Prometheus
Vol. 29, No. 2, June 2011, 131–161

RESEARCH PAPER

Theoretical underpinnings and future directions of European Union research policy: a paradigm shift?

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Emerging tendencies in research policy call forth the cohesion–competitiveness dichotomy and implicitly advocate the hollowing out of cohesion objectives from future European Union (EU) research policy design. We trace the origins of this debate to the incomplete paradigm shift from the 'mechanistic' to the 'systemic' construal of technological change in policy discourse, manifest in the decisive influence the former still exercises on the objectives and instrumentalities of EU research policy. We look at some indications of this influence and we claim that they draw largely on reductionist conceptual schemes and sparse empirical evidence. We also examine the rationale for public intervention in the innovation process in two contrasting theoretical contexts, the neoclassical and the neo-Schumpeterian. We argue that the new tendencies in EU research policy stem from a mechanistic conception of cohesion and competitiveness as antagonistic notions and a normatively biased interpretation of neo-Schumpeterian arguments, and we scrutinise their inconsistencies.

Introduction

Forging a common European research policy has been a relatively recent undertaking. The founding treaty of the European Economic Community, ratified in Rome in 1957, was not explicitly concerned with issues of science and technology, and the void was only partially addressed by the Euratom Treaty in the strategic (at that time) field of nuclear energy. In the 1960s and 1970s, European states preferred, instead, to follow an inward-looking technology policy of 'national champions' dictated by purely domestic considerations. As Peterson and Sharp (1998, p.5) observe, this period has been the age of a revived 'techno-nationalism' with detrimental effects on the overall competitiveness and cohesion of the European technology market, such as further fragmentation, isolation from international competition, technological lock-in in 'sunset' technologies, and a widening technology gap with the US.

Mounting concerns about Europe's technology gap not only with the US but also with rising Japan led to the launch of ESPRIT (European Strategic Programme for Information Technology) in 1983.[1] ESPRIT was the precursor of the main instrument of EU research policy, the Framework Programme for RTD (FP), first

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ISSN 0810-9028 print/ISSN 1470-1030 online

http://dx.doi.org/10.1080/08109028.2011.600829
http://www.tandfonline.com

launched in 1984. Formally, Community competences in research and technology were established by the Single European Act in 1986 and enhanced by the Maastricht Treaty in 1992. The latter attached an explicit cohesion objective to research policy. At that time the creation of a 'common technological space' was seen as a politically non-contentious (since technology policy was out of the realm of 'high politics') opportunity for further European integration in the 'functionalist' tradition. The FPs were designed in this spirit: they were set to support 'pre-competitive', collaborative research with no national bias as to the types of technologies promoted and the distribution of funds. The pre-competitive character of supported research ensured that Community funding did not clash with the competition principles of the Common Market and did not function as a form of industrial subsidy. The collaborative character of research and the cost-sharing provisions were seen to guarantee the diffusion of technologies and the involvement of various types of actors from the whole technological knowledge creation spectrum, such as large firms, SMEs, universities and public research institutes.

Initial fears that this mode of fund allocation would benefit asymmetrically 'core' European countries with established research systems were eventually dispersed. Recent FP evaluation analyses have shown that economically peripheral countries play an increasingly pivotal role in the formation of FP-funded research collaboration networks, often disproportionally to the size of their research systems (Muldur *et al.*, 2007). This is often taken as an indication that the *a priori* distributional neutrality of FPs promotes – or at least does not obstruct – the cohesion objectives, while at the same time it rewards scientific 'excellence'.

In recent years, certain strands of policy discourse have emphasised the need for an EU research policy focused on strengthening the overall competitiveness of the EU *vis-à-vis* its main technological and economic rivals, if necessary at the expense of internal socio-economic cohesion. This goal can be achieved, the argument goes, through policy-induced concentration of R&D resources aiming at increasing returns to scale. Such an approach implies that EU research policy should abandon its traditional 'selection unbiasedness', and become more thematically focused and 'directional' on the basis of measurable performance criteria. Although these tendencies have not yet materialised into concrete policy measures, they are expected to exercise significant influence on following programming phases of existing, recently introduced, or future EU research policy instruments. The proposed policy reorientation poses fundamental questions with regard to the relevance and consistency of its rationale and brings to the foreground the long-standing 'cohesion versus competitiveness' dilemma. In this paper, we put under scrutiny core theoretical concepts, analytical methodologies and normative assumptions that drive this discourse, and we claim that it is often built on reductionist conceptual schemes, sparse empirical evidence and normative bias.

The first part of this paper focuses on a number of recurring issues in research policy discourse placed in the broader context of two conflicting paradigms of innovation and technological change, the 'mechanistic' and the 'systemic'. These theoretical issues include the perception of high technology as a driver of macroeconomic growth, the quest for 'excellence' and benchmarking practices in policy design, the setting of blanket public R&D investment targets, and the questions of causality and returns to R&D investment. In the second part, we examine the normative aspects of public intervention in the production of technological knowledge in two distinct theoretical settings, the neoclassical and neo-

Schumpeterian. Finally, in the third part, we examine the theoretical and normative ramifications of the perceived cohesion–competitiveness dichotomy, and we scrutinise emerging tendencies in research policy discourse that advocate the hollowing out of cohesion objectives on the grounds of arbitrarily evoked neo-Schumpeterian arguments.

Theoretical issues in research policy discourse

An incomplete paradigmatic shift?

Two classes of construals subsume most theories and models of innovation and technological change and constitute competing paradigms with decisive influence on policy discourse: we shall call them the 'mechanistic' and the 'systemic' paradigm. The former has been considerably more influential both at the positive and normative levels, mainly because of its simplicity, analytical tractability and epistemological affinity to neoclassical economic theory. The latter has begun to emerge more recently, but its influence does not yet reach much beyond academic circles.

The notorious 'linear model' of innovation belongs to the former class of theories.[2] Traces of a 'linear' construal of the innovation process can be found in a plethora of policy documents and academic papers with policy orientation from the 1950s and 1960s (see, for instance, Bush, 1945; Maclaurin, 1953; Griliches, 1958; Nelson, 1959). In the context of the Fordist/Taylorist techno-managerial paradigm still dominant in those times, a simplified 'assembly line' conception of the innovation process may have had some descriptive value, but in that of modern post-Fordist knowledge-based economies the model loses its relevance. Indeed, from the late 1980s onwards the 'linear model' of innovation has been battered by theorists of technological change from all sides and even its existence has been put into question.[3] Despite its purging from academic circles, many elements of the linear construal of innovation and of the deterministic perception of the effect of R&D expenditure on growth still persist in the general discourse that drives research policy.

The popular 'knowledge production function' concept belongs to the same paradigmatic class of mechanistic construals of innovation. This concept builds on the idea that knowledge (or ideas) is a factor of production in its own right, and a cumulable asset that resembles physical capital (although not necessarily constrained by the usual assumption of constant returns). The knowledge production function approach has gradually become the standard way of empirically estimating the effects of R&D expenditure on the flow of new ideas (Griliches, 1979; Jaffe, 1989; Eaton and Kortum, 1996; Porter and Stern, 2000), and on economic growth (Fagerberg, 1987, 1994; Coe and Helpman, 1995; Coe *et al.*, 1997; Fagerberg *et al.*, 1997). Such studies usually employ tractable proxies of knowledge generation, such as patent counts, as indicators of technological change [see Griliches (1990) for a review] or scientific publication counts as indicators of scientific progress [see van Raan (2004) for a review].

The knowledge production function concept has been popularised through the sprawling literature of endogenous growth, which came as a significant improvement to the limitations of neoclassical growth theory, and in particular its inability to account for technological change.[4] Endogenous growth models incorporate in the production function important determinants of economic growth related to technological change, such as human capital and R&D investment (see Uzawa, 1965; Romer, 1986, 1990; Lucas, 1988; Grossman and Helpman, 1991a, 1991b; Aghion and Howitt, 1992; Jones, 1995a). In the reference model for R&D-driven macroeconomic growth by Romer (1990), the steady-state growth rate of the knowledge stock, and consequently that of *per capita* output, is proportional to the accumulated stock of past ideas and the amount of labour employed in the R&D sector of the economy. This implies that a single policy variable, such as public R&D expenditure, can permanently shift the balanced growth path of an economy. However, as the well-known 'Jones critique' asserts, at least in the case of the postwar US economy, this conclusion is not supported by statistical evidence. Between 1950 and 1987 there has been a fivefold increase in the number of scientists engaged in R&D in the US, whereas increase in *per capita* GDP exhibits nothing remotely similar (Jones, 1995a, 1995b).[5]

The systemic paradigm stems from an epistemology that tracks its origins back to general systems theory and cybernetics and has little in common with that of neoclassical economics. This line of theory has drawn inspiration from heterodox approaches to economic theory as diverse as Schumpeter's conceptualisation of the process of capitalist development (Schumpeter, 1934, 1942), Veblen's institutional movement and his evolutionary thinking (Veblen, 1898), and, more recently, evolutionary and neo-Schumpeterian economics (Nelson and Winter, 1982; Hodgson, 1993; Dopfer, 2001), the neo-Veblenian strand of institutional economics (Hodgson, 1988), and complexity economics (Anderson *et al.*, 1988; Arthur *et al.*, 1997). On the other hand, it has inspired theories of national systems of innovation (Lundvall, 1992; Nelson, 1993; Edquist, 1997), regional innovation systems (Cooke, 1992; Braczyk *et al.*, 1998), the Triple Helix (Etzkowitz and Leydesdorff, 1997), and Mode 2 knowledge production (Gibbons *et al.*, 1994).

