KNOWLEDGE SPILLOVERS AND LOCAL INNOVATION SYSTEMS: A CRITICAL SURVEY

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1. Introduction

This paper provides a critical assessment of the recent fortunes met by the concept of "localised 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 important knowledge sources to introduce innovations at a faster rate than rival firms located elsewhere. As such, they are the key object of enquiry of a fast-growing stream of econometric and statistical studies, which deal with the impact of academic and industrial R&D on the localisation of firms' innovative activities (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, and frequently invoke the existence of LKSs to comment upon their findings. 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 have become increasingly popular within economic geography, witness some cross- and common references between Krugman (1991, 1995), Martin (1999), and Feldman (1999).

In particular, LKSs are frequently acknowledged as a key agglomeration factor by what Martin and Sunley (1996) label as "New Industrial Geography" (NIG), 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 (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, they are frequently questioned, as a meaningful or useful research category, by the so-called "New Economic Geography" (NEG), 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; Ottaviano and Thisse, 2000; see also David, 1999)[3].

In this paper we cannot attempt to survey two bodies of literature as large as NIG and NEG. Our main concern will be with the econometric and statistical literature on LKSs, which has been most influential in popularising the LKS buzzword.

We will argue that, despite its widespread use, the concept of LKS is no more than a 'black box', whose contents remain ambiguous. On the one hand, its frequent mentioning serves merely an 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.

The main reason for our dissatisfaction with the LKS-based quantitative literature is the suspicion that its increasing popularity may:

a). distract far too many research energies from the study, both theoretical and empirical, of the role of geographical distance in the economics of knowledge transmission, which is still rather controversial (Rallet and Torre, 2000);

b). lead to naive policy implications, which remind of not-so-remote unfortunate experiences with science parks, growth poles, and the likes (Massey et al., 1992).

The first risk is revealed by the far too ready acceptance, even within NIG and NEG, of the concept of *knowledge spillover* (or "knowledge externality") as an unequivocal summary variable for a number of knowledge flows, each of them being vehicled, at a closer look, by its own specific transmission mean. Too little attention has been paid to the origins of the LKS concept, which is a by-product of a "production function" view of innovation processes (strictly functional to neoclassical growth theory), and not the outcome of a specific enquiry on the circumstances under which scientific and technical knowledge may (or may not) take some public good features.

Things are made even worse when the LKS concept is supported by calling in an even fuzzier conceptual category, namely that of "tacitness", to be intended as an intrinsic property of scientific and/or technical knowledge. Indeed, the concepts of "spillover" and "tacitness" form an odd couple, which we will show to be ill-equipped to help us highlighting, and possibly solving, the conceptual problems that stand in the way of a full understanding of the role of geographical distance in knowledge transmission.

The second risk derives from the potentially self-reinforcing view of LKSs as a "stylised fact", i.e. as a quasi-automatic consequence of a sufficiently high 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 localised, i.e. they will be retained by the same communities that took their burden.

Suggestions like Jaffe's (1989; p. 968) that "… a state that improves its university research system will increase local innovation both by attracting industrial R&D and augmenting its productivity" sound too daring if confronted with the conceptual fuzziness of LKSs.

Once again, size constraints force us to limit the scope of our review, so we will devote all our efforts to illustrate only the first of the two risks we listed above. In particular, in sections from 2 to 5 we will try to show that the existence of LKSs is far from being a "stylised fact", i.e. a non controversial starting point for research. We will suggest that innovators' spatial proximity, when found to be significant, may not depend upon any intrinsic feature of knowledge, such as its degree of "tacitness", but on a much more complex interplay between the economics of knowledge codification, the labour market for scientists and technologists, and the innovators' appropriation strategies.

Then, in section 6. we will make a few steps towards opening up the LKS black box. In particular, we will examine a few recent studies on the geography of innovation that do not start from any "knowledge production function", some of which go to the extreme of questioning the link between knowledge diffusion and spatial proximity. Above all, these studies show how many different knowledge flows link together universities, public labs, private companies, and individuals, each of them serving different purposes and, as a consequence, being affected in different ways from physical distance.

In section 7. we will conclude by offering some research questions which build upon the literature we have reviewed, and may help stopping the indiscriminate hunting to LKSs.

