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Knowledge Spillovers and Local Innovation Systems: A Critical Survey

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Abstract

The paper re-examines critically the growing literature on localized knowledge spillovers (LKSs), and finds the econometric evidence on the subject still lacking of a firm enough theoretical background, especially in respect of the more recent developments in the economics of knowledge. Therefore such evidence, and even more the concept itself of LKS, should not be read as supportive of new industrial geographers' work on industrial districts, hi-tech agglomerations and 'milieux innovateur'. Rather, they represent a threath to the necessary efforts for gaining more theoretical rigour and getting more empirical fieldwork done.

1. Introduction

This paper provides a critical assessment of the recent fortunes met by the concept of "localized knowledge spillovers" (LKS), and in the particular of the debate on the spatial boundaries of spillovers from both private and public or academic R&D laboratories.

LKSs can be defined as "knowledge externalities bounded in space", which allow companies operating nearby the knowledge sources to introduce innovations at a faster rate than rival firms located elsewhere. As such, they are a typical Marshallian externality[1] and are frequently invoked as a key agglomeration factor by what Martin and Sunley (1996) label as "New Industrial Geography", i.e. that vast and heterogeneous literature dealing with regional agglomerations from a non-mainstream (non neoclassical) economic viewpoint, best represented by influential case studies on hi-tech clusters in the US (Piore and Sabel, 1984; Saxenian, 1994; Storper, 1995) or industrial districts, learning regions and 'milieux innovateur' in Europe (Cossentino et al., 1996; Camagni, 1991 and 1995; see also Phelps, 1992, for a critical survey). At the same time, LKSs are frequently rejected, as a meaningful or useful research category, by the so-called "New Economic Geography", started by Paul Krugman's authoritative re-assessment of location theory and soon developed into a research field of its own (Krugman, 1991, 1995, 1998 and 1999; see also David, 1999).

Above all, LKSs are the key object of enquiry from a fast-growing stream of econometric and statistical studies on the impact of spillovers from 'local' academic and industrial R&D to firms' and regions' innovative output (see references in Baptista, 1998). These studies exploit the increasing availability of large data sets on the innovation input and outputs of firms and regions (whether measured by R&D, patents, innovation counts, or questionnaire results). Although originally proposed as an extension of previous research on the relationship between public and private R&D, innovation, and productivity growth (Mohnen, 1996), these studies are increasingly referring to, or are originated by, the debate within economic geography, witness some cross-references between Krugman (1991, 1995), Martin and Sunley (1996), and Audretsch and Feldman (1996).

Despite its widespread use, however, the concept of LKS appears to be a 'black box' to which different authors often attach different meanings. On the one hand, the frequent mentioning of LKSs serves a merely evocative purpose, i.e. it helps signalling a strong interest in coupling 'geography' and 'innovation' as research themes; on the other hand it helps the researcher to avoid studying the specific mechanisms through which the two phenomena are linked.

Therefore, the increasing popularity of LKSs, both as a buzzword and a research target, is likely to generate two risks:

a. it may hamper a key research field in the economics of technical change, such as the one dealing explicitly with the study of innovation networks and sectoral systems of innovation;

b. it may lead to naive policy implications, which remind of not-so-remote unfortunate experiences with science parks, growth poles, and the likes.

The first risk comes from the conceptual confusion generated by the concept of *spillover* as such, whose nature is eminently 'residual'. This means that the concept can accommodate both true externalities and measurement errors, which in turn may be due both to lack of data and lack of theory. Biggest errors come from the failure to acknowledge the importance of other key innovative actors beside firms, namely those 'innovation networks' composed either by firms and/or individuals. Since the research on networks, and in particular on their geographical features, is extremely demanding (both on the theoretical and the empirical front), insisting on LKSs as a meaningful category seems both misleading and wasteful.

The second risk derives from the potentially self-reinforcing view of LKSs as a "stylized fact", i.e. as a quasi-automatic consequence of a sufficiently high flow or stock of geographically concentrated R&D activity. This in turn may lead to:

i. a comeback of innovation policies mainly designed to recover from market failures due to 'information externalities' of some kind, possibly by means of incentives, subsidies or contract R&D;

ii. the erroneous belief that social returns from policies of that kind are necessarily localized, i.e. they will be retained by the same communities that took their burden[2].

* * *

In this paper we cannot attempt to survey two bodies of literature as large as the New Economic Geography (NEG) or the New Industrial Geography (NIG). Even producing a detailed account of the very lively debate on the role of LKSs as an agglomeration force seems too daunting a task. Besides, our main concern is with the econometric and statistical literature on LKSs, which has been most influential in popularizing the buzzword within the economic geography debate.

Therefore we review first and more extensively the econometric literature and point out its twin debt to a modelling tool such as the "knowledge production function", and to a few conceptual categories derived from the economics of knowledge, such as those of knowledge "tacitness" or "codification", as well as the contrast between "knowledge" and "information" (section 2).

Then we recall much more concisely the key issues of the NEG-NIG debate, just to point out a few logical dead ends that, once again, are the (often unintended) consequence of adopting a " production function" perspective (section 3).

In section 4. we make a few steps towards opening up the LKS black box, and examine a few recent studies on the geography of innovation that do not make use of any kind of "production function", some of which also question the link between knowledge diffusion and spatial proximity. We also try to argue that the existence of LKSs is far from being a "stylized fact", i.e. a non controversial starting point for research. Finally, we suggest that spatial proximity of innovators, when found to be significant, may not depend upon any intrinsic feature of knowledge, such as its "tacitness" or "codification", but on a much more complex interplay between those characteristics, the labour market for scientists and technologists, and pointing at a few dead ends the innovators' appropriation strategies.

In section 5. we conclude by offering some alternative research questions which build upon the literature reviewed in section 4., and may help stopping the ongoing indiscriminate hunting to LKSs.

2. The econometric and statistical evidence on LKSs

The past fifteen years have witnessed the growth of a new breed of empirical literature on the “geography of innovation”, which tries to asses to what extent knowledge spillovers exist, and are bounded in space. Research objectives and methodologies often differ from study to study, but all the studies seem to be unanimous in concluding that knowledge spillovers are important and that they are strongly bounded in space.

For the sake of reviewing, these contributions can be grouped into two broad categories. A first, most influential category comprises all the econometric studies based upon the ‘production function’ approach. These come from the convergence of three different lines of enquiry: *(i)* the large, well-established body of research on the social rate of return to R&D, *(ii)* evaluation studies on the effectiveness of specific public R&D projects and/or R&D incentive schemes, and *(iii)* the narrower, but more focussed stream of research on the impact of external R&D (especially public and/or academic) on private firms’ innovation capabilities[3]. Type *(i)* econometric research has been surveyed effectively and extensively by Mohnen (1996) and David, Hall and Toole (1999), while selected pieces of work dealing with *(ii)* are discussed by Klette, Møen and Griliches (1999). Therefore, in this paper, we focus on research addressing *(iii)*, which has more openly dealt with the issue of LKSs, sometimes with explicit references to the NEG-NIG debate (as in section II of Audretsch and Feldman, 1996; see also section 3 below).

A second category includes a much narrower and more mixed set of recent attempts to quantify, in a direct way, the existence and the importance of LKSs. These studies come from both innovation economists, and urban or regional economists, and are often very innovative with respect of the data sets and methodology they employ.

