Learning and cooperation for innovation at local level: conceptual aspects and indicators of RedeSist

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1. Introduction

The role of knowledge in economic dynamics has been increasingly studied in the last few years. The way by which each economic agent acquires and develops his set of capabilities is rooted in knowledge accumulation. On the other hand learning is the vehicle by which generation and diffusion of knowledge occurs. In this sense knowledge acquisition is primarily based on cooperation via different forms of interaction. Although traditionally these concepts have been treated at the sectoral level it is being increasingly recognised that in the knowledge economy this dimension is not the most appropriate one. The pervasiveness of the diffusion processes associated to the knowledge economy and the increase in the use of knowledge and innovation reveals in fact the inadequacies of the traditional classification of economic sectors in capturing situations where industries are constantly changing and where market structures are becoming increasingly fluid (Lastres and Cassiolato 2002). Space should also be take into account since knowledge generation and innovation are localized, context specific and socially determined processes allows the demystifying of ideas about the possibilities of generating, acquiring and diffusing technologies in less developed countries (Lastres and Cassiolato 2002). RedeSist developed the concept of local productive arrangement precisely in order to cope with these problems.

The aim of this article is to provide a contribution about how to analyze and evaluate learning and cooperation in local productive arrangements. More specifically the proposed contribution is to develop a set of indicators for measuring forms of interaction and learning in local productive arrangements. In this perspective the questionnaire used in the empirical research of RedeSist will be the basis for setting up the indicators. The article will start with a proposed classification of interaction forms and then discuss the indicators.

2. - Knowledge, learning and interaction

2.1 Tacit and Codified Knowledge

The ‘learning economy’ concept (Lundvall and Johnson 1994, Lundvall and Borràs 1999) is based upon the hypothesis that over the last decades an acceleration of both knowledge creation and knowledge destruction has taken place. However, it is well established that the distinction between tacit and codified knowledge is of paramount importance for any discussion about knowledge as economic activity it is important to distinguish. This distinction was firstly set up by Polanyi (1958/78) and relates to the degree to which pieces of knowledge can be written down and transferred (Lundvall, 1997).

It is clear that the codification is a process by which “knowledge” is transformed into 'information' which can be easily transmitted through information infrastructures. It is also clear that new information technologies significantly increased the possibilities for codification of knowledge since they make cheaper and more controllable this process of reduction and conversion of knowledge and easier its the transmission, verification, storage and reproduction. As explained by David and Foray (1995), codified knowledge is typically expressed in a format that is compact and standardized to facilitate and reduce the cost of such operations.

It is also well established that, in contrast to codified knowledge, tacit knowledge cannot be easily transferred because it has not been stated in an explicit form. Tacit knowledge is strongly associated with skill and its codification remains very complex since as Polanyi, (1958 p.49) pointed out, the skilled person follows rules not known to him/her. According to Polanyi, as tacit knowledge is implicit but shared beliefs and modes of interpretation, the only way to “transfer” it is through a specific kind of social interaction similar to the apprenticeship relationships.

The distinction between tacit and codified knowledge is important, because tacitness implies that it is not possible to separate the knowledge from its carrier. Tacit knowledge can be accessed only by hiring skilled people or through merger with other organizations. It cannot be transferred and sold as separate items in the market. In the learning economy, where the pace of change is high, tacit elements remain at the core of individual as well as collective knowledge even though some analysts have consistently argued that information technologies significantly augment the propensity to codify knowledge.

Lundvall and Johnson (1994) proposed a now well-known distinction between different kinds of knowledge which are important in the knowledge-based economy: know-what, know-why, know-how and know-who. Know-what (knowledge about "facts") andKnow-why (scientific knowledge of the principles and laws of nature) components of knowledge are in fact information, "commodities", and bound to be codified. Know-how (skills or the capability to do something) and know-who (information about who knows what and who knows how to do what) are tacit in nature

Paradoxically the trend towards augmenting the possibilities for codification of knowledge is accompanied by another trend which is associated with an increase in importance of tacit knowledge. In fact, know-how (and skills in selecting and using information)- and know-who grows in importance as information becomes more complex and abundant (Johnson and Lundvall 2003). Know-how is really embedded in regions and organizations (Arrow, 1994). As a consequence it may be suggested that it is embodied into collective units. In this sense knowledge acquisition is fundamentally obtained through collective process.

Of course learning occurs differently depending of the kind of knowledge. Information (know-what and know-why) is associated to formal education while; the other two kinds of knowledge are rooted primarily in practical experience. Know-how will typically be learned in situations where an apprentice follows a master and know-who is learned in social practice and sometimes in specialized educational environments. Lundvall and Borras (1997) suggest that learning tacit knowledge develops primarily develops in day-to-day dealings with customers, sub-contractors, etc independent institutes. It is essentially a learning-by-interaction process.

We will see next some of the implications of the degree of tacitness to formal and informal learning processes in LPAs (Local Productive Arrangements).

