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Policies for Science, Technology and Innovation: Translating Rationales into Regional Policies in a Multi-level setting

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Abstract

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Key words (max 5): Rationales; Public policy; Regional policy; Innovation policy; Innovation theory

1. Introduction

Departing from a number of theoretical perspectives from which rationales for science, technology and innovation (STI) policy can be extracted, this paper discusses the suitability of such rationales to inform the design and implementation of regional STI policies. "Rationales" in this context are more or less formalised models implicitly or explicitly drawing upon academic theories or concepts that could inform policy design, implementation and evaluation. Rationales contain assumptions about the nature of the system within which an intervention is to be made. Implicitly or explicitly they articulate, problematise and justify the need for intervention and outline the logic through which that policy intervention is expected to lead to the intended outcomes. Uncovering the theory and the rationale behind policy action or inaction is essential if any meaningful evaluation is to occur (Salmenkaita and Salo 2002).

How does theory inform STI policy choice? Do influential theories and concepts provide clear-cut answers to policy dilemmas? What does theory have to say about the interventions policy makers should make? At what territorial level should they best be implemented? Despite important conceptual and methodological advances in the economics of science and innovation in recent years, there is still little agreement as to what 'good' science, technology and innovation (STI) policy should look like, which instruments should be used, and at which territorial level. Theories of innovation and technical change seldom yield detailed prescriptions for policy and in particular the 'new thinking' related to evolutionary economics, systems of innovation and knowledge economy theories go little further than general principles and policy taxonomies for public intervention (Teubal, 1998, 2002). Indeed some theoretical approaches may be positively ambiguous in this regard - for instance a variety of very different interventions may be justified by 'systems' approaches (Abramovsky et al., 2004).

The literature exploring possible STI policy rationales has centred on the differing implications of evolutionary and neoclassical approaches (Lipsey and Carlaw, 1998; Teubal, 1998; Moreau, 2004; Hauknes and Nordgren, 1999; Metcalfe, 1998; Nauwelaers

and Wintjes, 2003), but these have been either studied at the nation-state level or have adopted an 'aspatial' perspective. STI policies are increasingly being designed and/or implemented at the supra- and sub-national levels (Bache, 2004; Lyall, 2007; Keating, 1998; Oughton et al., 2002). However, the territorial implications of different economic theories of innovation and technical change are unclear[1] (Stengberg, 1996; Boschma and Lambooy, 1999). Whilst the links between geography and innovation have been the focus of much work by economic geographers (Cooke 2005), there have been few attempts to explicate the various rationales which could be derived from these perspectives, and still fewer attempts to attribute existing policy instruments or policy mixes to different rationales.

This paper focuses on three questions. First, what *rationales* for public intervention can be derived from different theoretical perspectives? Second, what *forms* of intervention can be associated with the various rationales? Third, what do these theories and associated rationales tell us about the *territorial level* or levels at which STI policies can usefully be designed and implemented?

To answer these questions we review a number of theoretical perspectives from which possible rationales for STI policy action at the regional scale can be derived. As Nelson and Winter (1982, p.372) rightly pointed out "the ability of a theory to illuminate policy issues ought to be a principal criterion by which to judge its merit". To this aim, our purpose is to extract explicit and implicit normative implications which can clarify the role of regional policy. This includes identifying possible complementarities, contradictions or commonalities between the different rationales. Before stepping into the realm of theories and concepts however, we begin with an attempt to clarify the ambiguous term 'rationale'.

[1] For instance, what 'systems failure' may mean at the sub-national level will depend very much on whether sub-national spaces can qualify as "systems", whether closed or not.

2. Policy rationales and theoretical insights – a definitional problem

Bach and colleagues suggest there are at least two kinds of 'rationales' shaping policy choice: *Governance policy* rationales are visions of how to (and perhaps when to) make and effect policy action. In contrast, *production* rationales are those derived from specific concepts and theories which inform the design and implementation of specific policy instruments (see for instance Bach, 2006). Whilst they see these two kinds of rationales interacting on a continuous basis to influence policy choice, we prefer to think of them as two *layers* of rationales – what Bach and colleagues call governance policy rationales in our view become *meta-rationales* (high-level philosophies about the proper modes and limits of government action – often informed by ideological positions) which influence in turn the way in which specific ideas are taken up and interpreted in the policy process. Those ideas which are taken up become *specific policy rationales* (See Figure 1). So, for instance, the array of specific policy rationales ruled appropriate under a meta-rationale of "corporatism" is likely to be somewhat different from that ruled appropriate under a meta-rationale of "neo-liberalism". Meta-rationales can prevent certain sorts of conclusions being drawn from otherwise influential theories and concepts. This can lead to an over-emphasis on one lesson from a body of theory at the expense of other, possibly equally significant, lessons[2].

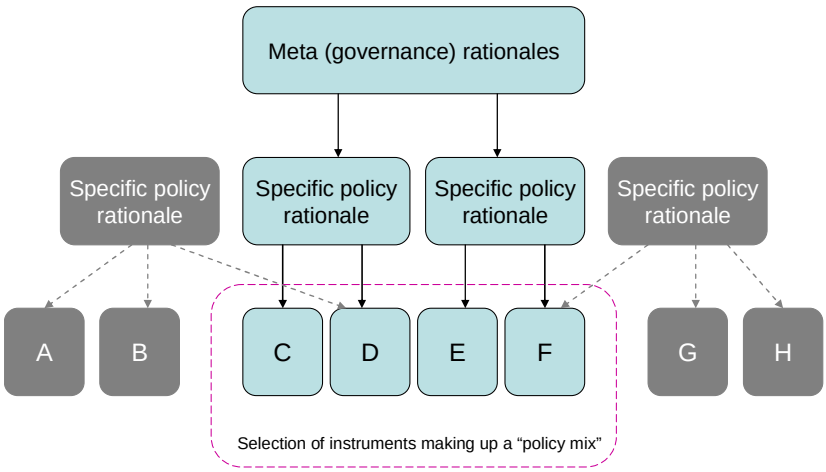

Figure 1: Two levels of policy rationales and their role in instrument choice.
(The greyed-out boxes represent rationales and instruments not chosen.)

[2] For instance one explanation for the persistence of 'market failure' rationales is the dominance of the neoclassical view as a meta-rationale. The dominant discourse of public policy intervention in all policy spheres continues to be framed by this view.