2.1 LKSs and the knowledge production function

The starting point of recent econometric studies on LKSs is the observation that innovative activities are strongly concentrated at the geographical level, both in the US and in Europe, and that firms located in certain areas are systematically more productive than firms located elsewhere. As a way of explaining these patterns, it is then argued that firms located in regions with high flows (or stocks) of both private and public or academic R&D (as well as other innovative inputs) are more likely to be innovative than firms located elsewhere, since they benefit from knowledge leaking out from these sources. In turn, the reason why ‘distance’ matters in determining who are the beneficiaries of knowledge spillovers is found in the distinction between tacit and codified knowledge, and in the resulting importance of physical proximity to absorb tacit knowledge.

Most often, the distinction between tacit and codified knowledge is taken, quite expeditiously, as synonym of the distinction between knowledge and information, where the former is assumed to be by and large tacit, and the latter fully codified. Information (i.e. codified knowledge) is thought as immediately accessible to whoever has a chance to hear or read it, and therefore can be easily reproduced and travel at a long distance. Knowledge (i.e. tacit knowledge) can only be transmitted either through jargon or hands-on training, both requiring face-to-face contacts and mutual trust between the knowledge source and his/her recipients. As Audretsch (1998, p.23) puts it:

> “The theory of knowledge spillovers, derived from the knowledge production function, suggests that the propensity for innovative activity to cluster spatially will be the greatest in industries where tacit knowledge plays an important role. (…) it is tacit knowledge, as opposed to information, which can only be transmitted informally, and typically demands direct and repeated contacts”

As the above quotation makes clear, this approach makes combines the “tacit vs. codified knowledge” distinction with the use of a *knowledge production function*, i.e. it relates R&D (and other innovative inputs) to *innovation* output measures, such as patents or innovation counts. As a result, a distinction is usually put forward between local vs. distant external innovation inputs, i.e. between inputs coming from outside the observation unit, but within its geographical area (or in a nearby one), and those inputs originated not just outside the observation unit, but also far away from it. Significant differences between the estimated parameters of the two kinds of R&D are then interpreted as evidence in favour of the existence *and* the localization of R&D spillovers. A closer look at the design of these studies, however, reveals some serious weaknesses in the proxies used to infer knowledge spillovers.

Taking a quasi-chronological perspective, the first breakthrough in this field, apart from Thompson's (1962) pioneering effort, is due to Jaffe (1989). Aiming to assess the *Real effects of academic research*, Jaffe first reclassified patents into a restricted number of technological areas, and then showed that the number of patents of each US state for each technological area was a positive function of the R&D performed in a comparable area both by corporate laboratories and by universities (after controlling for the state size, as measured by population). The relationship between patents and university R&D was interpreted as a sign of the existence of some localized "technological spillovers" from the academic institutions into the local business realm.

A more careful examination of Jaffe's data reveals a number of drawbacks, which we can find, more or less unaltered, in many other econometric studies. First, state boundaries are a very poor proxy for the geographical units within which knowledge ought to circulate. States simply are too large geographical units to allow us to assume that inventors, entrepreneurs and managers living in one state will have more chances to have face-to-face contacts among them than with people living elsewhere. Similarly, there is no reason to presume the existence of a common cultural background, nor a close set of parental or friendship ties, which ought to make mutual understanding and trust easier, and reduce transaction costs. Second, Jaffe's technological areas are far too broad to let us presume any serious matching between firms' technological competencies, corporate R&D objectives and university research topics and expertise. Indeed, technological and scientific distances *within* areas as broad as "Electronics, Optics, and Nuclear Technology" or "Mechanical Arts" (just to quote areas 3. and 4. out of Jaffe's six) are far too great to let us presume that people active in the specific disciplines comprised in such areas will be more likely to share or combine their knowledge than people active in disciplines belonging to different fields. Again, arguments militating in favour of localisation of knowledge spillovers, such as the highly specific and tacit nature of technical and scientific knowledge, are at odds with the proxies available for the econometric studies.

Of course, Jaffe was well aware of these problems and tried to work out some remedy. First, he corrected for the inadequacies of the state as unit of observation by calculating an index of co-localisation, within each state, of corporate and University R&D labs active in the same area[4]. Such index, multiplied by the level of university R&D is then added in the knowledge production function, as a measure of the distinctive input provided by the "geographical coincidence" of university research and patent output. However, its significance is admittedly poor.[5]

Acs, Audretsch and Feldman (1992) build upon this last point and replicate Jaffe's (1989) exercise by substituting patents with innovation counts, coming from the Small Business Innovation Data Base (SBDIB)[6]. The authors' aim is to show that innovation counts, which they consider a better proxy of innovation output than Jaffe's patents, may capture the effect of "geographical coincidence" that escaped to patents. However, their exercise refers only to two technological areas (namely, "Electronics" and "Mechanics"), both possibly defined even more widely than in Jaffe (1989). In addition, they do not control for the state size.

Finally, they relate innovation counts for one single year (1982) to R&D undertaken by industry labs and universities just a few years before, and take the same years for both kinds of R&D. Notice that although we can believe that industrial R&D may turn out into "innovations" in a few years time, this is not the case for academic R&D, which is usually of a much more basic kind. And even if we concede that, nowadays, academic R&D is more readily exploitable than 20 or 30 years ago, then we must be consequential and presume that (large) business companies will be readier than before to finance it.

If it is so, academic R&D results may not "spill" at all, since it could be sold *via* standard commercial transactions to business companies. Therefore, if there is any location advantage for firms in the same state or city of the R&D-producing university, we should first look at it as a pecuniary externality (on the re-interpretation of LKSs as pecuniary externalities, see the discussion in section 4).

Acs, Audretsch and Feldman (1994), however, insist on the "spillover interpretation" and propose two different innovation production functions, one for large firms, the other for small ones. They find that "geographical coincidence" is significant only for small firms, and suggest that this is so because university R&D is a substitute for firms' internal R&D, which in turn is too costly for small firms. However, we observe that this result does not prove the existence of direct externalities. It may rather suggest that *innovative* small firms may be readier than larger ones to subcontract their research projects to academic institutions simply because they cannot afford to integrate vertically. Besides, they are possibly *forced* to refer to local institutions, due to their difficulties in getting in touch or paying for the services of distant (and possibly more efficient) universities. Finally, nothing is said about how many *non-innovative* small firms in the same geographical area do not benefit at all from local universities' research activities, i.e. are not touched by any externality whatsoever.

Audretsch and Feldman (1996) improve upon their previous work both by trying to test more directly the role of university R&D inputs in the production of localized innovations, and by making use of less aggregated technological areas (proxied by 4-digit SIC sectors). In particular, their cross-section exercise shows that the geographical concentration of the innovation output is positively related to the R&D intensity of the industry (after controlling for the spatial concentration of production). This result reveals the "propensity for innovative activity to cluster spatially", but the authors rush to relate it to what they call the "considerable evidence supporting the existence of knowledge spillovers" (i.e. their own and Jaffe's previous work). That is, they do not prove, but assume the existence of knowledge externalities (on the basis of the same empirical evidence whose reliability and interpretation we have questioned) and then recall it as the only reasonable explanation for their results.