2.2. Learning and cooperation in local productive arrangements

One of the central arguments of the concept of local productive arrangements is about the importance of tacit knowledge which is localized. Cassiolato, Lastres and Maciel (2003) point out that some of the advantages of the concept are that it: "symbolizes the real locus and covers the whole space where learning takes place, productive and innovative capacities are created and where tacit knowledge flows and represents the locus where policies to promote learning, innovation and competence building can be more effective, by allowing the definition of specific policies and instruments. In this case we would stress

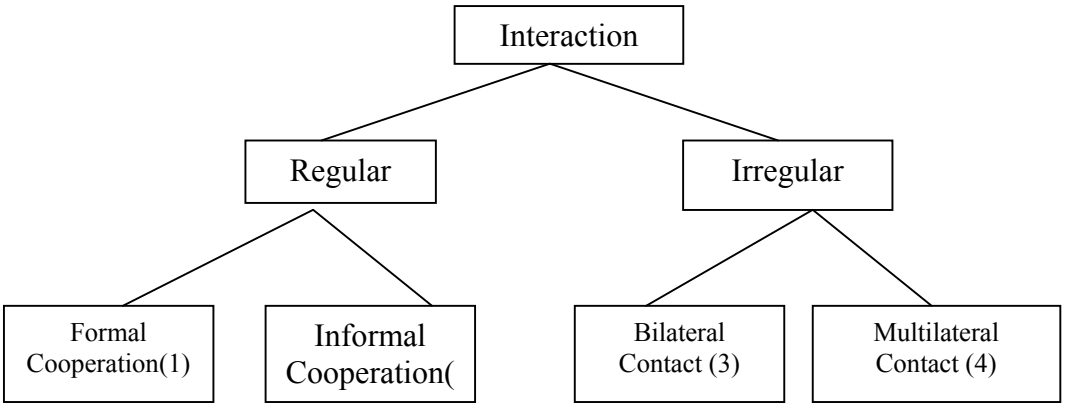
the relevance of the participation of local agents and to deal with collective actors, as well as importance of national coherence and coordination".

Learning-by-interaction is fundamental for RedeSiist's definition of local productive arrangements and for the purpose of this paper. Given the tacit character of knowledge, learning cannot occur in the form of codifiable exchange of information and procedures. So, innovation and several activities of production and generation of value require several forms of interaction among economic agents, who in turn interact with institutions.

The creation of specific forms of communication among the agents under is a determining factor for the development of *learning-by-interacting*. Nevertheless, in most cases the technological development of a firm depends on the capabilities of other firms through the production chain, competitors, clients and other agents and organizations. As\ an outcome, the greater the complexity of a learning process, the larger the frequency required for interactions. Typically, interactions may develop in the form of a cooperative effort, that it, cooperation is regarded as a particular case of *learning-by-interacting*.

Given the different forms of interaction as well as their idiosyncratic impact upon the improvement of the agents' performance under interaction, it is relevant that the taxonomy of forms of interaction among economic agents be sought for. Thus, the taxonomy shown below aims at helping with interpreting the *learning-by-interaction* process.

Diagram 1



The main method for classifying interactions is done by means of observing their occurrence. Interactions that have an indefinite or sporadic frequency are called *irregular* in the sense that they lack a defined repetition pattern. Interactions that present a defined recurrence pattern, chronological or interface periodicity of the productive process (generation of value) are called regular.

The regular/irregular classification leads to the four types of interaction numbered above. A regular interaction may be associated to a formal cooperation or to an informal cooperation. But a irregular interaction unfolds into bilateral contacts or into multilateral ones. We shall then discuss the justification for each one of these interaction types:

(1) **Formal Cooperation** - It does not only occur when interaction among the agents is not only regular, but also when there is a defined purpose and an expected result for the interaction. In that case, besides seeking a mutual benefit in the interactions, the agents under interaction define a method and an objective to be achieved. For example, Firms **A** and **B** agree on the development of a new product as well as on their participation in that part of the activity. In this case, the objective is to develop a new product. This form of cooperation may occur within the exchange of different stages of the production process (generation of value) as long as the interaction purposes are defined.

(2) **Informal Cooperation** - Unlike formal cooperation, neither the objective nor the purpose of the interaction has been defined. Cooperation may be recurrent and future repetitions are expected; however, it does not have a delimited scope for its objective or method. In that case, agents interact frequently and are aware of the reciprocal benefit of cooperation, but such interactions flow for several reasons without crystallizing into a specific project. For example, firms **A** and **B** establish recurrent interchanges for multiple ends inherent in the productive process such as consultation and information exchange. Nevertheless, neither the scope of the objects or methods of cooperation have been defined nor a result is expected for those interactions.

(3) Bilateral Contact - it refers to interaction between two agents which occurs out of a defined repetition pattern. In truth, this type may be the *once-and-for-all type*, or rather; it may be the first step towards the constitution of a future cooperation. The crucial point is that both agents are acquainted with each other without being sure about the benefit derived from the interactions. For example, firms **A** and **B** establish a dialog channel between themselves without necessarily discussing whether, how and how much it will be used. In short, although firms may occasionally switch on this exchange channel, they do not know if they will ever do it again.

(4) **Multilateral Link -** In this case**,** unlike the bilateral contact, interaction does not occur between two parts, rather, it occurs among a group of agents who share

some common identification mechanism; for example, firms that share the same sector or region. Typically, fairs, courses, and seminars covering the sector issues, which generate the gathering of several agents, some of whom are likely to establish bilateral contacts which may lead to future cooperation.

It should be pointed out that rather than representing a hierarchy of those interactions, the typology expressed above characterizes one of the possible forms of interaction among the economic agents embodied in local productive arrangements. The next section exploits the way in which the learning process and interaction develop locally

2.3 - The *learning-by-interacting* process and territorial dimension

Among the characteristics of *learning-by-interacting* previously discussed, one of the most important according to the evolutionary approach is that the consolidation of these interaction and cooperation processes contribute to the constitution of their own economic space. These spaces have a particular institutional frame as well as a determined stage of development, which conditions the precise way in which the generation and diffusion of codified and tacit knowledge take place.

In other words, the complexity of the relations and the degree of cooperation among agents, as well as the kind of partnership between research organizations and companies, the degree of qualification of the workforce and also the organization of the education system, for example, are factors which interfere in the decisive manner in which the learning processes take place, and therefore, in the generation, diffusion, and employment of knowledge. Due to that, local characteristics and, in this way, territorial dimension establish relevance in this analysis.

