provide evidence of non-constant returns of new idea generation that is currently compensated (for what concerns the effect on economic growth) by an increasing employment of research labor force.

Turning from invention to innovation, Figure 2a–c provides a view on the number of innovation active/successful firms in Germany. Data are taken from the German Community Innovation Survey (CIS) and the Mannheim Innovation Panel (MIP) for the years 1992 to 2012. A distinction is made between research-intensive and other industries as well as between research-intensive and other services.

From Figure 2a, it becomes evident that, starting at about the year 2000, the share of innovatively successful firms in all firms is declining considerably—less so in the research-intensive industries. In parallel with the research productivity decline, this tendency started already before the 2007/2008 crisis. There is a clear difference between manufacturing and services, the former characterized by a comparatively higher rate of innovators throughout. However,

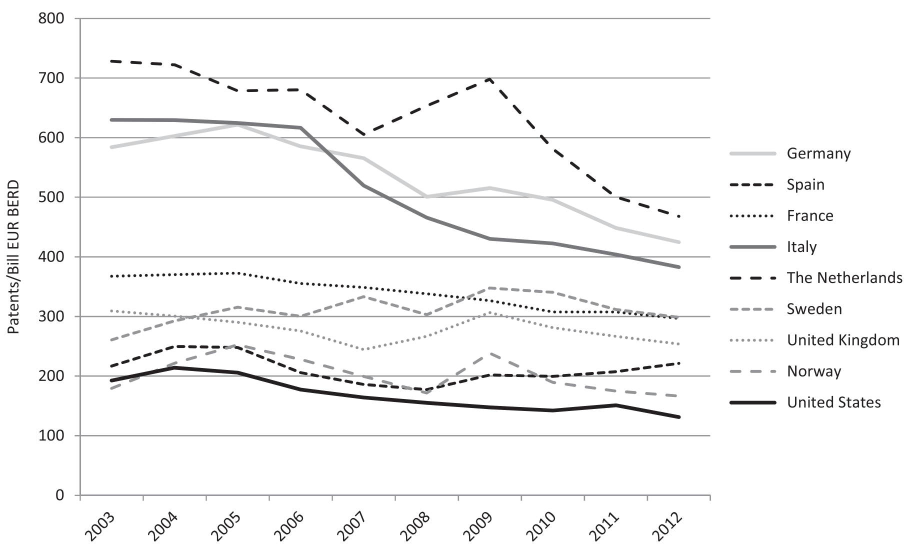


**Figure 1**. Research efficiency of selected OECD countries 2008–2012.

*Source:* Eurostat.