Similarly, Feldman and Audretsch (1999) make use again of the innovation production function (by state *s* and 4-digit SIC industry *i*) to test the role of specialisation vs. diversity. That is, they test whether the number of innovations from sector *i*, in state *s*, owes more to the state's specialization in sector *i*, or to the presence, within the state, of other industries whose science base is related to that of industry *i*. They reach the conclusion that diversity matters more than specialization.[7] More interestingly, they interpret this as evidence that knowledge spills over across sectors rather than within sectors, although they have provided no evidence whatsoever on the existence of knowledge spillovers as such. That is, firms in related industries (and even those in the same industries) are readily identified just as "sources of knowledge", as if innovations could be produced just by exchanging knowledge, and not by purchasing inputs and services, and by conducting standard production activities:

> "...external sources of knowledge are critical to innovation. [...] the boundaries of the firm are but one means to organize and harness knowledge. An analogous means of organizing economic activity are

> spatially defined boundaries. [...] Geography may provide a platform upon which knowledge may be effectively organized."[8]

Such bold conclusion contrasts heavily with Jaffe's (1989) caution in judging his own exercise as a first step towards a more careful test of the "localised knowledge spillover hypothesis", to be conducted at a finer level for both the geographical and the technological areas. Jaffe's main reason to go on studying the role of academic R&D was the high estimated elasticity of patent "output" with respect to academic R&D "input". Above all, Jaffe was quite clear in stating that, whatever association he could found between local R&D and innovation output, nothing in his estimates could explain the reasons for such association.

> It is important to emphasise that spillover *mechanisms* have not been modelled. Despite the attempt to control for unobserved 'quality' of universities, one cannot really interpret these results structurally, in the sense of predicting the resulting change in patents if research spending were exogenously increased.[9]

This amounts to say that the econometric results obtained by using a knowledge production function do not necessarily suggest the existence of properly defined "spillovers", i.e. *pure knowledge* externalities. It may well be that university research provide *pecuniary* externalities. In section 4, we will try to argue that once one enters the black box, not much remains of the LKSs interpretation.

2.2 Other statistical tests on LKSs

Despite being the most influential, at least within mainstream economics, the production function approach is not the only methodology for measuring LKSs in circulation. On the contrary, a number of, possibly sounder, alternatives have been recently proposed, which make use of large data sets and quite creative statistical tests.

One of the most influential approaches has been proposed by Jaffe, Trajtenberg and Henderson (1993). Using patent citations (rather than patent counts) these authors manage to track direct knowledge flows from academic research into corporate one. They find that innovative firms are more likely to quote research from a co-localized university that conducts relevant research, than from similar universities located elsewhere[10]. Almeida and Kogut (1997) conduct an analogous exercise for semiconductors-related patent citations, reaching similar conclusions. Once again, the result is interpreted (and has been popularised) as strong evidence that knowledge spillovers from University research to firms are highly localised. However, there is no reason to believe that the knowledge of the local university's research results may not come from contractual arrangements with the latter, i.e., once again, from rent externalities (we will come back to this in section 4).

A variant on this approach has been also proposed by Maurseth and Verspagen (1999), and Verspagen and Schoenmakers (2000). Their exercise is based upon counting the numer of patent citations between pairs of regions, and then estimating a model where these counts are related to the geographical distance between pairs of regions. Their estimates show that the number of cross-citations significantly drop as the distance increases. Finally, Brouwer et al. (1999) found that firms located in agglomerated Dutch regions tend to produce a higher number new products than firms located in more peripheral regions. They explicitly argue that this result adds to the literature on regional knowledge spillovers.

A further attempt to quantify the importance of localised knowledge spillovers is carried out by Kelly and Hageman (1999), who make use of US patent counts at the state level, classified by 2-digit SIC sectors. Using a quality ladder model, they show that patenting activity exhibits strong spatial clustering independently of the distribution of employment and that "knowledge spillovers" (as measured by the stock of patents in a given state in all other sectors) are important determinants of a state's innovative performance.

A further set of empirical literature on LKS has to do with two specific issues within urban economics, namely the attempt

- to estimate the relative importance of natural resources' endowment vis a vis knowledge externalities in affecting the location of industries,
- and to distinguish between Marshallian externalities and more specific 'urbanization' externalities.

Marshallian externalities are given a prominent role in the literature we have reviewed so far, but they refer exclusively to intra-industry flows of inputs, labour and knowledge. By contrast, it may be argued that innovation opportunities are also enhanced by some cross-fertilization among technologies and sectors, i.e. inter-industry externalities, which are most likely to appear within large urban centres[11].

Key contributions in this field has come from Glaeser et al. (1992), Ellison and Glaeser (1997, 1999), Head, Ries and Swenson (1996), Henderson (1999), and Black and Henderson (1999). Once again, however, the evidence on LKSs is by and large of an indirect kind (sometimes bringing back the production function tool, as in Henderson, 1999), and cannot be taken as definitive. For example, Glaeser et al. (1992; p.1151) conclude their paper by admitting that:

> "...our evidence on externalities is indirect, and many of our findings can be explained by a neoclassical model in which industries grow where labor is cheap and demand is high."

3. NIGs, NEGs, and LKSs

A further contribution to the popularization of LKSs as a relevant research category has come from their frequent mentioning in what we have called the NEG-NIG debate, which has been keeping busy quite a large number of journals devoted, or at least open to non-mainstream economics.

Since the early 1990s, NEG has been one of the fastest growing fields in contemporary economics. Following Krugman's (1999) assessment of the literature, we can characterize NEG as a re-discovery of classical location theory, where most emphasis is placed upon Marshallian externalities as the key agglomeration force, and new theoretical elements consist mainly in the application of models of monopolistic competition to describe firm behaviour, in contrast with former assumptions of perfect competition. By means of their models, NEGs insist on location being driven not by exogenous distribution of natural resources in space, but by path-dependent trajectories set in motion by historical accidents.

NEGs assume the 'tendency of production activities to cluster in space' as a styilized fact. Although they do not commit themselves to stylize *formally* the scale at which clustering ought to be measured (cities, regions or states, all being dots and spots on a Cartesian space) a general preference seems to be given to "large inter-regional agglomerations such as the "Manufacturing Belt" in the US and the "Hot Banana" [sic] in Europe" (Ottaviano and Thisse, 2000; pp. 8-9).

Rather than checking empirically for the accuracy of the assumed 'stylized fact', NEGs concentrate on theoretical models, which they charge with three tasks:

1) To explore the extent at which different market structures (perfect vs. monopolistic competition) and technological conditions (constant vs. increasing returns) are more or less conducive to agglomeration;

2) To discuss which kind of externality, pecuniary vs. technological, is more likely to drive agglomeration[12].

3) To promote 'mainstream' economic modelling as the best way to deal with the stylized facts, in contrast with less rigorous, non-formal theorizing coming from other social scientists, in particular more traditional economic geographers[13].

Tasks 2. and 3. are closely linked. Most NEGs are wary of explanations based upon knowledge spillovers, and insist upon pure pecuniary externalities, with labour market and demand externalities coming top of the list[14]. One typical argument is that knowledge transmission is costless, or that costs do not depend on distance, so that there is no *a priori* reason to believe that proximity may ease access to knowledge spillovers; or, more cautiously, that knowledge flows leave no track, so that no LKS-based theoretical model can be seriously tested (Krugman 1991, p.53). Alternatively, it is suggested that LKSs cannot (yet) be properly modelled, since they are the result of complex non-market social interactions, whose analysis require modelling techniques that are presently missing from the mainstream economists' toolbox (Ottaviano and Thisse, 2000; p.9).

These remarks explain why NEGs' preferred polemical target, when it comes to task 3., are New Industrial Geographers (NIGs), who in turn have increasingly recognized NEG as a serious threat to their disciplinary status[15].

Despite being a much wider and more heterogeneous group, NIGs accept, and often openly propose LKSs as a very important agglomeration force. Indeed, many research efforts within NIG are placed upon explaining how and why knowledge spillovers are most likely to be highly localized. Most favourite explanations call in, once again, the distinction between tacit and codified knowledge that also informs the econometric studies we reviewed in section 2.