It is also important to differentiate between rationales derived by academics from (or directly implied by) scholarly theories and the specific rationales explicitly or implicitly used by policy makers to justify the design, selection and use of a particular policy instrument or mix of policy instruments (Figure 2). Much of the existing literature on rationales for science, technology and innovation policy deals almost exclusively with the former 'derived theoretical rationales' whilst generally ignoring the role of ideas in the actual policy process. Yet a relationship between the two kinds of rationales cannot simply be assumed. The fact that a certain prescription can be derived from an academic theory and mapped onto a policy instrument observed to be in common use does not demonstrate a cause-effect relationship between the two.

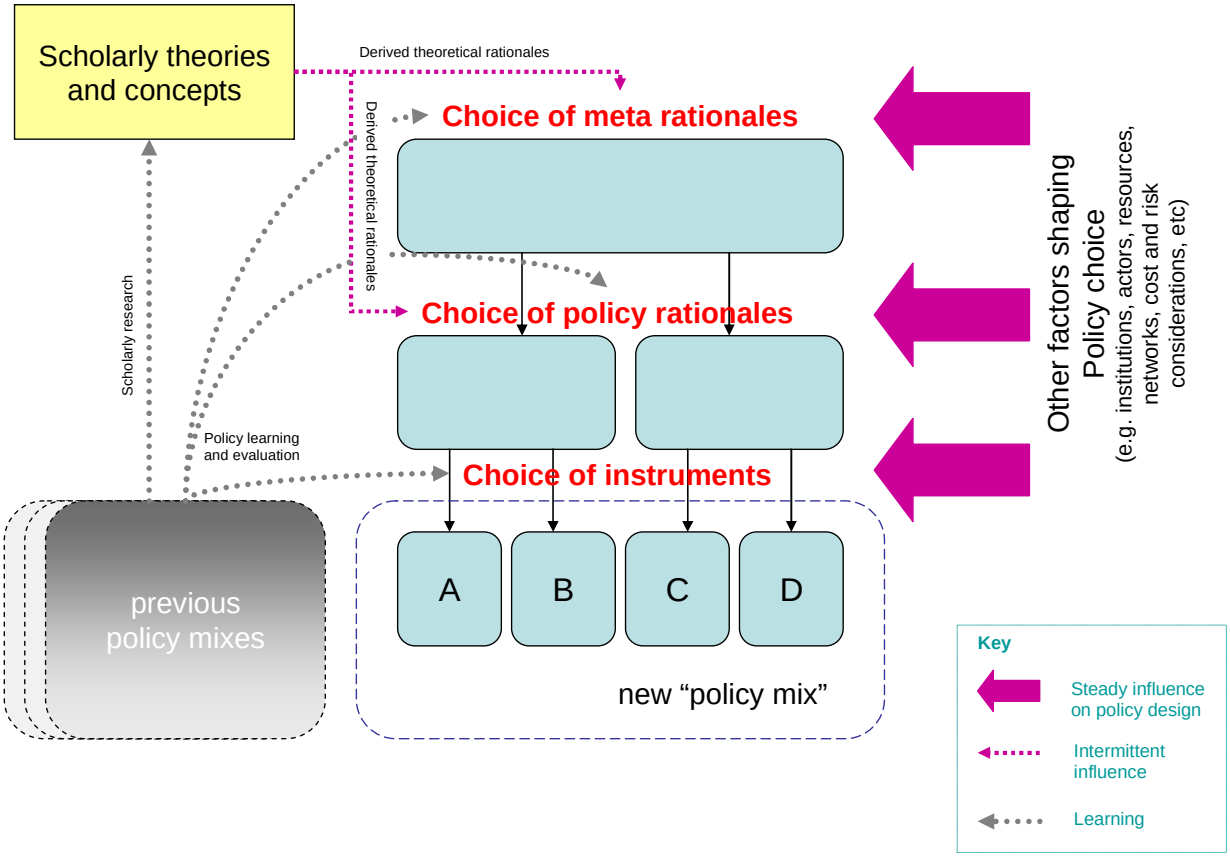

Figure 2: The interaction between scholarly concepts and policy choice

We would argue that theories are seldom directly taken up by policy-makers and unproblematically translated into specific policy rationales. Aside from the obvious influence of policy makers' learning (Mytelka and Smith, 2002) and of multiple factors and contingencies other than ideas on the evolution of policy[3], when theory based rationales interact with policy making they can often be more important as justifications for action than for informing policy choice and the design-implementation of specific instruments. Even where scholarly theories carry clear implications for policy instrument design and implementation, these implications may not always be fully explored or explicated. Added to this, theories often have a high degree of interpretative flexibility in policy terms. Indeed the most influential theoretical ideas in policy circles may be precisely those which offer larger interpretative flexibility.

Theories may seldom be adapted wholesale in a one-to-one transfer of ideas to policy. Rather, attractive elements may be 'cherry-picked'. We would further argue that policy rationales are not necessarily directly substituted one for the other. New scholarly perspectives may influence the development of policy rationales which are often simply overlaid over existing ones shaped by earlier, often incommensurable, ideas. Add to this the inevitable information asymmetries and bounded rationality of policy actors, a tendency to vertically separate policy making into 'silos', the increased complexity of policy making in a situation of multi-level, multi-actor governance and a 'natural' tendency for certain kinds of policy instruments to become institutionalised over time and we have an explanation for the sometimes surprising degree of continuity and contradiction seen in multi-level 'policy mixes'.

If theories seldom lead directly to detailed prescriptions about the choice of specific policy instruments or mixes, how then do they come to influence policy choice? In our view theories at best suggest specific actors, institutions, relationships, spaces or other phenomena as targets of policy action in order to achieve certain objectives. In turn these specific policy rationales may themselves imply (or at least) inspire specific instruments

[3] For instance, policy choice may be shaped by institutions, networks of actors and interests, by the mobilization of power and resources, and by the preferences held and choices made by individuals. Practical considerations such as the costs and risks of implementation also apply.

or policy mix choices. In this view concepts and theories developed and critiqued by scholars on the one hand, and specific policy rationales held by policy makers on the other, constitute distinct, albeit interacting, bodies of knowledge. Fundamentally, the specific policy rationales, whether implicit or explicit, are the starting point for any evaluation of the effectiveness of policy action.