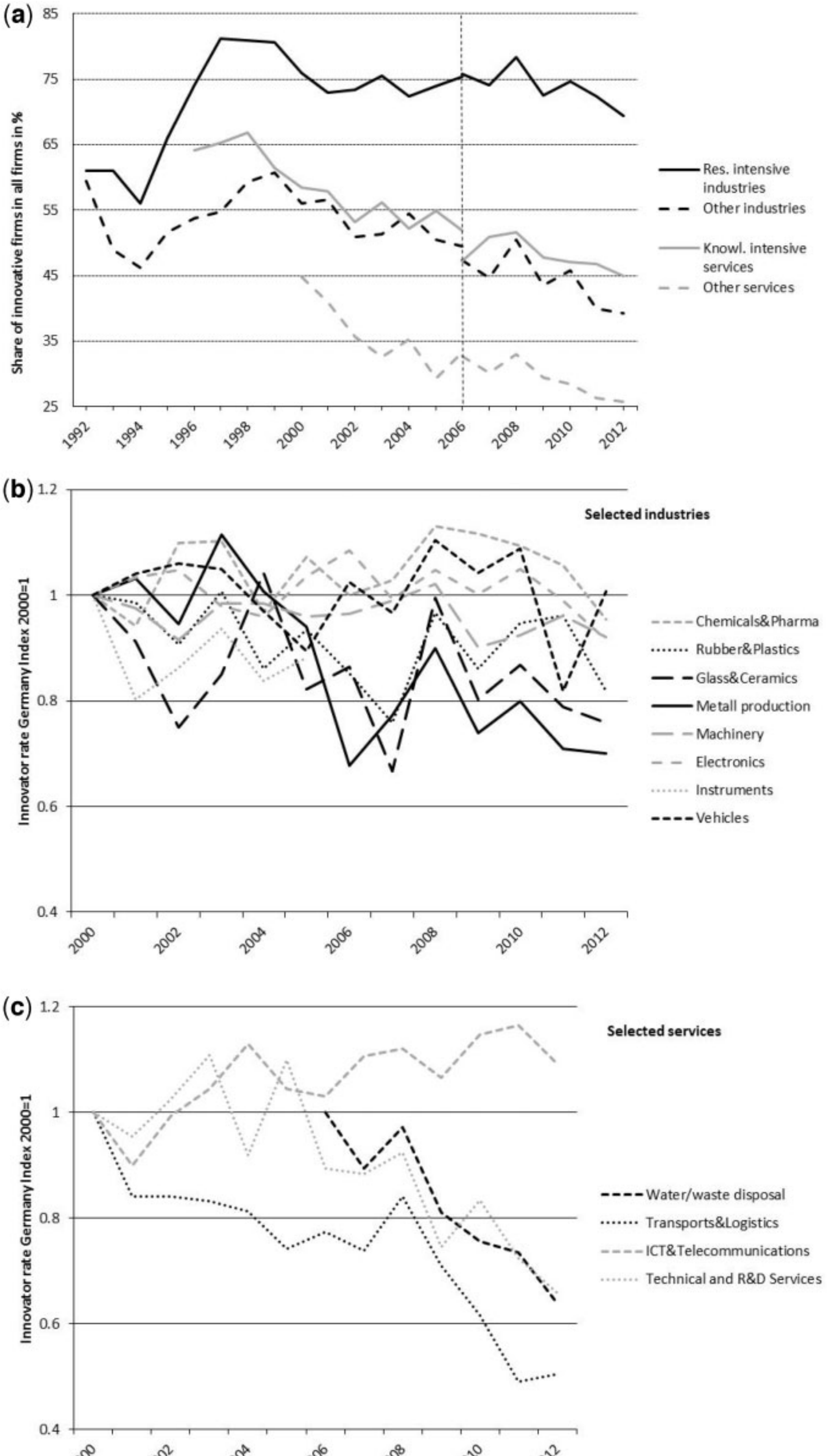


**Figure 2.** (a) Innovator rate Germany 1992–2012. (b) Innovator rate Germany in selected industries 2000–2012. (c) Innovator rate Germany in selected services 2000–2012.

*Source:* Mannheim Innovation Panel.

for both sectors a decline in that indicator is easy to detect. A development equivalent to this one is found for nearly all European countries (see Rammer et al., 2018).

Splitting up the aggregates of industry and services delivers that this decline in the share of innovators is not only an aggregate phenomenon but applies also to each industry and service category considered in isolation. Figure 2b and c depicts this pattern—here an index based presentation is used with the year 2000 being set to 1. For most of the selected industry there is an upward trend until the mid-1990s, and then all industries experience a decline in that indicator. For services the same picture is found, with the exception of services related to information and communication technologies (ICT) and Telecommunications.

The evidence presented here applies to Germany; to have a more robust identification of innovation slowdown trends, a broader empirical account would be helpful.

To strengthen our claims, we analyze another measure related to innovative activities: the annual number of new firm founding. In general, newly founded firms—while characterized by low survival rates and subject to the "liability of newness"—are considered to be carriers of more radical innovations (whereas larger firms show more incremental innovations). Hence, figures on new firm founding can be considered as a rough proxy of the proportion of "radicality" of technological change. Evidence from Germany is in line with the trend of declining innovation activities. Figure 3 shows a declining trend of newly founded firms in Germany since 2005; the stock of young firms declines too, by a leakage to "large firms," and this is reinforced by less new firms. An equivalent decline in new firm formation is found for other countries, e.g., the United States (see Haltiwanger et al., 2014) or Canada (see Cao et al., 2017).

The declining indicators of innovator shares that parallel the decrease in productivity growth can be interpreted as a signal of technological opportunities getting exploited (or being more concentrated on a few actors). In such a situation it becomes increasingly costly to achieve further innovative results; in addition with concurrent technologies becoming exploited and new alternative opportunities not yet visible or only costly to enter, uncertainty among potential innovators tends to increase. Consequently, the willingness (the incentive) to engage in R&D and launch investments and new projects will be low.