In addition, social homogeneity is called in as a key requirement to access spillovers, because it is only within dense social networks that mutual trust and understanding can be preserved and nurtured. The next logical step is to assume that social proximity requires frequent interactions, which in turn are eased by (or, possibly, strictly require) physical proximity, as in Italian industrial districts or open-minded hi-tech communities such as Silicon Valley. The final step is then to suggest geographical clusters as a legitimate 'observation units', both for analysis and even more for policy purposes, often in contrast to large vertically-integrated firms (Storper, 1995).

Case-study accounts and generalizations about what is really going on inside these clusters vary a lot. As pointed out by Lazerson and Lorenzoni (1999), on the one hand there are suggestions of (small) firms within the clusters to be tightly linked by stable networks (Storper and Harrison, 1991; de Vet Scott, 1992), while on the other hand most emphasis is placed on the quasi-perfect competition conditions that supposedly reign, with high turnover rates and frequent changes of vertical specialization (Dei Ottati ….). At a superficial glance, this variety of knowledge-localization mechanisms looks like a fascinating collection of sensible explanations. At a closer look, however, a number of logical twists and dead ends come to the surface.

Although both types of local firm networks (stable vs. quasi-competitive) can be perfectly suitable and effective, one should also recognize that the mechanisms supporting knowledge flows are very different and do not need to involve any kind of knowledge spillover.

In the case of stable networks, local firms are tied together in a transaction-intensive system of production. This set of network-mediated transactions, far from being an organisational arrangement to allow for spillovers, is a key mean for *internalizing* knowledge: network-specific technologies are developed by cooperation and/or long term supply relationship, and it is totally appropriated by network participants. The localized nature of these firm networks (and therefore the resulting agglomeration of innovative activities) has not much to do with the need to access a (exogenous) pool of knowledge spillovers. Rather, when firms are constantly innovating and are frequently changing process and product configurations, there is the need to be *close* to a constellation of allied firms and specialised suppliers in order to smooth input-output linkages. These observations have two important implications:

a) The same geographical area can host *competing networks*, and therefore it may not represent a meaningful observation unit as such.

b) Localized labour mobility *and* the co-existence of competing networks within a region may be mutually incompatible. At the very least, if it is labour that embodies top-rate knowledge, labour mobility can hardly take place across competing networks, because that would undermine the latter's stability (even vertical mobility inside the network may need to be ruled by tacit agreements and rules of compensation among firms). On the contrary, if network knowledge is embodied in organisational routines and cooperation practices, mobility may be confined to unskilled workers, while skilled ones will be wary to move around, as their knowledge assets are highly complementary to the firm wherein they developed them.[16]

Concerning the quasi-competitive interpretation of local networks, these are more correctly seen as made of individuals, rather than firms. In addition those individuals, far from being described as "economic agents" as in standard microeconomic textbook, are first and foremost defined by their belonging to a "local community", which has a well-defined cultural identity and is often seen as an inexhaustible reservoir of entrepreneurial forces.

Therefore, according to this view, it is not the firm that innovates, but the local *milieu* (or *district* or *learning region*). That is, it is the surrounding social community that share the relevant knowledge and diffuse it by informal conversation, while producing incessantly small entrepreneurs eager to exploit and refine it. Alternatively, it is individual workers who are supposed to embody all relevant knowledge, and it is suggested that high, but localized labour mobility and firm spin-offs ensure both fast diffusion inside the area, and no diffusion outside it.

In studying the networks located in Silicon Valley, Saxenian (1990, pp. 96-97, italics added) writes:

> It is not simply the concentration of skilled labour, suppliers and information that distinguish the region. A variety of regional institutions (…) provide technical, financial and networking services which the regions' enterprises often cannot afford individually. These networks defy sectoral barriers: individuals move easily from semiconductor to disk drive firms or from computer to network makers. (…) An they continue to meet at trade shows, industry conferences, and the scores of seminars, talks and social activities organized by local business organizations and trade associations. In these forums, relationships are easily formed and maintained, technical and market information is exchanged, business contacts are established, and new enterprises conceived. (…) *This decentralized and fluid environment also promotes the diffusion of intangible technological capabilities and understandings*.

These words are echoed by Brusco's (1996, pp. 149-150):

> "The underlying idea [behind the industrial district theory] is that the decisive factor in determining development [...] is knowledge in its various forms [...]
>
> The first of these two [forms] is that of *codified* knowledge [...] The site of this knowledge is the scientific community, whose members are able to exchange this culture and knowledge with relative ease.
>
> The second type of knowledge is *local* [...] This local know-how is passed on by doing things and seeing how other people do things, through informal chit-chat. [...]. Above all, this form of knowledge is necessarily rooted in a specific area in which people are linked by the bonds of a shared history or values, where specific institutions work to the benefit of people and where codes of behaviour, lifestyles, employment patterns and expectations are inextricably implicated in productive activity."

What strikes us most of this type of descriptions is the mixing-up of radically different forces. On the one hand, it is argued that critical knowledge inputs diffuse through the markets for specialised services and through the market for skilled workers, both of which are *embodied* and *pecuniary* kinds of spillovers. On the other hand, it is also argued that *intangible* knowledge diffuses through informal contacts and meetings at the bar, namely through localised knowledge spillovers.

At the very least, one should keep these two notions well distinct, and not equate them under the heading of LKSs, as many authors tend to do. Even more desirable it would be to sort out what is the relative importance of these mechanisms supporting the diffusion of knowledge. In this respect, apart from anedoctal evidence and casual observation, there are but a few studies that have attempted to identify and examine the mechanisms by which technical knowledge is disseminated (von Hippel, 1988; Schrader, 1991, Allen, 1983; Appleyard, 1996; Rogers, 1982). Although generalizing from these studies is quite difficult, some points are worth being remarked:

a) *Private* knowledge sharing is less likely in industries that are experiencing a rapid pace of technological change. Thus, for example, semiconductors developers are reluctant to provide specific technical information to their peers at competing firms. As Allen (1983) has rather convincingly shown, 'collective invention' is a suitable way of organizing the innovation process if and only if firms do not devote appreciable resources to the discovery of new knowledge, and it is very costly or simply impossible to keep relevant information secret, it is individually profitable to release technical information. How many industries fit these quite stringent conditions?

b) The higher the level of turnover in labour market and the stronger the intellectual property regime, the more likely is that the departed employees will resort to previous co-workers for technical advice. However, this knowledge sharing is also likely to involve the exchange of 'small ideas', whose disclosure will not jeopardize the originators' rights over related more strategic knowledge. Given common work experience, both parties are in the position to carefully estimate what can be requested and what can be disclosed without resulting in a 'competitive backlash' for the disclosing company (Appleyard, 1996).

c) Inter-personal channels of communication (i.e. face-to-face contacts) are relatively more important for sharing knowledge with customers (possibly being the spy of transaction-intensive relationships), than for sharing knowledge with competitors. Moreover, the ties of friendship do not play any significant role in heightening the likelihood that two engineers will share knowledge (Schrader, 1991).

Furthermore, NIGs' use of the distinction between tacit and codified knowledge clashes against some recent developments in the economics of knowledge.

The latter point out that technical knowledge is not just 'tacit': it is so because it is highly specific, and the jargon by means of which it can be transmitted is not the same jargon of the broader social community which hosts the firm and its workers. Rather, it is the jargon of a much closer and restricted community (an 'epistemic community'). Members of the community learn it by joining it to practical experience, and cannot transmit it to any outsider by informal means (Steinmueller, 2000; see also Cowan, David and Foray, 2000).

