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WORKING PAPER

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The Unit of Analysis for  
the Study of Innovation

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## **Introduction**

Different units of analysis are commonly used in literature to discuss the topic of innovation. In this essay I will try to show the advantages and disadvantages of looking at innovation through the lens of the firm, the industrial sector, and the territory. The first section briefly introduces the topic, with a short discussion about the phenomenon of innovation and technological change, and how this is discussed in the literature. In the second section the firm and the organization as a unit of analysis are introduced. I argue that this is the most obvious unit of analysis to be used to the study of innovation, and a very powerful one for model building. However, one of its main disadvantages is the fact that it is difficult to discuss externalities when using the firm as the unit of analysis. The next two sections cover the sector and the territory as a unit of analysis. Here the focus is on the interrelations that take place within an industrial sector or a region. Both these approaches share the advantage of being able to capture the phenomenon of externalities and the advantages of clustering and network management that are very important for innovation. However, the main problem with these units of analysis is the difficulty to move away from the case study and to build robust and generalizable models. Another problem for these units of analysis is the difficulties in the operationalization of the concepts and the analysis of the interactions that cut across sectors and territories.

**The Economics of Innovation: What's inside the Black Box?**

Economy of innovation departs from a neoclassical understanding of technology, and it claims that to achieve a convincing explanation of economic growth that overcomes Solow's paradox, it is necessary to reach a better understanding of technology choices and change that happen "inside the black box" of the firm (Rosenberg, 1982). This leads to the fact that the traditional research question on the definition of the conditions for a stable walrassian equilibrium is not the most relevant one. Economists should focus on the conditions that lead to change, cumulative causation, and ultimately evolution and growth, which are the most common characteristics in a capitalist economy (Nelson and Winter, 1982). In turn, a better understanding of the economics of innovation provides the elements to define innovation as an interactive process (Lundvall, 1988) and shed some light on the dynamics of the local system of innovation.

According to Freeman (1994) the economics of innovation started from the recognition of the intuitions but also of the limits of Schumpeter. The approach of the Austrian economist, and the role that he assigns to the entrepreneur "tends to obscure many important aspects of innovation and diffusion, which have been illuminated by later research". In particular:

1. the importance of external linkages for learning, and the cumulative causation that networking can provide;
2. the different forms of learning, and the accumulation and absorption of technological know-how, through R&D, learning by doing, and imitation, which in turn leads to a particular attention to be paid to the understanding of the ways organization learn and adapt to new knowledge;
3. the different role played by incremental and radical innovation, and the different degree of dependence and use of science and technology by industrial sectors;

4. the importance of inputs that come from the interaction with specialized and challenging customers that lead to a demand pull as a trigger of technological change;
5. the different paths of institutional change and the use of technology trajectories and paradigms to describe the evolution and lock-ins of technological change.

Innovation is a complex phenomenon, and not a homogeneous one. Multiple taxonomies of innovation have been suggested over time. A brief discussion of two of the most important ones, will help in the description of advantages and disadvantages of the three units of analysis that I chose to look at.

Freeman and Perez (1988) point out four different patterns of technological change: incremental, radical, technology system transforming, and technoeconomic paradigm shifts. What distinguishes these four types is the degree of change implied and the “proximity of the effect of change”, with respect to a certain unit of analysis, which can be the firm, a particular geographical location, or an industrial sector. Freeman and Perez point out the fact that different innovations lead to different level of discontinuity for the preexisting system of production and use. So **incremental innovations** depend mostly on “demand pressures, sociocultural factors, technological opportunities and trajectories”. They don’t alter significantly the technological trajectory of an industry, and they add to the technological progress of a sector in a cumulative way. This type of innovation shares very little with Schumpeterian “creative destruction”. **Radical innovation**, on the other hand, is characterized by significant discontinuities, and is generated from “deliberate R&D efforts”. They lead to new products or concepts of production that change quite dramatically the rule of competition and the competitive advantages within an industry. Suppliers and clients are affected, but the impact over the rest of the economy is not completely pervasive. **Technology system-transforming** innovative change has, on the contrary, an effect that is felt not only in the immediate proximity of the center of technological change, but permeates and affects quite radically the rest of the economy. Most of the time, the discontinuity that they lead to transcends the

technological realm and has significant effects also on the managerial practices. **Technoeconomic paradigm shifts** are radical changes that have consequences on the entire economy. A whole new set of technological, managerial but also socioeconomic systems is the result of the advent of a new paradigm, where the rules of the game, the language and the institutions are likely to be incommensurable with the old paradigm, like with the result of a scientific revolution (Kuhn, 1962).

