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Knowledge diffusion and innovation policies within the European regions: Challenges based on recent empirical evidence

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ABSTRACT

This article builds upon empirical results concerning localised knowledge spillovers to highlight some policy implications within European regions. The analysis emphasises the role of regional innovation policies in supporting the institutions that generate knowledge and learning. However, the variety of regional features presented in the empirical literature suggests that the search for universal policy tools is unrealistic. From this perspective, we argue that original strategies must be generated to cope with the various dilemmas faced by regional innovation policies. Such specific strategies require accurate knowledge of local features. Improving data and indicators to diagnose and monitor regional innovation is therefore presented as a key issue for policy makers.

JEL Classification: O38, C12.

Keywords: innovation policy, localised knowledge flows, European regions, knowledge-based economy.

Mots clés : politique d'innovation, flux de connaissances localisés, régions européennes, économie fondée sur la connaissance.

1. Introduction

In his 1994 article, Metcalfe identifies two main profiles in technology policies: i) those that take the possibilities of innovation as given, and thus seek to stimulate innovation by reducing the cost of R&D activities or by increasing the profitability of private innovation; and ii) those that seek to expand the opportunities for innovation.

This paper, based on the results of the empirical literature devoted to knowledge spillovers, locates itself in the second policy perspective. This supposes that innovation policy must go beyond providing R&D subsidies. We argue that, in a knowledge-based economy, taking into account the sources, paths and the underlying mechanisms of knowledge diffusion, the primary role of innovation policy is to create a variety of mechanisms to facilitate the capture and assimilation of local and external knowledge.

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One major finding of the research field devoted to innovation is that technological knowledge is not only an output of the R&D activity, but also its principal input. A wide range of empirical studies have demonstrated the positive impact of R&D spillovers on firm productivity[1] by introducing various external inputs into the production function or cost function. These results have been confirmed by more recent estimations (Sena, 2004, O'Mahony and Vicchi 2009, Autant-Bernard et al. 2009). The empirical literature therefore emphasises the relevance of focusing on knowledge flows and provides evidence consistent with the hypothesis of positive knowledge externalities. The spatial dimension stressed in some of these studies is of primary interest to regional policy makers.

Following the conclusion of Marshall (1920), spatial proximity is believed to ease firm interactions and knowledge diffusion. More recently, the Economic Geography and Endogenous Growth models (Lucas 1988, Martin and Ottaviano 1999, Baldwin and Martin 2005) explain the differences in regional growth paths through geographically constrained knowledge externalities at the root of increasing returns and localised economic growth. The spatial dimension of knowledge externalities finds empirical support with the literature referred as the "Geography of Innovation" , [2] based on the pioneering works of Jaffe (1989), Acs et al. (1991), Jaffe et al. (1993), Feldman (1994), Audretsch and Feldman (1996, 1999), Acs et al. (1997), and Almeida and Kogut (1999).

Within the literature, it is generally argued that the existence of local knowledge flows would favour innovative capacity and drive regional economic dynamics. At the same time, however, public policies designed to establish a technology area similar to Silicon Valley have had only limited success and are now widely considered to be utopian (Maggioni, 2002, Rallet and Torre 2007). Thus, although the theoretical and empirical literature confirms that regional innovation policies are important (Tödtling and Trippl, 2005; Howells, 2005; Laranjaa et al. 2008) and that they intervene at a critical level to support institutions that generate knowledge and learning (Morgan, 2004), the fundamental question remains of how to concretely affect knowledge flows and their geographic dimension. The answer is not obvious and is at the heart of this article.

Our analysis builds on the empirical results of the Geography of Innovation concerning localised knowledge flows to highlight some policy implications within the European regions that support the Lisbon Strategy. This econometric literature is interesting for regional science and innovation policies because the results of applied econometrics provide comparisons between various institutional contexts. Furthermore, the observation levels are generally government-defined areas,[3] which are highly relevant for regional policy makers.

Taking into account the main initial contributions founded on American and European data, this paper is more specifically based in the latest analyses, many of which result from the European program devoted to Intangible Assets and Regional Economic Growth (IAREG).

Recently, measurement of the geographic dimension of knowledge externalities has been significantly improved by the introduction of more complex processes of knowledge diffusion and the use of individual data along with new spatial econometric tools. This refines the way to model externalities in knowledge production functions and enables testing for spatial auto-correlation (Acs et al. 2002; Fingleton and Lopez-Baso 2006; Autant-Bernard et al. 2008).

The geographic dimension of knowledge externalities - whether they flow from science to industry, remain intra-industrial, or are intra-firm - is confirmed by the empirical literature. This

[1] See Sena (2004) for a review.
[2] The term is taken from the title of Feldman (1994) which stands as a major reference in this empirical literature.
[3] States or metropolitan areas in the United States, regions or departments in France.

result places importance upon interventions at the regional level, which are adequate to exploit the geographic externalities. However, because proximity is not a sufficient condition, specific actions must be conducted to favour knowledge flows within regions. These are discussed in Section 2. In addition, the empirical studies also clearly show that, even where they exist, the effects of proximity are never exclusive and interact with national and international effects. Regional innovation policy therefore has another equally important role to the promotion of local spillovers: promoting an opening up to the rest of the world. As shown in Section 3, this involves developing the regional absorptive capacity and connecting the regional innovation system to the national and supranational systems, hence the explicit choice to articulate the different territorial levels of public intervention within the European Union: regional, national, and EU-based. Subsequently, one major finding of the empirical literature is the complexity of knowledge diffusion. The flows vary according to the context, notably with regard to sector-based specificities, local industrial specialisation, institutional structures, and the means of communication. Some debated questions remain concerning the conditions under which the effects of proximity may act positively. In Section 4, we argue that the relevant answers at the basis of any policy recommendation cannot be generalised and require case-by-case analysis to specify the local context and strategy. Finally, a summary and concluding comments are provided in Section 5.

2. Spatial distance matters: to what extent?

Empirical studies, including recent analyses, highlight the influence of spatial proximity on knowledge flows and interpersonal relationships, noting that geographic proximity is a prerequisite for learning and innovation (Autant-Bernard and Massard 2009).

However, the spatial range of the positive effects of knowledge flows is observed to vary substantially depending on the institutional context and on the technological field (Peri, 2005). Therefore, the existence of organisational frontiers may prevent knowledge flows. It is obvious that such frontiers exist between public research and private firms, but they also occur between firms (Autant-Bernard et al., 2009). The variety of knowledge may also explain its unequal transmission through space. For example, depending upon the nature of the specialisation and upon the maturity of the industry, the sharing of embodied knowledge may hinder knowledge flows. The diffusion of tacit knowledge and its absorption would necessitate more than mere physical proximity. It would rely on effective interpersonal interactions among a variety of actors. Thus, to have a significant impact, geographic proximity effects must be combined with other dimensions such as organisational, institutional or cognitive proximity. One major conclusion of the empirical studies that consider the various aspects of proximity is that the geographic proximity *per se* is neither a necessary nor a sufficient condition for learning. Nevertheless, it generally facilitates interactive learning by strengthening the other dimensions of proximity and thereby contributes to the positive effects of local knowledge externalities (Boschma 2005).

Recent advances in both the mechanisms of science-industry knowledge and in cross-industry knowledge flows provide us with new evidence to be used in the design of regional innovation policies. They are presented in the next paragraphs.

2.1. The conditions for geographic knowledge flows

2.1.1. Spillovers from science to industry

Many papers highlight the role of public research in the production of knowledge externalities. In most advanced countries, universities are a major source of new knowledge and a critical component of the public research system. The public/private relationship generally refers to the relations between universities and industry.