All of this is not to say that attempts to identify the implicit or explicit policy prescriptions of key scholarly theories and concepts are not useful – indeed this is a key aim of the present paper. We merely hope to clarify an important distinction which is sometimes lost in the enthusiasm of those seeking to derive policy recommendations from current scholarly thinking[4]. In future work we hope to go further and explore the complex relationships between *derived theoretical rationales* and the *specific policy rationales* advanced by policy makers as they affect the evolution of multi-level policy mixes for science, technology and innovation. For the moment we content ourselves with making this distinction explicit from the outset and restricting our attention in the present paper to the task of exploring the theoretical rationales for regional STI policy which can be derived from scholarly approaches by mapping STI policy instruments or mixes onto key academic concepts and theories.

3. The neoclassical rationale for public intervention in STI policy

In the production function models of economic growth developed in the 1950's (Abramovitz, 1956; Salter, 1960; Solow, 1956), technology was taken as exogenous "manna from heaven" i.e. it was taken as a given without questioning its origin. However, after Solow's studies showing that only a limited share of total increase in American output could be attributed to capital and labour, economists started to recognize that technology could not be treated as an exogenous residual factor. Nevertheless,

[4] There remains a danger that, in opening the black box marked 'technology', some scholars of innovation have inadvertently created a new one labeled 'policy'. Policy rationales, mixes and specific instruments emerge and evolve from a complex, contingent and path-dependent process and this has important implications for the extent to which scholarly thinking can hope to influence policy choice. It may be no more possible to conceive of an 'optimal' policy choice or design than it is to conceive of an 'optimal' economic outcome. Many factors and actors influence the outcome of policy processes and theoretical insight can only ever be one of these.

technology was generally treated as information (i.e. as codified knowledge and therefore present in a perfectly usable form) about technical and scientific issues that different actors "transmit" to each other. In this perspective technology-information can be instantly and evenly diffused throughout the economy and firms are considered as having equal capabilities to incorporate the same technologies into production at negligible costs. In addition any two firms facing technology-information alternatives will rationally choose the same alternative that maximizes their expected return.

Taking technology as endogenous, Arrow (1962) argued that the process of producing and using technology-information generates positive spillovers as a result of indivisibilities in both inputs and outputs, uncertainty and low appropriability & excludability. Due to the public good features of the technology-information and the difficulties and uncertainties in appropriating returns from innovation, firms face disincentives to invest in technology and would therefore produce a sub-optimal level of technological innovations, resulting in market failure. Typical policies associated with this market failure rationale are those directed at compensating for the less than optimal allocation of private resources to science and to communication and those oriented towards diffusion and transfer of technology-information. The former tend to revolve around incentivising private innovation through subsidy or the tax system and through the protection of intellectual property rights, as well as through the direct provision by the State of infrastructure producing technology-information which would otherwise not be produced[5]. The latter tends to revolve around mechanisms for the passive dissemination of codified technology-information[6]. Overall, then, the neoclassical view would imply that the policy maker takes the role of an optimiser attempting to maximize social collective benefits (Metcalfe and Georghiou, 1998).

Neoclassical approaches do not pay attention to spatial issues. Economic growth takes place in a somehow 'neutral' space (Boschma and Frenken, 2006), with no regard to

[5] For instance establishing and supporting a public infrastructure for basic research.
[6] Passive information intermediation is taken as a non-proactive mechanism consisting in simply gathering and displaying codified technological information concerning R&D results, patents or licensing opportunities. University liaison offices promoting information about R&D results to potential market applicants can often be taken as examples of such passive intermediation mechanisms.

preconditions or specific contexts. Moreover, because of rational maximisation and equal access to technology-information, a unit of expenditure in technology would create the same expected marginal value no matter where it occurs and therefore space and location are irrelevant. In other words, public intervention is justified on the basis of overcoming market failures but these, in turn, are not associated with territory, location or space. Moreover, neoclassical equilibrium economics based on perfect competition and constant returns to scale would assume that, provided there are no barriers to the working of market forces, natural market mechanisms will gradually eliminate any economic disparities between and within nations.

4. Schumpeterian Endogenous Growth Theory

Building on the contribution of Arrow, the so called endogenous growth theories relaxed the neoclassical assumptions of perfect competition and constant or decreasing returns to scale. Endogenous growth theories portray innovation as the result of learning by doing and investment in R&D. R&D and learning results are no longer "freely available information", being non-rival and non-excludable and hence difficult to appropriate fully. Making technology an endogenous factor allows for increasing returns to investment in R&D (Romer, 1994) and therefore incentives to innovation are taken to be the potential partial monopolistic gains from R&D investment (Scherer, 1965). However, partial monopolistic gains and increasing returns may not be enough to encourage sufficiently high levels of private commitment to R&D investment, as knowledge created by R&D is likely to spill-over. This perspective also implies that knowledge is not disseminated instantaneously and freely but rather needs to be acquired (Langlois and Robertson, 1996), and that this may be conditioned by the R&D capability of the recipients. This argument implies policy interventions similar to those associated with the notion of neoclassical market failure: that is, government intervention is justified by the need to promote higher levels of private investment in R&D and innovation. The emphasis is again on promoting the supply of scientific and technical knowledge and information but there is potentially a broader role for policy implied in the move away from simply

correcting failures towards a more positive promotion of R&D and the formation of 'human capital'.

An important difference is that this perspective suggests that regional disparities will increase over time due to the effects of increasing returns. For the same level of R&D investment, regions with greater concentrations of R&D capabilities will generate greater economic returns. The policy implication is that targeting knowledge resources at these locations will maximise the effect of increasing returns. Moreover, some studies show evidence of a lower threshold or critical mass necessary for regional spillovers to be effective (Varga, 2000). Lagging regions are therefore likely to lack the minimum absorptive capacity to be able to access and utilise technologies developed elsewhere (Rodriguez-Pose 2001). Thus the combined effect of increasing returns and dedicated R&D policies is likely to result in greater spatial concentration of R&D efforts and increased inter-regional disparities.

Surprisingly, territorial implications of endogenous growth theory have rarely been discussed explicitly (Martin and Sunley 1999). Although there are a number of studies analyzing the presence and significance of localised knowledge spillovers of university and private R&D, arguing that their effect decays with geographic distance (Jaffe et al., 1993; Almeida and Kogut, 1997; Audretsch and Feldman, 1996; Feldman, 1994), there is little guidance on how agglomerations would result in increasing returns at certain locations. In fact endogenous growth theories assume a linear association between the concentration of knowledge resources at a given location and the transformation of this knowledge into economic and social value at the same location/territorial scale. It may well be that, at least in part, these knowledge externalities and spillovers are mobile and transferable across industries and sectors and even between different regions and countries (Martin and Sunley, 1999).