Where this first taxonomy focuses on the nature of the disruption and its consequences, Pavtt (1984) suggests a different taxonomy for the sources of technological change. Innovation, therefore, can generate from four different sources. These four sources of technological changes are absolutely not alternative paths, but are rather ingredients for the innovation recipe, which might result from a different degree application of the four different types of innovative activities. This second taxonomy will also be useful in my discussion of the different units of analysis, since it points our attention to the sources of knowledge change that are external to the firm. We talk about **formal R&D processes**, when a centralized effort is applied to a problem solving activity for a specific scientific or technological problem. **Informal processes of technological diffusion** happen when the barrier to learn and imitate a specific imitation are quite low or nonexistent, and innovations travel from firm to firm, from sector to sector quite informally, without the intervention of too much tacit knowledge. **Learning by doing and by using** happens when externalities are internalized by a firm, which is able to absorb tacit knowledge by simply performing or adopting a specific practice or product. **Learning by incorporation** happens when this process of internalization is deliberate, and it is the first goal of a specific move. Innovations developed by others are then absorbed and incorporated into another organization, which recognizes a certain value for the exploitation of a specific innovation for its own productive process.

### **The firm as the unit of the analysis**

The use of the firm as the unit of analysis for the study of innovation stands on the grounds that the firm is the main actor in the innovative process. Microeconomics and technology management at the firm level are therefore the best tools to understand and deal with the nature of innovation. The focus is on decisions that are taken at the firm level, and that influences the direction of change for the organization that seeks to better exploit financial and human resources. Such a problem could not be effectively seen through the lens of neoclassical microeconomic theory. Three different sets of concepts are critical to understand the big turn from neoclassical theory and the progress of the economics of innovation and the micro-foundation of technological change. These in turn have embedded the seed of the limits of the firm as the only unit of analysis.

**Bounded rationality and absorptive capacity.** In a context characterized by bounded rationality a la Simon (1972), it is important to look at ways that organizations combine tacit and codified, external and internal knowledge in their effort to learn and imitate. The main tenant of Simon's theory is that individuals (and organizations), are not optimal in their decision making process and only in some cases "locally optimal" in the process that leads to the accumulation of information that is relevant for their choices. There are costs associated with the acquisition and processing of information, and, therefore, most of the situations that individuals and organizations operate in are characterized by uncertainty. It follows that, in order to understand agents' behavior, it is necessary to dismantle the rationality assumption that lays at the hearth of the classical economic theory. Simon suggests that the best way to understand individuals' behavior is to assume "bounded rationality", where agents behave in a manner that is "nearly optimal with respect to their goal and the resources that are available to its accomplishment". Following this line of reasoning though, in terms of innovation and technological change, Cohen and Levinthal (1990) introduce the concept of absorptive capacity, which in a bounded rationality setting represents one of the most

important assets that firms have to use and improve. The concept of absorptive capacity helps explain the way individuals and organizations learn since,

prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it to commercial ends. These abilities collectively constitute what we call a firm's "absorptive capacity". Cohen and Levinthal (1990)

Organizations differ from individuals since the forms of "collective learning" they develop have the goal to achieve commercial exploitation of ideas and competence. Communication within the organization is also critical, since learning happens at various levels that do not always share the same tacit knowledge and language. There is a tradeoff between the flexibility that the organization needs to allow its sub-structures to operate (and develop tacit forms of knowledge) with whom to pursue new forms of knowledge, and the function of "gate-keeper" that the organization needs to embody in order to assure a codified and shared form of knowledge which becomes the form of communication to assure a fruitful transfer and exploitation of knowledge absorbed from outside. Both the intensity and direction of learning are therefore critical to explain organizations' innovativeness and growth. Investments in formal in-house R&D investment is only one way through which firms grow their knowledge and experiment new technologies, but R&D is also important to make the organization able to absorb and exploit knowledge produced elsewhere. The returns on this investment and learning are highly cumulative since "learning performance is greatest when the object of learning is related to what is already known." The direction of R&D investment and learning shapes the direction of the organization's absorptive capacity and leads to a constant reshaping of the boundaries of bounded rationality and situations of lock-in and lock-out, with respect to specific technological realms.