Following Jaffe's work (1989), early studies mainly focus on the United States and are based on data from the 1980s. All of these studies conclude that technological externalities have a localised aspect or that the science-industry relationship is sensitive to geographic proximity within states and metropolitan areas.[4]

These initial studies were extended using data from more recent period and other countries, providing a range of findings.[5]

The role of the institutional context

Concerning France, Autant-Bernard (2001) and Autant-Bernard et al. (2005) show that technological externalities from public research are present within innovation and private research. The local dimension to these externalities is not very pronounced, however. One explanation for this difference from the previous results involves the institutional factor. Despite a noticeable evolution, links between universities and industry are less pronounced in the French institutional context than in the US. In particular, the self-reinforcement effect between public and private research observed in the US does not exist in France. A "Paris-provinces" structure is also prevalent, which could explain weaker diffusion of knowledge.

Administrative frontiers are also likely to reduce the diffusion of knowledge, giving rise to border effects. The intensity of knowledge flows decreases significantly beyond the country's border, even when regions are contiguous. Lundquist and Trippl's (2009) study clearly highlights that knowledge flows can be impeded by administrative borders, but also that passing these borders can favour knowledge flows. Such border effects apply equally within countries due to administrative borders between regions.

Thus, the specificity of each local institutional context and the existence of border effects impacting knowledge flows have been highlighted through statistical analysis.

[4] Mansfield (1995a); Mansfield and Lee (1996); Acs et al. (1991); Feldman (1994); Zucker et al. (1998); Acs et al. (1997).
[5] Antonelli (1994), Paci and Usai (2000), Bottazzi and Peri (2001) for Italy; Kenney and Florida (1994) for Japan; Blind and Grupp (1999), Beise and Stahl (1999) for Germany, Autant-Bernard (2000) for France.

The nature of the knowledge transmitted and the temporal dimension

Other obstacles to the diffusion of knowledge over space seem to emerge from the nature of the transmitted knowledge. Early works within the Geography of Innovation tackled this question through the categorisation of knowledge into codified and tacit knowledge. Such a dichotomist and static approach has since been abandoned for diverse reasons.

First, from a practical point of view, it is difficult to identify knowledge as codified or tacit, and the correspondence between these categories and other relevant distinctions for the Economics of Innovation, such as the public/private or academic/applied distinctions, is unclear. Second, studies that attempt to distinguish different sorts of knowledge to evaluate their potential for spatial diffusion have often been led to consider the temporal dimension of the diffusion process as well. It is now clear that the spatial dimension of knowledge flows is also related to transmission over time, and not merely to the nature of the knowledge transmitted.

Thus, to differentiate between academic and applied research, Feldman (1994) considers the observable differences between the upstream phases of the innovation processes (research phase) and the downstream phases (innovation, filing a patent). Similarly, for the French case, the geographic dimension of technology spillover varies according to how their effect on R&D (upstream phase) or patents (downstream phase) is considered (Autant-Bernard, 2001). Both studies confirm the idea of a stronger localisation at a time when knowledge, still poorly codified, requires a physical proximity between individuals to be transmitted. Conversely, when defined as a patent, knowledge becomes less tacit and can be transmitted across a distance. It may also be argued that the stronger influence of geographic proximity on research spillover than in France could be explained by the fact that public research in the US is more "applied."

The influence of the temporal dimension on the geographic feature of knowledge flows has also been emphasised by studies based on patent citations. Jaffe et al. (1993) for the United States case and Maurseth and Verspagen (1999) for Europe note a decline in the localisation of patent citations over time.

Nevertheless, this result poses a few problems of interpretation because it supposes that tacit knowledge is more characteristic of the upstream research phases, whereas the application of innovations would bring codified knowledge into play. No simple relationship can be established pertaining to this point because all research and innovation activities often combine both forms of knowledge.

Here again, the institutional context appears to be a determining factor. In particular, within the French, and more broadly, the "European model" of public-private relationships, the transfer of knowledge between academic research and industry occurs less via direct - hence specific and localised - relationships than via a widespread diffusion of scientific achievements, which are likely to benefit the system as a whole. Such an institutional organisation acts as an incentive to rapidly codify academic knowledge (to achieve its widespread diffusion). However, at the same time, this codification is generally insufficient for the commercial exploitation of a scientific achievement. Part of the new knowledge remains tacit, i.e., embodied in the researchers.

This is the reason why the importance of having different diffusion channels is emphasised by the empirical literature on spatial knowledge spillovers.

The importance of the diffusion channels: effective connections and open science

A recent set of studies has explored the role played by different types of knowledge diffusion channels between public and private research. Aharonson et al. (2007) highlight the key role of universities in the location of new insiders in the biotechnologies industry, and the importance of face-to-face relationships in the knowledge flows between academic researchers and firms.

As pointed out by Cohen et al. (2002) for the US and by Bekkers and Bodas Freitas (2008) for the Netherlands, knowledge transfer channels between universities and industry are numerous, including scientific publications, influx of students, participation in conferences, collaborative and contract research, patents, and so on. These authors also show that the role of knowledge transfer channels differs according to the industrial context of firms (in regards to 'sectoral effects' and 'size effects' in particular).

These two studies point to the idea that the most important channels are scientific publications, scientific collaborations and informal relationships. Moreover, they suggest that formal collaborations are not the main mechanism for science-industry transfers. Cohen et al. (2002) observe that the most important channels for accessing public research are the public and informal channels (such as publications, conferences, and informal interactions), rather than formal interactions like licenses or cooperative ventures.

In this sense, they confirm a result previously stressed by Zucker et al. (1994) concerning the positive role played by effective collaborations. The few works that have since emerged dealing simultaneously with direct relationships between researchers and the local dimension of knowledge flows may be grouped into three categories.

Using joint publication data as an indicator of effective scientific collaboration, an early method maps the coincidences between the structure of scientific relationships and the geographic structure: see Katz (1994) on joint publications and more generally the bibliometric literature establishing cartographies for scientific relationships.

With a more interpretative content, a second type of work ties innovation output to scientific connections at different geographic levels. Within this type, Zucker et al. (1998) show the importance of local relationships between companies and university researchers in harnessing externalities. More recently, they demonstrate the so-called "virtuous circle," i.e., that both academia and firms can benefit from such an effective relationship (Zucker and Darby, 2007).

Lastly, the third type of analysis relies on the same data, but reverses the problematic using econometric methods to assess the determinants of the observed scientific relationships. To be specific, the aim is to define the importance of the explanations based on geographic proximity (Maurseth and Verspagen, 1999).

All of these study types analyse the links between the geographic dimension, interpersonal interactions and knowledge externalities. The tested hypothesis is as follows: externalities are mediated by interactions between individuals, and these interactions are in turn facilitated by geographic proximity. Hence, the marked influence of interpersonal relationships on knowledge flows is undoubtedly one of the main reasons for proximity effects. Because mobility is geographically circumscribed and the likelihood of encounters is facilitated by proximity, publications are particularly fostered within built-up areas. However, empirical works in this field are still rare. They come up against the difficulty of finding data that are representative of the diversity of the formal and informal interactions that could lead to knowledge publication.

It should not be forgotten, however, that collaboration is only one strategy among others to benefit from public research spillovers. As argued by Bekkers and Bodas Freitas (2008), if such collaborations are efficient channels of knowledge transfer in some cases, open science channels should not be neglected.