Cantner et al. (2018) provide a more systematic analysis of the compositional nature of the innovation slowdown. Comparing industry-level indicators elaborated from Bloom et al. (2017) across OECD countries, the innovation slowdown appears evenly distributed. This suggests that the request to policy-makers to debate the direction, rather than the enhancement of intensity of innovation, is not misplaced.

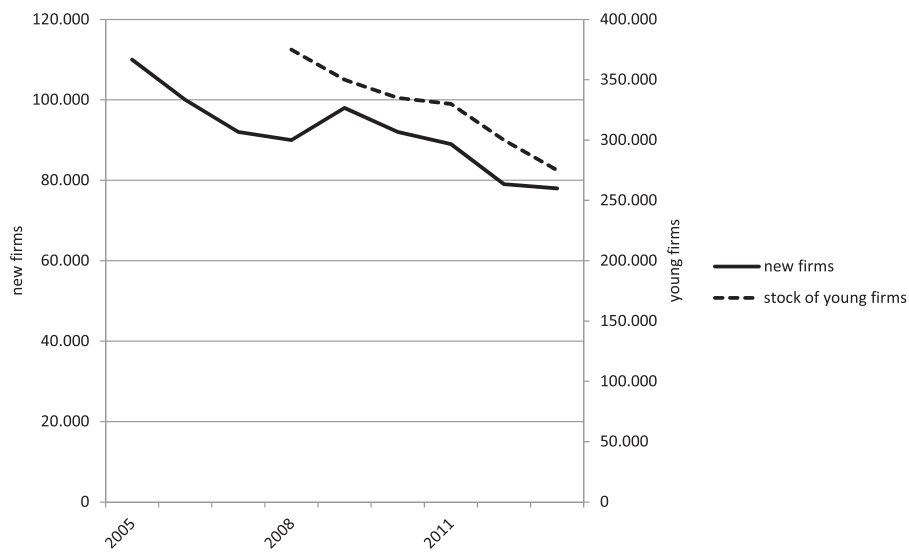


**Figure 3.** New firms and stock of young firms (<4 years).

*Source:* Mannheim Innovation Panel.

### 3.3. Policy designs: accounting for intensity and direction

Keeping in mind the exploratory evidence presented in the previous section, we have now a compelling argument to demand for direction to be accounted as a priority in the design of R&I policies. This holds in particular as we are entering a phase in the development of policy styles that is once again sensitive to mission orientation. Policy designs and styles change over time; they evolve (Cantner and Pyka, 2001). Theoretical advancements and new insights, the historically dependent accumulation of successes and failures of policy measures implemented as well as rather general changes in context conditions are driving forces of such evolution. As an example—that however we consider rather prototypical of the evolution of R&I policy designs across the decades—the development of R&I policy designs in Germany since the 1950s, as depicted in Figure 4, evidences the aforementioned changes in policy styles. Four grand (mutually not exclusive) paradigms in policy design can be distinguished.

#### 3.3.1 Mission orientation

A *first* one evolved in the close post-World War II period, from 1950 to the mid of the 1960s. In this phase of reconstruction and restructuring, a clear *mission orientation* of R&I policy was pursued. The goals of these missions were set by the advanced economies in the Western industrialized world, strong in basic research on the one hand and large-scale research on the other. Catching up to these levels was the target. The theoretical basis for any policy intervention in this paradigm focused on new ideas as purely public or merit goods, and these features were considered at the core of all activities within basic research and large-scale research. Private actors are not expected to have strong incentives to engage in these fields—also because of their relatively low economic power, state policy-defined objectives, and mobilized resources (Ergas, 1987). The rationale for such type of intervention was the same informing "the endless frontier" philosophy of US science policy (Lundvall and Borrás, 2005) and that helped scholars to frame the linear model of the innovation process (Balconi et al., 2010). In this sense, a mission-oriented policy design appeared. Direct project subsidies in large-scale research laboratories and universities, in large-scale industry as well as institutional facilitation combined with some measures of indirect global measures (mainly addressing research personnel) characterize this policy design.