2. Three critiques to the LKS story

The past fifteen years have witnessed the growth of a new breed of empirical literature on the "geography of innovation", which tries to asses whether knowledge spillovers exist and are bounded in space, and to what extent they are better described as "Marshallian" rather than "urbanisation" externalities.

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

1). *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.

2). *Labour market economies*. Localised industries attract and create pools of workers with similar skills, smoothing the effects of business cycle (both on unemployment and wage) through the effects of large numbers.

3). *Knowledge spillover.* Information about novelties flows more easily among agents bcated within the same area, thanks to social bonds that foster reciprocal trust and frequent face-to-face contacts. Therefore, geographical clusters offer more *innovation opportunities* than scattered locations. Innovation diffusion is also faster [4].

Urbanisation externalities economists occur whenever job or innovation opportunities are enhanced by exchanges and cross-fertilisation among technologies and sectors, i.e. inter-industry externalities, which are most likely to appear within large urban centres [5].

Entries 1. and 2. in the list above are often referred to as "pecuniary" or "rent" externalities, as opposed to 3., and its homologues in urbanisation theories, which more clearly represent "technological" externalities (Scitovsky, 1954)[6]. Rent externalities allow co-localised firms to access traded inputs and labour at a lower price than rivals located elsewhere; as such, they pass through market interactions. Technological externalities, on the contrary, materialise through non-market interactions and, in principle, are accessible to all members of the local community.

However, 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 underestimate the former, and overestimate the latter, because of measurement errors (Griliches, 1992). The typical example is that of the influence of business R&D on sectoral productivity: we know the latter to be positive, but we find it hard to say why. It may be the case that a few firms' successful R&D projects bring about new or improved inputs, which increase the marginal productivity of a number of other firms in the same industry. But it may also be the case that the overall R&D effort of the industry contributes to the increase of a common pool of knowledge, which enhance the innovation opportunities for all the firms contributing to it. Although we can distinguish the two effects on the theoretical ground (as well as in terms of policy implications), we find it hard to do the same empirically.

Despite this, all the best-known studies on LKSs (as surveyed by Feldman, 1999) seem to be unanimous in concluding that knowledge spillovers, either intra-industry or inter-industry, are important and strongly bounded in space.

The (unverified) story that is usually told assumes that by being near to universities (where leading-edge research is carried out) as well as to a number of innovative firms, employees and owners of local firms will be the first to be acquainted with the results of important discoveries, or with the accessory knowledge that is necessary to exploit them commercially, thus gaining an innovative edge over distant rivals. More precisely, this story can be broken down into a *three-step logical chain*:

a). knowledge generated within innovative firms and/or universities is somehow transmitted to other firms;

b). knowledge that spills over is a (pure) public good, i.e. it is freely available to those wishing to invest for searching it out (non-excludability), and may be exploited by more than a few users at the same time (non-rivalry);

c). despite this, knowledge that spills over is mainly "tacit", i.e. highly contextual and difficult to codify, and therefore is more easily transmitted through face-to-face contacts and personal relationships, which require spatial proximity; in other words, it is a public good, but a local one.

One can level three critiques to such a logical chain.

First, it might be that what standard methodologies (such as the production function), data sets (patents and innovation counts), and concepts ("tacit knowledge" vs. "freely available information") suggest to be pure externalities will turn out to be, at a more careful scrutiny, knowledge flows that are mediated by market mechanisms (Geroski, 1995). These mechanisms influence local firms' innovation opportunities indirectly, that is *via pecuniary*, rather than *knowledge* externalities. In section 3, we show how the prevailing interpretation of the quantitative evidence on LKS has either mentioned many of these market mechanisms as *examples* of localised externalities (with little regard for the logical twists behind this claim), or simply ignored them, hiding behind the (supposedly) comprehensive label of LKS.

In section 4 we level a second, deeper criticism against the *a*.-to-*c*. logical chain, which addresses the prevailing conceptualisation of "tacitness" as an intrinsic property of some scientific or technical fields' knowledge base. We suggest that tacitness, if referred to knowledge flows rather than stocks, is a key *exclusionary* mean, which can be wilfully manipulated to prevent a number of actors (even local ones) from understanding the content of scientific and technical messages. At the same time, tacit messages can be sent to long distances either through written (possibly public) media or phone conversations, thus allowing knowledge to be shared within physically dispersed "epistemic communities", as a common property or a club good.