A common meta-theoretical thread in this otherwise heterogeneous group of theories that subsumes them under the rubric 'systemic paradigm' is the rejection of methodological individualism implicit in the neoclassical paradigm in favour of structurality, contextuality and systemicity. Within the limits of this paper it is impossible to review such a diverse group of theories in any reasonable detail. We can, however, reconstruct a set of generic features regarding the conceptualisation of technological knowledge and innovation common in most of them. Technological knowledge is generated and diffused in complex systems of heterogeneous agents with bounded rationality and limited and asymmetric information on their economic environment (Simon, 1955, 1956). Economic activity is embedded in a structured, network-like, relational space (Granovetter, 1985) that bears little similarity to the isotropic neoclassical market. This space is configured by an informal normative and a formal institutional structure that co-evolve with the economy. The informal normative structure is generated by untraded interdependencies, which, according to Storper (1997, p.5), are 'conventions, informal rules, and habits that coordinate economic actors under conditions of uncertainty'. Such informational or 'soft' externalities form social capital and are a very important channel for the diffusion of technological knowledge. Populations of economic agents, as well as norms, institutions, and technologies, go through a co-evolutionary process that involves selection, variation and retention. At the same time, individual agents co-adapt through three types of interactions: through competition, mutualism and exploitation. Competitive co-adaptation is responsible for 'Red Queen' type technological dynamics.[6]

There are clear indications that the mechanistic paradigm has reached its limits: mechanistic explanations of innovation fail to capture essential aspects of the knowledge creation and diffusion processes, such as path dependence, nonlinear dynamics, emergence and complexity, which can be straightforwardly explained within the systemic paradigm. Inevitably, systemic construals of technological change are gradually gaining ground in academic circles. However, despite concerted efforts to inject a systemic understanding in research policy [see, for instance, the discussion in Pellegrin (2007, pp.208–9)], the reductionist logic of mechanistic thinking still permeates many facets of EU research policy discourse – with sometimes misleading policy implications. These facets are scrutinised in the following section.

Elements of mechanistic thinking in research policy discourse

The transition to the knowledge-based economy is commonplace in academic and policy discourses. This transition has often been identified with technological breakthroughs that expand the global technological frontier and the subsequent techno-economic evolution. This type of high-tech economic activity takes place in a very limited number of localities around the globe, the most celebrated being Silicon Valley (Saxenian, 1994). The fascination of economists of technological change, economic geographers and sociologists with this very particular type of techno-economic system and the proliferation of related literature has inadvertently contributed to the perception of high-tech-driven economic growth as a panacea for regional development. This has prompted policy emphasis on technology- and R&D-intensive economic activities and fed aspirations in many EU countries and regions for developing high-tech capacities.[7]

What has to be emphasised here, however, is that, by any standard of economic and statistical analysis, high-tech clusters qualify as outliers rather than representatives of the functioning of the knowledge-based economy as a whole. Local economic systems that expand the global technological frontier are too few and too exceptional to be taken as generalisable and reproducible models of regional techno-economic development. Moreover, high-tech capacities are neither a necessary nor a sufficient condition for wealth creation in regional economies. While on the whole R&D intensity and economic growth are statistically correlated (Fagerberg *et al*., 1997; Bilbao-Osorio and Rodríguez-Pose, 2004; Howells, 2005), there is no substantive causal link between frontier-expanding R&D and regional growth.

There are two straightforward explanations for this last point. First, in the interregional division of labour in research and innovation, the niche of regional economies that shift the technological frontier is sparsely populated, whereas a significantly more populous group occupies the niche of knowledge brokers and mediators, and an even larger group that of knowledge users and consumers. These last two types of regional economies are most likely to make only minor contributions in the initial stage of the process of technological evolution (i.e. the stage of radical innovation) – if any – but they play an essential role in the subsequent stages of diffusion of technological knowledge, its integration in productive activities, the standardisation of its use, and finally the establishment and consolidation of techno-economic regimes. Second, interregional knowledge spillovers of all sorts, including spillovers through trade and labour mobility, always occur in the longer run. These spillovers diffuse the benefits of new technological knowledge beyond the limited group of those that generate it to the larger group of those who can tap it and use it, especially in the consolidation and maturation stages of a techno-economic regime.

Eaton and Kortum (1995) find that even for an economy with the size and technological capacities of the United States, foreign technological improvements accounted for roughly half of productivity gains (cited in Howells, 2005, p.1222). If this holds for such large geographical entities (see also Coe and Helpman, 1995; Coe *et al*., 1997), then the relative importance of non-domestic technology is likely to be greater at the level of the region (Howells, 2005, p.1223). It is justifiable to conclude, therefore, that regional techno-economic development is more the consequence of technology diffusion and adoption than of radical innovation. Ample historical evidence also contributes to the conclusion that developing technology-frontier capacities is not a one-way road to growth and prosperity. Common to the development experience of technological latecomers as diverse as Germany in the 1850s, the US in the 1870s, Japan in the 1960s and the newly industrialised countries of southeast Asia in the 1980s is that long before attaining their positions as technological leaders they proved particularly good at incorporating foreign technological knowledge to their productive activities, mainly through concerted imitation [see the detailed accounts of Mokyr (1992) and Landes (2003)]. Similar evidence can be found at the regional level. The experience of these national and regional latecomers demonstrates what is also highlighted in numerous microeconomic studies of innovation – that a large chunk of the economic benefits from R&D (Cohen and Levinthal, 1989; Griffith *et al*., 2004), and certainly most of its social benefits (Rosenberg, 1976, p.189), stem from the *adoption* and *use* of technology that is, for much of the time, invented elsewhere.

By no means do the above conclusions put into question the legitimacy of national or regional aspirations to develop high-tech capacities in emerging technological fields. As a matter of fact, technological leapfrogging is not impossible when new windows of technological opportunity open and techno-economic regime shifts take place. Moreover, international or interregional competition in emerging fields may instigate increased rates of innovation and push the global technological frontier outwards. What we argue, however, is that success stories of outliers are results of unique historical conjunctures that can only be explained in hindsight and cannot be replicated; and that, even though it is legitimate for any country or region to develop research capacities for exploring new windows of technological opportunity, high-tech aspirations cannot form the basis of a regional or national techno-economic development strategy.

The proliferation of innovation rhetoric in academic literature, and its almost compulsive tendency to emphasise stories of techno-economic success, has exercised a noticeable influence on research policy. A manifestation of this influence is policymakers' quest for 'best practices' in R&D. The proclaimed objective of this quest is to pinpoint R&D and innovation policies that have proven successful elsewhere and to transfer them to technologically under-performing national or regional economies in order to accelerate their pace of development. The best practice approach can be useful in familiarising policymakers with broadly generalisable policies, and it also appears less risky in that such policies have been already tested elsewhere. However, when faced with the specificities of regional or national techno-economic systems, best practices prove difficult to contextualise and implement effectively (Howells, 2005, p.1229).

The popularity of benchmarking exercises is another manifestation of the influence of the quest for excellence on the policy debate. Benchmarking exercises assume that all countries or regions can be ranked on the basis of their performance in the knowledge economy, usually measured by simple indicators of knowledge output [see, for instance, Iurcovich *et al*. (2006) and references therein]. Implicit in this approach is that techno-economic systems can be placed along a single axis of technological development, and, therefore, that there is a one-dimensional technological development path carved by leaders and inevitably trailed by laggards.

Such approaches frequently fail to take into account the specificities of regions, such as their factor endowments, their industrial structure, their knowledge-creating and diffusing institutions, the history of their techno-economic trajectories and their relationships with other regions (Tödtling and Trippl, 2005, p.1204). More broadly, there is a fundamental contradiction between the benchmarking mentality that currently permeates research policy and the inherent complexity and uncertainty surrounding research outcomes. As Barré (2001) points out, in complex systems such as those characterising the R&D process, it makes little sense to link specific economic inputs (e.g. R&D expenditures or numbers of researchers) to a narrowly defined set of outcomes (e.g. scientific publications or patents) because of the non-deterministic nature of the R&D process. Certain institutional arrangements, ranging from legal instruments, such as the intellectual property rights system, to social capital and trust, reduce uncertainty, but their effects are difficult to quantify and to account for in simple measures of performance. In that sense, benchmarking and the best practice mentality are testaments to the persistence of mechanistic reductionism in research policy.