Focusing on these public channels, Cowan and Zinovyeva (2009) compare the role played by scientific publications and patents as drivers of knowledge flows between public and private research. They conclude that publications are more important than patents. The tradition of fundamental research in the academic sphere, as well as the existence of "pure knowledge spillovers" is therefore supported by these empirical studies.

2.1.2. Inter- and intra-firm spillovers

Whereas the initial studies in the field of the Geography of Innovation mainly focused on science-industry externalities, recent advances emphasise the role of spatial externalities among firms as well as within multi-plant firms.

Inter-firm spillovers

Recent empirical studies confirm that universities are not the only emitters of externalities and that inter- and intra-firm localised knowledge flows have a significant impact on externalities as well. Along these lines, Autant-Bernard and LeSage (2010) evaluate the respective roles in regional innovation played by public and private R&D. Using panel data concerning French patents granted to private and public research over the period 1992-2000, they estimate a knowledge production function. The results highlight geographically bounded spillovers from public research, but also show that the largest direct and indirect effects are associated with private R&D activity that spills across industry boundaries. The importance of spatial distance is also stressed by Maggioni et al. (2007) in their estimation of a spatial knowledge production function from aggregated data at a Nuts2 level. Their results show that spatial autocorrelation prevails over relational autocorrelation, thus supporting the idea that the regional propensity to patent benefits more from local knowledge spillovers than from those resulting from distant collaborations.

Bergman and Usai (2009) survey the empirical studies that use patent citations as proxies of knowledge flows, from Jaffe et al. (1993)'s contribution on data provided by the United States Patent Office (USPTO) to more recent studies on European data, principally based on data provided by the European Patent Office (Le Sage et al., 2007; Paci and Usai 2009), or combining American and

European data (Lukatch and Plasmans 2003; Criscuolo and Verspagen 2006). They find that this literature highlights the importance of geography on knowledge flows between patent-inventors.

This result is confirmed by Bergman and Usai (2009), who provide an empirical analysis of patent applications and citations in the OECD/EPO and REGPAT databases to analyse knowledge diffusion across European regions. In a first step, a descriptive analysis enables them to consider three dimensions simultaneously: temporal (over the period 1980-2000), spatial (278 regions, most at the NUTS2 level, in 22 countries) and industrial (22 ISIC sectors). The results show that despite a gradual evolution, citations and patents are spatially concentrated. Clusters of innovative regions appear, and this heterogeneity among regional flows can be related to geographic, institutional and industrial settings. On this basis, a spatial econometric analysis is performed, based on a gravity model, to assess the role of several potential determinants of the flows. The analysis of the impact of space includes the role played by the removal of the barrier between Eastern and Western Europe. The econometric results reveal the impact of geographic distance and of the weights of the origin and destinations regions on knowledge flows, measured by GDP per capita and R&D investments. These results vary with sector specificities.

Recent advances expand the intangible assets taken into account as a source of knowledge flows among firms. This confirms the existence of spatial spillovers. In this manner, Dettori et al. (2009) highlight geographic spillovers from technological, human and social capital.

Intra-firm spillovers

One main contribution of the recent studies is to provide evidence that intra-firm knowledge flows have also an impact on firm performance and on the geography of innovation due to the location of the plants. This original perspective takes into account the influence of intra-firm flows on innovation and productivity.

Using French data over the period 2000-2002, Autant-Bernard et al. (2009) investigate the role of agglomeration forces and knowledge externalities on firm productivity. They first measure productivity changes over the period. Several components of productivity are distinguished using the Luenberger Productivity Indicator. A Maximum Likelihood Random Effect model is estimated in a second step to study the influence of intangible assets on productivity.

The most interesting result provided by this study for a knowledge-based regional policy is the impact of intra-firm spillovers across multiple locations whose influence on the technological component of productivity is even stronger than that of inter-firm spillovers. This result draws attention to the importance of knowledge management.

This is precisely the focus of Schienstock (2009). As with the preceding contribution, this paper shows that in addition to the need for firms to acquire external knowledge, internal knowledge flows must not be neglected. From a firm survey conducted on a sample of medium- and low-tech Finnish firms, this study investigates the impact of organisational and knowledge management methods on firm performance. Several objective and subjective performance indicators are taken into account.

The results emphasise the positive impact of knowledge management on firm performance. More specifically, the study evaluates performance measured in terms of innovation capacity and efficiency of collective learning. In addition, the study shows that there is no generic best practice in knowledge management. This means that the best strategy in this field depends on the sector and more generally on the context, as well as that the strategy has to be firm-specific.

2.2. Policy implications: fostering local knowledge flows

The local economic system is unique, and the existence of geographic externalities bears witness to the idea that regions are characterised by certain non-transferable interdependencies. Being neither static nor irreversible, such specific interdependencies are subordinated to the public action. Different combinations of proximity can be relevant in different local contexts.

Hence, a challenge for local policies is to contribute to the self-sustainment or reinforcement of the local knowledge-based dynamics within a changing context. This is why regional factors are key in innovation policies. Bearing in mind the principle of subsidiarity, the regional level appears to be adequate to exploit the diversity of the local technological connections and to valorise regional comparative advantages in technology. From the empirical literature presented above, which stresses different contextual elements likely to hinder knowledge flows at the local level, we draw some policy orientations. They involve bringing together different spheres that do not "naturally" exchange knowledge: science and industry, different types of industries, and different types of firms.

2.2.1. Relying on the presence of a university

Ensuring the compatibility of two logics

The results of the empirical literature devoted to geographic knowledge spillovers show that, within some institutional contexts, public intervention is required to improve the links between science and industry at the regional level. This finding refers to the well-known debate concerning “The European paradox”, according to which Europe is characterised by excellence in research together with a limited industrial base in terms of innovation, in addition to the European delay in relation to the US regarding the transfer of technology and knowledge between universities and industry (European Commission, ERIK, 2007). Our perspective however, differs strongly from a simple catch-up approach and, in contrast, insists on the importance of the institutional and geographic context that underlies knowledge flows.

Despite its strategic importance in a "science-based economy", the science-industry connection may turn out to be inadequate because it is not natural. Universities, which occupy a central place in the generation of knowledge, and industry belong to two different worlds with specific codes, cultures, reward systems and final objectives. Such characteristics involve bridging problems between these two spheres.

A second fundamental reason legitimising public intervention in this field is the need to monitor the conditions under which science and industry unite. Indeed, this is accompanied by the danger of nullifying the advantages of "open science" (Dasgupta and David, 1994).[6] The scientific community has traditionally played a key role, not only in the creation of knowledge but also in its widespread diffusion. In this system, the "knowledge dilemma”[7] is resolved by means of remuneration specific

[6] This is the pioneering work on the opposition between “private technology” and “open science”.
[7] The dilemma between the logic of opening-up - that is to say the widespread diffusion of knowledge that increases its social value - and the logic of clamping down (such as intellectual property rights) necessary to stimulate research (Fadairo, 2002).

to the university (reputed within the scientific community through publications), which ensures an effective compromise by simultaneously stimulating research and knowledge communication initiatives.

Today, the knowledge dilemma is stronger whenever there is an evident link between the scientific and industrial domains (Joly, 1992). Academic research, which generates strong knowledge externalities, has traditionally been conducted in the public domain. For this reason, the nature of the technological knowledge as public property (Arrow, 1962) did not pose a problem. In addition, the patent has traditionally been exclusively used by industry. Founded on exclusion,[8] this incentive system has shown itself to be adequate, bearing in mind the fact that the externalities of the applied research are weak.