The third criticism refers to a common "modified version" of the *a.*-to-*c.* chain, wherein step *c.* is substituted/complemented by the suggestion that LKS is not (just) the result of inter-firm, or university-to-firm, communication, but also of localised inter-firm mobility (see again Feldman, 1999). In this case tacitness is invoked to assume that knowledge is embodied in a few people, who move it around across firms when changing job, with changes always occurring within a pool of local employers. In section 5 we outline a number of contradictions between this assumption and the treatment of knowledge as a local public good

3. Interpreting LKS studies: logical traps and open questions

In this section we discuss the prevailing LKS-based interpretation of the leading quantitative studies on the issue of innovation and geographical clustering. For the sake of reviewing we focus on a selected number of papers, and group them into two broad categories. A first, most influential category comprises all the econometric studies based upon the 'production function' approach, which address the impact of external R&D (especially public and/or academic) on private firms' innovation capabilities, sometimes with explicit references to the debate between different schools of economic geography (subsection 3.1)[7].

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 a more heterogeneous group of innovation, urban or regional economists, and can be quite innovative with respect of the data sets and methodology they employ (subsection 3.2).

3.1. 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" knowledge and information, the latter being often taken as a synonym for "codified" knowledge. 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 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 localisation of R&D 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 reclassifies patents into a restricted number of technological areas, and then shows that the number of patents of each US state for each technological area is a positive function of the R&D performed by local universities (after controlling for both private inputs and the state size, as measured by population). The relationship between patents and university R&D is then interpreted as a sign of the existence of some localised "technological spillovers" from the academic institutions into the local business realm.

A more careful examination of Jaffe's data reveals two key 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. US 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 between each other 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* product 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. That is, 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 most easily available econometric proxies.

Of course, Jaffe is well aware of these problems and tries to work out some remedy. In particular, he corrects for the inadequacies of the state as a 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. Such index, multiplied by the level of university R&D is then included 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 [8].

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) [9]. The authors' aim is to show that innovation counts, which they consider a better proxy of innovation output, 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, there is no control for the state size.

Above all, innovation counts for one single year (1982) are related to R&D undertaken by industry labs and by universities just a few years before, with the same lag for both kinds of R&D. 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 over" at all, since they could be sold *via* standard commercial transactions to business companies, or distributed to a selected number of sponsors via *club* arrangements, as we discuss in section 5.

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 localised 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 question) 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 city *s* and 4-digit SIC industry *i*) to test the role of specialisation vs. diversity, i.e. Marshallian vs. Jacobs LKSs. More precisely, they test whether the number of innovations from sector *i*, in state *s*, owes more to the city specialisation 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 specialisation (for some evidence pointing at the opposite direction, see Henderson; 1999) and, above all, interpret this as evidence that knowledge spills over *across* sectors rather than *within* them, although they have provided no evidence whatsoever on the existence of knowledge spillovers as such.

This tendency to force an interpretation on the data is even stronger in Feldman and Florida (1994). They employ again the innovation production function for thirteen 3-digit industries, in each US state. They also include, among other explanatory variables, the value added coming from firms that, within each state, belong to the 2-digit industry that encompasses the 3-digit one under consideration. That is, they test the existence of some (very generic) agglomeration effect. However, they insist upon calling this "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 specialised workforce, i.e. a Marshallian externality of the second kind, while network effects can be either defined as the outcome of non-market relationships among firms or as a Marshallian externality of the second type, i.e. one mediated by specialised 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.

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.[10]

3.2. Other statistical tests on LKSs

Despite being most influential, at least within mainstream economics, the production function approach is not the only methodology for testing the existence and exploring the nature of LKSs. A number of 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 these authors manage to track direct knowledge flows from academic research into corporate R&D. They find that innovative firms are more likely to quote research from a co-localised university that conducts relevant research, than from similar universities located elsewhere[11]. 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.

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 number 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 of 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 LKSs 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.

