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Knowledge life cycles inside local economic systems

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Summary

Knowledge in production is important in at least three respects. It confers value to products, it favours the creation of relations amongst economic actors, and attracts activities, thus generating dynamism on a territory. It can be the knowledge incorporated into capital goods (technology) or labour. It can be the outcome of past experiences, the fruit of intuition and research, or the result of imitation. Contextually, knowledge can be also diffused amongst actors, within a locality or outside it. With respect to local production systems, we will talk about localised knowledge, which consists in the capability to learn and internalise the tacit knowledge diffused in a particular space of production and to recombine it with the individual knowledge of each actor.

With these foundations, our paper addresses the mechanisms that favour the production, re-production and diffusion of knowledge within firms, territories and amongst local economic systems. We set out our analysis around two main ideas; the first concerned with the relationship between knowledge dynamics, firms and local economic systems, the other explaining knowledge dynamics inside firms.

This double perspective on knowledge life cycles inside local systems and firms, from our point of view, is largely related to the fact that production is essentially about knowledge, and that production decisions are mainly taken by firms. Of course, production does not take place in a vacuum. Therefore, the knowledge retained by firms may (or may not) have an impact on the knowledge capital of localities and, vice versa local economic systems influence the extent to which local knowledge can be cumulated over time.

The answers to our questions – what are the mechanisms and factors that make knowledge capital either grow, consolidate, or decay – require the introduction of a new concept, that of *knowledge life cycles*, which aims at capturing declining and ascending flows of knowledge within firms and local economic systems.

The relationship between the knowledge retained by firms and local systems can be, for instance, illustrated by the image of a large firm that, at different points in time, absorbs knowledge from a territory (for example, in terms of labour) and then releases it outside when increasing, for instance, the knowledge capital of a territory in the form of spin-off firms and new competencies. In this case, the firm works as a "territorial lung": when the firm first settles down it destroys knowledge; but when interaction starts with the outside system, the firm can stimulate the establishment of new firms and competencies. Under particular conditions, oppositely to what happens when a firm releases its knowledge, the presence of a large firm could bring to the destruction of the local capital of knowledge and, consequently, to the production potential of a territory. We support the theoretical analysis of the elements that lag behind knowledge cycles with more than 200 interviews undertaken in the Italian provinces of Reggio Emilia and Forli'-Cesena.

In parallel with territorial analysis, we develop a perspective on knowledge life cycle inside firms. Our main conclusion is that, over time, a firm's knowledge capital reaches the stage of maturity and must therefore continuously renovate its competencies. Knowledge does not always grow following a cumulative process, but it can evolve or stagnate.

♣ This paper builds on previous works of the authors, in particular: Poma, L. (2003) *Oltre il distretto. Imprese e istituzioni nella nuova competizione territoriale*, Milano, Franco Angeli; and Sacchetti, S. (2003) *Knowledge as Capital. How the Organisation of Production Impacts on Local Development*, Working Paper No. 4 (April), University of Ferrara, Department of Economics, Institutions and Territory. The empirical work relies on original data that belongs to Antares (Research Centre for Industrial and Territorial Policy) where Lucio Poma is president and Silvia Sacchetti researcher. The empirical work relies on original data that belongs to Antares (Research Centre for Industrial and Territorial Policy) where Lucio Poma is president and Silvia Sacchetti researcher. We are especially grateful to Lorenzo Ciapetti and Antares research fellows who have actively contributed to the empirical research projects to which we refer in this work. This paper has been presented at the Pisa Regional Studies Association Annual Conference, March 2003. A modified and reduced version is forthcoming in Cooke, P. and Piccaluga, A. (ed.s) *Regional Development in the Knowledge Economy*. London: Routledge.

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1. PRODUCTION SYSTEMS AND KNOWLEDGE

Within production systems, knowledge is important for a number of reasons: it confers value to products, it generates innovative dynamics, it simulates technological development, it creates competitive advantages, it favours the creation of relations amongst economic actors, and attracts activities. As a consequence, knowledge generates dynamism in local production systems.

We keep our focus on those aspects of the relationship between knowledge and the economy that are related to production. However, we approach a particularly vast concept, which can refer to the knowledge incorporated inside technologies, human capital, firm organisations, networks of firms, or within linkages amongst firms and other actors on the territory. Knowledge can be the outcome of past experiences, the fruit of intuition and research, the result of the imitation of secrets of production. Knowledge can be contextual, or the tacit capacity which derives from specialisation and successful experiences. In parallel, knowledge is subject to diffusion: amongst individuals, organisations, within a locality or between different territorial systems.