Further evidence of the influence of the mechanistic paradigm on research policy is the arbitrary setting of simple quantitative targets for public R&D expenditure – a prominent example of which is the well-known 3% target. Setting quantitative targets, in general, is the logical consequence of a dominant perception of increasing R&D investment as a *sine qua non* of economic development. As a matter of fact, increasing R&D expenditure occupies a central position in the arsenal of EU policy prescriptions to the extent of becoming an objective *per se*, overshadowing the more fundamental objectives of macroeconomic growth and employment, which R&D investment is supposed to serve.[8] This is often justified by the ostensible relationship between R&D expenditure and macroeconomic growth.

There is broad academic consensus, supported by empirical evidence, on the correlation between macroeconomic growth and technological progress on the one hand, and between total factor productivity and R&D investment on the other. Among others, Coe and Helpman (1995) find a strong positive correlation between a country's total factor productivity and domestic R&D, as well as R&D of its trade partners, in a group of economically advanced countries, and estimate that the rates of return to R&D for this group are high. Coe *et al*. (1997) find that this result holds for a large group of developing countries too. In a study of 10 OECD countries for the period 1971–95, Zachariadis (2004) also finds that R&D intensity is positively correlated with the growth rates of productivity and output. Porter and Stern (2000) and Furman *et al*. (2002) in their cross-country studies, find a (weak) positive correlation between patent output and total factor productivity.

However, correlation does not mean causation (the opposite would be the typical *cum hoc ergo propter hoc* fallacy). In the above accounts, it remains unclear whether there is a *causal relationship* between increasing R&D investment and levels or growth rates of wealth and, even if there were, what the *direction of causality* would be in such a relationship, i.e. whether R&D investment causes economic growth or whether it is simply the case that economic growth causes a shift towards increasingly technology-intensive activities and hence a tendency to invest more in R&D (Lederman and Maloney, 2003). The problem of undetermined causality in empirical studies can simply be interpreted as a typical endogeneity problem.

Even if we accept the explanation that R&D investment causes economic growth, we would still need to know the magnitude of this effect for different types of economies (i.e. advanced industrial, service-based or agricultural economies) and at different levels of economic aggregation (i.e. sub-national, national and supranational). More importantly, we would like to estimate the opportunity costs (i.e. the foregone potential gains from best alternatives) in each of these cases with regard to alternative forms of (public) investment given the budget constraint and the scarcity of resources. The issue of causality becomes further complicated when we attempt to isolate and measure the effects of *public* R&D expenditure.

There are clear indications that not all economies can reap comparable benefits from a given level of R&D funding (Jones and Williams, 1998; Lederman and Maloney, 2003; Griffith *et al*., 2004; Crescenzi, 2005). The rate of return to public R&D expenditure is largely determined by the capacity of an economy to absorb, integrate in its productive structures and tap the outcome of domestic or foreign research activity, which, in turn, is determined by the existing local industrial fabric, quality of human capital, historical experience with R&D activities, institutional structure, and the level of social capital accumulation. It is, therefore, highly debatable whether countries (or regions) with weak industrial structures, human capital deficits and inadequate institutions can reap the full benefits of exogenously determined increases in R&D investment. As a result of these limiting factors, there is a certain threshold of public R&D expenditure for each type of national or regional economy above which further increases in R&D expenditure will be suboptimal, given the associated opportunity costs. Moreover, the optimal level of R&D expenditure is largely dependent on the proximity of an economy to the global technological frontier. It is reasonable to assume that economies already close to it engage in Red Queen type of technological competition and are, as a consequence, more likely to benefit from higher levels of R&D expenditure. This is not necessarily true for economies away from the technological frontier. In their case, an optimal strategy may be to invest in the development of their absorptive capacities.

A parallel argument to the above is that some EU economies exhibit satisfactory rates of macroeconomic growth or income levels despite their persistently low levels of R&D investment. An explanation of this paradox is that wealth in such economies is generated in sectors with naturally low technological intensity and returns to R&D (e.g. exploitation of such natural resources as oil, and such services as tourism), and hence their current mode of macroeconomic growth is unrelated to technological innovation. In such economies, the optimal level of R&D investment, given their sectoral composition, is naturally low and the tendency of the private sector to under-invest in R&D is economically justifiable. This puts into question whether policy-induced increases in R&D investment will have positive effects on their growth performance *ceteris paribus*; increasing R&D in such economies in an efficient way would require industrial restructuring in favour of new sectors with high R&D returns (Klevorick *et al*., 1995).

For all the above reasons, simple quantitative targets raise major issues of economic efficiency and optimality: The underlying socio-economic structures in some countries or regions may not be able to support such objectives, and thus the exogenous imposition of such targets would lead to inefficient resource allocation and deadweight losses. In that respect, recent policy calls for uniform R&D investment increases across EU regions seem to be ill-conceived, given the even greater variation in the capacity to benefit from R&D investment in regions as opposed to countries.[9]

All the above concerns notwithstanding, much of research policy discourse implicitly treats the questions of causality, opportunity costs and differential returns to R&D investment as if they had been settled in favour of the conclusion that increasing R&D investment will always be beneficial to an economic system. A possible explanation of this policy single-mindedness is the difficulty of measuring, explaining or predicting by traditional models of technological change the way systemic factors, such as human and social capital and institutions, determine the rate of return to, and the opportunity costs of, R&D investment.

Rationale and limitations of policy intervention

Static versus dynamic efficiency

In the previous section, we examined some contrasting arguments concerning the leverage of (not necessarily public) R&D expenditure on macroeconomic growth, concluding that there are indications of correlation, but not an irrefutable causal relationship, between the two. Even if theory or empirical evidence could conclusively establish a causal effect of general R&D expenditure on growth, this alone would not count as proof of *public* R&D expenditure leverage, nor would it suffice to justify government intervention in research activities. The rationale for such intervention can be sought in two distinct theoretical strands: the mainstream approach of neoclassical welfare economics based on the concepts of Paretian allocative efficiency and market failure, and a broad neo-Schumpeterian approach that dispenses with the concepts of competitive equilibrium and Pareto optimality altogether, in favour of a more pragmatic acceptance of deviations from the competitive market ideal as prerequisites for (rather than obstacles to) the dynamic efficiency of economic systems.

Mainstream welfare economics justifies government intervention in the market in cases of market failures, by which is meant any deviation from necessary conditions for attaining competitive (Walrasian) equilibrium leading to Pareto efficiency.[10] Market failures include asymmetric market power (monopoly, imperfect competition, etc.), non-convexities in production in the form of increasing returns to scale, inappropriability caused by externalities and spillovers, missing markets and incomplete contracts requiring allocation of property rights, transaction costs induced by the allocation of property rights, under-provision or need for rationing of some types of goods because of non-excludability (as in the case of pure and quasi-public goods, or as in the case of collective goods respectively), information asymmetries (such as the principal–agent problem), and uncertainty deterring economic agents from participating in the market [see Bator (1958) for an early complete exposition of the topic]. Other cases that are considered to justify government intervention, albeit on a normative basis that remains beyond the scope of neoclassical welfare reasoning, are the provision of merit goods (i.e. private goods that are deemed socially beneficial but under-provided by the market), the cases in which national interest is involved and, finally, equity concerns, which are not an efficiency but a distributional issue.[11]

Several characteristics of the production and diffusion of technological knowledge make a *prima facie* case for government intervention. They are incomplete appropriability of some types of technological knowledge (which we discuss in detail later on) that gives them a public good attribute and results in their under-provision by the market, indivisibility of technological knowledge implying increasing returns to scale, and uncertainty inherent in emerging or future technologies (Arrow, 1962).