All of these studies certainly strengthen the case for the existence of important localisation effects in innovation activities, but do not prove, despite their authors' claims, the existence of LKSs. For example, there is no reason to believe that knowing about the local university's research results does not come from contractual arrangements with the latter (or with individual researchers therein), as indeed suggested by many of the case studies we review in section 6.

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

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

Key contributions in this field have 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."

Once again, the econometric evidence does not necessarily suggest the existence of properly defined "spillovers", i.e. *pure* knowledge externalities. As we will see in sections 5 and 6, we will build on these self-doubts and argue that, once one enters the black box, not much remains of the LKSs interpretation.

4. "Tacitness" reconsidered, and the property regime of knowledge

The distinction between tacit and codified knowledge plays a central role in much of the literature we have reviewed so far, but clashes against some recent developments in the economics of knowledge.

The latter point out that technical knowledge, and even more scientific knowledge, may be considered as 'tacit' not because it cannot be articulated (as, for example, the craftsman's knowledge) but because it is highly specific. Far from being vehicled only by practical examples and hands-on apprenticeship, it is usually reported orally or by means of written words.

That is, technical and scientific knowledge can be (and most often are) codified by developing an appropriate vocabulary, which may or may not be stored in a dictionary or codebook, but in any case retains well-defined meanings. At the same time, though, the *messages* that vehicle that knowledge can be tacit, in the sense that only a few portions of the relevant codebook are usually referred to *explicitly*, with many others left to the understanding or the intuition of the addressees, whose capability of disclosure vary according to their expertise in the field (Cowan, David and Foray, 2000).

The language used for exchanging technical or scientific messages is not the same language of the broader local community which hosts the firms (or the academic labs) that produce those messages. Rather, it is the language of a much closer and more restricted community, an 'epistemic' one, whose members learn how to communicate by developing their vocabulary through prolonged studies and, possibly, a few common experiences (Steinmueller, 2000)[12].

As long as the members of the epistemic community do not disclose their common codebook, the latter may act as a powerful exclusionary device, even for local actors who live and work side by side to the community members, but cannot understand the messages (openly) exchanged by the latter. At the same time, since tacitness (in this new definition) and codification are mutually compatible, tacit messages can be sent even to long distance by means of a variety of communication media (both written and oral).

It follows that it is up to the epistemic community members to agree about some rules for sharing (and possibly diffusing) the benefits of the discoveries they make by using/developing their language. As long as they reach and enforce a clear agreement, they have nothing to fear from communicating openly, or even from publishing papers and articles. These publications may convey (to whatever distance) tacit messages concerning the authors' knowledge assets, in order to arise the interest of potential research partners, wherever they are located (Hicks, 1995). The ensuing contract research agreements (or informal knowledge sharing deals; see below) will then provide, if necessary, for co-location or visiting arrangements. In this case, it is physical proximity that follows epistemic proximity, and not *vice versa*.

These observations are consistent with up-to-date definitions of the concept of "externality", which see the latter as the outcome of specific institutional arrangements, rather than the consequences of some natural properties of specific goods or services. As Cornes ad Sandler (1996) observe:

> "[t]he literature often treats certain types of physical goods or services as inherently possessing rivalry or nonrivalry, excludability or nonexcludability. However, this can sometimes be dangerous. For one thing, the economically relevant characteristics of a good or service derive from the structure of incentives provided for its production and/or consumption. A loaf of bread typically may be thought of as a private good, but a collective enterprise that bakes loaves and distributes its output equally among it workers creates an incentive structure that is similar to that encountered in the context of public good provision. […] In many contexts there are alternative ways of providing and distributing consumption services to individuals [with] varying degrees of excludability and […] nonrivalry.." 13

That is, the sharing rules agreed upon by the epistemic community may encompass a large number of intermediate cases between the two extremes of pure private and pure public goods, such as price-excludable public goods, common property, and club goods[14]. Knowledge property regimes are not exhausted by the dichotomic couple "private *vs.* (local) public good"[15].