**Routines, technological paradigms and dynamic capabilities** (Nelson and Winter, 1982; Dosi, 1982; Teece et al., 1997). When the assumption of perfect information is abandoned,

technology is no longer a trivial maximization problem. For the economics of innovation, the main consequence of the bounded rationality assumption is that technological change choices are “ill defined problems,” with multiple possible (suboptimal) solutions. An organization has to solve these problems relying on both codified and tacit knowledge. Nelson and Winter (1982) suggest that through experience, organization builds memory and experience and actually develops routines for problem solving activities. Firms are seen as a bundle of routines that in fact represent one of the most important assets of the organization. Routines evolve through time, and in a competitive environment typical of non-centrally planned economies, they go through a selective process, which resembles Darwinian evolution of different DNA setting and biological species. Routines optimization is therefore not a useful way to look at firms’ dynamics, whereas survival and evolution of the organizations that rely on a specific set of routines is a more relevant research question. Routines act as “focusing devices” (Rosenberg, 1982), to explain firm specific choices regarding technology and technological change. Dosi (1982) specifies the nature of these devices suggesting an analogy between scientific and technological paradigms:

Both scientific and technological paradigms embody an outlook, a definition of the relevant problems, a pattern of enquiry. A technology paradigm defines contextually the needs that are meant to be fulfilled, the scientific principles utilized for the task, the material technology to be used. (...) a "pattern of solution" of selected technoeconomic problems. (Dosi, 1982)

Technology is therefore a variable that does not only define the operations of the firm, but technological change has to be part of the strategic decisions of an organization. In order to look at this specific issue, Teece et al. (1997) define the concept of dynamic capability of firms and argue that in environments characterized by rapid technological change, anticipation, early adoption and adaptation to new strategies and technologies might well be among if not the most important factors to determine the competitive advantage of firms.

**Path dependency and technological trajectories.** Technological paradigms are selective, finalized and cumulative in nature. Their systematic application leads to the emergence of particular technological trajectories. Path dependency (David, 1986) is a consequence of cumulativeness. David argues that the emergence of sub-optimal technological outcomes can only be explained through a cliometrics perspective that shows how the development of a market got locked in a specific technological trajectory. The direction of learning and change in industrial sectors, as well as the development of local economic systems (Krugman, 1991), are determined by “accidents leading to a cumulative process”.

### *Advantages & Disadvantages*

The main advantage of this unit of analysis is the similarity in language and analytical tools used in neoclassical theory. Even if indeed the economics of innovation leads to a deep discontinuity with neoclassical theory, the fracture is not complete, and methods and models are still somehow compatible. This leads to the advantage that model building remains the main goal for both the microeconomics of innovation and the management of technology. Generalization of theories is therefore quite an achievable result.

The limits of the firm as a unit of analysis are recognized by the same literature that recognized the values of the “micro-foundation” of innovation (Dosi, 1984 and 1988). The attention on the firm and on the routines used by the firm to manage technological change, leads to the recognition of the fact that some of the resources needed to excel in innovation are not to be found within the boundaries of the firm but rather in the ways that the firm interacts with the local system and external resources. If on one hand this perspective enforces the importance of the firm as a unit of analysis and leads researchers to focus on absorptive capacity or search strategy of the firm (Kalila and Ahuja, 2002), on the other hand it becomes critical to explore the issue of the conditions that lead to the availability of (or lack of) key resources necessary to organizations. This takes the

analysis beyond the boundaries of the firm to explore the sources of knowledge and of innovation that are then absorbed and exploited by the firm, and more in general to the study of externalities.

Going back to Pavitt taxonomy, the firm as the unit of analysis is particularly suited to explain the technological changes that result from a centralized and deliberate formal R&D investment. In this setting, the Chandlerian firm, which decides the appropriate investment in research, and controls the exploitation of results, is the most relevant unit of analysis. The “typical” innovation that is explained through this model is either incremental or radical. As I’ve shown, however, these types of firms, innovations, and sources of technological change are not able to explain the entire phenomenon. In particular, deliberate formal R&D investments are not the only source of technological change, which in many cases comes from the absorption of research and inventions that take place outside the borders of the firm. Using the firm as the only unit of analysis might help understand how the firm develops absorptive capacity to get access to these resources (Cohen and Levinthal, 1990), but it is also important to focus on the nature of these transactions, how they come to be, how they distribute and concentrate, and how they travel through a sector or a cluster. The analysis therefore of technological diffusion and learning by doing, requires the focus on externalities and on the dynamics and interactions of an environment that goes beyond the borders of the firm.