The market failure rationale for government intervention restricts optimality concerns to an allocative type of static efficiency within existing production technology sets. As a result, it does not constitute an entirely adequate framework for government intervention in economic systems exhibiting intertemporal dynamics with punctuated equilibria, such as those undergoing technological change. By extension, it is not fully adequate for research, technology and innovation policy either. An alternative framework for such cases has to take into account concerns of dynamic efficiency. This type of efficiency often proves to be (in historical hindsight) more relevant than the allocative one for economic systems in transition between technological regimes. Schumpeter's conceptualisation of capitalist economic development and its modern variations provide such an alternative framework. In the (neo-) Schumpeterian context, market power, increasing returns to scale, information asymmetries and other deviations from the competitive market ideal are considered as moving forces of the processes of innovation and creative destruction.[12] In this vein, Metcalfe (1997, p.269), observes that the generation of technological knowledge is an intrinsically uncertain process that involves information asymmetries, and that these are essentially two sides of the same coin. As a consequence, such asymmetries cannot be characterised as market failures since they are necessary conditions for technological change in a market economy. Metcalfe (1997, p.269), concludes that 'innovation and information asymmetries are inseparable and thus innovation and Pareto optimality are fundamentally incompatible'. A fundamental difference between the neo-Schumpeterian and the neoclassical approaches to government intervention in the process of technological development is that the former is seen as proactive (enabling), whereas the latter is predominantly counteractive (corrective). In the former context, government intervention would aim at supporting and accelerating the process of technological development rather than restoring competitive market conditions, and hence it would be justified in cases of technological lock-ins caused by path dependence, problems of transition between technological regimes, and shifting techno-economic paradigms (Smith, 2000).

Unfortunately, there are no generally accepted criteria of dynamic efficiency, given the open-ended nature of technological change and the impossibility of defining global and *ex ante* optimality in dynamical systems with discontinuities, nonlinearities and novelties, such as evolving techno-economic systems. Local, adaptive and *ex post* optimality is often defined in an *ad hoc* way within evolutionary and complexity contexts consistent with Schumpeterian theory. For these reasons, it is not always easy to draw definitive normative conclusions in these contexts.

The theoretical underpinnings of EU research policy are very eclectic with regard to the two theoretical strands we examined above, and at the same time they are very pragmatic. Whereas the jargon of market failure is widely used to justify various recommendations or decisions for public intervention in the R&D process, the whole discourse on the need to promote innovation, to accelerate the pace of technological change and to restore Europe's position as a global technological leader, embedded, for instance, in the Lisbon Strategy, bears the hallmarks of a strong Schumpeterian influence. In our analysis of emerging tendencies in regional and research policies, and also in the conclusions of this paper, we return to some of the neo-Schumpeterian arguments in more detail.

Structural limitations to the policymaker's knowledge

Taking the neoclassical assumptions at face value, there should not be market failures at all. The invisible hand has the capacity to restore perfectly competitive market conditions. Indeed, neoliberal theorists often attribute such observed failures to government failures and excessive regulation. On the other hand, the rationale of government intervention in the face of market failures implies that the social planner – just like all neoclassical economic agents – possesses full and perfect information of the market structure. Moreover, unbounded rationality entails that his choices be consistent with the maximisation of his objective function, which in turn should be indistinguishable from public interest or social welfare (assuming that social planners are by default benevolent). In practice, as well as in theory, we know that this is not the case. First, government is not a unitary agent with a simple objective function. Second, the objective functions of social planners do not necessarily coincide with public interest: budget-maximising (Niskanen, 1971), regulatory capture (Stigler, 1971), and rent-seeking (Krueger, 1974) are some of the causes of this discrepancy. Third, social planners are neither unboundedly rational nor do they possess perfect and full information of the market. Policymakers can have only very limited knowledge of the micro-structure of the market and even less so of its evolutionary trajectories and of the whole set of future technological opportunities. This impossibility to know is not trivial and practical, but deep and structural. Even if social planners were benevolent and fully rational, and policy implementation were frictionless and costless, it would still be impossible to determine the optimal path of technological evolution because of the complexity, emergence and endogenous novelty of self-organised techno-economic systems (Metcalfe, 1997; Metcalfe and Ramlogan, 2005). This should be a very important consideration for those who call for direct structural interventions in the technological knowledge production system.

Scope for intervention by type of technological knowledge

Mechanistic accounts of technological knowledge as a capital-like (albeit intangible) asset overlook the heterogeneity that stems from its specific attributes, such as its degree of embodiment in individual economic agents or organisations, its appropriability (Levin, 1988; Grant, 1996), which in turn depends on the excludability and rivalry of its use, and its codifiability. On the basis of these criteria, we distinguish four types of technological knowledge (see Table 1):

Table 1. Types of technological knowledge

Knowledge type	Embodiment	Codifiability	Appropriability	Diffusion
Scientific	None	High	Public good	Unlimited, rapid
Technical	None	Medium-high	Quasi-public good	Costly, less rapid
Corporate	Collective	Medium-low	Quasi-private good	Costly, slow
Individual	Individual	Low	Private good	Limited, slow

(a) Scientific knowledge that is both non-rival and non-excludable, and is hence a public good. This knowledge is formal and codifiable, it is non-embodied, and it can be easily transferred within networks of scientific communities.
(b) Technical knowledge that is non-rival but (partially) excludable,[13] and is hence a quasi-public good. This knowledge is also codifiable and non-embodied, but its applied nature makes it more contextual and less reproducible than the previous type.
(c) Corporate knowledge that is both rival and excludable, but with spillovers that in the longer run erode its excludability, and consequently, its private nature. We call this type of good 'quasi-private'.[14] This knowledge is embodied in organisation structures, and as a matter of fact, it is their most valuable asset (Kogut & Zander, 1992). The technical aspects of this knowledge are often protected as trade secrets, which ensures its excludability. It is only partially codifiable and limitedly reproducible, and it can be transferred either within firms' own corporate networks or between firms through various forms of inter-firm collaboration, mergers and acquisitions, or through trade and imitation.
(d) Individual knowledge embodied in economic agents in the form of technical skills or know-how that is both rival and excludable, and hence a private good. This knowledge is non-codifiable, tacit (Polanyi, 1967), highly contextual, and it can be transferred only through labour turnover or, between individuals, through formal or informal teaching.

The first type of technological knowledge – scientific knowledge – is the product of Bohr-type basic research, whose measurable outputs are scientific publications. The second type – technical knowledge – is produced by Pasteur-type application-oriented scientific research or Edison-type applied technology research (Stokes, 1997; Mokyr, 2002), whose most common measurable output is patents. The third type – corporate knowledge – is produced by Edison-type research, and learning-by-doing, or more generally through the co-adaptation of economic agents that participate in the process of technological cognition within organisation structures. The last type – individual knowledge – is produced through individual learning-by-doing, apprenticeship and teaching, and formal vocational education.

The scope for government intervention differs by type of knowledge. The scientific type has strong spillovers on general economic activity and is socially beneficial. However, because of its non-excludable nature it cannot be directly exploited on a private basis, and hence the market will have the tendency to under-produce it. As a consequence, public institutions have to intervene in order to assure its sufficient production for the benefit of society at large. The technical type also has significant spillovers. However, the adoption and use of this type of knowledge is limited by intellectual property rights – usually patent grants, which ensure its sufficient production by the market. In this case, public intervention comes mainly in the form of providing the institutional framework that ensures allocation of intellectual property rights and their enforcement.

The corporate type of knowledge is collectively produced by the workers of the organisation, and it is owned, protected and exploited by the organisation as an entity. This private asset confers technology rent to the organisations that own it, at least in the short run. In the longer run, however, trade, labour turnover and imitation by competitors results in its spillover to other economic agents. Government scope for intervention in the generation of this particular type of knowledge is limited, given its quasi-private nature, and should focus on the facilitation of its spilling over in the innovation systems by promoting networking and other knowledge sharing practices. However, it is not uncommon for governments to subsidise the generation of this type of knowledge under the guise of support for innovation. The individual type of knowledge offers even more limited scope for government intervention. Government should primarily focus on its social dimension by promoting continuous education and labour mobility.

Cohesion–competitiveness dilemmas in future policy directions

An efficiency–equity trade-off?

There are mounting indications that a process of methodical hollowing-out of cohesion objectives in favour of a particular construal of efficiency and competitiveness may be underway. These tendencies have arisen in spite of the fact that cohesion remains essential for the survival of an EU that is ever-enlarging and divided across prosperity lines. An indication of this policy trend is the ground-gaining perception that the competitiveness goal of the Lisbon Strategy may be well served through concentration of R&D resources in order to promote increasing returns to scale in technological knowledge production.[15] Preeminent among such tendencies is the policy objective of 'smart specialisation', now one of the main pillars of the EU's Innovation Union strategy with a horizon to 2020 (European Commission, 2010a, 2010b). This can be achieved, the story goes, by increasing the thematic focus of EU research policy and its ability to target specific types of research actors (individual firms, regions or even entire national economies) according to their performance, and, if necessary, even with the use of additional funding through the traditional regional policy instruments.[16]

In the same vein, some policy documents suggest that greater research specialisation might be a way for Europe to become a more attractive destination for R&D investment [(Foray, 2006, pp.10–11; Foray and Van Ark, 2007), and see the emergence of European centres of excellence (European Commission, 2007a, p.14)]. The overall assessment of the current situation, in such documents, is that research efforts are too dispersed in numerous and possibly uncoordinated actors scattered around Europe (European Commission, 2000; Soete, 2005; Foray and Van Ark, 2007; Foray, 2009; Foray *et al.*, 2009; Soete *et al.*, 2009).[17] These documents generally come out strongly in favour of policies intended to promote research specialisation and the elimination of what is seen as unnecessary duplication and fragmentation of research efforts.