As pointed out by Lam (1998, p. 5) " *the knowledge of the firm is socially embedded: what firms can do, how their knowledge is configured, generated and developed is specific to the societal and institutional context within they are located"*. To put differently, "i*n emphasising 'localised capabilities' and 'untraded interdependencies', it has been shown that socio-institutional settings, interfirm communication and interactive process of localised learning play decisive roles in process of innovation and growth"* (Batheld, Malmberg, and Maskell , 2002, p. 10).

Considering all of these aspects, *RedeSist* researchers realize that the local setting should be regarded as an important unit of analysis that goes beyond a geographical delimitation unit, since the socio-economic, institutional, and cultural characteristics of a

specific space/territory condition the competitive and innovative performance of local agents.

Therefore, RedeSist defines local productive arrangements as territorial agglomerations of economic, political and social agents focusing on a specific class of economic activities, which present relationships even though they may be incipient. Generally, they involve participation and interaction among firms whose businesses include consumer goods, raw materials, and equipment supply, consulting, trade and service, among others - and their various forms of representation and association. They also include several other public and private institutions in the education and training of human resources, such as polytechnic schools and universities oriented to research, development, engineering, politics, promotion and finance (Cassiolato, Lastres and Maciel 2003).

To the concept of LPA is juxtaposed the definition concept of local innovation systems which happen to be those productive arrangements within which consistent interdependence, articulation and partnership result in interaction, cooperation, and learning with potential to enhance the endogenous innovative capacity, competitiveness, and local development. The LPA and local innovation systems concepts should be read together to provide an idea of dynamics

Lastly, it is important to point out once again that this focus is justified on the basis that all arrangements and productive systems consist of relevant interactive learning spaces in which their particular characteristics allow the existing communication channels to facilitate the diffusion of knowledge, thus allowing companies located within to obtain advantages concerned with innovative performance. In this way, geographical closeness not only creates private institutional and cultural conditions but also allows exchange of knowledge - especially tacit knowledge, among agents.

3. Proposal of cooperation, learning and innovation indicators within local productive arrangements.

3.1– Redesist Methodology of Empirical Studies in Local Productive Arrangement

The evaluation of Local productive Arrangement requires a investigation of their firms. Indeed, the empirical researches of *Redesist* use its owned questionnaire to collect information of local productive arrangements. This questionnaire is designed not only to understand the interactive and innovative firms embedded in a local productive

arrangement, but also to evaluate the externalities of the local level and other characteristics of local productive arrangements that improve their firms' performances. By collecting information of firms, public and private institutions, those surveys aim to describe crucial characteristics of the arrangements.

The current questionnaire is an improvement of previous empirical research tools in local arrangements used by *Redesist*. Moreover, this questionnaire is connected with Brazilian Technological Innovation Research (PINTEC). This questionnaire is structured in five blocks. The first block intends to describe some basic characteristics of the firm, such as the size and number of employees. The second block discusses more deeply some aspects of the production process and employee's qualification. The third intend to capture the main question involved in the innovative process, cooperation and learning among firms embedded in a local productive arrangement. The forth block discuss the main aspects related to the local externalities, such as local access to utilities, Finally, the fifth block discuss the impact of public policies to the performance of the firm in the local productive arrangements.

Third block of the questionnaire is the base to the proposal of indicators of learning and cooperation in local productive arrangement. In this block there are question to evaluate the origin of the information to the learning process, if these fonts are internal or external to the firm. Moreover, other questions discuss the cooperation of the firm in the local productive arrangement. All of these question, ask the firm to show the intensity of the interactions and the strength of the relationship with other agents in the local productive arrangement.

Despite the relevance of the questionnaire to the analysis of local productive arrangements, there is a missing step in consolidate de main information of the questionnaire in learning and cooperation indicators. This is the goal of the present paper.

3.2. Measuring innovative activity: problems and methodological aspects

The evaluation of both regular and irregular interactions of the firms within a certain productive arrangement requires a system of information. In addition, there is a need to elaborate criteria for evaluation of technological capabilities and consolidation of a regional innovation system and it is also necessary to speed up the mechanisms of development of S&T activity. In conclusion, it is a question of how to measure the cooperation for acquisition of knowledge, an essential tool for the firms' performance and technological innovation. But it is important to see how it can provide tools of public

policies towards the technological development, and more specifically, it is important to see it as a way to evaluate the performance of the productive arrangement.

But the evaluation of the innovation degree of potential within an arrangement, or more generally, within the innovative process in certain industries involves the elaboration of indicators which not only point out at the quality and volume of inputs used, but also evaluate the efficiency of the processes involved with focus on the achieved results (input indicators). It is true that the input indicators end up being privileged in most attempts to measure this aspect of measuring R&D expenses and formal education of human resources involved. However, it does not occur due to a supposedly unrestricted adherence to the so-called sequential linear approach. More often it occurs due to the difficulty in measuring precisely the results of innovative activity. This happens mainly because the input indicators have strategic importance for the firm and so, they are likely to kept confidential as they unfold within the firm and within the arrangement itself process, product or even another type of innovation involved. In consequence, such results tend to be underestimated.