We are witnessing a growing tendency to protect the knowledge resulting from public research (a consequence of a new concern to valorise the results of this research), as well as the development of externalities resulting from private research (a consequence of the increase in private funding of R&D activities and the growing involvement of large industrial groups in basic research). This is the reason that universities are decreasingly the only generators of new knowledge, although they are more often the central point of the networks of public actors and private participants in knowledge generation and diffusion. Foray and Mairesse (2002) argue that such specificity constitutes the very definition of a knowledge-based economy: an economy in which knowledge externalities are more powerful than before. This does not change the nature of the knowledge dilemma, only its intensity. This is why "*the institutional compatibility of open knowledge with private incentive structures is one of the most important compatibilities for the future of knowledge-based economies*." (Foray and Mairesse, 2001).

It now seems vital to emphasise the interaction between the two spheres of knowledge represented by universities and industry. Universities are under pressure to open up to external players (particularly firms) and to discover how their research results can be valorised to contribute to regional economic development. However, to realise the benefits of the interaction between science and industry, each sphere must retain its own specificities. Indeed, according to Dosi et al. (2006), the “European Paradox” would not be global, European paradoxes would appear at the two extremes, with weaknesses in both the scientific research systems and the corporate industries. This explains why interactions between science and industry should not be fostered as a negation of the specific role of each sphere, but instead to reinforce the role of each. Among other things, this means that universities should not be confined to the role of a service provider for industry.

A related issue pertains to the ability of the ERA to retain qualified academic personnel. The results of Bergman’s survey (Bergman, 2009) show that the main reasons underlying the preferences of academic personnel for destinations outside the EU are the lack of attractive salaries and research opportunities offered within the ERA. Therefore, policy makers can foster attraction to the EU by improving these two factors.

[8] Because it establishes a monopoly of exploitation.

Promoting science-industry transfers and cooperation

The objective is to enhance the transformation of scientific results into competitive performance, or, in other words, to improve the diffusion of academic knowledge throughout local industrial structures, while ensuring that the "open science convention" (Foray, 1997) is not fundamentally challenged.

In spite of the main differences between the scientific and the industrial fields outlined above, it is possible for these two areas to interact due to the existence of common or complementary objectives on which public intervention can be based. Hence, the accumulation of knowledge has a common objective for both the industrial and the scientific fields. Moreover, there are emerging complementarities between the search for technological advances in industry and the search for financial resources at the scientific level.

At stake for public authorities is the implementation of "distribution-orientated institutions" that favour the diffusion of technological knowledge (David and Foray, 1994) while ensuring that the level of research incentive is sufficiently high.

The science-industry relationship can take diverse and complementary forms according to the extent of its embodiment: it can be anything from a simple transfer to complete cooperation between the two spheres.

At a first glance, it may seem that regional authorities have little to do with the disembodied channels. As argued by Fadairo (2002), because of its informational content, the patent is the most disembodied transfer medium between science and industry, along with publications specific to "open science". For this reason, this institutional mechanism (industrial propriety) is at its most effective level when it operates at the highest territorial scale - at the level of the European Union. However, the regional authorities have a double role to play here: both facilitating access for local firms to the information contained in the patents, information, advice, and tax incentives for license purchasing; and encouraging local universities, which in the European case are not accustomed to this approach, to adopt patenting as a diffusion channel.

Nevertheless, the interaction of science and industry at regional level more often takes a more embodied form, whether formal or informal. Hence, a number of studies that examine the local character of relationships between universities and industry note the importance of informal links like seminars, consultations or visits to laboratories. These informal links are a good way to provide opportunities for interaction.

Formal relationships between science and industry take the form of contractual arrangements with varying durations, including university funding granted by private companies, research shared between public and industrial laboratories, and the "hiring" of students.

The highest degree of transfer embodiment is the creation of incubators by university laboratories ("academic incubators") that accommodate and support the project carriers prior to the formation of a company. Analysing the impact of labour mobility, Audretsch and Keilbach (2004) and Schiller and Revilla-Diez (2009) recognise the spinoffs and startups initiated by university scientists as key drivers of knowledge flows. Almeida and Kogut (1999) and Breschi and Lissoni (2003, 2006) indicate that the higher the mobility of scientists, the greater the diffusion of knowledge. This labour mobility not only refers to spatial mobility and career mobility (mobility from one position to another), but also to organisational mobility from public research to industry. The science-industry relationship may also take the form of cooperative/joint research, which goes far beyond a simple transfer. In this case, integration exists, for example, through the formation of the common institution of a joint research centre. Such a sharing of research between the academic sphere and the private sector involves the joint definition of output, a long-term strategy, and a mutual acquaintance with working habits.

It therefore appears important that the regional technology policy provides the incentives necessary for the development of a variety of forms of transfer and cooperation between science and industry.[9] This assumes the emergence in the academic world of an open attitude towards the local economic environment that favours the valorisation of the research output, as well as the supply of advice or training to companies. This attitude must not hide the essential mission of the university, which is to create knowledge and to ensure that it is distributed widely through publications and training.

Finally, whatever modalities of interaction are established between universities and industry, the local influence of the university still actively depends on the environment in which it is located. Depending on whether it is surrounded by high-tech industries or mature industries, more specialised or more diversified industrial structures, large companies or micro-businesses, a university will develop different potentialities. In addition, as showed by D'Este and Iammarino (2009), the features of the university itself influence the manner of local cooperation. Analysing the specific nature of the relationship between firms and universities through joint research, D'Este and Iammarino clarify the spatial profile of relations that require face-to-face contacts. Based on the UK case, they show that differences exist in the spatial patterns of cooperation, depending on the sector and scientific fields concerned. Moreover, the quality of academic research - measured according to a ranking of UK universities - also has an impact on the spatial dimension of cooperation: large and top-ranking universities display a higher propensity to collaborate locally.

To favour science-industry transfers and cooperation, regional policies must account for all of these local features. Region-specific studies are therefore necessary to better understand local characteristics.

2.2.2. Local networking and knowledge management

Bringing different spheres together

Measures that encourage direct inter-industrial contacts stimulate an exchange of the tacit knowledge accumulated within firms. This type of interaction is important because it restricts the phenomenon of the depreciation of pertinent technological knowledge over time. This public policy objective attempts to create a situation similar to Antonelli's (2002) observation that within districts, knowledge assumes the characteristics of a collective activity resulting from the common effort of a variety of connected agents. Even if one admits that it is deceptive to try to artificially reproduce this type of spatial organisation for innovation activity, the reality of technology districts in this case provides lessons that are likely to steer public action. Moreover, it should be noted that accentuating

[9] It is interesting here to refer to the emerging empirical literature on the role and efficiency of Technology Transfer Offices (Conti et al. 2007)

the collective character of innovation may attenuate the “public/private dilemma” surrounding technology knowledge.

Such policies are designed to encourage companies from different fields to collaborate. In particular, by promoting linkages between high-tech sectors and traditional industries, public authorities can improve the diffusion of generic technologies and the hybridisations that are sources of innovation.

Stimulating the generation of variety is also a major role assigned to technology policy by Metcalfe (1994) and Cohendet and Llerena (1997). Expanding diversity means increasing the number of available technical options. In short, the role of diversity within innovation is of particular importance in the current era, when innovation occurs mainly through recombination. Empirical research has shown that this diversity may be important for the more traditional sectors, which find their innovation opportunities externally.