Besides, technical knowledge, far from being static, is highly dynamic: incremental technical change takes place in all sectors of activity, and brings about new codes of communications as well as new artefacts, which change the practitioners' vocabulary: outsiders, however close, may learn nothing of that vocabulary. Moreover, physical proximity may not imply any social proximity, and not only in large urban centres: social networks are never as wide as to include all members of a community, and in many cases not even a significant minority of them. Therefore, knowledge may be far from accessible to most of those who are located nearby its sources.

Similarly, social proximity may arise from shared work or study experiences, or former cooperation efforts that required face-to-face contacts and a high degree of socialization, but then survive to their end. Although highly dispersed in space, members of these 'epistemic communities' share more jargon and trust among each other than with any outsiders, no matter how spatially close. More generally, social proximity has many more dimensions than the spatial one.

If anything these remarks point out that informal knowledge as an explanation for the existence of LKSs have been probably overrated. In a sense, by insisting on it, NIGs do not serve well the cause of countering NEGs' dismissal of innovation as an agglomeration force, no matter how just and righteous that cause may be.

4. Opening the LKS black box

The major limitation of the empirical literature on LKSs we have reviewed in section 2. is that virtually no contribution has explored the ways by which knowledge is actually transferred among people located in the same geographic area. The (unverified) story that is usually told assumes that by being near to universities, where leading-edge research is carried out, and other innovative firms, employees of local firms will hear of important discoveries first and thus be able to utilise them before others are aware of their existence (Zucker at el., 1998). More precisely, this story can be broken down into a three-step logical chain:

1) knowledge generated within firms and Universities spills over to other firms;
2) knowledge that spills over is a public good freely available to those wishing to invest for searching it out, i.e. it is non-rivalrous in nature (knowledge developed for any particular application has economic value in very different applications);
3) knowledge that spills over is mainly tacit, highly contextual and difficult to codify, and therefore is more easily transmitted through face-to-face contacts and personal relationships (spatial proximity).

However, since the story is not verified, it might be that what standard methodologies (such as the production function) and data sets (patents and innovation counts) suggest to be pure externalities will turn out to be, at a more careful scrutiny, knowledge flows that are mediated by economic mechanisms (Geroski, 1995).

In order to solve our doubts, we are therefore required to open the black-box of LKSs, and explore a rather vast and heterogeneous body of literature dealing with the organization of innovative processes.

In particular, this literature helps us arguing against points 1) and 2) in the above-mentioned logical chain, since it suggests that in many cases knowledge spillovers are more apparent than real, and certainly less pervasive than is usually suggested. On the one hand, one can identify both market and non-market mechanisms through which knowledge flows between universities and firms, as well as across firms, so that ‘rent’ externalities in knowledge transactions ought to be given back much of the scene stolen by LKSs (sections 4.1. and 4.2). On the other hand, one should recognise that even the most open among firms and academic institutions can exert some control over their knowledge outflows, and manage to keep the latter within the borders of well-defined networks of relationships. Far from representing any kind of externality, these network-bound flows can be viewed as a way of appropriating the relevant knowledge (section 4.3).

Finally, we tackle point 3) in the chain and suggest that rigorous research ought to consider not only locational advantages in accessing the results of academic or other firms' research, but also some diseconomies, as well as the relationship between the time dimension and the geographical dimension of spillovers (section 4.4).

4.1 Why are local Universities so important for firms' innovative activities?

Let us start with the impact of University R&D on firms' innovative performance, which is so often cited as a clear instance of LKSs. The relevant question is: do the estimated impact of University R&D on local firms' innovation output, and those firms' frequent citations of local universities' patents, represent convincing evidence that academic knowledge circulate locally as 'manna from heaven'?

The most fashionable answer is certainly 'yes'. However, a careful reading of some recent literature on the role of Universities for firms' innovative activities suggests otherwise.

In the first place, it must be clearly stated that local Universities provide critical inputs for firms' innovative activities even without producing any research which is *directly* relevant for firms' current innovation projects, namely *training* and *consultancy*. For example, universities with high reputation for research may attract brilliant students, thus providing a big push for the creation of a localised market for highly skilled labour, which will be reinforced by increasing returns. Similarly, research-oriented universities (or individual researchers therein) may turn out to provide key specialised intermediate inputs, such as consultancies at critical stages of firms' product development. Notice that for both kind of externalities universities may not need to produce any research which is directly relevant for firms' current innovation project: brilliant students and key consultancy competencies can be produced just by teaching, keeping in touch with the research frontier and following one's own specialised field, as many scientists actually do. More importantly, by producing graduates and offering services, universities help enhancing local firms' capabilities *to appropriate* the results of their research efforts, rather than giving them any *opportunity* to innovate. In both cases, no knowledge externality arise, and knowledge is diffused in the local context via the labour market and the market for specialized inputs, that is via *pecuniary externalities*.

In the second place, local Universities' *research* activities may have a direct relevance for firms' current innovative projects not just by providing them with innovation opportunities (as stressed repeatedly by the LKS story), but also by enhancing their appropriation capabilities, quite often *via* market mechanisms.

First, local firms may end up quoting the results of the local universities' research projects simply because they were directly involved in those projects, either as service customers or research sponsors. A survey conducted by Mansfield (1995) supports this view. Corporate R&D managers were asked to mention any academic researcher who had played some role in the development of their companies' new products and processes. In the large majority of cases, the most frequently mentioned academic researchers were also those who had received higher-than-average research funds from industry, had continuing consulting relationships with the firms supporting their academic research, and tutored students who later on took up jobs within those firms. None of these links can be claimed to be a pure knowledge spillover.

Second, localized patent citations (or even a positive correlation between University R&D and firms' innovative output) can hide the University researchers' willingness to appropriate their own findings, either by setting up a new firm or by devising some contractual arrangements for existing firms to exploit (and therefore quote) them. Similarly, working with local firms may help university researchers to appropriate the economic returns from *their own* scientific discoveries. This line of interpretation has been offered by a few recent contributions (Zucker, Darby and Brewer, 1998; Zucker, Darby and Armstrong, 1998). They argue that the standard notion of LKS, according to which firms 'social' ties between employees and university scientists, or to the possibility to attend informal seminars at the university, are the main vehicles for knowledge exchanges, does not seem to apply to the case of the biotechnology industry, at least in the phase of its emergence. Rather, they argue that discoveries in this field are characterised by high degrees of *natural excludability*, since the *techniques* for their replication are not widely known. Anyone wishing to build upon recently generated knowledge must gain access to the research teams and labs setting that generated that knowledge. Under these circumstances, the scientists who make key discoveries ('superstars') tend to enter into contractual arrangements with some existing firms or start up their own firm, in order to extract the supra-normal returns from the fruits of their intellectual human capital. Quite naturally, when doing so, those scientists tend to prefer jobs or to create their own start-up within commuting distance from home or their university (where they tend to retain affiliation), thus creating localised effects of university research.

Zucker's and Darby's research effort is extremely important also from a methodological perspective, since it represents the first attempt to study the knowledge transfer mechanisms between university scientists and business companies. In particular, the authors show that the innovative performance of biotechnology firms is positively associated to the *total* number of articles by local university 'star' scientists. However, when a distinction is made between the articles written in collaboration with firm scientists ('linked') and the remaining ones ('untied'), the explanatory power of the latter nearly vanishes. Previous evidence on the existence of indiscriminate localised knowledge spillovers seems therefore to have resulted from a specification error, i.e. the inability to control for the contract arrangements linking *individual scientists* to *local firms*.[17]

This line of research suggests some preliminary conclusions:

a) At least in the early phases of new industries, knowledge is not 'in the air', but is embodied in individual scientists and research teams. Social ties and personal contacts are not *sufficient* to gain access to naturally excludable knowledge. This requires deep involvement in the research process and bench-level scientific collaboration. If anything, this result tends to support the idea that there are not 'free lunches' and that one must invest resources not simply to *search for* new knowledge, but to build the competencies to *absorb* the knowledge developed by others and to understand the highly context-specific "codes" into which knowledge is translated (the classic reference here is Cohen and Levintahl, 1989, 1990).
b) Naturally excludable and rivalrous knowledge does not spill over: it is people that move (locally) across organisations in order to exploit their knowledge assets. In other terms, localised effects of university and industry research are most likely to

result from a combination of appropriability of tacit non-replicable knowledge and low geographical as well as organisational mobility of researchers, than from undifferentiated geographically localised knowledge spillovers.