Thus, there are no clear answers as to when and where knowledge spillovers are likely to be relevant and about the specific ways in which knowledge spills over (Howells, 2002), i.e. the geographical delimitations of the spillover effects, the scale and nature of specific

networks, and whether this will be more prominent within or across industries. In other words, endogenous growth theories pay little attention to the characteristics of the knowledge creation and diffusion processes and to the "complex, locally-embedded and emergent socio-historical process of technological, institutional and social evolution" (Martin, 1999: 76; Langlois and Robertson, 1996). Theoretical elaborations of production functions and growth models tend to adopt a black-boxed view of both firms and regions, overlooking the technological, institutional and social factors of growth.

As in the neoclassical rationale, endogenous growth theories strongly focus attention on public intervention to boost the supply of science and technology, promoting R&D and the formation of highly qualified human capital. One difference, however, is that this rationale lends a strong support to STI policies that favour regions with greater concentration of knowledge and R&D resources. By concentrating policy attention in these regions policy makers will probably increase rather than reduce the gap with less developed regions, thus further aggravating territorial cohesion.

5. Neo Marshallian approaches: Industrial Districts, Clusters and Innovative Milieu

In contrast to the above approaches, neo-Marshallian approaches emerging in the 1980s are more empirically-informed, learning lessons from selected 'successful' regions in order to explain their relative economic performance. Particular attention is paid to the contingent social, cultural and institutional conditions of growth within the region. These accounts represent a territorial logic of analysis as opposed to the functional logic present in standard explanations of regional growth and location (Crevoisier, 1990). Here, the territory is depicted as an agent of change and not as a 'recipient' of economic processes[7]. So, the Italian 'industrial districts' concept (Pyke, Becattini, and Sengenberger, 1990) emphasises economic and social externalities of agglomeration, flexible networks of small firms, and localised learning processes. Similarly, the concept of 'innovative

[7] These perspectives are inspired by the earlier writings of Alfred Marshall, who argued that it was the effect of external, as opposed to internal, scale economies which explained the regional concentration of industries. They are also influenced by regulationist approaches focusing on the shift from a Fordist to a post-Fordist regime of capital accumulation (e.g. Piore and Sabel, 1984).

milieu' put forward by the GREMI group (Groupement de Recherche Européen sur les Milieux Innovateurs) (Aydalot, 1986; Camagni, 1991, Maillat, 1995), stresses the importance of proximity for "collective learning" and "uncertainty reduction"[8]. Finally, the "cluster" concept formalised by Porter (1998) already implicit in the earlier writings of Marshall, has been very influential in inspiring regional/national policies for gaining "competitive advantage".

In short, the economic and social externalities argument in neo-Marshallian approaches appear to suggest that geographical proximity (physical, economic, social) is important not just because of reduction of physical distance and associated transport and location costs, but also because it facilitates information exchange, lowers uncertainty, increases the frequency of interpersonal contacts, facilitates trust, diffusion of common values and beliefs, and promotes learning

However these approaches seem to suggest that uncertainty reduction and appropriation of learning and economic externalities is deemed unproblematic and automatically driven by co-location (Breschi and Lissoni, 2001, Antonelli, 2000). This perspective implies that firms located within a particular cluster or network will automatically benefit from their location and will therefore innovate more than firms located outside. Indeed, as Antonelli points out, too much emphasis is placed on "technological externalities as if external technological knowledge could be acquired freely in the `atmosphere' without dedicated efforts" (Antonelli, 2000: 539). He argues that whereas localized technological knowledge is collectively generated, it is quasi-private from an allocation viewpoint, thus communication conditions and communication costs need to be accounted for. Moreover, ascribing to the cluster or network most if not all of the credit for determining regional innovation levels implies a reduced role for other factors - for instance individual firm behaviour and capabilities.

[8] An innovative milieu may be defined as "the set or the complex network of mainly informal, social relationships on a limited geographical area, which enhances the local innovative capability through synergetic and collective learning processes" (Camagni 1991: 3).

Arguably, and despite their empirical roots, neo-Marshallian approaches are less useful for inferring a general framework for deriving policy rationales than for understanding the social context in which technology externalities arise in specific cases. Almost by definition it is hard to generalise policy prescriptions from these approaches. In part, this is because there is no agreement on what constitutes an "industrial district", a cluster, a localised network or a "Milieu" (Simmie 2005) [9]. There is also controversy as to whether clusters and districts can ever be created as a result of policy intervention as opposed to emerging as a result of a spontaneous process of development.

Although not associated with general policy prescriptions of the kind more associated with the neoclassical and endogenous growth perspectives discussed earlier, these neo-Marshallian views often identify specific policies as playing an important role in the 'success stories' analysed. These tend have less to do with accumulating supply-side capabilities in research and more to do with enabling SMEs to face changing demand, securing skilled workers and encouraging business cooperation and entrepreneurship.

One instrument often discussed in relation to the development of industrial districts is the so-called "servizi reali" (real services) (Bellini, 2000)[10], based on common technology infrastructures (e.g. local development agencies or local technology associations) for sharing of specialized services, including training, technology transfer, information support, smaller R&D projects, etc. While often suggesting similar policy actions to those inspired by the market failure/information asymmetry rationale, here those actions are justified by the need to reduce uncertainty, promote learning, and most importantly to promote labour externalities through common education and training. Thus it is clear that similar policy instruments and actions can be suggested by very different rationales.

[9] According to Storper (1997: 17), the GREMI group "cannot seem to specify the logic or content of the intangible they are after. As such, they do not reveal what it is about regions in innovation that is essential to contemporary capitalist development".

[10] 'Real services' refer to "those service activities to manufacturing companies that are expected to increase the competitiveness and market opportunities of user firms" (Bellini, 2000:711). Typical policies are those provided by ERVET, the regional development agency of Emilia Romagna, as well as other cases such as Business Link in the UK.