Experience has shown the difficulties in the implementation of local multidisciplinary cooperative structures generating collective innovation processes. There exists a problem of how to combine these institutional networks, which are created and maintained by regional institutions, with the local industrial system. Further, setting up transverse cooperation between the local players becomes difficult when these players do not enjoy organisational proximity.

Because of this, cooperation cannot be imposed. Intercompany contacts, however, may be stimulated by local programs that use a good understanding of local actors to support cooperation projects. In this context, it seems important to encourage trans-sector based cooperative structures and, on a wider scale, meetings on a transverse theme. In addition, numerous theoretical and empirical papers highlight the importance of supply-demand relationships in providing new opportunities for inter-sector cooperation. It may therefore be advantageous to move forward with policies that are purely oriented towards research and innovation supply to promote local demand.

Studying the extent to which the innovative performance of firms depends on the type of cooperation they develop and how they reveal regional differences, Iammarino et al. (2009) have demonstrated the positive effect of diverse types of cooperation: between firms, with suppliers, with consumers, with public research laboratories, and with institutions of higher education.

Access to knowledge management within local businesses

As mentioned earlier, Autant-Bernard et al. (2009) and Schienstock (2009) provide evidence that intra-firm knowledge flows must not be neglected because of their positive impact on individual performance (in terms of productivity or innovation). Moreover, Schienstock (2009) highlights the potential of knowledge management methods and organisational innovation.

These results define a field of intervention for the regional policy. They demonstrate the benefits of helping local SMEs to integrate recent methods of knowledge management. This can be done by organising seminars for local firms; the objective here is to develop awareness. In addition, it seems necessary to provide SMEs with specialised technical consultants to help them to design methods appropriate to their particular case.

Indeed, Schienstock (2009) emphasises the importance of flexibility because there is no generic knowledge management model. Such a result reflects the specificity of each enterprise, sector-based specificities, and the impact of the changing environment, which mitigates the relevance of generalisations.

3. Local/Global connection and absorptive capacity

The empirical literature shows that when they occur, knowledge spillovers are not purely local phenomena. They appear to be simultaneously local and global and to emanate from a variety of sources. In fact, when supported at various geographic levels (for example, counties, metropolitan districts or states in the US), the existence of externalities internal to the zone is revealed each time. When studies compare different geographic scales (for example, Autant-Bernard 2001, for France and Bottazzi and Peri, 2003, for Italy), several levels of diffusion appear, even if the local effects take precedence in certain circumstances. Such combinations are related to the manner and the conditions in which technological externalities are transmitted, which partly refer to the concept of absorptive capacity (Cohen and Levinthal, 1989). In the next section, new evidence on this issue is reviewed and implications for regional innovation policy are drawn.

3.1. Shortcomings in the regional absorptive capacity

3.1.1. Asymmetries regarding the level and diversity of internal competencies

It is now widely acknowledged that an initial condition necessary for the flow of knowledge is the constitution of an absorptive capacity. According to Dosi (1988) and Cohen and Levinthal (1989), internal skills and competencies (internal research, diversity of available competencies) are a precondition to capture technological externalities, or to identify and exploit knowledge that is newly available in the environment. This idea, however, has stimulated few empirical works at the aggregate level of geographic zones.

From their analysis of the French case, Autant-Bernard and LeSage (2010) argue that the research level and its degree of diversity may not simply affect the level of externalities captured within a local context, but also their geographic origin. A high and varied level of internal competencies appears to be vital in the capacity to take advantage of remote knowledge sources. Conversely, zones that are not very active on the research side or that are very specialised seem better able to take advantage of neighbouring sources of externalities. Therefore, the absorptive capacity relies more on the capacity to tap into remote sources of externalities than on the level of externalities captured.

Paci and Batteta (2003) find that differences exist between traditional and more innovative industries. Geographic distance reduces the technological flows in traditional sectors that are characterised by tacit and un-codified knowledge. In high-tech sectors, the exchange of codified and standardised knowledge can take place even among firms located in remote regions.

3.1.2. Regional lock-in

Asymmetries of firms or geographic zones in their capacity to absorb external resources appear to be a major problem when added to the localised feature of technology (Antonelli, 1999; Metcalfe, 1994). Path dependency in technology explains the possibility of a regional lock-in, which means that the local tight industrial network excludes strategic knowledge (Carlsson and Jacobsson, 1997; Ernberg and Jacobsson, 1997). This risk is also related to local institutions, which may stimulate or hinder innovation depending on the context. The risk is even greater if we consider that institutional change is characterised by a phenomenon of inertia, which generally makes change incremental and slow. Therefore, regional dynamics may be positive, but they also involve a risk of technological lock-in. A firm may be stuck with an old technique because the local system does not supply the appropriate technology.

For this reason, public intervention is justified so that regional dynamics becomes an asset for local firms instead of a weakness. The objective here is to provide the conditions necessary for the evolution of the regional innovation system. This objective requires the systematic encouragement of opening towards the outside and diversity in the broadest sense. This point is crucial in a time of change, which triggers a greater level of uncertainty (Johnson, 1992).

3.1.3. Barriers to entering networks

One of the main features of the knowledge-based economy is the importance of international networks through which pertinent knowledge flows (Lundvall, 1998, David and Foray, 2002). Strategic skills are developed in an interactive manner and shared within networks. The empirical literature on knowledge spillovers takes the impact of scientific and technological networks into account. These international networks are likely to create social forms of proximity that favour the transfer of knowledge. The intensity of bilateral collaboration determines the relational proximity between agents. As stated by Amin and Cohendet (2004), relational proximity can compensate for the absence of spatial proximity and enable long distance knowledge flows.

Recent advances on this issue come from two different research fields. The first, stemming directly from the Geography of Innovation, involves social network analysis (Granovetter, 1985), whereas the second comes from the theory of network formation (Jackson and Wolinski, 1996), which emphasises the role of network effects (Jackson and Wolinski, 1996, Bala and Goyal 2000). To assess the benefits of a bilateral relationship, we must take into account not only individual knowledge partners, but also the knowledge that each partner can access through his/her own collaboration networks. Therefore, the agent position within the network is considered to be a key determinant of the ability to benefit from knowledge flows (Bala and Goyal, 2000)

Studies based on patent data highlight the relevance of social proximity in evaluating the degree of knowledge spillovers: they consider the influence of social distance on the probability of citing a patent (Singh, 2005, Sorenson et al., 2006, Gomes-Casseres et al., 2006).

Varga and Parag (2009) analyse the structural characteristics of networks as underlying mechanisms of knowledge flows, as well as the impact of individual positioning within networks. They show that the capacity of the research centres of the University of Pecs to file patents is linked to their position within the international network of publication. Several characteristics of the network structure, such as its concentration, size and the degree of integration are included as explanatory variables within a knowledge production function. The higher the quality of the network positioning, the greater the number of patents filed.

Finally, as noted by Autant-Bernard and Massard (2009),[10] a mix of connectivity based on geographic proximity with emote connections is often considered the best way for a network to induce efficient knowledge flows. Access to these international networks, however, is not open and free. Among other things, it presupposes the sharing of tacit knowledge or of codified knowledge where the codes are difficult to acquire (Cowan and Foray, 1997; Maskell, 2002). However, the capacity to join these tight networks determines the access to knowledge, which is currently the most strategic resource. The existence of barriers to entering networks in which knowledge is produced and transmitted presents a field of intervention for regional innovation policies.