#### 3.3.2 Diffusion orientation

A new phase in research and R&I policy started in the mid-1960s and dominated until the mid-1980s. Key technologies to be adopted by the private sector, the pros and cons of labor saving technologies, first concerns with the environment, and more broadly spread innovative activities following fast development of the industrial base characterized the German innovation economy. Improving efficiency in the industrial sectors and catching up toward the international frontier in industrial innovation became main targets. In view of that and based on further theoretical developments a *second* phase of policy design emerged, a *diffusion orientation*, implying to involve on a broad scale mainly private actors into adopting and generating new technologies.

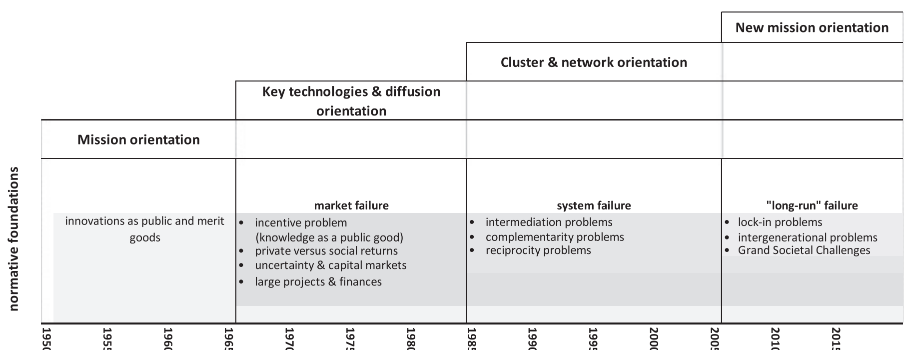


**Figure 4.** Evolution of German R&I policy.

*Source:* Authors' elaboration based on Fier and Harhoff (2003)

Theoretical contributions in the early days of economic of innovation relevant to this policy paradigm addressed the issue of knowledge as a public good, the beneficial effects of IPRs, and the discussion on the Neo-Schumpeterian Hypotheses (Cohen, 2010). From a normative point of view, these dimensions were integrated into the discussion on markets and their functioning, and the results indicated that non-negligible *market failures* can be expected—the market failure approach to research and R&I policy was born. Incentive problems related to imitation, gaps between private and social returns, uncertainty not insurable via future markets, problems with access to financial markets, and, related, the size of innovation projects are considered the main causes for rates of innovation activities being below a theoretically computable optimal level. The intensity of innovation (and the activities driving that such as R&D&I) is then considered being too low. Policy measures to work on that are meant to activate and incentivize potentially innovative actors to return to the optimal intensity of innovation activities.

### 3.3.3 Systemic innovation

With a growing need to internationalize and stay internationally competitive, the innovation system as the *deus ex machina* became the center of interest. To be successful on these terms it is not only the isolated innovator but also the integration of innovators into a system—meant as innovation-related networks, clusters, and systems on various analytical levels—that became important. A related system oriented or *systemic R&I policy* already emerged in the mid of the 1980 and started dominating until the early 2000s.

This move was pushed by theoretical developments on the systemic dimension of innovation activities. A modified conception of knowledge serves as starting point and is at the core of this new type of policy design. Challenging the concept of knowledge as a public good and highlighting its latent public (Nelson, 1991) if not tacit character, the systemic approach to innovation changed the view on spillovers. Innovation is driven by the (re)combination of knowledge and this recombination depends to a large degree on the existence of knowledge spillovers (Romer, 1986). The systemic approach extends this discussion and asks for the very conditions of positive externalities of new knowledge; in short, it extends the market failure discussion to considering system failures. These failures account for a (too) low level of positive externalities and are due to the problems of intermediation (actors who potentially could successfully exchange and recombine knowledge pieces do not know each other), complementarity (actors do not fit together in the sense that the different knowledge pieces have no creative potential), and reciprocity (the exchange of knowledge necessary for recombination does not take place in a bilateral way and issues of mistrust come up). Just like market failures, these system failures are considered responsible for a too low rate of innovation.

Policy measures tackled system failures by funding research and innovation cooperation on top of normal project funding. Conditioning cooperation by focusing on specific partner combinations, e.g., university–industry, or on the involvement of specific groups, e.g., small and medium enterprises (SME), allowed to additionally addressing other problems such as the transfer of ideas from academia into the economic sphere or the low rate of innovation by small firms. Going beyond funding-specific R&I cooperation projects at a small scale, funding clusters and networks with numerous partners on various stages of the innovation process became prominent. By these measures not only the intensity of innovation activities increased but also the level of knowledge exchange and cooperation.