Further, neo-Marshallian approaches say little explicitly about the appropriate level(s) at which public intervention should be formulated and administered. These perspectives would seem to yield strong support towards decentralised forms of intervention at regional or local level, such as the "real services" referred to above. Regional and local levels might be taken as more appropriate for the so called "technology proximity policies", acting upon trust relations, inter-regional complementarities and building of learning networks. These approaches would also suggest the suitability of investing in less favoured regions, and more particularly in regional networks of industrial SMEs, to improve their economic performance. Investment in peripheral areas is perceived as a way of keeping talent in the area, generating local spin-offs, improving attractiveness for firms to relocate in the area, and preventing congestion in the core (Rodriguez-Pose 2001). Research centres and universities in peripheral regions would help to produce highly qualified personnel as well as new knowledge to be used and adapted by local firms.

6. Systemic institutional approaches to regional development

Another rationale for regional STI policy can be derived from the so called systemic institutional approach to innovation. Systemic institutional approaches accept that the non-rival nature of technology-knowledge creates beneficial externalities but see these as being specific of the institutional context that promotes and shapes the learning interactions. These approaches have latterly taken a regional turn, emphasising the importance of "institutional thickness" and governance structures underpinning regional innovation 'systems' or 'networks' (e.g. Amin, 1999; Cooke et al., 1997).

A key feature of these approaches is this explicit emphasis on institutions and networks of interactions as the key elements shaping the direction and rate of learning and innovation (Hirst, 1994). In this view differences in innovation performance at the aggregate level are linked to differences in institutional settings, implying that there must be an ideal institutional set-up for the promotion of innovation and learning (Steen, 1999). This institutional set-up could include (formal) institutions for coordination,

business laws and regulations, patenting and technology appropriability regulations, technical standards, etc., or rather more informal institutional structures (also present in the neo-Marshallian approaches) such as cultural and social norms[11].

For example, the 'innovation systems' approach (Freeman, 1987; Lundvall, 1992; Edquist, 1997; Nelson 1993) has sought to explain innovation patterns in terms of technology-knowledge flows mediated by institutions and involving conditioned choices, initially at the level of the nation. Formal and informal institutions are taken as focussing devices for accumulation of knowledge types along technological trajectories. More recently the approach has been applied at the regional level. Regional innovation systems are defined as "a geographically defined, administratively supported arrangement of innovative networks and institutions that interact regularly and strongly to enhance the innovative outputs of firms in the region" (Cooke and Schienstock, 2000: 273-274; see also Cooke et al, 1997; Braczyk et al, 1998).

The rationales for policy intervention that are implied by this perspective have often been summed up by the notion of systemic failures[12]. These arise where connections and linkages of the system are poor or not sufficiently conducive to knowledge generation. System failures can however take many forms (Smith, 2000), some of them emphasising aspects of connectivity, learning failures, 'lock-in' and stalled trajectories of development (Grabher, 1993).

[11] In the so called "institutional theory" we find complementary arguments regarding the important role of *informal institutions*, here taken as the traditions, rules, norms and beliefs surrounding economic activity, that to a certain extent define or enforce socially acceptable economic behaviour (see Scott 1987). For 'institutionalists' private and public actors operate within a framework of values and taken for granted assumptions about what constitutes acceptable behaviour. That is: choices are constrained not only by information and economic limitations (as the neo-classical approach would emphasize), but also by socially constructed limits. In a sense institutionalism sees economic and business practices as influenced by the fact that individuals and organizations are approval seeking, susceptible to social influence and seek conformity to social expectations

[12] Morris Teubal (1998:156) defines a system failure as the "failure to stimulate in a timely fashion the emergence of a new component of a NSI [national system of innovation] which is deemed to be of strategic value for the economy. More generally, system failures reflect deficiencies in the set of complex activities which should be undertaken both by the policy mechanism of a country and by market forces in order to stimulate such a NSI component."

The task of policy actors here is to improve systemic performance by helping to overcome institutional inertia and to promote institutional configurations that stimulate learning, adaptive behaviour, interactions and associations between actors. A 'systems' approach implies a key role for policy-makers as "organisers" of the different roles and functions of national and regional actors and their interactions rather than planners. Policy actors, in common with other actors, have bounded rationality, and face uncertainty and unpredictability in attempting to organise system transformation across a wide range of institutions. This suggests an emphasis on policy experimentation, monitoring and in policy learning (Metcalfe and Georghiou, 1998; Teubal, 2002).

The 'systems failure' rationale implies that public intervention can promote collective learning and that the relationships of the system with its components, coherence and possible dysfunctions can be acted upon, institutionally coordinated and perhaps even constructed (Rondé and Hussler, 2005). However, it provides little guidance with regards to the formulation or selection of specific policy instruments appropriate for the construction and coordination of dynamic interactions between the various system-components and for inducing new attitudes and changes of behaviour (Abramovsky et al., 2004; Teubal, 2002). Perhaps as a result the rationale is often associated with 'soft' or 'procedural' policy instruments intended to shape institutions, promote learning, alter policy and governance processes etc[13]. The EU-funded RIS/RITTS initiatives are a good example of initiatives aimed at awareness and stimulation of generating institutional change at the regional level. RIS initiatives produce as an output a 'regional innovation strategy', usually mobilising a mix of instruments intend to "socially engineer" regions by creating the right environmental, and in particular institutional, conditions for increasing the innovative capacity of the regional economy (Bellini and Landabaso, 2005; Landabaso and Reid, 1999; Morgan and Nauwelaers, 1999). These mixes tend to include both 'hard' and 'soft', 'old' and 'new' instruments. The 'old' instruments may be used in 'traditional' or in new ways – for instance R&D subsidies may be implemented with different criteria which reflect the concerns of the systems failure rationale, or public

[13] For more on the distinction between 'procedural' and 'substantive' policy instruments emerging from the 'instrument choice' literature see Howlett, 2005).

procurement may be used to strengthen key suppliers. New 'procedural' or 'soft' instruments such as 'foresight' and other forms of 'strategic intelligence' are intended to facilitate the creation of dynamic learning processes in order to arrive at a common vision about which "key technologies" and which priorities to adopt, hence contributing to behavioural change (see for instance Smits and Kulhman 2004).

In principle systems failure rationales are equally (and perhaps simultaneously) applicable at different territorial levels. However there is increased attention being paid to the region as a particularly appropriate level at which to induce institutional change and enhance cooperation (Uyarra, 2005). It is at the regional level that policies can be more "context-specific and sensitive to local path-dependencies" (Amin, 1999). Moreover, at least some European regions already appear to have all the necessary elements for the governance of innovation, i.e. innovation-support instruments, financial capacity, shared culture, devolved administrative powers (Cooke et al., 1997; Braczyk et al., 1998).