In these documents, it is usually difficult to deduce a formal definition of R&D specialisation (European Commission, 2000, 2007b, 2010a, 2010b; Foray and Van Ark, 2007; Foray *et al*., 2009; Soete *et al*., 2009). At its most basic, the term could refer either to the sectoral or thematic concentration of R&D funding within a specific scientific field or technological class, or to its geographical concentration within particular localities (e.g. countries, regions, cities), or a combination thereof. Alternatively, it could refer to R&D specialisation within a division of labour, involving the vertical (quasi-)integration of different stages or modules of research activity, from basic science to applied technology, in a knowledge production chain.[18]

In the rest of this paper, we scrutinise the above arguments from the following point of view: contrary to the traditional perception that identifies *cohesion* with distributional equity and competitiveness with efficiency and, therefore, considers cohesion and competitiveness as antagonistic notions, we argue that they are two equally necessary conditions for dynamic efficiency of socio-economic systems – especially when it comes to the production of technological knowledge. Based on this theoretical premise, we further assert that the perception of efficiency and competitiveness which underpins the abovementioned arguments may eventually prove to be ill-conceived and potentially detrimental for the technological and economic future of the EU as a whole. In the following sections we examine these claims in detail.

Policy-induced R&D concentration and specialisation

Various empirical studies find that R&D investment exhibits positive returns to scale in innovative output at both the micro [for a review see Dosi (1988)] and the macro levels (Porter and Stern, 2000; Furman *et al*., 2002), and that some scientific fields or technological sectors are more fertile, in that respect, than others (Schmookler, 1954; Klevorick *et al*., 1995). These are often taken as compelling arguments in favour of concentration of scarce R&D resources in selected technological sectors, and especially in those where the micro- or macroeconomic entities involved already possess some form of competitive advantage. Further down this line of thinking, some voices call for the concentration of *public* R&D investment, and in particular of EU R&D funding, in specific sectors of established or latent competitive advantage across EU countries or regions (Foray and Van Ark, 2007; Barca, 2009; Soete *et al*., 2009), or for the targeting of individual (usually leading) R&D performers on the basis of recorded performance [Soete (2005) with reference, in particular, to universities]. What is implicitly suggested here is a shift from the traditional (almost) sectorally neutral and generic orientation of EU R&D funding instruments to a sectorally focused one; and also a shift from the existing competitive selection procedure, whereby funding eligibility is mostly determined on the basis of merit of the individual research proposals, to targeting individual research performers (or groups or networks of performers).

This line of reasoning draws largely from a particular interpretation of Schumpeterian theory, namely the belief that industrial concentration may have positive effects on innovativeness and technological progress. Reviews of empirical studies of industrial concentration suggest that a good few find a positive correlation between industrial concentration and innovativeness only up to a certain scale of operation, beyond which the correlation becomes negative. In other words, innovative output with regard to the distribution of firm size follows a sigmoid curve. Very large firms are, therefore, more likely to face diminishing returns to scale in innovative output [Scherer (1970), Kamien and Schwartz (1975); and see Dasgupta and Stiglitz (1980) for a theoretical model consistent with these empirical conclusions].

An alternative evolutionary interpretation of the Schumpeterian argument of creative destruction is that diversity, not concentration, promotes (or at least does not hamper) innovation and technological change. In this line of thinking, Dosi (1988, p.1156), referring to firm-level diversity, makes the following interesting observations:

> If such asymmetries are a factor of diversity among firms that correspond, in a loose biological analogy, to different degrees of 'fitness', there is yet another source of diversity which, in the same analogy, corresponds to roughly equal fitness and 'polymorphism' ... Call this second set of sources of diversity technological variety, to mean all those technological differences that do not correspond to unequivocal hierarchies (i.e. 'better' and 'worse' technologies and products).

He goes further to observe that 'technological asymmetries and technological and behavioural variety are both the outcome and a driving force of technological and organisational change' (Dosi, 1988, p.1158).

The policy implications of this debate are very important. If concentration of resources in R&D does not always have demonstrable positive effects on innovative output, then it is even more unlikely that thematically and sectorally focused public R&D investment will bring about such desirable results. Moreover, as already discussed, there is only limited scope for government intervention in the production of technical type knowledge, and direct public support is probably not the most appropriate instrument there. Finally, even if we disregard the plentiful arguments in favour of diversity as driver of innovation and we accept that industrial concentration up to a certain threshold generates increasing returns in innovative output, we still need to ensure that concentration-promoting public R&D policies target the particular segment of the industry that lies below this threshold. This will be an extremely complicated and elusive task for policy design.

The issues of economies of scale and agglomeration economies are central themes in the specialisation debate (Foray and Van Ark, 2007; Cooke, 2009; European Commission, 2010b). The notion of agglomeration economies, in particular, directly links the specialisation debate with the spatial dimension of R&D and, on a normative level, regional and research policies. Agglomeration economies are a spatially embedded form of external economies of scale. Alfred Marshall (1920) was the first to distinguish between internal and external economies of scale. The former refers to economies of scale ensuing from the expansion of the scale of operation of an individual productive unit, while the latter refers to economies of scale from the expansion of whole industries. Usually, the source of the latter is geographical clustering, but it can also be some other type of spatially non-embedded networking. Traditional Marshallian externalities arise from spatial proximity of firms *within the same industry*, and are known as 'localisation economies'. To a large extent, these externalities have the form of untraded interdependencies and informational externalities, but they are also related to labour pooling, and to the density of markets for intermediate products and outputs. On the other hand, spatial concentration of various industries generates what is known as 'urbanisation economies'.

Glaeser *et al*. (1992) identify Marshall–Arrow–Romer (MAR) type externalities, which are dynamic localisation economies caused by knowledge spillovers between firms within the same industry. Externalities of this type arise from local accumulation of human and social capital, and they are usually generated by vertical quasi-integration (inter-firm division of labour in the same value chain and vertical spillovers), and hence specialisation. As Glaeser *et al*. (1992, p.1127) remark, 'the MAR theory also predicts, as Schumpeter does, that local monopoly is better for growth than local competition, because local monopoly restricts the flow of ideas to others and so allows externalities to be internalized by the innovator'. Glaeser *et al*. (1992) also identify Jacobs-type externalities, which are dynamic urbanisation economies corresponding to inter-firm division of labour in parallel value chains with horizontal, inter-industry knowledge spillovers similar to horizontal quasi-integration, and hence differentiation. As observed by Glaeser *et al*. (1992, p.1128), Jacobs (1969) considers that 'variety and diversity of geographically proximate industries rather than geographical specialization promote innovation and growth', and also that industries located in areas with highly diversified industrial fabrics should grow faster. In their study of industrial growth in a large number of US cities during the second half of the twentieth century, Glaeser *et al*. (1992) found that Jacobs' theory is consistent with empirical data, that the role of MAR externalities is unimportant when it comes to industrial growth driven by knowledge spillovers, and that urban sectoral clusters grow faster the less specialised the rest of the urban economy.

These remarkable findings challenge the regional specialisation debate, especially when we consider that R&D-intensive industries are more dependent on knowledge spillovers, and hence on Jacobs-type externalities, than any other industry. This conclusion is reinforced when we consider the impact of the current techno-economic regime shift on the way of doing R&D. At the pinnacle of the second industrial revolution, the dominant form of technological knowledge production involved an R&D process that was almost fully internalised by large corporations with abundant resources and specialised, vertically integrated R&D departments. In the era of the third industrial revolution, the emphasis has shifted to the synergetic character of modern R&D, the open innovation concept (Chesbrough, 2003; von Hippel, 2005), and the tendency, in some technological/scientific fields more than others, to collaborate or to externalise and outsource (Howells, 1999). In this context, smaller but well-connected firms in the network economy may link better to sources of technological knowledge, such as universities and research institutes, and they may play a crucial role as knowledge brokers (Zook, 2004; Graf, 2007). Under this new techno-economic regime, horizontal (inter-disciplinary and inter-sectoral) knowledge spillovers may be more important for the creation of new technological knowledge than other forms of knowledge spillovers.