Bearing this variety in mind, one can go back and re-examine the increasingly rich literature on sharing arrangements between scientists and engineers (Von Hippel,1987; Kreiner and Schultz, 1990; and all the studies quoted by Cowan and Jonard, 2000). In most cases knowledge is shared 'on request', i.e. members of the community are bound to help other members to solve well-defined technical problems, even if those other members work for rival firms. It follows that the members of the community are bound by reciprocity obligations, which complement the codebook disclosure rules as a powerful exclusionary device, and may be or may be not coupled to other similar devices based upon physical distance[16]. Therefore, even when distance matters, reciprocity obligations may exclude many neighbours from the externality flow. At the same time, such obligations may force the community members to refuse contacts outside their inner circle, and forgo their chances to access externalities generated outside it, even if at a short distance.

In summary, when tacitness is no more considered an intrinsic property of knowledge, but a property of the messages exchanged within an epistemic community, as well as the result of a system of incentives, one is forced to recognise that physical proximity may play a far more complex role of than that of a necessary enabling condition for benefiting from knowledge externalities.

It is possible to object that, although physical proximity *per se* does not imply any epistemic proximity, the former may be needed to create the latter, that is to create the language and codebooks whose sharing will then define the boundaries of the epistemic community. In fact, during the early stages of some research projects, or the pioneering of some technology, much of the relevant still has to be codified, so that it can only be transmitted by continuos interaction, practical demonstrations, and so forth.

However, epistemic communities may well survive to the end of co-localisation of their members. Even when dispersed in space, the latter will share more jargon and trust among each other than with any outsider member of their present local communities. And even when occasional meetings will be required, their frequency will be not necessarily as high as to impose co-localisation as a necessary requirement for belonging to the community. Besides, the extent and speed of the codification process will depend, once again, on economic calculus: codification costs entails some fixed costs, but help saving upon re-location and travel costs, by enabling some long-distance communications (vonHippel, 1994). As a consequence, even the length of time during which the community members will be co-located (or the time spent by a new member at close contact with some fellow ones) is not entirely dependent upon some exogenous characteristics of the knowledge base.

5. Localised mobility of skilled workers as a carrier of knowledge

An alternative (or, sometimes, complementary) knowledge diffusion mechanism that is often invoked by the LKS-story supporters consists in the *localised mobility* of individual workers, particularly the skilled ones.

However, labour mobility generate ‘pure knowledge spillover’ if and only if, as workers move from one firm to another, they help creating a common pool of knowledge from which *all the firms* they have been employed at are capable of drawing. That is, labour mobility must be supposed to help spreading knowledge (in particular frontier knowledge that is immediately relevant for enhancing innovation opportunities), instead of merely shifting it from one place to another.

Unfortunately, such a knowledge-diffusing function of labour mobility is not entirely compatible with the depiction of knowledge as “tacit” and “embodied” in human capital: if the latter is true, workers who move across firms may take away their knowledge with them, unless they have willingly shared it with their colleagues or bosses. This may require, once again, some codification effort and the definition of a proper sharing-inducing incentive system.

It follows that interpreting the evidence on the self-reinforcing mechanisms set in motion by labour mobility, especially in hi-tech complexes, with the very rough guide of the “public good vs. private good” dichotomy, is very dangerous, since it may suggest the existence of LKS, where indeed there is none (compare the studies we quote below with their interpretation by Feldman, 1999 - section 2C).

This line of interpretation is supported by a few recent contributions by Zucker, Darby and Brewer (1998) and Zucker, Darby and Armstrong (1998). They argue that the standard notion of LKS (according to which 'social' ties and meetings between local firms' employees and university scientists 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 lab settings 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 start-up locations within commuting distance from their home or university (where they tend to retain affiliation, also for reputation purposes and as a source of young assistants), thus creating localised effects of university research. Such localisation, however, is not the necessary consequence of any intrinsic characteristic of knowledge.

In the same vein, a very interesting piece of research has been recently produced by Almeida and Kogut (1999). Using a sample of semiconductors-related highly cited patents, the two authors replicate the exercise carried out by Jaffe et al. (1993). In addition, they focus upon the mobility patterns of individual patent holders (engineers) in a number of industry clusters, and find them to be high and highly localised, but only in Silicon Valley, which is also the only cluster wherein such mobility affects positively the innovation rate of local firms.