The indicators employed to show only the R&D and human resources expenditure can furnish little information since they just show the process inputs. In consequence, they end up serving as a starting point for measuring the innovative activity within the arrangement. Nevertheless, the bibliometrical and patent indicators, which compose the principal forms of mensuration of scientific and technological research, also show impaired efficacy in peripheral regions. Those problems stem both from loose partnership between college-sponsored research and privately-sponsored R&D activity and from the fact that peripheral countries' journals do not always meet the requirements to be included on the referential bases. At best, they will just suit the most internationalized areas of scientific activity. (Licha, 1998)

Apart from the limitations of a few indicators, the attempt to develop the indicators of innovative activity and interactive processes which provide support (dig. 1) is still subject to other problems. Such problems stem both from the incipience within the effort to measure the S&T activity in peripheral countries and the limitations of the normalized information produced. Because that type of information complies with methodological approaches based on the perspective of organizational schemes of developed countries, it fails to detect local specificities of structural and institutional nature.

Many efforts have been directed to adapt methodologies of European manuals to the characteristics of the innovation processes in underdeveloped countries. *RedeSist*'s

methodology of empirical research clearly illustrates such application. However, It does not mean that the comparability in regard to the more fundamental S&T activities developed in such countries should be discarded. To put it briefly, it is necessary to elaborate (or adapt) a methodology of empirical research that detects specificities of technological activity of agents within those regions. But such methodology should keep the comparability with succedaneum statistics in regard to the same activity in developed countries.

It is necessary to go beyond the conventional input indicators (financial resources and training of workforce engaged in S&T activity) and product (articles, quotes, and patents) and develop paradigms that reflect specificities of the region and the distinctive elements of the S&T activity dynamics. Paradoxically, it should be highlighted that such problems/limitations will not be definitively solved. In this direction, the proposal of indicators which will be discussed soon allows a quantitative interpretation of the information collected from questionnaires used by *RedeSist* thus systemizing more clearly the primary information with regard to learning and cooperation processes in LPAs.

3.3. General Characteristics of Indicators

Cooperation and Learning, the subjects of this article, are concepts, which not only have an open research agenda in the economics literature, but also their mensurations involve an extra analytical effort. In this way, the characteristics of the present subject of study originate the basic attributes of its indicators.

Firstly, it should be highlighted that cooperation and learning are magnitudes which are expressed in the form of degree. In other words, such variables require an intensity measure. Otherwise, one would affirm that two hypothetical firms, **A** and **B**, possess a cooperation larger than that between firms **C** and **D**, while actually it seems correct to discuss whether exists more or less cooperation.

Notwithstanding, unlike other variables relevant to the economic analysis, cooperation and learning are not countable magnitudes, that is, they cannot be viewed from an absolute measure scale. As a result, the elaboration of indicators for these variables must observe this restriction. It is pertinent to balance it against other indicators commonly present in the topics of economics of knowledge and innovation. It is common to "measure" the innovative performance of firms, sectors, and countries through simple quantification of some proxy, such as the number of applied patents. Logically, this indicator format is not feasible for the study developed herein.

The set of indicators proposed in this article not only contemplates the central specificities of the variables considered, but also aims at satisfying the analysis of local productive arrangements inherent in the different sectors, regions, and institutional contexts. This last restriction leads to the need to elaborate indicators that are not so responsive to a certain arrangement profile, as to the number of firms or to the volume of economic transactions between the firms.

The structure of each indicator will be discussed individually below; however, some general characteristics will be anticipated. The main characteristic is that the result is featured in the interval between 0 and 1, thus indicating an intensity measure of the attribute. Predictably, considering the cooperation for an example in the superior limit of the interval it represents the hypothetical case of maximum cooperation between the agents within an arrangement. Another general characteristic is that although values are calculated for each firm, the final indicator considers the mean number of the questionnaire respondents. Lastly, it should be remembered that the questionnaire questions of reference are not responsive to the firm size, so they may be applied ---except for a few careful considerations, to different activity sectors.

3.4. Indicators of cooperation, learning and innovation: definitions and analytical properties

Evidently, due to the connected characteristics existing among the firms involved, a series of questions in the questionnaires used by *RedeSis*t may subside the formulation of indicators of cooperation, learning and innovation under an analytical perspective that privileges the local productive arrangements. This is possible due to the nature of the information provided, not only because it is within their spaces that capability processes are developed, but also because they assume an organizational format that is likely to facilitate the construction of technological capabilities and the development of innovative potential of such firms.

Most proposed indicators regard the cooperation processes within the productive arrangements; they aim at measuring the importance and the degree of pervasiveness such processes as well as other aspects that can be drawn from the questionnaires and which allow to detail the "structural" characteristics of the *inter-firm* cooperation in the LPAs. Among such characteristics are their innovative or productive efficiency, their degree of endogenous cooperation, that is, how local the cooperation relations are within the arrangement, and the degree of formalization. Even so, there is also an indicator which

explicates by analogy to what has been done for the cooperation how locally the learning processes are accomplished by the firms.

From *n* firms' answers on its involvement at cooperative activities is possible to define that

$$\widetilde{C}_A = \frac{1}{n}\sum_{i=1}^{n} c_i \qquad (1)$$

as being an cooperation indicator in the local productive arrangement, where

$$c_i = \begin{cases} 1 \text{ if firm i cooperate} \\ 0 \text{ c.c.} \end{cases}, \text{ so that } 0 \le \widetilde{C}_A \le 1;$$

Despite being a relatively simple measure, such indicator makes it possible to infer the degree of existence from both formal and informal cooperative agreements within the arrangement. It is true that such indicator itself is quite limited when it comes to the characterization of the innovative potential within the arrangement; therefore, it is necessary to elaborate a series of other indicators that qualify the degree of cooperation indicated in (1) in regard to various aspects: the importance that the several types of cooperative alliances may have for each firm within the arrangement, the degree of formality of the activity in which they are involved, and the space location of their sources of cooperation - referred to as degree of endogenous cooperation.