We turn now to examine point b) in some depth.

4.2 Localized mobility of skilled workers as a carrier of knowledge

A crucial mechanism through which knowledge flows across firms and regions is represented by the *mobility* of individual workers, particularly the skilled ones. Quite surprisingly, this mechanism has not received too much attention within the field of research we are assessing. By now it should be clear, however, that (localized) labour mobility does not represent a 'pure knowledge spillover', but should be more correctly categorised under the heading of 'rent' (or pecuniary) externalities. As workers move from one firm to the other, they help diffusing knowledge through a certain region production complex, thus creating a local manufacturing environment in which firms build *cumulatively* upon a *common* stock of technological successes and failures. Apparently, this outcome looks like the LKSs story, but it does not require any face-to-face or inter-personal or inter-firm *sharing* of tacit knowledge.

What do we know about the patterns of workers' mobility and their relationship with firms' innovative activities? On this subject, a very interesting piece of research has been recently produced by Almeida and Kogut (1999). Using a sample of semiconductors-related highly cited patents, they replicate the exercise carried out by Jaffe et al. (1993). In addition to that, however, they also focus upon patterns of mobility of individual patent holders (engineers). Their findings suggest that patent citations are strongly localized, particularly so in Silicon Valley. However, this region also features a strong inter-firm mobility of those inventors (engineers) whose patents are highly cited. Moreover, the level of intra-regional mobility is very high, whereas the extent of inter-regional mobility is much smaller. These results raise more than one suspect about the "LKS interpretation" of the econometric and statistical findings reviewed in section 2. Once again, we observe that they may actually emerge from a problem of model mis-specification, namely from the failure to take into account the local mobility of skilled workers as a carrier of knowledge.

To the extent that the mobility of workers is an important carrier of knowledge flows, there are some fundamental implications, both for researchers and for policy-makers.

In the first place, knowledge is 'sticky' and tends to remain within the borders of specific regions not simply because of its tacitness (thus requiring social as well as physical proximity to effectively support its sharing), but because workers that embody relevant knowledge tend to move 'locally', for a number of other reasons (e.g. risk aversion, localization sunk costs, and so on). This is not to deny the importance of the institutional and social context. Quite on the contrary. In order to work smoothly, this kind of inter-firm workers mobility must be supported by a local industrial culture, like the one that prevails in Silicon Valley, in which the allegiance of engineers and scientists is not so much to any individual firm, but to the production complex as a whole (Angel, 1991). The point is rather that this collaborative atmosphere serves only the purpose of reducing for firms the costs associated to search and screening procedures. In other words, the so-often cited face-to-face contacts serves only to ease the access to *information* about *who knows what and where is employed*. Technical knowledge only passes through the actual mobility of workers.

A second important implication is that if labour mobility is crucial for knowledge diffusion, regions with smoother labour markets are likely to perform better than others. It is worth stressing how this view contrasts with the LKSs perspective. According to that perspective, regions with higher flows (or stock) of private and public R&D must perform better because firms located therein will benefit from higher levels of knowledge spillovers. In our view, there is no guarantee that this will happen as a quasi-automatic response. If the regional labour market works rigidly, a policy intervention in support of private or academic R&D may not achieve the purpose of enhancing regional innovative capabilities and may lead to a waste of resources.

A third crucial point concerns the fact that localized labour mobility, while producing positive effects through knowledge diffusion, may also generate tensions and contradictions. After all, the loss of individual (or even teams of) highly-skilled workers to the advantage of competitors can have damaging effects upon the ability to appropriate the rents from innovative activities, which are not necessarily counterbalanced by easier access to the local pool of skilled and experienced workers. In these circumstances, firms may attempt to keep a proprietary control over new technologies and over manufacturing experience upon which these technologies are based. Apart from enforcing intellectual property rights, firms can manage to achieve this objective by deliberately strengthening network relationships with a selected number of local users and suppliers. However, to the extent that firms attempt to do so fluid labour market transactions and the stability of network relationships come to a clash and appear as mutually exclusive agglomeration factors, as we suggested in section 3.

4.3 Appropriability and the market for technology

While reading the literature on LKSs one is struck by the fact that almost no reference is made to the now vast body of research dealing with on the sources of knowledge and the means of appropriability (see references in Geroski, 1995). After all, LKSs are likely to arise only if, for any reason, there is incomplete appropriability of knowledge, i.e. some agents are able to use the new knowledge generated by other agents relatively costlessly. Therefore, one more question arises: is the LKSs interpretation consistent with what we know about the ways firms acquire new knowledge and the strategies they follow to protect it from imitation?

First, we observe that problems of appropriability are clearly evident in a wide variety of sectors, and the effectiveness of the solutions to this problem differ from sector to sector, so that one cannot rule out, in principle, the relevance of knowledge spillovers. However, there is no evidence to support the view that these spillovers must be necessarily ‘localised’. In the first place, many mechanisms by which firms can learn the ‘secrets’ of competitors are not sensible to geographical distance: reverse engineering, patent disclosures, trade journals and fairs. In the second place, some studies have demonstrated that the time to imitate a rival’s innovation is comprised between 6-12 months (Levin et al., 1987) and that rivals generally learned about decisions to develop major new products or processes 12-18 months after the decision has been made (Mansfield, 1985). Unless one demonstrates that the quickest imitators are firms *closer* to the source of knowledge, there is no a priori reason to believe that *distance* matters to take benefits of these spillovers.

Second, Levin et al. (1987) showed that independent R&D was rated by R&D managers as the most effective mean of learning about rivals’ technology. This raises two points.

On the one hand, to the extent that investing in R&D is necessary to develop a firm's ability to 'assimilate and exploit' external knowledge and that a considerable number of firms do not invest in R&D, spillovers may benefit a few firms in each industry. On the other hand, the observation of a significant co-localization of innovation inputs (i.e. R&D) and outputs (i.e. patents) might be simply the coincidental and more or less development of similar answers to commonly perceived problems which a group of co-localized competitors all arrive at by drawing on a pool of common scientific knowledge. In other words, what are apparently localised knowledge spillovers are no more than simultaneous independent drawings from a common pool of know-how (Geroski, 1995).

The third point we wish to raise concerns exactly this last point. In our view, the LKSs literature, by arguing that innovative activities are spatially clustered because of the existence of localised knowledge *spillovers*, has obscured the real terms of the problem. In our view, this is to find an explanation of why it happens that innovative firms are often agglomerated *even in the absence of localised knowledge spillovers*. A very interesting attempt to answer this question has been given by Lamoreaux and Sokoloff (1997, 1999). Using historical patent data for the US, they are able to keep track of inventors' career patterns and to relate the production of inventions with regional manufacturing activities. The main results emerging from their analysis are:

a) although there was some clustering in both production and patenting activities, the geographic patterns were quite different. Some production centres did not have any inventive activity, while areas with very little production had very high rates of innovation;
b) firms in clusters of production were using obsolete technologies and their locational choices reflected the search for cheap material inputs. Firms using newer technologies were thus more spatially dispersed than those using older methods;
c) patenting activity tended to be higher in regions where patenting rates *had long been high* and where a *market for technology* (as measured by the sales of patents) had evolved more fully, irrespective of the share of industry production. In regions with such well developed markets inventors tended to be more specialised, numerous and productive in terms of number of patents per inventor.