### 3.3.4 New mission orientation

Globalization, economic integration, and the catching-up successes of East Asian economies as well as the BRICS countries came along with tremendous new challenges with respect to energy use, environmental burdens, mining and degrading rare earth materials, climate concerns, neglected and lifestyle diseases, and others more. The economic and financial crisis and the structural reconfiguration of economic production around global value chains and fuzzier boundaries between manufacturing and services made the challenges just listed even more severe. To solve these challenges, new materials and energy resources, cleaner production and land use, new drugs and medical devices as well as new ways of behavior and new attitudes are required. Relatedly, innovation activities oriented toward these new directions are in need.

Policy plays a role in this context, as quite a number of these problems show an intergenerational dimension on the one hand and requires radical changes of current behaviors on the other. The former aspect implies that the demand for problem solutions is not properly revealed; a high time-preference (discount) rate of the current generation tends to make future problems as negligible, while future generations, potentially negatively affected, cannot reveal their preference on today's markets. For potential innovators such a situation implies that there is no demand for solutions to intergenerational problems, and hence activities in such new directions will not be started and developed. As to the dimension of disruptive changes, the envisaged solutions not only will affect (and by that devaluate) currently pursued activities; they are also affected by a comparatively high degree of uncertainty—uncertainty in a technological sense of problem solution and in the economic sense of addressing demand and offering a "right" and viable allocation of resources. In sum, the failures observed here arise from not-revealed demand, lock-in effects into existing technologies, and a high degree of uncertainty. These three factors prevent private actors to engage in new technological directions. It appears that collective action may help overcoming such trap by initiating (and financing) technological search and experimentation, by inducing a way out of lock-ins and by the sheer number of new activities in new directions reducing uncertainty. Hence, for any policy intervention in this context, it is not so much the *intensity* of innovation activities that matters, but rather their *direction*.

A policy design, labeled here as *new mission orientation*, has been developed to cope with these issues. It pinpoints a handful of societal challenges and demands and asks for solutions. The role of the state is here becoming fully "entrepreneurial" and innovation direction gains an increasing relevance as compared to innovation intensity.

#### 3.3.5 Generalization

The development of policy designs just considered is not specific to Germany and can be considered representative for the Western industrialized world. Market and system failure-oriented policy measures have been implemented in all of these countries, although to varying degrees and with specific designs. The latter applies especially for the designs under the umbrella of new mission orientation. Whereas in Germany it is the *High-Tech-Strategy* that resembles the orientation toward the Grand Societal Challenges, we find equivalent programs in other countries: *the Industrial Strategy* in the UK, *the 5th Science and Technology Basic Plan 2016–2020* in Japan, *Creative Economy* in Korea, *Smart Industry* in Sweden, *France Europe 2020* in France, *Inclusive Innovation Agenda* in Canada, and *Strategy for American Innovation* in the United States.

The new mission orientation paradigm represents the fertile framework over which to install R&I policies that are capable to address the bottlenecks to which innovative activities are subject in advanced economies. For these policies to be successful, a focus on how to steer the wheel of innovation direction is a necessary condition. After having placed the empirical and the historical pieces of the puzzle on the table, we can now proceed with elaborating a rationalization of the shifting involvements of innovation activities and policy between intensity and direction.

## 4. A Schumpeterian catalytic R&I policy

In the previous sections, we provided both some evidence of trends of innovative activities pointing to the possibility of an innovation slowdown taking place, and an account of the evolution of R&I policy. The discussion suggests a swing of policy orientation back to mission-oriented designs and a broad indication that in the "intensity vs direction" space, the opportunity-cost for the exploration of new directions of innovative activities supported by policy may be low, given the decreasing returns to support intensity-oriented activities. While the showed trends are not fully representative, we claim that some general lesson for the design of R&I policy can be drawn, as it seems that evidence of innovation slowdown shows up in a rather persistent manner (Bloom et al., 2017; Cantner et al., 2018).