3.2. Policy implications: connecting the local innovation system to international levels

3.2.1. Learning

The concept of "a learning economy" (Lundvall, 1998) synthesises the idea that if knowledge is currently the most strategic resource, then learning constitutes the most important process in economics. Accessing scientific and technological knowledge does not simply presuppose that the system has the "distribution power" (David and Foray, 1994) necessary to ensure availability of this input, but also that firms have the capacity to absorb external resources. This is a very challenging exercise given the current speed of development. From this perspective, it is clear that there is a minimum activity threshold in research below which "nothing happens", which means that no learning dynamic is likely to develop. This involves a specific challenge for small structures - firms or regions.

If the available diversity of skills is to be favourable for local learning, the development of poles of specialisation must not be overlooked, because without them, it seems impossible to capture the leading knowledge from distant centres of excellence (see Autant-Bernard and Massard, 2009).

Because learning is deeply affected by institutional architecture (Carlsson and Jacobson, 1997), public authorities are responsible for developing the means of learning and the capacity to communicate. Such a target presupposes long term interventionism because learning is far more than a transfer of information and cannot be reduced to a single transaction (Fadairo and Massard, 2000). For this reason, we argue that an education policy is an integral part of the innovation policy, which extends beyond the quantitative issue of funding. The education system is involved at every level: "*from nurseries to the training of engineers and scientists*" (Lundvall 1992).

[10] See also Autant-Bernard and Massard (2009) for a survey concerning the applications of game theory within the theory of network formation.

More concretely, developing an education system requires improving physical infrastructure, equipment and human resources. Here, the key role played by universities becomes apparent (Caracostas and Soete, 1997; Lundvall, 1992). Training also helps maintain the "creative forgetting" that is necessary to move from one technology to another. In addition to developing the means to learn, public interventions may also help stimulate “a culture to learn”. As an example, one such intervention might involve individual rewards for learning and creative efforts (Lundvall, 1992).

Education may also favour better integration within international networks as well as a better diffusion of knowledge. Guiri and Mariani (2007) observe that the level of education has an impact on the size of the network: The higher the level of education, the larger the network. Peri (2005) also finds broader spatial knowledge spillovers that stem from the leading regions.

3.2.2. Communication infrastructures

As mentioned earlier, the results of the literature on knowledge flows favour innovation policy in the broadest sense, including public actions in education and training. This long-term interventionism involves establishing conditions that are favourable for innovation instead of providing direct, targeted intervention. This characteristic also occurs in another measure necessary for the capture of external knowledge: the development of all forms of communication infrastructure.

It is worthwhile to make several comments on this point. First, in the ideal situation defined by Dasgupta and David (1994), access to new knowledge is broad, fast and free. These features determine a "system's distribution power" and naturally depend on the quality of the communication infrastructure. From this point of view, all actions encouraging the codification of new knowledge constitute the first stage in communications policy.

In addition, it is important to have a diversity of means of communication. This is because new information and communication technologies are critical in determining access to external knowledge. Promoting their development and diffusion at the local level diverts potential partitioning. Even though the geographic dimension still has an effect – as shown by econometric studies – these technologies considerably weaken the constraints of physical distance. The role of spatial dispersion is therefore secondary to the role of professional cyber-communities, which share a code, a language and more: a culture.

3.2.3. Access to European programs for local businesses

In the European Union, the existence of a community technology policy is an undeniable asset to the regions. The formation of international cooperative structures, driven by the European programs, gives local businesses the opportunity to correct any weak points in their absorptive capacity. It is a means of escaping from the dependency on the local path to access closed networks and tap into international technological externalities.

This participation in European programs constitutes a major element in the local dynamism of small businesses, which largely rely on external sources of knowledge (Audretsch, 1995). Today, a major problem is that despite efforts,[11] the proportion of SMEs participating in European programs and their capacity to benefit from those programs remain low.

This is an important field of action for regional innovation policies: to remove institutional barriers and encourage the participation of SMEs, and more generally of regional firms, in European programs.

The role of training and codification discussed above, merits further emphasis: they are the conditions necessary to access common and evolving languages. Moreover, advisory activities for SMEs at a regional level should be encouraged to allow them to join the European collaborative structures.

3.2.4. Attractiveness

Finally, an important aspect of local/global interactions is the ability of a region to attract workers, researchers, professors and firms, which are important channels of embodied knowledge. Note that the objectives presented above (learning, communication infrastructure, local businesses' access to European programs for) concern both the regional absorptive capacity (i.e., the ability to capture diffuse external knowledge) and regional attractiveness (i.e., the ability to capture external embodied knowledge). This second point refers to the quality of the local environment and the promotion of a comparative regional advantage. It must be mentioned that attractiveness of a territory depends upon its dynamic comparative advantage, which goes beyond the static competition factors provided locally such as costs and wages.

Investment in physical capital plays a major role in creating "local public goods contributing to competitiveness" (OECD, 2009). Infrastructure and quality services appear essential to attract new skills. For example, communication and transport infrastructures play a key role for companies because they promote access to a wider reservoir of manpower, offering a broader range of skills. They also favour faster access to suppliers and customers.

However, it is known that quality infrastructure is not sufficient for territory attractiveness. Focusing on the provision of communication and transport infrastructures can generate a phenomenon of "leaking by linking" (Hirschman, 1958). Whether transport infrastructure becomes a binding factor ("link") or a loss factor ("leak") depends on its insertion into a wider regional strategy that is business friendly, skilled-worker friendly and that limits the brain drain.

Among the various measures that provide a supportive environment for the local economic actors are the promotion of human capital, universities and learning. Research centres and universities help produce highly qualified personnel and new knowledge to be used and adapted by local firms. They therefore appear as a key factor of attractiveness.

[11] Of the European Commission, notably, but also in many case of national policies.

4. The need for original strategies

Finally, a major finding of the empirical literature devoted to spatial spillovers emphasises the complexity of knowledge diffusion and the great diversity of contexts. According to Boschma (2005), different types of proximities related to knowledge flows can emerge, develop, and disappear; they might not only reinforce each other, but also sometimes act as substitutes. For this reason, local knowledge externalities are not unchanging and universal. Consequently, there is a need to consider the dynamic nature of proximity interactions and to take into account that the regions display different capabilities to benefit from local knowledge flows.

This is why, beyond the general recommendations made above, there is room for specific and dynamic regional strategies. Howells (2005) highlights the diversity of possible approaches to regional innovation policy. Tödtling and Trippl (2005) stress the need for differentiated regional innovation policies, showing that there is no ideal model because innovation activities differ greatly between regions. It is therefore unrealistic to search for universal policy tools.

In addition, analysis of the results obtained in the literature shows numerous ambiguities that are central to the following public policy debates that generally necessitate strategic trade-offs: equity *vs.* efficiency, commercial valorisation *vs.* scientific excellence, and specialisation *vs.* diversity. These dilemmas are discussed in the following sections.

4.1. The equity/efficiency dilemma

The equity/efficiency dilemma appears as a main result of the Economic Geography-Endogenous Growth models, which show that the agglomeration of R&D means and innovative activities may lead to unequal levels of economic growth across regions and to greater economic growth at the global level. This result is based upon the hypothesis of the existence of local barriers to the diffusion of knowledge flows. The current literature on the mechanisms of knowledge diffusion, however, leads us to question the relevance of such a hypothesis because this literature takes also into account the existence of remote knowledge flows. It is crucial to note that knowledge production may result from diverse forms of knowledge diffusion using local and global linkages with variable intensity. Some forms are still strongly based on the existence of agglomeration economies and push the development of greater and increasingly diversified agglomerations of innovative activities. Other forms rely on fine specialisation dynamics and generally require relationships between smaller clusters. Hence, higher efficiency does not always correspond to higher concentration.