The specialisation debate, and the notion of 'centres of excellence' that forms part of it, resonate an older and highly influential discourse, that of Perroux's *pôles de croissance* (growth poles) or the notion of 'growth centres' in the US literature. This connection is also evident in some of the policy instruments intended to reinforce specialisation, such as the *pôles de compétitivité* programme and other similar measures promoting spatial clustering of research activity (science or technology parks, science cities, etc.).[19] The underlying idea of this family of theories is that economic growth and technological development are processes inherently polarising and unevenly distributed in space – where 'space', in Perroux's formulation in particular, is taken to mean not geographical but, more accurately, abstract economic space. Their spatial concentration gives rise to poles of growth, out of which growth may sooner or later trickle down to the whole economic system in which the poles are embedded. The normative conclusions drawn arbitrarily from this family of theories is that techno-economic development can be instigated or accelerated by promoting the spatial (spatial here is taken in its literal sense) concentration of resources in selected localities with the hope that once the target of inducing a growth pole has been achieved, the whole economy may benefit from its trickle-down effects. These normative conclusions transformed into policy prescriptions have guided regional economic planning for a good part of the second half of the twentieth century with unsuccessful or even distortionary results [see, for references, Parr (1999)]. A similar type of *problématique* is evident in recent debate on specialisation.

We believe that the failure of experimentations with measures that promote artificial industrial clustering and specialisation is attributable to the high complexity of real local economic systems. In such self-organised multi-agent entities, clustering and specialisation ensue from an organic division of labour among a plethora of interconnected economic agents. This division of labour resembles natural ecosystems in both its complexity and its vulnerability to exogenous interventions. This is even more true in innovation systems. The scope for government intervention in the functioning of such systems or in the creation of new ones *ex nihilo* is hampered by the bluntness of the policy instruments and by the planners' incomplete knowledge of the real economy. The only leeway for intervention is with instruments that promote synergies and competition instead of offering direct structural subsidies; i.e. with policies that facilitate the natural process of allocation of specialisation niches to economic agents instead of dictating it.

A frequently evoked argument in the specialisation debate is the perceived problem of R&D duplication, which, it is argued, the EU should avoid in the light of the limited resources available and the importance of scale for competing internationally (Foray and Van Ark, 2007;[20] European Commission, 2008b). A *sensu stricto* perception of the notion is taken to be the overlapping of research priorities in national research policy frameworks, or what is sometimes identified as the uniformity of related programmes (Foray and Van Ark, 2007, p.2). A *sensu lato* perception of the notion implies that technological knowledge spans a measurable and finite space in which agents (the researchers) conduct research. Duplication occurs whenever different agents move in the same neighbourhood of the finite technological space, hence running the risk of re-discovering the same instances of technological knowledge that have already been discovered by others. Both perceptions of duplication have inherent negative connotations with normative implications. Duplication is considered to entail obsolescence and waste of scarce financial and human resources, which prompts obvious policy recommendations – namely the promotion of sectoral (thematic) or spatial concentration and hence of specialisation. Here we examine a number of cognitive and economic reasons that go against this line of reasoning.

As we have already seen in a previous section, knowledge is indivisible and some types of it, such as individual and organisational knowledge, are highly contextual. As a result of these characteristics, all types of technological knowledge, with the possible exception of the fully codifiable one, are incommensurable. Moreover, new technological knowledge is not (only) the outcome of the permutation of a finite set of existing cognitive elements, but (also) of the emergence of genuine novelty. Incommensurability and emergent novelty make it impossible to conceive of technological space as a measurable and bounded topological space. This implies that no two search processes in technological space will ever be identical, and hence literally duplicate, even if they share similar initial conditions, given the contextuality and open-ended nature of the search process. In a non-finite space of incommensurable technological opportunities, each researcher or research team will inevitably contribute its own tacit knowledge, often resulting in substantively different results. By extending this argument to the EU level, we observe that what on the basis of rigidly defined, integral, thematic priorities appears as duplication may, in reality, conceal an enormous (and continuously evolving) subtlety of research pathways and alternative scientific practices that in fact contribute to the diversity and resilience of the European research system.

Even when the term 'duplication' refers to the similarity of search processes in terms of search paths, it is difficult to support economic arguments against it. Concurrent search processes along similar search paths are major sources of competition for innovation (and hence of Red Queen-type technological dynamics), and a perfectly normal phenomenon in competitive capitalist markets. Consecutive search processes, whereby one emulates the methods or even the outcomes of the other, facilitates the adaptation of existing knowledge in new contexts, the diffusion of scientific advances and their productive assimilation in local economies. Moreover, the overlapping of search paths may facilitate scientific collaboration and integration in knowledge networks, resulting in increased horizontal knowledge spillovers.

For developing techno-economic systems, the consecutive type of research duplication is a necessary condition for building up local absorptive capacities. As discussed earlier, the economic history of today's advanced industrial economies is replete with such examples. Consecutive search is also an inevitable first step for those who wish to enter the race for frontier research. Learning how to perform research in a particular field entails the acquisition of context-specific knowledge, a large part of which is tacit and can be obtained only by hands-on experience. Scientific excellence is the end product of a process that involves competition, imitation and collaboration rather than an innate quality with which only some research teams are *a priori* endowed. In that sense, the imitation of research programmes that from a global (or European) perspective may appear obsolete, may be seen from a local perspective as a first step for participating in world-class research. Providing opportunities for new entrants makes sense from a European perspective, too. In the longer run new entrants may contribute to a diversified and dynamic research system that may, after all, position Europe better in producing and exploiting radical innovations.

Selectivity of R&D policy instruments

Until now the main instrument of EU research policy, the Framework Programme for RTD, granted research funding on the basis of the fulfilment of some minimum participation criteria by the applicant research teams and on the assessment of the merits of the research proposals in their own right, rather than on the assessment of the applicants themselves on the basis of past performance record, perceived excellence, or expected capacity to conduct research. This mode of fund allocation has been exemplary in supporting new initiatives and the emergence of new ideas (Luukkonen, 2001, p.215), and in attaining a distributional neutrality, at least *a priori*. Were policy-induced R&D concentration to be adopted as an EU research policy strategy, its implementation would require significant modifications of this *modus operandi*. EU research policy instruments would inevitably have to become selective in targeting individual performers or consortia of performers on the basis of past performance record, perceived excellence and expected capacities to generate scale effects in innovative output. This would require the establishment of new selection criteria, such as current size of innovative output, and various other measures of past excellence.

If research policy instruments target the most important industrial R&D performers in terms of size, this can only have a limited marginal effect on their performance: large corporations already hold resources, good access to private funding, and risk-taking capacities that allow them to invest in R&D close to their optimal (efficiency) scale. In such cases, public R&D funding can be a guise for industrial subsidies otherwise they are not permitted in explicit form by current EU competition policy that may lead to rent-seeking practices, deadweight loses, and a crowding-out effect on private R&D investment. As Pavitt (1998, p.567), observes, direct R&D funding of (large) firms should be given a low priority 'since it is too small to have a major influence, and the influence would become perverse if it became large'.

If research policy targets excellence, a similar argument applies. Best performers already invest (almost) optimally in R&D. Moreover, the merit of awarding funds to excellent researchers is ambivalent. Observed excellence in a particular field of research at a particular point in time is by no means a guarantee of future excellence given the nonlinearity of the process of technological change and the inherent uncertainty of the innovation process. Extrapolating expected performance from realised performance is a near impossible task for all the reasons we have already demonstrated in previous sections.

Apart from its potential adverse effects on microeconomic efficiency, individual targeting in public R&D funding and winner-picking practices also have serious effects on distributional equity at the aggregate level. In modern pluralist and democratic societies, it will be difficult to support policies that are seen to enhance monopoly power and to transfer welfare counter-intuitively in a direction that serves neither distributional nor commutative justice.

The setting of thematic priorities in the Framework Programmes (FPs) always reflected, to a certain extent, the perceived political and economic priorities of the EEC (later EU) at the time of their conception and programming (Peterson and Sharp, 1998). However, the commitment of the FPs to the support of pre-competitive research, and the broad definition and large number of their priorities that practically cover the whole spectrum of research activities in the EU (combined with a tendency to expand this spectrum in consecutive FPs) always meant that the FPs were endowed with a lot of flexibility in funding a great variety of novel research projects throughout the EU.

A natural extension of the arguments in favour of policy-induced concentration of R&D resources is that the research policy instruments themselves need to become not only more discriminating in favour of performers – as we saw in the previous section – but also more thematically focused (Foray *et al.*, 2009; European Commission, 2010a, 2010b). By this is meant that the spectrum of research activities supported by these instruments should become narrower, thus permitting concentration of resources in fewer prioritised and select fields of research.

We have previously covered a plethora of arguments against this view. The first important argument against thematic selectivity in EU research funding relates to the problem of who selects the narrower priorities and how, given the structural limitations to the social planner's knowledge and the impossibility of predicting the dynamics of technological trajectories in an immensely complex techno-economic system like that of the EU. Any government intervention in the complex selection process of technological opportunities, which normally is carried out by the decentralised market mechanism, would require extremely detailed information on the micro-structure of the market, which policymakers cannot possess (Metcalfe, 1997). As a result, structural subsidies – if they are substantial – can have serious distortionary effects comparable to those of centrally planned economies. The second major argument, directly related to the first, relates to the dangers from reducing variety and inter-disciplinary spillovers in a way that would resemble a technological monoculture.