### **The industry as the unit of analysis**

The competence-based view of the firm argues that the main source of a firm’s success and development is its own investment in R&D, and the skills that are developed internally by actually being involved in productive activities (Penrose, 1959). Sources of knowledge, competences that are acquired or internally developed, and organizational skills and routines are therefore the main source of competitive advantage for the Chandlerian’s model of the firm. As I have argued, most of researchers are today convinced that ideas can come from sources other than the firm’s R&D

department. Interactions on the market, with institutions other than the market, and not directly involved in production, can indeed make the difference for a firm's performance in transforming ideas into innovation. This ultimately depends on how the organization is able to identify and interact with different sources of knowledge in the "learning economy" (Teece, 1986; Lundvall, 1988; von Hippen, 1988; Cohen and Levinthal, 1990; Lundvall and Johnson, 1994).

The competitive diamond introduced by Porter (1990) stands on the assumption that it is critical to explore the interactions that take place within an industry, and related industries, in order to understand the sources of competitive advantage of a firm. Externalities do matter in the study of competitive advantage and in the study of innovation.

This is particularly clear, and the study of innovation at the industry level becomes necessary, in those sectors where the vertical control of the technology "from the laboratory to the market" is not feasible, since the complexities and heterogeneity of competences necessary to be applied is such that different actors specialize and control different phases of production (Borras and Zysman, 1997). In these cases, the use of time series and case studies is a very important analytical tool that helps the definition of the sector dynamics. Results of these efforts can be models (see for example Porter, 1990) that explain the conditions which allow firms to create and maintain competitive advantage. Other studies focus on the emergence and disappearance of particular business models, thanks to the introduction of particular "technology system-transforming" innovations (see for example Macher and Mowery, 2003 on the semiconductor industry in the age of e-business; or Glasmeier, 2000 on the paradigm shifts in the watch industry). The focus can also be on the linkages and on the relational capabilities of firms, and the goal of the model is to try and map the interrelations between agents, describe the different strategic positioning, and try to predict behavior of the agents in the innovation network (Conway and Steward, 1998).

### *Advantages and Disadvantages*

There are serious shortcomings if we look at innovation as a linear flow, from research to development to production and markets (Stokes, 1997). The most obvious one is the lack of emphasis on the feedbacks and inverse causal relationships (Kline and Rosenberg, 1986) that are common if we admit the assumption that innovation comes from very different sources. Going beyond the boundaries of the firm is therefore useful to understand these types of innovation, especially those that don't come out of a deliberate R&D effort. The industry is indeed a much more useful unit of analysis to properly appreciate the importance of these interconnections.

Sectors differ in the way they depend on innovation and the way that they evolve. Pavitt (1984) uses his already cited taxonomy to measure the dependence of the various sectors to the four different types of technological change. Since the description of the sector dynamics is the main focus of the analysis, the generalization to other sectors is not the primary goal. Also, sometimes, the description of some sector dynamics are descriptive of a specific moment of the technological development of the sector, and their predictive power ends up with the exhaustion of a precise business or technology life cycle.

The definition of the unit of analysis is also a considerable disadvantage, for both the precision of the theory and the limits of its possible application. As I have mentioned, different analytical tools have been used to identify and capture the proper intra sector dynamics. However, the interactions with other related sectors might vary according to changing technologies. The sector as the unit of analysis to study innovation is useful to give a static picture of the sources of today's competitive advantages and innovation. However, most of these models have to be redefined once a "system shifting innovation" is introduced. This creates problems for comparisons and the definition of appropriate time series, which are very important analytical tools for this approach.

According to the already mentioned absorptive capacity theory, and subsequent works, the importance of the interactions and of the network as a source of competitive advantage and of

innovative ideas, does not diminish the importance of the emphasis on the firm. It is important for the firm to define ways to be able to interact efficiently with the network. The study of these “relational capabilities” necessarily uses the firm as the most appropriate unit of analysis (Lorenzoni and Baden-Fuller, 1995).