Once again these results raise more than one suspect about the "LKS interpretation" of the econometric and statistical findings we reviewed in section 3.

First of all, workers that embody relevant knowledge may tend to move 'locally', for a number of reasons (above all risk aversion and localisation sunk costs) which have nothing to do with their need to tap their colleagues in universities or rival companies for information and help (long-distance communications and regular meetings may do the trick especially if face-to-face contacts are needed only during the early stages of innovation processes).

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 the costs associated to search and screening procedures, as prescribed by the definition of Marshallian externality of the second kind.

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*, which is the only local public good. Embodied scientific and technical knowledge remain a private good, unless sharing agreements of the kind we mentioned in section 4 turn it into common property or a club good.

Secondly, we observe that localised labour mobility, while producing positive effects through knowledge diffusion, may also generate tensions and contradictions, i.e. congestion effects that, once again, are a characteristic of a local public goods. After all, the loss of experienced workers to the advantage of competitors can have damaging effects for those firms which are engaged in ambitious innovation projects. In these circumstances, firms may attempt to keep a proprietary control over new technologies and manufacturing experience by reaching some tacit agreements with other local companies, which prevent the participants from starting competitive bids for securing the local technical/scientific superstars, thus limiting skilled labour mobility (see interviews to Northern Italy textile machine designers in Lissoni, 2000; see also Saxenian's 1994 remarks about the labour market in Route 128). If this is true, labour mobility is never localised, but always cross-border.

6. Further explorations of LKS black box

The major limitation of the empirical literature we have reviewed in section 3 is that virtually no contribution has explored the ways in which knowledge is actually transferred among people located in the same geographic area. Besides working more on the issue of labour mobility (see section 5; we also we come back to this point in the Conclusions), we need to explore the price and non-price mechanisms through which knowledge may be traded between universities and firms (or individuals therein), as well as across firms.

First and foremost, we observe that much of knowledge transmitted from universities to firms has nothing to do with the public results of basic science, but consists of consultancy services to firms at the development stage. Rather than providing *innovation opportunities*, such knowledge transfer may enhance the customer firms' *appropriation capabilities* (subsection 6.1). Digging further in the issue of appropriability, we recognise that even the most open among firms and academic institutions may wish to exert some control over their knowledge outflows. This may be done by attaching some property rights or exclusionary arrangement to those outflows, thus turning them into a private good, to be exchanged via market transactions, or a club good, to be shared freely, but only within the borders of a well-defined network of relationships (subsection 6.2)

Finally, we 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 (subsection 6.3).

6.1. What do local Universities provide to firms? Innovation opportunities vs. appropriability means

The impact of academic R&D on firms' innovative performance is often cited as a clear instance of LKSs. The relevant question is: does the estimated impact of university R&D on local firms' innovation output (*via* knowledge production function or patent citation approaches) represent convincing evidence that academic knowledge may be dealt with as a local public good?

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

In the first place, one observes that local academic institutions and public research institutes may provide critical inputs for firms' innovative activities, such as *training* and *consultancy*, even if their current research is not *directly* relevant for those activities. Universities whose reputation has increased thanks to brilliant research records may attract brilliant students, thus providing a big push for the creation of a localised market for highly skilled labour, which will be possibly reinforced by increasing returns. The same kind of universities (or individual researchers therein) may also be the only ones capable of providing key specialised intermediate inputs, such as consultancies and testing at critical stages of product development. Notice that current research may be far from relevant for both kind of externalities: brilliant students and key inputs can be produced just by teaching and knowing about consolidated results in one's own specialised field, as many scientists actually do. More importantly, by producing graduates and offering services (or tolerating their staff when doing so), even universities with a lower research standing may help enhancing local firms' capabilities *to appropriate* the results of their own research efforts, even if they do not give them any *opportunity* to innovate. In both cases, no direct knowledge externality arise, as knowledge is diffused in the local context via the labour market and the market for specialised inputs.

In the second place, even those academic *research* activities that have a direct relevance for local firms' current innovation projects may have little to do with innovation opportunities (as stressed repeatedly by the LKS story), and much more with enhancing the appropriation capabilities of the beneficiary companies, once again *via* market mechanisms.