In corroboration of our general position, Pavitt (1998, p.565) says that the EU should avoid placing too much attention on specific thematic priorities on the basis of predicted practical relevance because the range of relevant scientific and technological fields is increasing over time and our ability to forecast future applications is very limited. He also observes that businesses, not government, largely control the rate of technological change and are responsible for its implementation, and that the experience so far indicates that the main impacts of government policy are indirect, mainly through incentives and the conditions they impose upon markets (to a large extent, on policy areas other than R&D) that, in turn, influence the volume and direction of R&D investment.

Conclusions and alternative policy directions

Cohesion versus or cum competitiveness?

A mechanistic construal of technological change has dominated policy discourse and practice for decades. Granted, the systemic paradigm has made some headway in the design of recent research policy (Pellegrin, 2007). However, in many current aspects and future directions of EU research policy, mechanistic thinking persists. The dichotomous perception of competitiveness and cohesion objectives is one such indication; the narrow perception of competitiveness as efficiency and of cohesion as distributional equity is another.

In response to the first perception, we assert that, for a dynamically efficient EU techno-economic system, cohesion is an indispensable condition as much as competitiveness. Cohesion should be interpreted as a systemic quality of techno-economic systems that allows them to behave as adaptive entities resilient to exogenous shocks. In this context, there is no inherent dichotomy but complementarity between these two notions: cohesive techno-economic systems are more competitive. To some extent, this truth is incorporated in conventional EU policy discourse, but it tends to result in blunt policy instruments (e.g. simplistic and arbitrary R&D expenditure targets).

In response to the second perception, which is implicit in the discourse in favour of promoting narrow competitiveness objectives in EU research policy at the expense of cohesion, we argue that cohesion should be interpreted, in Amartya Sen's terms, as basic capability equality (Sen, 1980). In the context of the knowledge economy, this translates into empowering local, regional or national economic systems to participate in the knowledge economy prior to any measures for reinforcing their R&D intensity.

Concentration or diversity?

A view on the future direction of research policy gaining ground is that it should induce scale economies in R&D by promoting R&D resource concentration through increased selectiveness and directivity of its instruments, as opposed to the distributional neutrality of existing research policy instruments. This entails a mode of fund allocation that serves the purposes of a clear sectoral R&D specialisation of EU regional or national economies according to their revealed competitive advantage, and implies the concentration of public R&D investment in the most advanced economies of the EU with the purpose of building further capacities for competing with the US and other emerging (mostly Asian) technological competitors. We have demonstrated in this paper that this line of thinking is fundamentally flawed both on economic and political grounds.

From the economic point of view, such policy orientation will be dynamically inefficient. The concentration debate echoes the quest for a centrally planned division of labour among economies under scientific socialism and raises concerns about the hazard of replicating its grave errors. Moreover, a targeted fund allocation – especially to large industrial leaders that already have the capacities to optimise their levels of R&D investment – will be another form of industrial subsidy that may have long distortionary consequences for the whole European economy. The overarching objective of dynamic efficiency can be supported not by greater concentration but, on the contrary, by promotion of diversity.

From a welfare point of view, promoting further concentration of R&D resources in the EU core raises serious concerns with regard to the distribution of benefits. Interregionally this will aggravate the technology gap and the processes of cumulative causation, which may be a more serious political and economic problem than the perceived technology lag with the US. As Pavitt (1998, p.562) observes, 'while the technological differences between Europe's leading countries, USA and Japan are often small and difficult to interpret, those amongst the EU member-countries themselves – present and potential – are large and unambiguous'.[21] Interpersonally it will transfer taxpayers' money to large corporations in the guise of R&D subsidies. The counterargument that regional concentration will generate technological and economic benefits that, in the longer run, will trickle down to the whole European economy is questionable. In order for knowledge spillovers to be beneficial to the periphery, technological laggards will need to build considerable knowledge absorption capacities that only a genuine cohesion policy aiming at upgrading human capital can support. Moreover, the core–periphery trickle down argument is not plausible in the EU under its current institutional configuration. The EU is not (yet) a unitary state. As a result of this, its redistributive mechanisms, compared with federal states like the US, are extremely weak and *ad hoc*, and labour mobility is also low compared with the US.[22]

From a political point of view, the intergovernmental decision-making mechanism of the EU, which is based on consensus building and on implicit principles of equal representation of national interests, will never permit such a policy re-orientation. Even if the efficiency argument were valid, the equity argument would prevail, given the legitimate concerns of individual member states to assure their participation in the knowledge economy.

Scope for policy synergies

The difficult goal of dynamic efficiency through cohesion and diversity in the EU techno-economic system cannot be achieved within traditional research policy schemes alone. Not one research policy intervention, no matter how carefully crafted, is likely to have much of a positive economic impact if performed in isolation from other policy domains. For instance, EU policies for competition, regulation and standards, policies for trade and foreign direct investment, public investment, as well as education and training, all influence corporate decisions on the scale and direction of corporate R&D (Pavitt, 1998, p.567). Only holistic, cross-cutting approaches to policy design that recognise the systemicity of the innovation process, the specificities of generating and diffusing knowledge of different types, and the institutional complementarities of different policy domains are likely to have profound socio-economic consequences. The current EU policy drive towards achieving an appropriate policy mix by aligning policy interventions in domains as diverse as industry, education and employment is encouraging. Research policy objectives must also be based on solid analysis of involved opportunity costs. The potential social returns to public R&D expenditure should be compared with those of alternative knowledge-related policy fields and the final policy mix should be customised for each type of regional or national socio-economic structure according to its specificities.

The challenge of new policy design lies in deciding not only what to change, but also what to leave intact. The EU possesses carefully crafted policies that have served their current purpose relatively well (Luukkonen, 2001). Identifying the scope for interventions without disrupting otherwise successful mechanisms is a challenging task that requires a good understanding of the European techno-economic system. Much of our earlier critique of current tendencies in EU policy discourse highlights the absence of empirical foundations for the diagnosed failures and the proposed course of action.

The conception of a European Research Area (ERA), situated within a wider Innovation Union (European Commission, 2010a) may be an appropriate policy framework to address the interventions needed for improving the (dynamic) efficiency of the European research system. The ERA has been envisaged as a complex multilayered system that spans the EU territory and is being built incrementally (in the traditional functionalist way of the EU). Building local knowledge capacities and empowering local techno-economic systems to participate in the knowledge economy is one side of the overall strategy needed for the reinforcement of the ERA edifice. The other side is the construction of a comprehensive supranational structure that will allow the systemic integration and exploitation of the diversity of local techno-economic systems. Building such a supranational structure is an unprecedented undertaking, and it is likely that new policy approaches will be needed to complement existing ones. The purpose of these policies will be twofold.

First, to promote connectivity among isolated research communities, and hence among local techno-economic systems, instead of artificial concentration. This will reinforce two tendencies, collaboration and competition, both of which will accelerate – in an evolutionary analogy – technological variation and selection. The process of specialisation can come only through this natural (i.e. self-organised as opposed to policy-induced) selection process. The second purpose is to provide, through direct funding at the EU level, knowledge of public good-type, European-scale scientific projects (mostly of basic and pre-competitive research) with strong spillovers that countries are unwilling to finance individually.

Acknowledgements

Part of this paper was completed while the authors were at the Institute for Prospective Technological Studies, DG JRC, European Commission, Seville, Spain. Responsibility for the views and any errors or omissions in this paper lies entirely with the authors. The views expressed in this paper are purely those of the authors and may not under any circumstances be regarded as stating an official position of the European Commission.