It is quite hard to generalise from these results. However, one can try to speculate a little bit on them:

i) Concentration of firms and production in a given area is not *per se* a necessary and sufficient condition to determine high rates of innovative activity. To put in slightly different terms, *static externalities* related to the current scale or size of an industry in a given city do not necessarily generate better (local) information flows to the advantage of innovative activities. What seems to matter most is the *accumulated* stock of knowledge (*dynamic externalities*) in a diversity of industries as well as the levels and types of human capital in a region. Regions that first emerge as centres of innovative activity in a certain industry tend to maintain their advantage over time.

ii) Industries may move across regional and national borders without a corresponding relocation of inventive activity. Inventive activity is more 'sticky' than production. Of course, it remains to be seen why it is so. On the one hand, there is the possibility that the locational stickiness of inventive activity derives from the reluctance or lack of incentives to migrate by people with knowledge and experience in an industry. On the other hand, a possible explanation could relate to the richness of *general technological know-how* in higher-order regions that serve as an effective substitute for specific knowledge and allows to find new applications across a wide range of industries.

iii) Institutions matter for regional innovation, but in a different way than frequently claimed by many NIGs. The latter tend to stress the role played by 'soft' institutions like trust, norms, codes of communication, conventions, in facilitating the process of information sharing among firms and individuals. According to another perspective, institutions are also important because they help to build those 'bridging' market (or market-like) mechanisms that mediate relations among inventors, suppliers of capital and those who are willing to commercially develop or exploit new technologies.

4.4 Global networks of innovators, and the time dimension of spillovers

Finally, we ask whether there is any strong reason to believe *a priori* that knowledge proximity is strictly required for firms to take advantage of the academic services.

Even the minimal acquaintance with the fundamentals of the economics of innovation would suggest to look first at the type of knowledge that is acquired. On the one hand, one can recall Nelson's (1959) classical observation about the huge time gaps that often separate a scientific discovery from its first industrial applications. Therefore, even if we can readily believe that quick access to the graduate pool and consultancy services of universities may require physical proximity, we may suspect that the long time interval between scientific discoveries and industrial applications will suffice for transmitting knowledge far away from the university which has produced it. That is, the results of *current research* do not necessarily spill from universities over to local firms, simply because they may spill after such a long time that they manage to reach over to long distances.

On the other hand, Mansfield (1995) convincingly shows that just a few top universities are up to the task of serving business companies by producing basic research rather than applied research. This is why the evidence he provides on the role of geographical proximity is mixed: companies that need basic research may go far away to buy it, but will do so only occasionally and will not need face-to-face contacts with the university researchers. On the contrary, companies buying applied R&D services will need face-to-face contacts, which can be provided only by local universities, which in turn do not have resources and competencies for producing valuable basic research. In both cases, no pure spillovers seem to be involved.

Looking back at the previous discussion, we recognize that there is hardly any doubt that innovation networks are often localised. However, the reason of this localisation has less to do with knowledge spillovers mediated by social and physical proximity, than with the need to access a pool of skilled workers and to establish transaction-intensive relationships with suppliers and customers.

If it so, one should recognize that knowledge tacitness, although being a possible explanation for co-localization, may be offset by the need establish close links with suppliers of new technologies or new customers, which may be located far away from the original network participants (Echeverri-Carroll and Brennan, 1999; Lyons, 1995). Particularly for firms located in regions and cities with a relatively small accumulation of knowledge, the development of relationships with universities and other firms (suppliers and customers) located in higher-order urban centres is a key factor in determining success in the development of new products and processes. The most dynamic and innovative firms look for knowledge embodied in engineers and scientists *wherever* they are available, and not necessarily constrained in this by geographical barriers. Moreover, these firms establish network relationships (i.e. alliances, join-ventures, collaborative research and so on) with customers and suppliers

Even more than that, a few studies have shown that *not* locating in a cluster may actually hold some advantages, by allowing firms to safeguard their privacy and to introduce new products earlier than their competitors (Suarez-Villa and Walrod, 1997; Oakey and Cooper, 1989). In particular, Suarez-Villa and Walrod found that non-clustered electronic establishments spent on average 3.6 times more on R&D and employed 2.5 times more R&D personnel than clustered ones. Despite all the conventional assumptions, spatial clustering in and of itself is not as supportive of innovation as has been so far assumed. In particular, the evidence shows that non-clustered establishments achieved greater economies from the adoption of just-in-time methods and outsourcing and were more able to allocate these resource savings to support R&D, thanks to the greater physical isolation from other producers and the more limited obligations that weaker relational ties entailed. Quite interestingly, these results open the way to the hypothesis that *sectoral clustering* and broader (non-localised) linkages are more important than has been so far assumed.

5. Conclusions

This paper has provided a critical re-assessment of the recent literature on localised knowledge spillovers (LKSs). The central point we have stressed is that the notion of LKSs has been largely abused, thereby generating conceptual confusion and creating distortions in research agendas and misled policy implications.

Contrary to NEGs, we are not denying that knowledge flows are an extremely important agglomeration force, and that a very large part of these flows takes place at the local and regional level. What we question is the strategy of putting *all* these flows under the common heading of LKSs, as a way of (re-)discovering regions as the right unit of observation. The problem is not merely one of terminology.

In fact, as soon as one tries to open the black-box of LKSs, it becomes quite clear that:

a) What might appear at first as ‘pure’ knowledge externalities are actually ‘rent’ (or pecuniary) externalities, which are mediated by economics (market and non-market) mechanisms, such as the labour market and firm networking.

b) What might appear as involuntary (pure or rent) knowledge externalities are actually well-regulated knowledge flows between academic institutions (or individuals therein) and firms, or across firms, that are managed with deliberate appropriation purposes.

These observations set a tight research agenda for all those who want to understand why ‘geography’ really matters for firms’ innovative activities.

The first entry in the agenda is the labour market. A crucial mechanism through which knowledge diffuses locally is via the mobility of technologists and scientists, either across firms, and between firms and academic institutions. We expect that studying the career patterns of these professional figures will reveal a number of relevant aspects about how knowledge is diffused.

The second entry has to do with firm networks, and particularly with the geographical dimension of such networks. These are likely to be a much more fruitful unit of observation than the region or the state as such, since they are an organizational arrangement that allow firms both to circulate and to internalize many knowledge flows.

A third line of research should deal with the ‘real’ impact of local universities on firms’ innovative activities. Our opinion is that the ‘spillover’ perspective has obscured the wide set of mechanisms through which local universities actually contribute to firms’ research efforts. Local ties ought to be explored by overcoming the easy metaphor of the “local community”, and by studying in some depth the knowledge-based services sold by the academic institutions (or individual scientists therein) to local and non-local business companies.

Finally, an explicit link should be established between the geographical dimension of knowledge flows and the research on all the contractual arrangements that allow firms and individuals to appropriate their knowledge rents, as well as the disclosure rules foreseen in those arrangements.

In most cases, the existing data sets on R&D, patents, and innovations counts will still have to play a prominent role. But they will need to be coupled with additional evidence on the identity and the activities of individual firms and inventors; and their use will have necessarily to be much more creative than fitting them all into one production function.