There are at least three types of "class" of agents with whom each firm within the arrangement may make some type of cooperative agreement. According to our taxonomy, a type of regular integration whose degree will depend on the nature of its purpose of amplifying its technological capabilities: firms (suppliers, clients, and even competitors), research centers (universities, research institutes and workforce training centers), and other agents (unions, support agencies, and financial agents). With regard to the cooperative agreement that the arrangement firms may make with such classes of agents, it is possible to draw three types of qualification of the cooperation from questionnaire responses: their degree of importance, formalization, and localization. In the first case, if $n_{i,l}^{j}$ is defined as the degree of importance that the firm *i* confers to the cooperation with the agent *l* from class *j* - which may be of no relevance (0), low importance (1), medium (2) or high importance (3) -, so it is possible to define

$$\widetilde{I}_i^C = \sum_{j=1}^{n} I_j^C P_j^{S_i} \qquad (2) \quad \text{where}$$

$$I_{i,j}^C = \frac{1}{k}\sum_{l=1}^{k} \frac{n_{i,l}^{j}}{3} \qquad (3)$$

It represents an indicator of the cooperation importance degree to firm *i* with "class" *j* of agents, where $j = 1,2,...,m$ (class), $i = 1,2,...,n$ (firms) and $l = 1,2,...,k$ (class *j*'s agents) and $P_j^{S_i}$ indicates the "weight" that cooperation with the "class" *j*'s agents has to firms of local productive arrangement which belong to sector S_i; as the composition of a APL involves firms which belong to different sectors, the weight $P_j^{S_i}$ make possible become the indicator more sensible to specific sector patterns of cooperation that primordially privilege interaction with certain class *j* of agents, thus preventing results very biased due to a sector composition very diversified of firms within arrangement; anyway, we will assume, for simplification, that $P_j^{S_i} = \frac{1}{n}$, such assumption will be accurate as good as homogeneity of the distribution of APL´s firms sector.

Thus, it is possible define the importance indicator of cooperation in the local productive arrangement as being

$$\widetilde{I}_A^C = \frac{1}{n}\sum_{i=1}^{n}\widetilde{I}_i^C \qquad (4)$$

In such a way that, as $0 \le \frac{n_{l,i}}{3} \le 1$ follows that $0 \le \widetilde{I}_A^C \le 1$.

It should be noted that considering the indicator in (4) it is possible to draw trivially the mean dispersion of the importance of the cooperation for the arrangement firms; so, considering $\overline{n}^j$ the average importance for the cooperation arrangement with the agents from "class" *j*, - which is no more than the mean term of the importance for the *n* firms of the cooperation arrangement with the k agents who compose the class *j* - it is possible to define the dispersion of the importance of the cooperation of the arrangement firms with the class *j* (σ_j) of agents so that

$$\sigma_j = \frac{1}{n}\sum_{i=1}^{n}\left|n_i^j - \overline{n}^j\right|; n_i^j = \frac{1}{k}\sum_{l=1}^{k}\frac{n_{i,l}^j}{3} \qquad (5) \quad \text{and} \quad \overline{n}^j = \frac{1}{n}\sum_{i=1}^{n} n_i^j \qquad (6)$$

which allow us to obtain

$$\sigma_A = \sum_{j=1}^{k}\sigma_j P_j \qquad (7)$$

and so $0 \le \sigma_A \le 1$.

It can be regarded as an indicator which qualifies the cooperative activity within the arrangement as it allows the evaluation of the dispersion of the importance of the existing cooperative agreements.

3.4.1. Endogenous cooperation and formalization of cooperation

Any attempts to grasp the degree of technological dynamism of a productive arrangement must undergo evaluation of the local features of the interactions realized by the firms. Besides other aspects that characterize cooperation (importance and formalization), it is also possible to draw from the questionnaire the location of the agents from the various "classes" with whom the firm may form some type of cooperative alliance. In view of this, it is possible to define the degree of endogenous cooperation in the local productive arrangement, so that taking *n* as the attribute for the location of the cooperative activity between the various agents of the *j-th* class of agents - which takes the value 1 for the cooperation that involves agents of the arrangement itself, 2 in the State,3 in another state within the national territory and 4 if the cooperation involves foreign agents -, by means of using inclusively the values assumed by $n_{i,l}^{j}$ and $I_{i,j}^{C}$ aforementioned, it is possible to define initially.

$$I_{i,j}^{EC} = \frac{\frac{1}{k}\sum_{l=1}^{k}\frac{n_{i,l}^{j}}{3}\varphi(n_{i,l}^{L})}{I_{i,j}^{C}} \qquad (7)$$

as being the indicator of endogenous cooperation degree of firm *i* with the *k* class *j*'s agents, where

$$\varphi(n_{l}^{L}) = \frac{1}{3}\left(4 - n_{l}^{L}\right), \qquad (8)$$

Whence follows in a trivial way that the *i*' endogenous cooperation degree with the *m* agents' class (*m x k* agents, as a whole) is given by

$$\widetilde{I}_{i}^{EC} = \sum_{j=1}^{n} I_{j}^{EC} P_{j}^{S_i} \qquad (9),$$

what allow to draw the indicator of endogenous cooperation degree at arrangement ($\widetilde{I}_{A}^{EC}$); in order that, it is enough to compute a simple average from (9) for *n* firms which constitute the local arrangement, such that

$$\widetilde{I}_{A}^{EC} = \frac{1}{n}\sum_{i=1}^{n}\widetilde{I}_{i}^{EC} \qquad (10);$$

Note that, as $0 \le \frac{n_{l,i}}{3} \le 1$ follows, from (7), (9) and (10), that $0 \le \widetilde{I}_A^{EC} \le 1$.