What is also important to notice is that interactions that take place outside the boundaries of the firm might also take place outside the sector. One of the main disadvantages of the sector as a unit of analysis is the fact that it is not able to inform us about the importance of the territory and proximity for externalities to travel from firm to firm. On the contrary, even if sectoral differences and technological similarities are important, territory matters, and empirical evidence shows that knowledge and tacit assets are embedded in the territory, and they stick with it. The next section will explore more precisely why the local dimension matters in the study of innovation.

### **The territory as the unit of analysis, the nation and the region.**

The concept of National Innovation Systems (NIS) as defined by Nelson (1992), relies upon a precise definition of the three concepts of innovation:

the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, whether or not they are new to the universe, or even to the nation;

the concept of a system:

a set of institutions whose interactions determine the innovative performance, of national firms, where there is no presumption that the system was, in some sense, consciously designed, or even that the set of institutions involved works together smoothly and coherently;

and finally the appropriateness and the limits of the dimension of the nation.

In spite of the necessary simplifications that need to be done, and the limits of the national dimension, the theorists of NIS defend the “national identity” of the approach to innovation. The clearest advantage of the nation as the unit of analysis to study and innovation system is the possibility to establish comparisons across case studies, which seek to contrast the different approaches to the production of relevant scientific and technological findings and the process of knowledge transfer and exploitation. Key dimensions of the comparison are the direct policies for innovation, the IP protection settings, the relationship between industry, private and public research, the level of education of the workforce, and the spending policies of the government, among others.

Without rejecting the NIS paradigm, Nelson (2000) identifies five dimensions that make the concept of NIS not a “uniform unit of analysis”.

**The macroeconomic environment.** Innovation is a process very much embedded in society. Changes in the macroeconomic environment have repercussion on the capacity of a national system to excel in the rate of innovation. The challenges and the political priorities that the nation perceives shape the direction that technological change will take. The spillovers and civilian applications of findings first applied to the race to the moon and the cold war are only the best known examples.

**Interconnections of policies.** It is not possible to draw a precise line around the policies that have a direct or indirect impact on the NIS, also, some of these impacts can very well be unexpected.

**International dynamics.** International pressures interfere with the sovereignty of a NIS in three ways. (1) International trade and competition lead to the fact that decision taken in other NISs affect directly the course of development in another NSI. (2) A significant growth of FDIs lead to the fact that the once strong ties between large corporations and its original nation become much

looser. (3) The rules of international competition lead to homologation and standardization that diminishes the peculiarity of national systems.

**Nations are not uniform.** There are different ways that firms and other organizations are impacted by a national character. The way that politics and government can direct change in key institutions and actors, depends much on a “shared historical experience and culture”. Probably the most important limit of NIS theory is the fact that it does not elaborate more on the implications of the lack of uniformity within the nation.

The privileged direction of analysis to improve the explanatory power of NIS has been the study of differences between industries, and that led to the recognition of the sector as an indispensable unit of analysis to study innovation, especially in a context characterized by a global redistribution of production and sources of innovation.

However another important dimension that undermines the descriptive power of NIS is the regional level. The mere application of an analysis of the NIS to the regional dimension is not feasible and the so-called RIS (Regional System of Innovation: Cooke, 2001) shift the attention of economists to different aspects of innovation.

De la Morte and Paquet (2000) claim that the NIS is a concept too broad to focus on the interactions that happen at a local scale, which are particularly relevant to explain the advantages that lead to interregional differences. Porter (1990) empirically proves that much of the exports within a nation concentrate in particular “traded clusters” where the agglomeration and local market interaction generate positive feedbacks for the competitiveness of the firms. The focus of NIS on formal R&D activities is not able to capture the “untraded interdependencies” (Dosi, 1988) that happen at a very local scale.

Krugman (1991) suggests that economists should focus on the first two of the three advantages of agglomeration identified in the Marshallian district (Marshall, 1920): the presence and quality of local labor force and the specialization and excellence of the subcontractors, since the

third dimension of clustering advantages, knowledge spillovers, is difficult to measure. This third dimension is however extremely important to fully capture the importance of the local dimension of innovation and to explain the reasons of regional excellence, if we want to go beyond the focus on competitive dynamics that we can find in the early studies of clusters.