The regional innovation systems view has sometimes been criticised for implying that regions can be considered as complete, closed systems – national systems writ small. However, in reality the scope of the regional political jurisdiction may not coincide with the geographical socio-economic space where the relevant "institutions" and "interactive learning" interactions are to be promoted (Rip, 2002). Further, at smaller spatial scales, system dysfunctions and lock-in situations may require access to knowledge outside the regional system. Thus, many of the relevant enterprises and public institutions as well as the key relationships may be extra-regional and regional policies would presumably also need to promote and support external linkages to other "innovation systems" at different territorial levels.

7. The Evolutionary-structuralist approach to regional STI policies

The central issue in the so called evolutionary-structuralist approach, introduced by Nelson and Winter (1977, 1982), is that technology is taken as a mix of tacit and explicit knowledge that cannot simply be reduced to pieces of information. Attention is therefore

focused on all kinds of learning and cognitive capacities of different public and private actors. Cognitive capacity concerns not only scientific and technical knowledge, but also other kinds of knowledge, related to markets or produced in business and organizational practices. It also includes dynamic aspects related to the capacity to change the cognitive capacity, involving changing the "way of thinking", the beliefs, the visions, the intangible resources, organizational routines, etc. This perspective emphasises that innovation and diffusion are collective, cumulative, path- and context-dependent processes, varying across different types of actors, firms, industries, regions, etc. Key tenets of evolutionary approaches are: the dynamic nature of the economic system, and the associated irreversibility and path dependency of economic actions; the uncertain nature of economic processes, and the heterogeneity of actors in the system. Evolutionary approaches view differences in firm behaviour as the driver of economic change and thus reject the idea of a 'representative' firm (Metcalfe, 1995). Firm behaviour is guided by routines by which they create, and adapt to, novelty through learning. Routines are understood as decision rules, or regular and predictable behavioural patterns of firms (Nelson and Winter, 1982, p.14).

There is a fair degree of overlap between systemic institutional ideas and evolutionary ideas. However, the key difference is that the evolutionary view is not reduced to how formal and informal institutions shape knowledge production and utilization processes, but takes a broader view, considering networks and sectors as key units of analysis, and exploring their characteristics and specific evolution. Co-evolution of institutions, technology and the structure and composition of economic output – the so called structuralist element of the evolutionary view –is therefore a key difference. Other key differences are the emphasis on diversity within the system and on its ability to selectively exploit "good" trajectories as well as ensure a "good" transition from one technology (or from one dominant type of knowledge) to the other, avoiding lock-in situations. The main condition for all this appears to be the ability to change the cognitive capacity of all agents or groups of actors at all levels of the system.

Putting cognitive capacity at the centre of the evolutionary-structuralist perspective, makes it more difficult, however, to identity, characterise and isolate different types of failures from which to extract rationales and policies for public intervention. According to Metcalfe (1995) the key role of policy in the evolutionary view is to favour learning processes and increase the probability of experimental behaviour. However, there is no guidance as to how much experimental behaviour is desirable, or how much variety is appropriate in the system. Different authors (see Lundvall and Borras, 1997; Metcalfe, 1995; Teubal, 1998), have used expressions and terms such as system dysfunctions, lock-in situations, technology or knowledge "gaps", to denote problems that limit the cognitive capacity of agents and groups of agents or limit their ability to change. However, from system failures to knowledge utilization and codification failures, there is no precise and unanimously accepted list of failures deriving from the evolutionary view.

In recent years the evolutionary-structuralist perspective has begun to be explored as a framework to explain persistent path-dependent disparities in regional growth rates (Boschma and Frenken, 2006; Boschma and Lambooy, 1999). There is an increasing interest on the part of economic geographers in the use of evolutionary metaphors such as selection and path-dependency to explain phenomena such as the spatial evolution of networks, the locational behaviour of firms and patterns of regional convergence/divergence. Martin and Sunley (2006) describe this as an embryonic 'evolutionary turn' in economic geography. The concept of path-dependency, initially employed by David (1985) to describe the evolution of particular technological trajectories[14], is now used by geographers to explain the quasi-fixity of geographical patterns of industrial activities and their evolution over time (Martin and Sunley, 2006). Evolutionary economists have also explored the geographical implications of key evolutionary concepts, for example looking at the geographical dynamics of

[14] Path dependence implies that, once a technological choice is made over other alternatives, it becomes dominant, cumulative and self-reinforcing. David's (1985) discussion of the QWERTY keyboard is an often cited example. According to Arthur (1989), these technological pathways or trajectories occur due to indivisibilities caused by vertical and horizontal network externalities, technological complementarities, localised learning by using processes and scale economies.

technological regimes[15] and sectoral systems of innovation (Breschi and Malerba, 1997; Breschi, 2000).

Evolutionary approaches present different implications in terms of location and agglomeration of innovative activities. New paths of development are instigated by forces or events that are generally external and arbitrary. A number of authors (cf. Arthur, 1994, Krugman, 1991) assume that the initial location of an industry may be driven by random events or 'historical accidents' (e.g. the decision of a firm to locate in a particular region)[16]. However, Martin and Sunley (2006) note that the location of new industries may depend less on random choice and more on place-context specific factors, such as previous industrial histories and local economic structures, since "as economic history shows, there are some areas and regions that have repeatedly been the site of path-forming".

Whether random or conditioned by regional specific factors, once variety or novelty is introduced, mutually reinforcing forces of technological and socio-institutional adaptation will start to shape the regional development process. According to Lambooy and Boschma (2001), the ability of the surrounding environment to adapt to the needs of the new technology and of the new types of knowledge would depend on the configuration of "structural parameters", including aspects such as the initial composition of the production structure, workers' skills, demand size, efficiency of market institutions, and the efficiency of fiscal and non-fiscal government regulations. The ability of the institutional context to meet the needs of new firms with new technological knowledge would provide the region greater 'first mover advantage' (Maskell et al., 1998). As at the national level a regional technology development cycle may be appropriate, with distinct

[15] technological regimes reflect the combination of "particular knowledge bases, sources and degrees of technological opportunities, conditions of appropriability, forms and degrees of cumulativeness of technological advances" (Orsenigo, 1993:42)

[16] Boschma and van der Knaap (1997) develop the concept of 'open windows of locational opportunity' (OWLO) to explain why the location of new high-technology industries is uncertain and unpredictable. Due to an initial mismatch between the demands of the new industry and the old conditions, there is a high level of locational freedom. However, once the industry is established and adaptation of the local environment has taken place, spatial factors and geographical differences would become more important, thus giving rise to localisation economies and industrial agglomeration. Until that time, the windows of locational opportunity would remain open (Storper and Walker, 1989).

infant, growth, and mature phases for policy towards specific sectors. Whereas the generation of a critical mass of projects may be the aim of the infant phase, policy in the mature phase might aim to reduce the support for routine projects and increase the support for more complex types of innovation (Teubal, 1998).