Notes

[1] Marshallian externalities refer to intra-industry economies of localization, and are most commonly listed (e.g.: Krugman, 1991) as:

a. Economies of specialisation: a localised industry can support a greater number of specialised local suppliers of industry-specific intermediate inputs and services, thus obtaining a greater variety at a lower cost.

b. Labour market economies: a localised industry attracts and creates a pool of workers with similar skills, smoothing the effects of business cycle (both on unemployment and wage) through the effects of large numbers.

c. Knowledge spillovers: information about new technologies, goods and processes flows more easily among agents located within the same area, thanks to social bonds that foster reciprocal trust and frequent face-to-face contacts. Therefore, geographical clusters offer richer innovation opportunities, than scattered locations; innovation diffusion is also faster.

Entries *a*. and *b*. in the list are often referred to as 'pecuniary' or 'rent externalities', as opposed to *c*., which more clearly represents "technological externalities" (Scitovsky, 1954). The former allow co-localized firms to access traded inputs and labour at a lower price than rivals located elsewhere; as such, they pass through market interactions. The latter, on the contrary, materialize through non-market interactions and, in principle, they are accessible to all members of the local community.

When it comes to empirical studies, however, the distinction between pecuniary and technological externalities becomes fuzzier. In particular, econometric studies on R&D productivity may overestimate technological externalities because of measurement errors (Griliches, 1979). This is a key issue of our paper and we discuss it at length in sections 3 and 4.

Some authors add to *c*. the provision of public infrastructure, which local or national authorities are forced/convinced to provide if and only if they recognise the importance of a specific industry for the welfare of the local communities (Henderson, 1986).

[2] For example, Jaffe (1989; p. 968) suggests that "(…) a state that improves its university research system will increase local innovation both by attracting industrial R&D and augmenting its productivity".

[3] In particular, research on *(i)* deal with R&D as a production input, thus using it as an explanatory variable for the growth of output or total factor productivity for the observation unit, while research *(ii)* and *(iii)* make extensive use of modified versions of Griliches' (1979) *knowledge production function*, thus relating R&D to *innovation* output measures, such as patents or innovation counts.

A key research objective of all studies is the measurement of R&D externalities, from which one can test the classical hypothesis of a divergence between the social and private returns from R&D. This requires introducing in the model a number of variables representing R&D flows (or stocks) taking place outside the observation unit. This is mainly done by adding weights to the external R&D sources, which can reflect either the technological or the physical distance. The observation units can be either individual firms, industries or geographical areas of various size, such as states, regions, or cities.

[4] Using data from commercial directories, he worked out, for each state, how many corporate and university R&D labs and employees were located in the same metropolitan area.

[5] More recently, Anselin et al. (1997) proposed to solve these problems by including explicitly in the model a *spatially lagged variable*, namely the University R&D expenditures carried out within varying distances from the recipient firm, and by adopting a smaller spatial unit of observation than the states (i.e. the so-called SMSA). Their results show that spillovers of university research have a positive impact on regional rates of innovation and that they extend over a range of 75 miles from the innovative region. In addition to that, they also applied spatial econometric techniques to take into account the possible effects of *spatial autocorrelation* either in the dependent variable or in the error term. This is quite a serious problem of which many other studies are apparently not aware.

[6] See Feldman and Florida (1994), page 212 and footnote 1 for a detailed description of this data set.

[7] For some evidence pointing at the opposite direction, see Henderson (1999)

[8] Audretsch and Feldman (1999), p. 427. This tendency to force an interpretation on the data by mixing up assumptions and evidence is even stronger in Feldman and Florida (1994). They employ again the innovation production function for thirteen 3-digit industries *i*, in each state. They also include, among other explanatory variables, the value added coming from firms that, within state *s*, belong to the 2-digit industry that encompasses the 3-digit one under consideration. That is, they test the exis-

tence of some (very generic) agglomeration effect. However, they insist upon calling this as "the network effect", and patently mix up what are very different kinds of externalities:

> "Concentrations or agglomerations of firms in related industries provide a pool of technical knowledge and expertise and a potential base of suppliers and users of innovations. These networks play an especially important role when technological knowledge is informal or tacit in nature [...]. Concentrations of these firms foster important synergies in the innovation process, as for example when innovations in semiconductors spill over into electrical, consumer electronics, and computers industries" (*op.cit.* p.220).

Notice that the "pool" of technical knowledge could easily consists in a pool of specialized workforce, i.e. a Marshallian externality of the first kind, while networks are better defined as non-market relationships among firms, and, at most, can be referred to as a Marshallian externality of the second type, i.e. one mediated by specialized suppliers. Above all, it is hard to believe that tacit knowledge, which requires mutual understanding of working practices, can be exchanged across 3-digit industries by means of informal contacts!

[9] Jaffe (1989), p.968 (italics in the original text). It is worth noting that this conclusion did not differ much from Thompson's (1962), albeit coming 27 years later. It is also quite curious to read similar observations in Audretsch (1998): "While a new literature has emerged identifying the important role that knowledge spillovers within a given geographical location plays in stimulating innovative activity, there is little consensus as to how and why this occurs. The contribution of the new wave of studies (..) was *simply* to shift the unit of observation away from firms to a geographic region" (p. 24, italics added).

[10] The spatial unit of observation is no more the state, but the Standard Metropolitan Statistical Area (SMSA).

[11] Common synonyms for Marshallian vs. urbanization externalities are respectively "MAR" and "Jacobs" externalities, where the former stands for "Marshall-Arrow-Romer" (Henderson, 1999)

[12] For a distinction between pecuniary and technological externalities see footnote 1. above.

[13] Promotion techniques vary a lot: not all NEGs share Krugman's patronizing attitude that offended so many economic geographers (Martin, 1999; pp. 82-83). However, even more appeasing authors such as Ottaviano and Thisse (2000) propose their work as a necessary toolbox for introducing some rigour in a field that for too long has been lacking it: "Although [our] insights are not necessarily new (…) we believe that their formalization is both useful and promising. First, there is a distance between 'ideas' and 'theorems' that social scientists sometimes underestimate. In particular, analytical economic models allow for a more precise description of the forces at work and of their interplay as well as for their welfare implications" (Ottaviano and Thisse, 2000; p. 2).

[14] Co-evolution of technologies and institutions (public administration bodies as well as rules and norms) is also neglected, along with research on National Systems of Innovation.

[15] On this point see Martin and Sunley (1996) who propose for NEG the alternative label of "geographical economics", in order to stress their dissatisfaction for its abstract features and lack of credentials as true 'geography'. Similarly, Martin (1999) counterpoises "regional science" (again a synonym for NEG) to true "economic geography".

[16] Several studies seem to confirm that in high-tech clusters the mobility of unskilled workers is normally much greater than the mobility of skilled ones.

[17] After these remarks, it does not surprise us to learn from Audretsch (1999) that, in such a highly academic R&D related field as biotechnology, many young scientists set up new technology-based firms within the same area of the university they are working for. Nor that they do so because they are willing to go on working within their university department, in order to build up both their knowledge base and their reputation. What we can hardly understand is why the author classifies the young scientists' knowledge contributions to their own start-ups as university R&D spillovers. They look like being fully appropriated, either by the researchers or by the universities that employ them (since they possibly pay them low wages, in exchange for allowing them to exploit some of their research results). In addition, there is no proof that the start-ups translate ongoing research results into viable products as such: young researchers may do very different jobs when dealing with basic science inside their university (in order to publish and build up their academic reputation), and when working on product development inside their own start-ups (which may exploit not-so-new ideas). And if they

quit their university department and work full time for their own start-up, they may decide not to leave the local area simply because they want to be ready to go back to their department if their business fail.

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