Jaffe et al. (1993) take up Krugman's challenge, arguing that knowledge spillovers among the firms in an industry are particularly relevant and that they actually "do leave paper trails" as evidenced by the analysis of patents and patent citations. Datamining techniques using patents prove to be particularly useful to explore concentration of technologies and the circulation of knowledge among firms and research labs that are inventing and wish to protect their IP for commercialization. Patent citations in particular are used as a proxy for knowledge spillovers. US patents have particularly desirable characteristics as a measurement tool, and in spite of the approximations and assumptions that need to be made in order to interpret their significance, they make possible comparisons through space and time. Jaffe et al. (1993) are able to show that the location matching probability of citing and cited patent is significantly higher than a "control frequency" which takes into account only the concentration of a specific technology. Assuming that patent citations do in fact measure knowledge flows, this approach is able to show that over time knowledge propagates from the center where new inventions are produced, to the proximities of the center, and over time to the periphery, like the wave produced by a stone in the water.

An early approach to explore the sub-national dimension of technical change can be found in the core-periphery models. Vernon (1960) justifies the spatial dimension of the industry life cycle, focusing on the importance and localization of external economies. He notices how, as an industry matures, firms tend to move away from the core, looking for other localization advantages in the periphery. This phenomenon frees resources in the core, for firms to focus on the next new industry. Norton and Rees (1979) empirically test the dynamism of this model, and they show that the "innovative capacity as a source of industrial rejuvenation" of the core cannot be given for

granted, and that the decline of the Manufacturing Belt in America shows that, as well as the localization of mature industries, so the rapid-growth industries can disperse. This study concludes recognizing the complex dynamics that enter into play:

It is not one cause per se but the accumulation of causal relationships that determined this dispersal of innovative capacity to the peripheral states of the U.S. (Norton and Rees, 1979).

In the knowledge based view of the firm, clusters become also a very useful unit of analysis. Maskell (2001) suggests that there are at least two dimensions to be kept into consideration, in order to explain the relevance of clusters for the study of innovation and the flow of knowledge. The first is a horizontal dimension: a cluster has the advantage to reduce transaction costs for information and knowledge flows between firms that operate in similar or related markets. The second dimension is vertical. Along this axis, firms located in the proximities of their clients and suppliers have clear advantages in terms of getting access to key aspects necessary to achieve incremental or even radical innovation for their products, by engaging in very frequent confrontation and problem solving activity. We can talk about suppliers and customers relationships both in terms of the service and manufacturing activity and in terms of the steps of the research, development and innovation (more or less linear) model. With both market and research partners the possibility of close interaction and feedback loops is an obvious advantage for technological change, and it is an aspect of analysis that is well captured by the literature that focuses on clusters.

The concept of learning regions (Florida, 1995) helps to embed the analysis of technological change in the understanding of regions. The concepts of absorptive capacity and local technological trajectories are applied to understand the dynamics of change that take place at a regional level. These trajectories of changes are found to be local and embedded in particular regional characteristics and dynamics (Harrison, 1992) that replicate, influence, and are influenced by the firm's specific technology trajectories.

Path dependency, cumulative causation and the importance of learning are therefore found to be extremely relevant at a regional level. The *innovation milieu* literature shows (see for example Camagni, 1995) that some places are able to activate conditions that are conducive to innovation, and that this is very likely to lead to positive feedbacks that augment the capacity of the local system to regenerate the sources of its competitive advantage. The mere co-presence of a research community and the industry doesn't necessarily lead to this particular environment. Other, more embedded, characteristics of the competitive environment are conducive to the emergence of "protean places" (Saxenian, 1994)

### *Advantages and Disadvantages*

The clearest advantage of using a unit of analysis that goes beyond the boundaries of the firm or of a specific industry is to capture the tacit and explicit knowledge flows that take place within a certain territory. In this case therefore, going back to Pavitt's taxonomy, territory as a unit of analysis performs much better than the firm to explain innovation that resolves through processes of technological diffusion, learning by doing and by using, and is not the result of formal processes of merging and acquisition.

Regions or nations and industries as units of analysis have the same limit of inability to focus on the firm's specific absorptive capacity and routines to absorb and exploit external economies. Two other main disadvantages can be defined for the territory. The first has to do with the difficulty to identify the most appropriate local scale of the unit of analysis, if we decide to abandon the NSI level. The second has to do with the fact that a local system is an open system, and therefore key interactions and knowledge flows are not local.