It is important to acknowledge the diversity of the forms of innovative concentration that can give rise to a great variety of local strategies. Some strategies offer a variety of opportunities for connections without being obliged to give specific incentives or to organise these exchanges. In contrast, other strategies are based on the quality of the relationships and on the organisation of knowledge exchanges between a reduced number of very specialised and well-known actors. The relevant question becomes how to efficiently articulate these diverse spatial organisations of knowledge flows.

The results obtained by Bergman and Usai (2009) highlight that, within the EU, knowledge flows (evidenced by patent citations) are strongly and permanently localised within core countries. They come from a small number of strongly agglomerated areas (see also Peri, 2005). In this context, the main issue concerns how to design policy at both the national and European levels while taking into account the concentration of the most frequently cited patents in the various centres of excellence throughout Europe. Bergman and Usai defend the idea that selective divergence may be necessary in the development of these critical capacities. This is why policy efforts should help attain and reinforce innovative excellence, which can then be shared with less innovative regions, rather than continue attempts to disperse the capacities to generate large numbers of patents. Finally, they suggest that more attention should be paid to the importance of innovation at border regions and that policies should be adjusted to tap these newly developed capacities to benefit regions at the interior and in more peripheral areas.

In these peripheral regions, the main problem is one of absorptive capacities. It is necessary for policy makers to determine the changes that are required at the local level to benefit from the innovation developed in remote poles of innovative excellence. There is no universal response to the question of critical economic weight. Instead, the answer will result from public local authorities' specific response to the following question: what are the minimum locally required means to engage a virtuous circle, whether based on pure agglomeration or on fine specialisation and integration in global networks?

4.2. Dealing with the commercial valorisation / scientific excellence dilemma

Different conceptions of efficiency may be considered. Within the Economic Geography-Endogenous Growth models, local knowledge externalities enhance local innovative efficiency by reducing the research cost, which allows new industrial activities to emerge. However, different conceptions of efficiency in terms of knowledge creation can be distinguished that underlie public policy decisions on science and technology. Some emphasise scientific breakthroughs from "star scientists" who diffuse their knowledge via scientific publications, whereas others emphasise the success of commercial applications of science. This fosters important debates because it is widely believed that the involvement of scientists with firms comes at the expense of scientific progress. In contrast, however, recent studies from Zucker and Darby (2007) prove that the commitment of talent, time and energy to firms would not come at the expense of science. Indeed, investigating the biotechnology case, Zucker and Darby (2007) reveal the existence of a truly "virtuous" circle of interactions between public and private research: private research is not the only beneficiary of such relationships because R&D cooperation connections with firms improve researchers' academic output. Within a context where the role of open science is reaffirmed, developing collaborative activities between public and private researchers is a good way to boost the dynamics of such a virtuous circle and to deal with this dilemma.

4.3. Dealing with the specialisation/diversity debate

A highly debated question deriving from the empirical literature on localised spillovers is whether local inter-firm knowledge flows are more encouraged by a specialised environment or by a diversified environment. We refer to the debate revived by Glaeser et al. *(*1992) that opposes "Marshall-Arrow-Romer-type externalities" resulting from interactions between specialised agents with similar competencies to “Jacobs-type externalities” based on the combination of diversified activities. As showed by Autant-Bernard and Massard (2009), the empirical literature does not allow us to decide this theoretical debate because the effects of sector diversity are heterogeneous with respect to the area considered in terms of the types of industry present locally, the degree of openness, and other factors. For example, De Groot et al. (2007) reveal the impact of the population density of the region: denser areas are more likely to exhibit positive effects of specialisation. This means that a single and simple policy rule does not apply.

From a policy point of view, Foray et al. (2009) propose the concept of Smart Specialisation, which supposes that specialisation strategies are chosen by each region in accordance with its own industrial characteristics and its relationships with other regions. This framework suggests strategies that can be pursued to the advantage of both regions that are at the scientific and technological frontier and strategies that are less advanced. Whereas the *leader regions* invest in the invention of a General Purpose Technology (GPT) or the combination of different GPTs (bioinformatics, for example), *follower regions* often are better advised to invest in the “*coinvention of applications*”, that is, the development of the applications of a GPT in one or several important domains of the regional economy. This may provide a concrete foundation for the idea of selective divergence proposed by Bergman and Usai. Hence, the specificity of the industrial structure of each region has to be taken into account to create an original strategy for each case.

This requires accurate knowledge of the local features and of the main strengths and weaknesses of the area. This calls for additional analysis based on smaller geographic and sectoral levels. The lack of localised data on innovation is therefore a major challenge from a policy point of view.

4.4. Policy implications: building specific local strategies

Knowledge of the local context and its global position is the most fundamental condition to define an original innovation strategy at the regional level. Unfortunately, the studies engaged in the IAREG project point to a lack of relevant data. Knowledge flows are by definition a phenomenon that is difficult to measure. However, some indirect indicators have been suggested during the last two decades. Patent citations, as a paper trail of knowledge flows, were the first suggested indicators, from the seminal work of Jaffe et al. (1993). Other indicators include the use of an external R&D pool in other industries and/or other areas, the use of intermediate inputs (based on input-output matrices or on technology flow matrices), labour mobility between firms or from science to industry, and integration within local and global networks.

Most of these data are available at aggregated levels. Several datasets are provided by each country in the EU or by the OECD. Some noticeable attempts to regionalise this information have been made recently (see, for instance, the regional patent OECD database). However, systematic information is still missing at the small regional scale and at the disaggregated sectoral. Studies on productivity highlight that knowledge diffusion mechanisms within and between regions favour productivity and growth. There is an urgent need to obtain precise information about these knowledge flows.

Therefore, the implementation of technological policies aimed at fostering knowledge flows between EU regions requires:

- Easier access to data. At the moment, the data are dispersed among various statistical offices (Eurostat, national statistical offices, international offices, etc.). It is therefore time consuming to obtain the data from these different organisations and then to build homogeneous databases for common data.

- More systematic collection of the data. Some data are collected only within certain countries or regions. This prevents the development of a general overview at the EU level. Other data are collected at the EU level by Eurostat. However, substantial missing observations prevent an exhaustive picture of the EU regions. Comparisons between sectoral and spatial data are especially difficult. Other data come from the OECD or from international reports that do not cover all EU countries.

- Improvement and diffusion of the indicators to adapt them to local needs. This requires organising the interactions between the data producers, policy makers, and researchers who specialise in these topics. For example, according to Bergman and Usai (2009), the European Innovative Scoreboard includes EPO patent application rates, which indicate quantitative levels of innovative effort but not its quality. Adding the number of OECD country citations to patents filed in each region as a measure of their quality may improve the attributes of the indicator. Moreover, the indicators of knowledge flows developed in the academic sphere are not yet available for policy makers. The information available at the local level relies on input and output indicators of innovation. This is insufficient to position a territory and to evaluate the impact of past technological policies, which is required to enable a learning process in public policy (Nauwelaers and Wintjes, 2008). It is crucial to provide policy makers with a detailed accounting of innovation in EU regions, especially regarding the local ability to benefit from local and global knowledge spillovers. At the same time, policy makers have specific needs that must be expressed to improve the data. Fostering interactions between the different actors would favour feedback likely to enhance our ability to understand and benefit from knowledge flows.