Similarly, from values assumed by $n_{i,l}^F$ – the attribute which point out if firm *i*'s cooperation activity with other potential agents is formal (1) or informal (2) – is possible obtaining an formalization degree indicator of cooperation in the arrangement. So that,

$$\widetilde{I}_i^{FC} = \frac{\sum_{j=1}^{m} I_{i,j}^{FC} P_j^{S_i}}{\widetilde{I}_i^{C}} \qquad (11)$$

Describe the formalization degree indicator of cooperative agreements made by firm *i* with the *m* others agents'class, where

$$I_{i,j}^{FC} = \frac{1}{k} \sum_{l=1}^{k} \frac{n_{i,l}^j}{3} \left(2 - n_{i,l}^F\right) \qquad (12)$$

and $P_j^{S_i}$, we had already mentioned; notice that if the whole cooperative activity at which the firm *i* is involved is essentially informal, in such a way that $n_{i,l}^F = 2 \ \forall \ l = 1,2,...,k$, so that, from (12), we have $\widetilde{I}_i^{FC} = 0$; if the latter is truth for the *n* firms which compose the local arrangement, and given that

$$\widetilde{I}_A^{FC} = \frac{1}{n} \sum_{i=1}^{n} \widetilde{I}_i^{FC} \qquad (13),$$

is the formal cooperation indicator in the arrangement, we have, by extension, $\widetilde{I}_A^{FC} = 0$. As the assumed values by $n_{i,l}^F$ necessarily exhaust all characterization possibilities of cooperation as for its formality, it is possible to obtain residually, from (12) and (13) (*mutatis mutandi*), an indicator of informality cooperation degree in local productive arrangement, I_A^{IC} say, seeing that is possible to show that,

$$I_A^{FC} + I_A^{IC} = 1 \qquad (14)$$

donde segue que $I_A^{IC} = 1 - I_A^{FC}$. Note that, as $0 \le \widetilde{I}_i^{FC} \le 1$, follows logically that $0 \le \widetilde{I}_A^{FC} \le 1$ and likewise that $I_A^{IC} \in [0,1]$, the latter by extension of property at (14).

3.4.2. Endogenous learning and profile of innovation

One of the most important properties of R&D activity and of technological learning itself is the cumulatividade *(Dosi, Marsilli, Orsenigo and Salvatore, 1995*): the results obtained by the various learning processes with which the firm is involved may bring increasing rewards (augmented benefits such as increased production by using equipment or, more generally, technological capabilities) as the relationships, which serve as sources of learning take an in-depth perspective and unfold across time. However, learning processes may not only originate from the firm's R&D activity, or even from its own experience in the productive process, but also from the interactions between the firm and the external agents (research institutes, suppliers and even competitors). Naturally, it makes way for a typology of the sources of learning as well as the types of learning (*by doing, by using*, etc).

However, it should be made clear that some aspects of the benefits deriving from *learning-by-interaction* are essentially improvement of knowledge. Such aspects are not to be confounded with the improvement of the productive capability yield by the learning associated with its own production process through the use of a certain technology.

The increments in productivity associated with the learning phenomenon are not likely to leak out through publishing, operational instructions or even through mobility between specialized workforce firms, as suggested by Silverberg, Dosi and Orsenigo (1988; p. 1041-42). It is important to point out that such increments occur in the very process of handling and operation of certain equipment/technology and in truth are a phenomenon of cognitive and mechanical improvement derived from repetition. In theory, this leakage would transfer its experience along with it. It is valid only for the cases in which the firms operate identical equipment. Even though those are regarded as usual tools for propagation of scientific and technical knowledge and formal learning and capability experiences, the real issue is how exactly a firm which still lacks a certain technology might benefit from *learning-by-doing* derived from the rival firms whose productive capacity is made possible partly due to such technology - which results from the intensity and duration of a specific activity. Thus, it should be clear that the benefits of learning that originate from the various types of interaction between the arrangement firms and other agents do not absorb the productivity gains resulting from the learning-by-doing by other firms, no matter if they operate similar technologies. However, the resultant productivity gains from technical improvements (via R&D activity) and organizational changes which can be associated with the use of certain technologies may be "transferred" to other firms within the arrangement through some type of interaction (e.g. some type of cooperative

agreement). What really matters is the acknowledgement opposed to what is usually affirmed. (*Malerba, 1992*). According to that, the nature of the productivity gains associated with the learning-by-doing type, which in turn is the result of efficiency and agility, which the firm operates its productive process with. Such qualities increase at the same rate as he firm strives to do "more than what it is already doing," and so it becomes unfeasible; and furthermore, appropriation of such benefits by firms that do not operate such technology become unfeasible and inconsistent. In this way, learning *curves (or learning-by-doing)* are phenomena of routinization of tasks within the productive process under a certain technical and organizational configuration. In other words, they are the effects of practice and although their result is a productivity increase. It has a distinct nature (for it demands little effort and is "nearly" involuntary) from technical improvement of machinery and equipment (transferable), which requires intentional effort, specialized knowledge and involves complex tasks that may not be known.

All in all, it is important to come up with an indicator which points out how the learning processes within the arrangement privilege the use of internal or external sources. To accomplish this, we shall use the information from the *RedeSist* questionnaire in order to know the agents who have served as a source of learning for the arrangement firms and their location related to the geographic space that circumscribes their location. Rather than distinguishing what is internal from what is external to the firm, our aim is to point out what is internal from what is external to the arrangement.