Taking stock from the discussion so far, we can now summarize our proposal for a *Schumpeterian catalytic R&I policy* by providing a broad definition. First, we chose *Schumpeterian* to emphasize that policy is not to be considered a repair shop restoring the incentives of private actors to innovate but rather a means to push forward specific innovative solutions for (pressing) problems by creating new markets and thereby redirecting and activating private entrepreneurs. We refer to the term *catalytic* to label this type of policy style, as in our view policy-making should intervene in the domain of innovative activities as a catalyst intervenes in a chemical reaction. A catalyst eases the reaction between other substances without being fully consumed, increasing the speed (timing) and the rate (intensity) of such reaction. In contrast with the "market creation" approach, in a catalytic public intervention is less persistent; it intervenes directly with its "visible hand," but it is smart enough to retreat its hand when the "reaction" leading to the enhanced innovative activities in old and new directions reaches self-sustaining threshold.

In a sense, a catalytic R&I policy is a form of "balancing" intervention: policy-making should focus on the framework conditions that can favor the establishment of "critical masses" (Witt, 1997) of choice in one or the other direction, after which economic agents can autonomously engage in exploitation of technological opportunities. These critical masses or needed critical thresholds to trigger the advancement of a given technological trajectory can be reached through a temporary direct intervention (e.g., through innovative public procurement), or by helping to define the blurring boundaries of competition between alternative directions. The former type of intervention means that public policy has to create arenas, or battlefields, where experimentation between competing alternatives is tested "in vitro." The latter type of intervention implies that public policy has to adopt sophisticated criteria to discriminate between alternatives in context of uncertainty and complex technologies evolving over time. An example in this sense is the re-elaboration of the Nelson–Sarewitz rules to assign scores to alternative technological directions (Almudi et al., 2016).

The focus on the temporary nature of a catalytic R&I policy can be supported by an argument provided by Erdmann and coauthors (2007: 980) as illustrated in Figure 5. When a dynamical system—for example, the dynamics of an economy driven by innovative activities—has a single point of rest, external forces such as R&I policy have to exercise a continues pressure on the relevant state variable to keep the system out of the unwanted point of rest. However, when the dynamical system is characterized by multiple (only locally stable) equilibria, a limited "push"—a catalytic intervention—may be sufficient to produce a transition to a new point of rest, or direction of technological exploitation.

In a nutshell, our catalytic policy is an extension of the mission-oriented framework. Indeed, we consider the market creation in the entrepreneurial state approach (Mazzucato, 2016) a special case of catalytic R&I policy, one in which the catalysis requires a persistent intervention. Whenever in redirecting innovation activities and creating new markets state intervention tends to have a longer duration, we approximate the concept of the entrepreneurial state; the more the intervention is catalytic, the more the pure Schumpeterian feature of R&I policy is approximated. A persistent intervention may not be the case for configurations of the economic system in which "reactions" occurs faster and easily. A catalytic policy framework renounces therefore to a "one-size-fits-all" philosophy and adds strata of complexity to the making to policy choices. Following Mowery et al. (2010), an effective R&I policy has to draw historical inspiration from flexible and tailored policies such as those followed in the United States in the agricultural, biotechnological, and ICT sectors, rather than from overarching endeavors like the Manhattan Project.

The generality of a catalytic policy is rooted in its wide scope of application and flexible structure, not in its unique recipe for success. Pushing a little further the chemical and biological similitude, a catalytic policy builds on a view of the economic system as an interacting population of "activators" and "inhibitors" (Turing, 1952) that shape morphogenesis, where activators hasten interactions, and inhibitors block it. While many biological systems—given the respective shares of activators and inhibitors—are autocatalytic and self-organize, economic systems—that are entrepreneurial in nature (uncertain and driven by restless competition of creative destruction)—require policy intervention to spark those catalytic reactions that allow the system to move them from one state to a more desirable one (where the desirability of a given structural equilibrium is defined by social and political challenges and priorities).