This is of interest for scientific research. Indeed, several points remain uncertain regarding the mechanisms of knowledge diffusion due to a lack of data. For instance, it is very likely that better disaggregation of the regional R&D data by industry would allow us to give new evidence on the MAR vs. Jacobs debate on intersectoral knowledge flows. Similarly, limited information is available regarding labour mobility and network relationships. Improving the available data would allow us to deal with these new issues, and help in the design of future technological policies.

This is also of direct interest for current technological policies. Policy makers, especially at the local level, are increasingly expected to spur innovation dynamics. Increasing financial resources are devoted to local actors (regions, agglomerations, clusters, etc). However, the available tools to build relevant strategies and to monitor these innovation policies are still rare.

A short-term improvement of the available data would therefore rely on the construction, at the EU level, of a specific place where data could be centralised and homogenised, where relevant indicators could be discussed and made available, and where information could be diffused, both to the scientific community and to policy makers.[12]

[12] Such a structure has been tested in France within the EuroLIO project. Its expertise in spatial data analysis and in the diffusion of technological information could be extended to the EU by including EU actors (research labs, data producers and representatives of policy markers). The French project implemented a Localised Innovation Observatory (EuroLIO, ww.eurolio.eu), which takes the form of a network between five research labs specialising in localised innovation dynamics, the innovation data producer offices and representatives of the national and regional technological policy makers. This is a specific place where data is centralised and homogenised, where relevant indicators are discussed and made available, and information is diffused, both to the scientific community and to policy makers.

5. Summary and concluding comments

In the context of multi-territorial governance, the regional level of intervention appears to be decisive in favouring the establishment of a regional comparative advantage based on knowledge flows between local public and private institutions. Indeed, both theoretical and empirical studies point out the specific role of space in knowledge production and diffusion. The most recent empirical studies provide us with new insights on the underlying mechanisms. The role of formal and informal interpersonal relationships and the role of mobile scientists as agents in knowledge spillovers show that the local diffusion of knowledge is neither obvious nor systematic. Policy makers can therefore favour knowledge diffusion between local actors by fostering scientists' mobility and interpersonal relationships to bridge different worlds (science-industry as well as across industries).

However, considering the complexity of knowledge diffusion, which is only partly localised, and the risks of regional lock-in, regional innovation policy must also encourage the entry of local actors in international networks where pertinent knowledge is created and exchanged. Indeed, theoretical approaches to network structure, confirmed by empirical studies, stress the importance of both intense local connections and global ties. However, pure networking policies, whether local or international, are not sufficient. Networks are more efficient when each node is sufficiently strong by itself and has a specific function within the process of knowledge production and diffusion. Because of this, building research potential and absorptive capacity is a key factor in firms' integration within international research networks. Technological policies promoting private R&D not only favour firms' own R&D activities, but also firms' ability to benefit from research network spillovers. Public incentives for R&D collaborations appear to be a complement, and not a substitute, to public support to private R&D.

Finally, an important outcome of recent empirical studies is the great variety of regional and sectoral contexts. There is, in particular, substantial diversity in spatial organisation, with some regions highly agglomerated and diversified and others relying on a lower level of agglomeration associated with a strong industrial specialisation. This result supports the idea that polarisation in very large cities is not the only model of spatial organisation likely to favour innovation production and diffusion. This explains why each region must create its own dynamics.

Innovation policies may therefore devote specific attention to lagging regions. Helping lagging areas reach a critical mass will allow them to benefit from knowledge flows within and across the region. In particular, policy makers should focus primarily on medium-sized regions that require initial assistance to access to global knowledge flows, instead of devoting too much attention to the largest areas that already benefit from agglomeration forces to build their own dynamics. It would allow lagging regions to improve their capacity to absorb investment in innovation activity (Oughton et al., 2002).

A related policy implication is the need for monitoring tools. The definition of regional policies adapted to each regional context requires a good understanding of local characteristics. This relies on economic studies to identify the characteristics of the region. The efficiency of local policies is based on a good understanding of scientific and technological potential, industrial structures, distribution structures, local demand features, local channels of knowledge diffusion, and other factors. Benchmarking with national and European regions would also provide useful information on the strengths and weaknesses of each territory. Such benchmarking is also required at the level of the innovation policy itself. Transnational policy learning is indeed important to identify best practices. This will provide policy makers with an evaluation of what works and what does not as well as with a clear idea of policy needs and existing arrangements, including public programs currently in place.

The relevant objectives and means defined above for innovation policies at the regional level are summarised in Table 1. This paper does not propose that uniform regional policies should be constructed. On the contrary, our results provide incentives for each region to be innovative in its policy design and to find the policy mix that best corresponds to its own strategic needs.

Table 1
Synthesis of objectives and means for regional innovation policy

	Means
Objective 1: **Good understanding of the local characteristics**	▪ Economic studies to identify what characterizes the region: efficiency of local policies is based on a good understanding of scientific and technological potential, industrial structures, distribution structures, local demand features … local channels of knowledge diffusion. ▪ Benchmarking with national and European regions.
Objective 2: **Trans-National Policy learning**	▪ Evaluation of past practices: necessity to know "what works" and "what does not", to have a clear idea of needs and existing arrangements including public programs currently in place. ▪ Policy benchmarking at a national and European level
Objective 3: **Fostering pure knowledge spillovers**	▪ Supporting local academic research and publications ("open science") ▪ Designing local scientific and technological poles of excellence ▪ Support to patenting by the local firms and universities ▪ Facilitating access by local firms to the information contained in local, national and international patents: information, advice, tax incentives for license purchasing. ▪ Local platforms that foster the dissemination of knowledge. These include transferring the results of public research to SMEs in an understandable form • Retaining Europe's academics within the ERA and reaping the benefits of knowledge flows within Europe, by improving academic salaries and research opportunities.
Objective 4: **Science-industry knowledge flows** (Transformation of scientific results into	▪ Promoting entrepreneurial culture within the scientific field. "Education for entrepreneurship" addresses not only students, but also researchers. ▪ Financial, technical and informational support to diverse and complementary forms of interaction, from simple transfer to complete cooperation. - Informal links: seminars, consultations or visits to laboratories (these informal links are a good way to generate opportunities).

competitive performances)	<u>- Formal relationships within a bottom-up approach</u>: contractual arrangements with various lengths of time, supply of advice or training to companies, private funding, research shared between public and industrial laboratories, "hiring" students, creation of incubators by university laboratories ("academic incubators"), cooperative/joint research, joint research centers.
Objective 5: **Inter and intra firm knowledge flows** (Setting up a regional comparative advantage)	▪ Financial, technical and informational supports to local multidisciplinary cooperative structures generating collective innovation processes. ▪ In accordance with local industrial structures, the promotion of local transverse cooperation programs (encouraging trans-sector-based and user-driven cooperative structures and on a wider level, meetings on a transverse theme). ▪ Supporting access for local businesses (mainly SME's) to the latest methods of knowledge management: seminars, financing specialized technical consultants.
Objective 6: **To connect the local innovation system to international levels** (Territorial absorptive capacity and attractiveness)	Promoting a regional "learning economy" ▪ Physical infrastructures, equipment and human resources for the education system. Higher education institutions. A key role assigned to University. ▪ Education and training policy, developing ways to learn, stimulating "a culture to learn" (for example rewards depending on learning and creative efforts) Developing communication infrastructures ▪ Development of communication infrastructures in all their forms. ▪ Diversifying means of communication. Supporting access for local businesses to European programs ▪ Advisory activities for SMEs in order to allow them to join the European cooperative structures

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