Similarly to the indicator of endogenous cooperation degree, we will do the variable $L_{i,s}^{I}$ be the average importance degree of source s of information, where $s = 1,...,h$ represents the number of sources of information (not including the internal information sources; then, in our particular case, h=3) to arrangement's firm I, so that, if we make $n_{i,l}^{s}$ be the attribute whose assumed value allow to knowing the importance degree attributed by firm for source s' agent l as long as a learning source. Then, as described before, follows that

$$L_{i,s}^{I} = \sum_{l=1}^{p} \frac{n_{i,l}^{s}}{3}; \qquad (15)$$

but such information, by itself, still does not allow us to infer the endogenous degree of the sources of information to the arrangement of the sources of information for the learning process; then, it is necessary to make use of the $n_{i,l}^{L}$'s value which denote the agents'localization which compose the h sources of information. So, by doing

$$\varphi(n_{i,l}^{L}) = \frac{1}{3}\left(4 - n_{i,l}^{L}\right) \qquad (16)$$

is possible to define an endogenous learning indicator from *s-th* source of information to the firm *i*, say $\Pi_{i,s}^{L}$, so that

$$\Pi_{i,s}^{L} = \frac{\frac{1}{p}\sum_{l=1}^{p}\frac{n_{i,l}^{S}}{3}\varphi(n_{i,l}^{L})}{L_{i,s}^{I}} \qquad (17),$$

the latter, when is known, allows us to get the *h* sources of information's average degree of endogenous learning to the firm *i*,

$$\widetilde{\Pi}_{i}^{L} = \sum_{s=1}^{h}\Pi_{i,s}^{L}P_{s}^{S_i} \qquad (18);$$

follows that a similar measure for the local arrangement as a whole (say $\widetilde{\Pi}_{A}^{L}$), which allow infer the endogenous learning of sources of information for the firms´ learning in the local arrangement can be obtained simply from the simple average of indicator at (18), that is:

$$\widetilde{\Pi}_{A}^{L} = \frac{1}{n}\sum_{i=1}^{n}\widetilde{\Pi}_{i}^{L} \qquad (19).$$

As $0 \le \Pi_{i,s}^{L} \le 1$ and from (18), follows that $\widetilde{\Pi}_{A}^{L} \in [0,1]$.

Last but not least, it is important to evaluate the predominant type of innovation which takes place in the productive arrangements. In the more theoretical literature and even in the methodologies that follow the early manuals for measuring S&T (Frascatti and Oslo), the innovative activity is distinguished by the nature of its results, which are: development of new products or improvement of the production processes. Nevertheless, it should be remembered that this dichotomic representation of the types of innovations operated by the firms in peripheral regions may not use up or even comprehend the innovation possibilities (*latu senso*) which might emerge in these spaces. It happens for the following reason: it is logic that a considerable part of the changes introduced by the firms may take place informally enough not to be stressed in the firm's very operations records. Indeed, organizational innovation not only has a great role in these regions but also can considerably improve firms' capabilities. Unfortunately, organizational innovation is unnoticed or ignored by research based on methodologies followed in the developed countries agenda of research on measuring innovative activity. The point is apart from the R&D department activities, the activities that generate significant changes for the small and middle-size firms in these regions tend to be connected to or associated with other

informal activities or even routine activities so that they are regarded as informal (e.g. new ways of commercialization, changes in the organizational structure). However, as aforementioned, these kinds of interactions probably are related to creation and diffusion of tacit knowledge.

It should be noted that a complex combination of historical, social and economic aspects tend to diminish the density of the interaction between the private companies in these regions and the public system of research (universities). Such interaction, together with other elements of infrastructure and the very educational system, allows the reproduction of innovative search schemes (*latu senso*). On the one hand, the absence of many of these elements conditions the speed or impairs the technological and organizational catching up processes; on the other hand, it brings forward creative processes (local) that aim at overcoming those limitations and so they enable some innovativity to make way in these arrangements. Their sequence may be accelerated due to the organizational frame that rules the economic relations between the firms in the local space no matter what the local productive arrangement may be.

It is true that in the very mensuration of the innovative activity the existing indicators are used up in the mensuration of the inputs (e.g. expenditure and formal education of the workforce directly involved in R&D) and the outputs of the innovative activity (e.g. bibliometrical and patents indicators), except for the mediations that turn such measurements mere approximations/estimates of the quantum involved in the processes and results of the innovative activity, to a certain point it cannot be exempted from evaluating the innovative activity for its results and for its mensurable aspects. However, the information obtained from the RedeSist questionnaire allows us to evaluate the predominant type of innovation in the arrangement in a simple way, or rather, evaluate the profile for the innovation within the arrangement.

Let us assume I^P and I^O be the relative number of firms in arrangement which make process/product and organizational innovations, respectively. As one innovation type not exclude another, allowing that one firm be involved with both innovation types, is effortless note that there is a number T so that, we can to do

$$I^P + I^O = 2T\,;\;\; T \in \Re^+ \quad (20);$$

from (20) we can to specify the variable V so that,

$$V = \frac{I^P - I^D}{2} \quad (21).$$

It is possible to show that

$$-T \leq V \leq T \qquad (21)$$

inasmuch as, from (20) and (21), we can to deduce that

$$I^P = T + V \quad \text{and} \quad I^D = T - V \,.$$

Then, the "profile" of innovation in local productive arrangement can be given by

$$\widetilde{V} = \frac{V}{T} \qquad (22)$$

where

$$-1 \leq \widetilde{V} \leq 1\,; \qquad (23)$$

As we pointed out before, this indicator can be useful for the following interpretation:

$\widetilde{V} = 1$: Entire predominance of process/product innovations in local productive arrangement;

$\widetilde{V} = 0$: Process/product and organizational innovation are equally distributed in arrangement;

$\widetilde{V} = -1$: Entire predominance of organizational innovations in local productive arrangement.