Following our discussion so far, we define below the characters of our proposal. A Schumpeterian catalytic R&I policy is:

*Schumpeterian*, as it intervenes on ever-changing structures with an ultimate focus on private actors and must allocate interventions between the support of exploitation (intensity) and the exploration of new trajectories

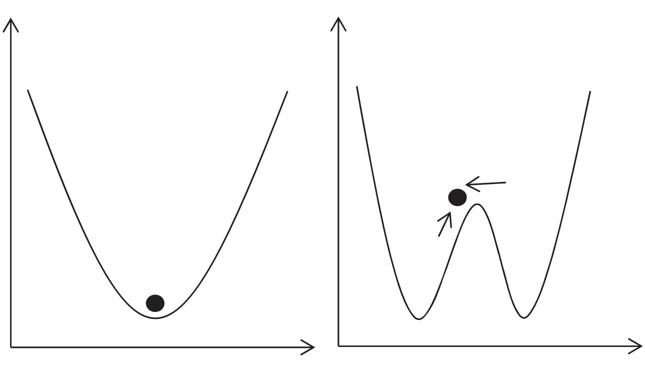

**Figure 5.** Examples of dynamical systems with one (leftmost figure) and two (rightmost figure) equilibria.

*Source:* Based on Erdmann et al., 2007: 980.

(directions). Furthermore, it is Schumpeterian in the sense that it relies on a micro-meso-macro (Dopfer et al., 2004) thinking and can borrow its interpretative and guidance tools and guidelines both from standard and complexity (Frenken, 2017) theories.

*Catalytic*, as it tries to limit persistent interventions and to adapt its scope to the particular shape of the economic system in a given period.

*Situation-sensitive*, as it combines a "continuity" rationale—justified by the presence of challenges to policy interventions into the innovation realm that remain stable and persistent over time—with a "discontinuity" rationale—motivated by the specific trends of innovative activities in a given historical period (e.g., societal needs and grand challenges).

*Experimental*, as—within its rationale and given a rather broad "mission"—it should create alternative competing arenas and platforms where competing technologies and directions can show their potential, reduce uncertainty, attract private actors to reach minimum thresholds of adoption or use that can trigger the exploitation of new directions. The experimental nature of catalytic R&I policy is particularly important, as it subsumes one important dimension related to innovative activities: the incentive for a (guided) bottom-up self-discovery (Hausmann and Rodrik, 2003; Foray, 2016). Self-discovery can be conceived as a criterion for action that has the potential to compensate and mild the risk of governmental failures, as the role of the public is to design the mechanism easing the directional exploration of new trajectories. The design of the experimental arena itself is key for the success of R&I policy. As in the case of institutional experimentation (Bednar, 2011), policy-makers can lower the welfare cost of experimentation and its societal acceptance if new directions are experimented locally and if—despite their being costly to explore—they readily generate positive spillovers outside the local "laboratory" where experimentation takes place. Finally, the experimental nature of a catalytic R&I policy includes also the identification and use of "demonstration projects" (Mowery et al., 2010: 1021) as benchmarks to guides exploration of direction and exploitation of intensity when new avenue for technological development is identified. These dimensions are key to this policy design, in that they induce private actors to step into the new directions. The experimental feature of a catalytic R&I policy requires also a degree of institutional experimentation. Indeed, a policy style that is multilevel and flexible should rely on an array of dedicated and yet general-purpose institutions. One example are infrastructure and state investment banks (Mazzucato and Penna, 2016; Vannuccini, 2015); another is the Defense Advanced Research Projects Agency (DARPA) model (Azoulay et al., 2018) developed in the United States.

*Wary*, as it has to be built on the awareness that even a limited intervention may lock-in the system into inferior technologies, standards, and directions. Lock-ins are rarely irreversible in the real world (Cantner and Vannuccini, 2017), but the costs deriving from the inflexibility they generate have to be kept lower than the benefits of directional exploration. A catalytic policy can be wary also be adopting a rather specific style: instead of promoting a specific direction for innovative activities, that is where innovative investments have to go, it can make clear where investments do not have to go. In this sense, a catalytic R&I policy removes dead-ends while helping to build new trajectories. Somehow, this strategy is echoing Shakespeare's Hamlet: "by indirections find directions out."