To understand this, one should first observe that local firms may end up quoting 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 names were those of whom had received higher-than-average research funds from the industry, had entertained continuing consulting relationships with it, and had tutored students who later on took up jobs within it. None of these links can be claimed to be a pure knowledge spillover.

The work by Zucker and Darby we mentioned in the previous section, is extremely important also from this, more methodological, perspective. In fact, it represents a key 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].

6.2. Markets 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 on the sources of knowledge and the means of appropriability (see references in Geroski, 1995). 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 are 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 needed to imitate a rival's innovation is comprised between 6-12 months (Levin et al., 1987) and that rivals generally learnt about decisions to develop major new products or processes 12-18 months after the decision has been made (Mansfield, 1985). Unless any direct proof is produced to show that the quickest imitators are located nearby the source of knowledge, such short lags cast some doubts over the assumption that *distance* affects imitation speed.

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 one 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 just a few firms in each industry. On the other hand, the observation of a significant co-localisation of innovation inputs (i.e. R&D) and outputs (i.e. patents) might be simply the coincidental development of similar answers to commonly perceived problems, which a group of co-localised competitors reach simultaneously by drawing on a pool of common (but well-established) scientific knowledge. In other words, what are apparently localised knowledge spillovers are no more than simultaneous independent findings (Geroski, 1995).

The third point we wish to raise digs further in this direction. In our view, any testing of the LKS hypothesis should compare the latter with non LKS-based explanations for the clustering of innovative firms. A very interesting explanation of this kind has been provided by Lamoreaux and Sokoloff (1997, 1999). Using historical patent data for the US, the two authors keep track of the career patterns of a number of inventors, 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.

Despite being it hard to generalise from these results, one is tempted to speculate about them and suggest that 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. Industries may move across regional and national borders without a corresponding relocation of inventive activity, as long as ‘soft’ institutions (such as trust, norms, and codes of communication) may be substituted by ‘hard’ institutions (such as property rights legislation and enforcement, and financial markets) that help building market mechanisms to mediate relations among inventors, suppliers of capital and entrepreneurs.

6.3. The time dimension of spillovers, and a few implications for firms’ localisation

Looking back to the previous discussion, we recognise that there is hardly any doubt that innovation networks are often localised. However, the rationale for co-localisation may have less to do with knowledge spillovers mediated by physical proximity, than with the need to access a pool of skilled workers and to establish transaction-intensive relationships with suppliers and customers.

Going back to the fundamentals of the economics of innovation, 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, we 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* may not spill over from universities to *local* firms, simply because the time they take before being fully understood (or coupled with the complementary innovations necessary for exploitation) is so long that they manage to reach over to long distances.

On the other hand, Mansfield (1995) convincingly shows that only a few top universities are up to the task of serving business companies by producing basic rather than applied research. This explains 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, although needing face-to-face contacts with the university researchers, those contacts will be far from being as frequent as to require co-localisation. On the contrary, companies buying applied R&D services will need almost daily contacts, which can be provided only by local universities, which in turn do not have resources and competencies for producing valuable basic research.

If it so, one should recognise that LKSs, although being a possible explanation for co-localisation, 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 are not necessarily constrained by geographical barriers. Moreover, these firms establish network relationships (i.e. alliances, join-ventures, collaborative research and so on) with customers and suppliers from all over a country, if not the world.

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.

7. 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 great conceptual confusion.

We have not denied that knowledge flows may be an extremely important agglomeration force. What we have questioned is the strategy of putting *all* of these flows under the common heading of LKSs, as a necessary step towards (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 pecuniary externalities, which are mediated by economic (market and non-market) mechanisms, such as the labour market, the market for technologies, and club or network agreements.

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

c). A large amount of the knowledge flowing this way has much more to do with enhancing the innovation appropriability strategies of local companies (by speeding up the development phases of new products and processes) rather their innovation opportunities (by providing them with new ideas).

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

The first entry in the agenda is the labour market, which we have examined in section 5. A crucial mechanism through which knowledge diffuses locally is the mobility of technologists and scientists, either across firms, and between firms and academic institutions. However, this is not necessarily true for all localities and all industries. Besides, it remains to be seen to what extent technologists and scientists, by moving across firms, contribute to the creation of a common pool of knowledge, or manage to retain control over their intellectual assets, either personally or along with selected members of the relevant epistemic community. Studying more in depth the career paths of a few key professional figures is therefore a research imperative.