The methodologies to identify local clusters, industrial systems, or regional innovation systems are not always robust, and regional scientists insist that localization and specialization quotients are not the only relevant measures. Many different solutions are suggested. Porter (2003)

focuses on the fact that clusters specialize in products whose demand is not only local, and he therefore identifies a set of “traded clusters”. Feser and Berger (2000) warn practitioners to be extremely careful with a mechanistic application of the concept of clusters; they explore the national input-output table to understand the market interaction between industries. Through a factor analysis, they then identify clusters, focusing on the intensity of sub-supplier relationships. The study of the industrial districts led the national statistics bureau in Italy to identify local production systems, focusing on the commuting patterns and local sub-contractor interactions (Sforzi, 2002).

Bergman and Feser (1999) argue against the determinism of Porter’s cluster. The self-enforcing mechanism that lies at the heart of the cluster theory cannot be taken for granted, since “changes in the social, cultural, or political environment could lead to altered relations between cluster firms such that the positive synergies are reduced.” These authors affirm the importance of inter- and intra-industry linkages as the most important unit of analysis, whereas the concept of (local) industrial districts and clusters might shift the attention away from what is the underlying mechanism that leads to external economies.

If the nature of linkages becomes the crucial aspect, the next step will be to realize that not every single key linkage, which contributes to competitive advantage and creates external economies, has to be local. Key links in the value chain might be also non-local, and cannot be captured if the study centers on the nature of competition and collaboration within a regional cluster. The local dimension is sometimes difficult to make coherent with some of the key aspects of innovation and technology transfer. In particular, the knowledge based view of a cluster (see for example Maskell, 2001) implies that quite few clusters are able to be totally self-sufficient in the sources of knowledge that they then exploit. Innovation processes that might take place at a regional level, and that might lead to radical changes, or even paradigm shift, usually rely on different sources of knowledge which is not always available locally, but rather nationally or even globally.

Nevertheless the territory, at a regional, city, or metropolitan level, remains an important and useful unit of analysis even if we admit that not all innovation by imitation or by technological transfer happen locally. Castells and Hall's (1994) argument (see also Bathelt, Malmberg and Maskell, 2002 on local collective learning) is in fact that we still have to look at the region to understand what the region has to offer to the network. This enables us to see how it can be "on the network" in a useful way by developing the interfaces with a global network of regions and also by developing the "content" that is necessary to give the region an important node in a large network. This argument is very similar to the tenants of the absorptive capacity theory (Cohen and Levinthal, 1990).

However, looking at a local dimension of the innovative phenomena, does not necessarily solve the problem of what is the most appropriate unit of analysis, since focusing on a local system implies opening up a Pandora's box what still requires conceptualization and modeling. For instance, Jacobsson (2002) suggests that the analysis of the local system of innovation requires looking at three dimensions: actors and their competences, networks, and institutions. The operationalization of these concepts is not obvious, and probably multiple alternatives are available. This is obviously true also if we take organizations and industries as our units of analysis. However, I would argue that probably complexity is higher when we consider territories, given the heterogeneity of actors, networks and institutions.

One last limitation of the concept comes from the fact that for many industries competition is global, and the flow of key resources so that the competitiveness and innovations that take place at a regional level depends on the ties of the region with the global economy (Scott, 1996) and with other regions (see for example Saxenian, 2001)., With the emergence of global production networks and progress in the ICT's, changes in the organization of production do not lead to the elimination of distance (Storper and Scott, 1995), but rather to a redistribution of the sources of competitive advantage in an economy that continues to depend on the dynamics of innovation and technological change and a global division of labor.

**Conclusion: Triangulation of different units of analysis**

The study of regions starts from the assumption that innovation is facilitated and directed by conditions that take place at a national and global level., Firm specific dynamics are particularly important, and they might follow sector specific dynamics, but also the specificities of a local system contribute to the creation of particular conditions conducive to innovation and technological change.

Borrowing from Storper (1997), the triad of technology, the territory and the organization seem to be the most useful unit of analysis to focus on a form of competition which is at the center of competitive advantage, innovation and technical change. I would argue that it is necessary to take into account a set of multiple units of analysis to fully capture the nature of innovation. The limits of the three units of analysis complement each other in the study of internal routines and strategies, external economies and knowledge flows that contribute to the different types of technological change.

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