To design a catalytic R&I policy is not costless. First, because the evolution of R&I policy-making is not a frictionless process, and the establishment of a new style entails adjustment costs and the necessity to invest effort to nurture appropriate skills for the protagonists of the policy change. Second, because policy-makers are subject to the "epistemological reservation" (Arrow, 1991: 473) as much as private actors. We consider the first issue less relevant than the second; sunk costs in shifting to a new policy style might not be that high, given that R&I policy experience has been incrementally accumulated, even though some elements nonlinearly acquired and lost weight as a function of the particular policy phase prevalent in a given period. Nonetheless, specific capabilities are attached to each of the characteristics of the catalytic design; in particular, the awareness of when to stop intervention can be reached only by actors and organizations capable to keep in constant update the relationship between the costs of market and government failure. Similarly, the attention devoted to long-run failures in the new mission orientation design requires skills to be "patient" as the patient capital they are supposed to complement. These radical requirements are all but trivial to match, and it will represent a priority when it comes to the practical implementation of catalytic policies.

As for the second issue, all economic actors are deeply rooted in uncertainty when it comes to innovative activities and exploration of unknown states of the world, and all economic actors hardly cope with dynamic efficiency, notwithstanding differences in discounting rates. However, following Rosenberg (1969), a catalytic R&I policy acts on the identification and evolution of those "focusing devices" that drive innovative activities where the value of policy-making is dynamic: the cost of policy failure can be compensated most of the time by the gains in learning, including learning of failures.

## 5. Conclusion

In this article, we posit that the current interest in R&I policies, driven by the structural evolution of advanced economies, calls for a renewed effort in developing a sophisticated theoretical rationale. We suggest extending the recent insights into market creation versus market fixing philosophies to outline the contours of what we labeled a Schumpeterian catalytic R&I policy.

We showed that a Schumpeterian reading of R&I policy is key to embody into the elaboration of policy prescriptions the structural tension between the need to foster innovation intensity and that to explore alternative innovation directions. We rationalized our argument by providing a conceptual framework for innovation activity and policy that accounts for both intensity and direction. We supported the claim to emphasize directions of innovative activities as a core element of R&I policies by providing some evidence of recent innovation slowdown—an indicator of exhaustion of technological opportunities in a prevalent trajectory. Next, we highlighted how a direction-aware R&I policy follows an historical evolution of policy style culminated in the recent new mission orientation paradigm. With this discussion at hand, we discussed how R&I policy can behave in a catalytic way, influencing the "chemical" reaction in the economic system in favor of "activators" of technological change against "inhibitors" of change. This holds especially in a context in which a new mission orientation style of policy-making is emerging and selecting the priority to be pursued—in particular those related to the intergenerational consequences of current grand challenges.

In sum, we represent the process of external intervention on innovation incentives, constraints, styles, and trajectories as an exercise in catalysis, where the type of the compounds and their combination is important as much as the duration of their interaction. A catalytic policy is one that does not show excess inertia; rather, it is one that can balance intervention and the working of market mechanisms.

The framework suggested in this article open room for a heterogeneous set of avenues for further research. Simulation models of innovation policy-making (Ahrweiler et al., 2015) can calibrate the features of a catalytic policy listed above to study counterfactuals and long-term effects of interventions; evidence from field experiments and quasi-field experiments can contribute to a more fine-grained understanding of the micro reactions unfolding within innovation processes facing the trade-off between intensity and direction. A promising direction for studies is the one developing measures, scores, and indicators to quantify costs and benefits of technological competitive experimentation and the value of alternatives (Almudi et al., 2016). Another research "direction" is the one assessing the (economic, institutional, and framework) conditions "enabling" policy-makers to adopt a catalytic R&I policy. Finally, scholars may orient their attention to the post-catalytic phase, meaning on the normalization of policy intervention to occur after the direction of innovative activities has been influenced. In this respect, studies on policy-mix already provides useful insights on the interplay of standard measures both from the technology push and the demand pull sides (Cantner et al., 2016).

To conclude, the mission-oriented framework for R&I policy misses the thorough microfoundations that we propose in this article. We consider this approach to R&I policy to be best-suited (i) to face the grand challenges and the societal needs of the current century; (ii) to be able to address some of the known issues related to R&I policy, namely, market and government failures, the risks of crowding-out, the need for policy additionality, and crowding-in; and (iii) to enrich the conceptualization of mission-oriented innovation policy. A catalytic policy is a style yet to be fully outlined and filled with tools and principles. However, we contend that it is now the right time to explore new directions also in policy thinking. After evolutionary economics reestablished the idea of the economy as a biological complex system, the idea of catalysis brings policy-making into the domain of chemistry, that is a field where timely intervention, precision, and deep knowledge are the necessary conditions for success.

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