A second line of research should deal with assessing more carefully the impact of local universities and public research institutes on firms' innovative activities. Our opinion is that the 'spillover' perspective has obscured the wide set of mechanisms through which those actors actually contribute to local and nonlocal firms' research efforts. These mechanisms ought to be explored by overcoming the far too easy, but obscuring metaphor of the "local community", and by studying in some depth the knowledge-based services which academic and public institutions (or individual scientists therein) sell to or share with local and non-local business companies. When doing so, more attention should be paid to the large number of club or common property arrangements that situate knowledge flows in between the two extremes of private vs. public goods. This, in turn, would require a big effort for establishing an explicit link between the geographical dimension of those knowledge flows and the disclosure rules foreseen in the related arrangements.

In both lines of research, the existing data sets on R&D, patents, and innovations counts will still play a prominent role, according to the new fashion of exploiting them as indicators of knowledge exchange links among individuals and/or organisations, or of knowledge stocks whose accessibility varies with distance (and not just as mere innovation output/input indicators, as it was the case with traditional studies on R&D productivity). However, we will need to couple those indicators with additional evidence on the identity and the activities of individual firms and inventors, in order to track the latter's movements in space, as well as their mutual relationships.

In any case, the urge to carry on more, and richer quantitative analysis must not lead us to avoid the most urgent task, which is that of re-assessing our conceptual framework, in order to introduce more sophisticated categories to describe both the contents and the property regimes of knowledge flows. Devoting time to such a re-assessment will possibly prevent us from running regressions for a while, but it will help keeping at bay the temptation to abuse, once more, of the LKS metaphor.

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Notes

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[3] LKSs play an important role also in some recent developments of trade theory, whose review, however, would go beyond the scope of this article. For a recent survey, see Barba Navaretti and Tarr, 2000.

[4] Some authors add to this list 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).

[5] Common synonyms for Marshallian vs. urbanisation externalities are respectively "MAR" and "Jacobs" externalities, where the former stands for "Marshall-Arrow-Romer".

[6] In a number of studies, Jacobs externalities of a pecuniary kind are also examined (Henderson, 1999).

[7] More generally, the production function approach to the theme of knowledge externalities can be seen as following three different lines of enquiry: *(i)* the large, well-established body of research on the social rate of return to R&D; *(ii)* the evaluation studies on the effectiveness of specific public R&D projects and/or R&D incentive schemes; *(iii)* the narrower, but more focussed stream of research we survey in this paper, which has more openly dealt with the issue of LKSs. 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).
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.

[8] More recently, Anselin et al. (1997) have 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.

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

[10] 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).

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

[12] Steinmueller also observes that 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 incessantly: outsiders, however close, may learn nothing of it.

[13] Cornes ad Sandler (1996; pp.9-10). Italics are ours.

[14] Price-excludable public goods occur when the producer can sell simultaneously to many consumers, and it is possible for individual consumers to consume any amount up to the total provision, and also for different consumers to face different prices. With common property goods, access to the good itself is typically restricted to members of a certain community. In addition there are restrictions on individual members' input levels and implications for the way in which total output is to be shared among the members. For example, in the case of fishing, instead of each taking home his or her own catch, there may be a strongly established tradition whereby the day's aggregate catch is divided up equally among the fishers. Club goods generalise the public good concept to situations in which the community size is endogenous. Any additional member of the club generates benefits to fellow members by reducing the per capita cost of a given quantity of public good, but contributes to a congestion phenomenon, which in the end places bounds on the desirable size of the club. All these definition summarise those provided by Cornes and Sandler (1996).

[15] Local public goods share with club goods the characteristic of community size is endogeneity, due to the existence of congestion effects. However, physical distance is the only exclusionary mechanism: all the people in the same area have access to the public good, but individuals are free to move around and finally choose the local community, or country, in which to contribute and consume public goods.

[16] For recent study on a sharing arrangement totally independent from physical distance, see Lakhani and vonHippel (2000).

[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.