4 - Conclusion

The present paper discussed the topic of learning and cooperation in local productive arrangements. This analysis was made in two perspectives, one conceptual and other related to the proposal of indicators to *Redesist* empirical research methodology.

In the conceptual approach, the concept learning is much wider than getting access to information, as usually though in the neoclassical approach, indeed, the interaction between economic agents is the best way of creating and diffusing knowledge. One determinant of the development of the learning by interaction is creating specific ways of communication among interacting agents. Correspondingly, in most of the cases, the technological development of an individual firm depends on the capability of the other firms in the same productive chain. Furthermore, when as much as complex the learning process more frequently the interaction should occur. Thus, the process of interaction among two can so well developed that it consist in a cooperation rather than an interaction in general. The present paper proposed a classification of interactions in order to classify the main possibilities of creating and diffusing knowledge among local productive arrangement agents.

The indicators proposed in this paper aim to characterize and evaluate the intensity of cooperating among local productive arrangement. In fact, this paper presented indicators that measure not only the *intensity of cooperation* but also the degree of *formalization of cooperation* activities. By using that indicator one can demonstrate the distribution between informal and formal interactions in local productive arrangement. The indicator of *endogenous cooperation* infers the role of the local in the intensity of cooperation activity, i.e., how much of that intensity of cooperation occur in local level. Moreover, the paper presented indicators of *endogenous learning* that express the rule of local level to the learning process to the firms and, consequently, to the arrangement. Finally, the *innovative profile indicator* explain the main area of innovative effort (production/process or organizational) of the firms, and consequently of the arrangement.

The future step on this research path will be the creation of cross indicator that show the correlation of indicator, such as *intensity of cooperation versus endogenous cooperation degree* and *endogenous learning versus innovative profile.* Moreover, by using these indicators will be possible evaluating the difference among the local productive arrangements studied.

5 – References

ALBORNOZ, M., MARTINEZ, E. *Indicadores de ciência y tecnología : balance y perspectivas.* In: ALBORNOZ, M., MARTINEZ, E. (eds.) *Indicadores de ciência y tecnología: Estado del arte y perspectivas*. Caracas, Venezuela: Nueva Sociedad (UNESCO), 1998.

BALCONI, M. "Codification of technological knowledge, firm boundaries and cognitive 'barriers' to entry", *DYNACOM Working Paper,* 2000.

BATHELT, H., MALMBERG, A., MASKELL, P. "Clusters and Knowledge: Local Buzz, Global Pipelines and the Process of Knowledge Creation". *DRUID Working Paper* nº 02-12. http://www.druid.dk/ , 2002.

CORIAT, B. & DOSI, G. "Problem-solving and coordination-governance: advances in a competence-based perspective on the theory of firm". *Revista Brasileira de Inovação,* vol. 1, n. 1, p. 49-84, jan-jun, 2002.

DAVID, P. & FORAY, D. (1995) David, P. and Foray, D. (1995): 'Accessing and expanding the science and technology-base', *STI Review*, no. 16, OECD, Paris.

DOSI, G. "Sources, procedures and microeconomics effects of innovation". *Journal of Economic Literature, 26,* Sept, 1988.

DOSI, G. "The contribution of economic theory to the understanding of a knowledge-based economy". In: OECD, *Employment and growth in the knowledge-based economy,* Paris, 1996.

DOSI, G., MARSILI, O., ORSENIGO, L., SALVATORE, R. "Learning, Market Selection and the Evolution of Industrial Structures", *Small Business Economic*s, v. 7, n. 6, 411-436, 1995.

GRIMALDI, R., TORRISI, S. "Codified-Tacit and General-Specific Knowledge in the Division of Labour among Firms. A Case Study of the Software Industry", *Research Polic*y, 2001.

LAM, A. **"**Tacit Knowledge, Organizational Learning and Innovation: A Societal Perspective". *DRUID Working Paper* n. 98-22. October 1998

LICHA, I. *Indicadores de gestión de la investigación y el desarrollo tecnológico.* In: ALBORNOZ, M., MARTINEZ, E. (eds.) *Indicadores de ciência y tecnología: Estado del arte y perspectivas*. Caracas, Venezuela: Nueva Sociedad (UNESCO), 1998.

LOGAN, G. D. *Toward an instance theory of automatization. Psychological Revie*w, v. 95, n. 4, PP. 492-527, 1988.

MALERBA, F. "Learning by Firms an incremental technical change". *Economic Journal*, v. 102, Jul., pp. 845-859, 1992.

MALERBA, F., ORSENIGO, L. "Knowledge, Innovative Activities and Industrial Evolution". *Industrial and Corporate Chang*e, v. 9, n. 2, p. 289-314, 2000.

NELSON, R., ROSENBERG, N. "Technical Innovation and National Systems". In: NELSON, R. (ed.) *National Innovation Systems: a comparative analysis.* New York: Oxford U. P., 1995.

POLANYI, M. (1978): *Personal Knowledge,* Routledge and Kegan, London.

ROMER, P. M. "The Origins of Endogenous Growth". *Journal of Economic Perspectives,* v. 8 (Winter), pp. 3-22, 1994.

SILVERBERG, G., DOSI, G., ORSENIGO, L. "Innovation, diversity and diffusion: a self-organization model. *The Economic Journa*l, v. 98 (Dec.), n. 393, p. 1032-1054, 1988.

STERNBERG, R. *Cognitive psycholog*y. Nova York: Cambridge University Press, 1996.

WINTER, S. "Knowledge and Competence as strategic Assets". In: ZACK, M. H. (ed.) *Knowledge and Strateg*y. Boston: Butterworth-Heinemann, 1999.