One possible rationale that can be extracted from evolutionary-structuralist thinking at the regional level is that intervention is justified by the need to avoid lock-in situations. Policy should promote dynamic matches between the specific evolving characteristics of technological trajectories and the characteristics of the region. This implies, first, that policy should "be sensitive to local path dependencies" (Lambooy and Boschma, 2001) and targeted at the need to re-structure technological and sectoral composition, not just acting on institutions and facilitating interactions as in the systemic institutional approaches revised above. Sufficient variety and redundancy (or sufficient 'related variety') need be promoted in order to avoid lock-in (Frenken et al., 2004). In this sense, highly diversified regions, presenting a variety of generic competences and open to extra local links are more likely to adapt to changing conditions.

There is also a need for a diversified set of policies, or policy-mixes supporting or targeted at different potential development paths (Lambooy and Boschma, 2001). Teubal (1998) refers to the idea of a dynamic policy portfolio perspective, understood as a range of different types of programmes (both general and targeted), rather than uniform general policies promoting R&D or innovation. In this context, policy makers "should utilize the full range of relevant policy tools [...] in varying mixes as appropriate for different industries, technologies and regions" (Branscomb and Florida, 1998: 464). In addition, because history matters, policies may need to cater for a period of adjustment or adaptation between the environment and the needs of the new technology. Much as in the system failure rationale, these views can be associated to policy experimentation, policy learning and 'strategic intelligence' (Metcalfe and Georghiou, 1998; Kuhlmann et al., 1999). However it could be argued that the emphasis here is not simply on learning but on adaptation[17].

At the regional level, then, the evolutionary-structuralist perspective suggests the need for a specific, dynamic and differentiated mix of policies, matching the knowledge and innovation processes taking place at any given time within the region. It therefore does not provide a generic framework to guide policy choice in the same way as neoclassical approaches. The rationale for policy under the evolutionary-structuralist perspective is far broader than simply overcoming market failures.

However, many policies associated with market failure rationales may be justified under an evolutionary rationale, in different mixes and with differences in emphasis and implementation in line with the new rationale. For instance we may think of subsidies and/or tax incentives for R&D as a specific instrument (directed at a specific sector with its associated technological regime) that supports learning and development of cognitive capacities, rather than as a generic, all purpose instrument. Similarly instruments associated with the supply-side emphasis of the market failure rationale such as public R&D or technology institutes may be seen as not as substitutes for private sector action or as nodes in a general system but as mechanisms for adapting and adjusting knowledge (generated inside or outside the sector/region) to specific local or sectoral conditions.

Finally, an important consequence of having evolutionary processes of selection, novelty and path dependency occurring at multiple levels (local, regional, national) and/or units of analysis (firm, sector, knowledge types, technological regimes), is that there is no precise way of determining the most effective scale and scope for public intervention. However, the importance of localised trajectories surely prompts the need to have a local or regional perspective in STI policy. For example policies that foster connectivity and interactions among the various elements of the innovation system at the regional level, as also follow from systemic institutional views, are key to encourage regional learning and innovation. In short the evolutionary-structuralist perspective suggests the need to adopt a

[17] For instance the emphasis on policy learning in the systems failure view may be more about understanding the characteristics of the existing system and acting to improve its performance than on actively adapting to new conditions.

flexible multi-scale approach, in which the regional scale is but one of the different levels in which specific targeted STI policies are designed and delivered.

8. Summary and concluding remarks

The objective of this paper was to critically assess the implications of different theoretical perspectives for regional STI policies. Key questions of whether and why to intervene (rationales), at which (territorial) levels and by which means (instruments), find different answers under different theoretical views.

While in the real practice of policy making, 'rationales' as justifications for the design of policies and policy-instruments for public intervention in science, technology and innovation policy are usually associated with pressures for results, rather than with economic theories, the above revision of conceptual appreciative theory suggests that rationales extracted from theories can provide useful directions for policy. This is especially true when, at the regional level, we go beyond a simple dichotomy between neoclassical and evolutionary theoretical rationales and consider the possible implications of other strands of theory related to space and territorial dynamics.

However, while economic theories provide principles for justification of public intervention and general directions for policies, they are not always prescriptive in terms of policy instrument choice. Concepts and theories underlining rationales for regional STI policies should be taken as heuristic tools providing some guidance for policy design, especially as regards goals, motivations and targets for policy. In particular, we found little in the way of conclusive guidance on how to directly associate different types of "failures" with specific policy instruments (or mixes).

Different approaches adopt different conceptualisations of technology, taken as information or as knowledge. They also differ in the importance given to space and proximity for scientific and technological innovation. Various rationales and types of failures can be derived from these different theoretical perspectives with consequences in

terms of policy objectives, level of intervention and conditions for policy design. This is summarised in Table 7.1 below.

Whilst the direct and optimising perspective of the neoclassical view justifies the need for intervention based on the notion of market and information-transmission failures, subsequent approaches have been less clear in terms of normative implications, even whilst often allowing for a more active role of policy. The Schumpeterian endogenous growth approaches relax neoclassical assumptions of perfect competition and constant or decreasing returns to scale, and broaden the role of policy in terms of enhancement of key inputs to innovation, i.e. investment in R&D and human capital. Neo-Marshallian views take account of social and institutional concerns at the regional level, as well as technological and learning issues, in explaining economic dynamics of territorial agglomeration. According to systemic approaches, intervention is justified with the need to avoid systemic incoherence (e.g. actors not playing their role or performing their functions). Finally, the rationale suggested by evolutionary theories is distinctive. Although some overlap with the systemic institutional view is evident, the key emphasis is on the need to increase cognitive capacity at all levels, across all types of actors, and for adaptive policy-makers to promotion of adequate diversity and experimentation in order to avoid lock-in situations.