Notes

1. ESPRIT was modelled on Japan's VLSI programme, and promoted 'pre-competitive', generic, shared-cost research undertaken collaboratively among the private sector, universities and research centres, whose broad priorities were set by the Commission of the European Communities in consultation with interest groups – in particular the so-called 'Big Twelve'. A common criticism of the programme is that it favoured the establishment of existing monopolistic 'national champions' (the Big Twelve) in the IT industry as pan-European oligopolists under the protection of the EEC (Guzzetti, 1995), instead of targeting technological change through industrial renewal, as mostly happened with IT in the US.
2. This model conceives the innovation process – from the stage of basic and applied research, through the product development and production processes, to the stage of product marketing and diffusion – as a linear and deterministic sequence of actions. A direct implication of such a model would be that when the level of R&D investment increases, a predictable increase in the level of technological innovation will follow and a matching rate of economic growth should be expected (Malecki, 1997, p.115).
3. As Freeman (1996, p.27) remarks,no model of the innovative process has been more frequently attacked and demolished than the so-called 'linear model of innovation'. At one time it was almost impossible to read a book or an article on technology policy or technological forecasting that did not begin or end with such a polemic.More recently it has even been suggested that the linear model has never existed as an analytical model of innovation *per se* but has rather been an historical construct that functioned as a 'straw man' in academic studies of science and technology (Edgerton, 2004).
4. In the Solow–Swan model, only shifts in the rate of technological change can affect the steady-state growth rate of per capita output and hence long-run growth. However, the rate of technological change itself is exogenously determined, and so, as Barro and Sala-i-Martin (1995, p.11) observe, 'we end up with a model of growth that explains everything but long-run growth, an obviously unsatisfactory situation'.
5. Alternative, data-consistent specifications of the knowledge production function result in quasi-endogenous models of technological change in which the steady-state growth rate of the knowledge stock is proportional to the population growth rate. The scale effects in the Romer (1990) model are the result of implicitly strong spillovers of R&D efforts in the whole economy. The Jones critique, however, implies that the absence of scale effects in empirical evidence may be an indication of much weaker spillover effects attributable to monopolistic competition associated with innovation.
6. The Red Queen effect is a term coined by Van Valen (1973), according to whom 'for an evolutionary system, continuing development is needed just in order to maintain its

fitness relative to the systems it is co-evolving with'. Baumol (2004), Markose (2005) and others use this notion in an economic context to characterise the dynamics generated by innovation-based competition aiming at preserving firms' market shares that are being eroded by entrants and imitators. The result of this arms race is a zero-sum game that maintains constant the relative fitness of competitors.

7. The EU's *Lisbon Strategy for Growth and Jobs* emphasises R&D-led growth. Introduced by the Lisbon European Council in 2000, the Lisbon strategy set as the main target for the EU in the first decade of the twenty-first century: '... to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion' (Lisbon European Council Conclusions, 100/1/00). Member states have responded accordingly as attested by their individual national reform programmes (individual reports are available from http://ec.europa.eu/growthandjobs/national-dimension/member-states-2008-2010-reports/index_en.htm), whilst numerous EU regional authorities have devised economic development strategies that foresee an important role for R&D.
8. The Lisbon Expert Group said:

   > The most important quantitative objective in the Lisbon Strategy is related to the main milestone approved in the Barcelona Council in 2002: to raise the level of R&D investment in the EU as a percentage of GDP in 2010 up to 3%, 2/3 of which should be funded from private sources. In fact, it is the most visible objective for public opinion (counted as the attention obtained in the mass media) and the basis for the reform commitments at the national level. (Lisbon Expert Group, 2006, p.6)

   In an economic evaluation of the 3% target, Mohnen (2005) is critical of the specific numerical target, even if broadly supportive of the need to increase R&D expenditures. He concludes with a caution that R&D is only a means to an end, not an end in itself. In a similar assessment, Meister and Verspagen (2004) are also critical of the singular emphasis placed on R&D and conclude that: 'the story of regaining European technological and economic leadership may be a more complicated one than the Lisbon and Barcelona summits want us to believe' (p.39).
9. This view is reflected, for instance, in the following passage from the speech of the Commissioner for Regional Policy to the European Parliament's Industry, Research and Energy (ITRE) Committee:Some EU regions already perform well in relation to the Lisbon target of 3% of GDP being invested into R&D. However, only one new Member State has a region where R&D intensity is above the 3% threshold ... In many Cohesion Fund countries, even the regions with the highest investments in R&D are below 1% ... However, low performance is not limited to the recently acceded Member States. R&D intensities of less than 1% can be found in regions in virtually all the EU-15 Member States as well, making strong regional concentration a feature of Europe's research landscape. Whilst this may be inevitable in some regions with particular natural handicaps, it is not a model we can allow to continue if we are serious about the EU's competitiveness and about reducing economic disparities. ('Research, development and innovation in new regional agenda: developing synergies', Brussels, 29 November 2005, SPEECH/05/751)Here low R&D intensity is seen as inevitable only in regions with natural handicaps!
10. According to the first fundamental theorem of welfare economics, any Walrasian equilibrium leads to a Pareto-efficient allocation of resources. Deviations from the conditions of the competitive market entail Pareto sub-optimal allocations that make possible Pareto improvements; i.e. re-allocation of resources in a way that makes none of the economic agents worse off and some of them better off.
11. The rationale for government intervention in the provision of goods on the grounds of social or national interest or equity is of a purely normative nature and unrelated to the conditions of Walrasian equilibrium.
12. In his sketch of the process of creative destruction, Schumpeter (1942, p.84) says that:

   > the first thing to go is the traditional conception of the modus operandi of competition ... in capitalist reality as distinguished from its textbook picture, it is not that kind of competition which counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organisation ...

competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives.

13. ‘Partially excludable’ in this case means that although it is publicly accessible, its economic exploitation is restricted by intellectual property rights during certain periods of time. Whereas property rights permit this type of knowledge to be privately produced, its public accessibility generates potential spillovers and social benefits.
14. Note that in some strands of economic literature this term is used differently, to characterise private goods provided by the government.
15. The European Commission communication launching the European Research Area (ERA) (European Commission, 2000) makes a strong case for greater European coordination of national research policies. The same communication makes the pragmatic recognition that in an enlarged EU the prospect of ‘variable geometry programmes and actions at European level’ comes into sharper focus (European Commission, 2000, pp.8–9). The recent Green Paper on the ERA (European Commission, 2007a) goes even further, observing that: ‘some concentration and specialisation is necessary to permit the emergence of both European centres of excellence competitive on the global scale and a rich network of universities and public research organisations across the entire EU’ (European Commission, 2007a, p.14). The recently founded European Institute for Innovation and Technology (EIT), an EU-sponsored institution loosely inspired by the prestigious MIT, has an explicit mission to address areas lacking critical mass (European Commission, 2008a). The emphasis on concentration is even more pronounced in the Innovation Union flagship initiative in the form of smart specialisation (European Commission, 2010a, 2010b).
16. An indication of this tendency is the reorientation of the objectives of the Structural and Cohesion Funds towards increasing regional R&D expenditure. The strategic priorities of the European Union Cohesion Policy for the period 2007–13, for instance, are identified as ‘research and technological development, innovation and the spirit of enterprise, a knowledge-based society, transport, energy, the protection of the environment as well as investment in human capital, employment market policy and improving worker and business adaptability’ (European Commission, 2007b, p.6). Other policy documents make an explicit commitment that approximately two-thirds of the Structural and Cohesion funds will be devoted to the Lisbon Strategy objectives, which implies that a measurable part of these funds will be spent on support to R&D and other knowledge-related objectives (European Commission, 2005, p.5; Council of the European Union, 2005, 2006, Article 9).
17. Others still counter-propose a shift towards mission-oriented research that could contribute towards tackling major societal challenges, such as climate change, energy and changing demographics [see Georghiou *et al.* (2008), Georghiou (2008) and the subsequent correspondence in *Nature*, vol. 453, p.857].
18. The concept of specialisation within a division of labour is considered a principal source of economies of scale, and this is one of Adam Smith’s fundamental observations in his *Inquiry into the Nature and Causes of the Wealth of Nations*.
19. Take, for example, the phenomenon of ‘science parks’, corporate estate developments with an explicit mission to influence the spatial concentration of research actors. Massey *et al.* (1992) review the creation and evolution of science parks in the United Kingdom and find notable discordance between regional policy rhetoric and empirical reality. They find that science parks are often associated with prestigious corporate housing projects, almost devoid of any knowledge or research activity. Geographical proximity between science parks and universities appears to have little effect on technology transfer activity.
20. ‘Limited resources may be spread too thinly to allow excellence to emerge or it may cause unnecessary duplication of projects and programmes’ (Foray and Van Ark, 2007, p.2).
21. There is also evidence that these disparities have increased since. A recent study by Vence Deza and González López (2008, p.570) confirms the existence of highly uneven capabilities within the EU and observes a gradual increase in regional disparities over time.

22. For comparison, the US federal budget represents approximately 20% of the annual GDP of the country (at $US2.77 trillion in 2007); the sum of national budgets of the EU Member States amounts to an estimated 45% of the aggregated gross national income (GNI) of the EU, whereas the budget of the European Communities represents a meagre 1% of the EU's GNI (at 115.5 billion in 2007), with a permanent ceiling currently set by intergovernmental agreement at 1.24%. Moreover, interregional income disparities in the US are much smaller than those within the EU, especially in its current configuration of 27 member states, while interregional labour mobility is much greater. The European Commission's *High Level Task Force on Skills and Mobility: Final Report* (Schumacher *et al.*, 2001, p.12) estimates that EU citizens have about half the mobility rate of US citizens.

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