With regards to instrument choice, while the market failure rationales carries simpler and clear implications about the "form" of intervention (i.e. what specific instruments to design and operationalise), other approaches are considerably less prescriptive. Systems failure rationales provide a general framework but are not very prescriptive on what kind of instruments should be designed and implemented, emphasising a role for policy in organising learning and the institutional "system" that supports it, and in promoting a transition towards a future more desirable set of institutions (both formal and informal). 'Procedural' instruments associated with improving governance of the system are found in use in combination with more traditional 'substantive' policy instruments typical of the market failure rationale. Other mixes of old and new instruments may also be associated with evolutionary rationales. Thus new rationales do not necessarily replace old with new

instruments, but in most cases result in different ways of justifying and implementing the same instruments, in different mixes.

The implication for our conception of space and territory of different perspectives differs substantially. Neoclassical and endogenous growth approaches tend to adopt aspatial view of economic growth. The territorial implications are however clear. For instance, endogenous growth approaches would imply divergence in regional growth patterns as a consequence of increasing returns and reinforcing processes of regional technological accumulation. Later approaches focus on contingent conditions of growth in particular regions. Neo-Marshallian approaches would stress the need to exploit external scale economies at the local level, including in those regions with a poorer endowment of R&D capacities. Systemic approaches see institutional inertia and systemic dysfunctions as key factors explaining relative underdevelopment in less favoured regions and hence a key target for policy. Evolutionary approaches support the need of regions to adequately adapt to new conditions by maintaining flexibility and diversity in the system. A key difference of evolutionary perspectives is that they particularly imply policy attention at multiple/overlapping scales. Another difference is that they adopts a more dynamic view of economic growth, in common with neoclassical and growth models, and in contrast with more static, snapshot-like views of neo-marshalian and institutional approaches. However, whereas they role of the policy maker is static in neoclassical approaches, institutional and evolutionary views see the policy maker as a learning agent with a more limited ability to direct the evolution of the economic system.

Different theories may imply different rationales - but there is a curiously cumulative effect in that newer rationales seem not to fully invalidate the instrument choices and goals associated with previous rationales. Rather they tend to add new ones, thereby increasing the complexity of public policy. Thus evolutionary approaches suggest broader roles for policy than earlier endogenous growth theories, which in turn conceive a more active role for policy than the neoclassical ‘market failure’ rationale. As a result rationales seem to be becoming less prescriptive about generic patterns of intervention, making the challenge of formulating public policy for innovation still more complex. In

the real world of policy making we can expect to find specific blends of theoretical justifications and policy rationales, often in tension with one another. In our view these blends will depend not only on specific regional/national characteristics (sector, technological or knowledge composition) and wider contingent factors but also on the extent of policy learning and policy transfer from jurisdiction to jurisdiction and level to level, not least due to the impact of policy advisors and the so-called “local industry of regional innovation” (Lagendijk and Cornford, 2000).

Having clearly distinguished between rationales derived by theory and the specific policy rationales used to select or justify policy action, we can agree that it is useful to map the relationships between theories, derived rationales and possible instrument choices. However ideas may often play only a small part in real policy choice. In order to fully understand the role of ideas in the regional STI policy process we will have to go far beyond an exploration of theory to examine the design, implementation and transfer of real policies for STI at the regional level.

Table 7.1: Synthesis of theoretical rationales for science, technology and innovation policy

	Neo-classical	Schumpeterian Growth Theory	Neo-Marshallian	Systemic Institutional approaches	Evolutionary
Consideration of technology	Technology as information and "incorporated" in capital investment	Technology as endogenous non-rival, non-excludable generated by R&D	Broad definition including social innovations	Broad (including social innovations). Technology as applied knowledge	Broad. Technology as applied knowledge
Consideration of space	No consideration of space beyond reduction of information costs, transport, location costs	Neutral but with implications for divergence/ convergence		Proximity (and space) play a role in inducing changes in behaviour	Space as on dimension for specific evolutionary processes
Rationale for public intervention	Market failures Information transmission failures Appropriability failure	Support to accumulation of endogenous R&D.	flexible "external economies of agglomeration" ,	System failure, Institutional failures System dysfunctions	Learning failures, Cognitive gaps, Block-in, dysfunctions Lack of diversity
Objective of intervention	Substitute for less than optimal use of resources	Create conditions for increasing returns to R&D	Reduction of costs in information, transports. Promote locally based networks of cooperation, and competition	Overall coherence of the system, roles and function of actors. Adequate institutional settings	Avoid lock-in Increase cognitive capacity Improve diversity and selectivity
Level of intervention	Centralised - national level No differentiation of levels of intervention	Centralised - national level, but with focus in more advanced regions	Regional level but also National level with regional focus (decentralized)	National and Regional levels	Multilevel Balances centralised with decentralised Intervention
Role of policy maker	Compensate for less than optimal private investment Optimise resources	Incentivate accumulation of "monopolistic" gains	Creation of a collaborative industrial community Education for creating pool of skills	Coordinating the system, help in networking "Animateur"	Identification of technology specific failures. Design of segmented targeted intervention. "adaptive role"

Table 7.1 (continued): Synthesis of theoretical rationales for science, technology and innovation policy

	Neo-classical	Schumpeterian Growth Theory	Neo-Marshallian	Systemic Institutional approaches	Evolutionary
Examples of Policy Instruments	Subsidies and tax incentives to R&D, Investment in local advanced technology infrastructure Parks for Science and Technology	Subsidies and tax incentives to R&D, Investment in local advanced technology infrastructure Parks for Science and Technology Large Mobilization projects.	Technology infrastructures Extension services ("servizi reali") ranging from technology to education and training Cluster policies	Subsidies and tax incentives to R&D, Technology infrastructures Extension services	Subsidies and tax incentives to R&D, Technology infrastructures Extension services Proactive intermediation brokerage (translation of implicit knowledge)
Mode of Operationalization (target, criteria elegibility, selectivity)	Targets different kinds of individual actors Favours supply side initiatives Science Push measures Return on Investment and opportunity for appropriation as criteria	Targets different kinds of individual actors Favours Science Push and large R&D projects. Favours R&D support to hi-tech, Criteria of concentration for increasing returns	Targets both individual actors and "collective" actions Favours demand approaches and provision of "shared" public services Use of the value chain or cluster concept	System as a target Criteria balances support to individual actors with increasing collaboration, interactions and networking Favours collective governance	Targets both individual actors and groups, networks of actors or systems of innovation Learning opportunity, and variety (increase or reduction) as criteria Favours collective governance

Source: adapted and extended from an idea in Uyarra (2003)

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