When talking about knowledge in production, the core dimension is the relationship between tacit knowledge, which involves human resources, and the knowledge codified inside production machineries. For Smith, the creation of wealth is due to dynamic rather than static elements of the division of labour. Static factors refer to the reduction of slack times, a concept that was subsequently developed by Taylor and applied to Fordist organisations. On the other hand, we associate dynamic effects with that part of learning which derives from the division of labour. Smith opens his monumental work with the following words: «The greatest improvement in the productive power of labour, and the greater part of the *skill*, *dexterity*, and *judgment* with which it is in any where directed, or applied, seem to have been the effects of the division of labour»[1]. Productive specialisation is a consequence of the division of labour and it allows, over time, to improve the speed (*dexterity*) of workers, the ability to make a better product (*skill*) together with the accuracy and capacity to discern (*judgment*). Workers thus develop critical capacities which enable them to evaluate not only their own work but also backward phases of production.

If in Smith's analysis the main focus is on *manufacture*, for which the tacit knowledge of the craftsman is fundamental, in the work of Marx the machine becomes the core of production. The technique (tools) applied to machines substitutes individuals, whose sphere of action shifts from that of physical production to the organisation, co-ordination and control of machineries. On the one side this impoverishes the knowledge and abilities of individuals with respect to manufacturing[2], to the factory[3], and inside the

[1] Smith A. (1994), *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776), The Modern Library, New York 1994, p. 3, our emphasis.

[2] *Cf.* A Ferguson (1767), *An Essay on the History of Civil Society*, D. Forbes (ed), Edinburgh 1966; Adam Smith, *An inquire*…., op. cit.; Charles Babbage, *On the Economy of Machinery and Manufactures*, London 1832.

[3] Cf. Karl Marx, Das Kapital. Kritik der Politischen Oekonomie. Italian translation: *Il Capitale*, Newton, 1996 [1867]. For a Marxist perspective on the impoverishment of workers' capacity caused by the division of labour, see H. Braverman, Labor and Monopoly Capital. The Degradation of Work in the Twentieth Century, Monthly Review Press, New York 1974.

modern firm with its automation systems[4]. On the other side the introduction of machines, over time, qualifies labour by substituting operational functions with more qualified tasks[5]. Machines can produce physical goods without the mediation of individuals. Men's production activities become those related to the organisation and control of machines as well as to their planning and design: it shifts from physical production to the production of knowledge.

Today, following recent technological changes, cybernetics tend to substitute also process control activities. Machines are programmed to "judge" situations, and even if this capacity is limited to specific instructions, their computing and simulation potentials have grown enormously, due to the development of very small but powerful silicon chips[6]. Thus, technique is progressing: on the one side it substitutes specific functions of individuals such as control, whilst on the other hand it supports individuals in advanced functions such as design. Some maintain that the future revolution of technique will be that of artificial intelligence, which will try to overcome individuals even on design and planning activities.

The economics of innovation has given to learning a crucial role. Stiglitz[7], in particular, maintains that, for innovation, the learning which derives from the use of techniques can be more important than R&D activities. Learning by doing and learning by learning are both ways to improve the knowledge capital of firms. Like a sort of Trojan horse, technologies embody the knowledge of those who have developed and produced them. To inject new technologies, therefore, means to introduce new learning possibilities, an opportunity which is facilitated where labour is necessarily qualified and has developed specific competences.

If Smith centred his analysis on manufacturing and Marx and Taylor on the factory, today the complexity which characterises production activities pushes an enquiry about knowledge beyond a strict focus on machines and human resources. Linkages amongst firms and between firms and institutional actors become important knowledge repositories as well. In this perspective, past and future receive a different meaning with respect to common connotations. We link past to the knowledge settled inside the firm; on the other side we see future as the capacity of a firm to generate new knowledge. This capacity develops along two directions. We call the first the *adaptive function* of firms, meaning that the capacity to create new knowledge is functional to an understanding of the evolving socio-economic phenomena with which the firm must interact. The firm adapts its internal organisation and knowledge to exogenous changes. We name the second connotation *innovative function*. In this case, the capacity to generate knowledge is functional to the ability to plan and design new production and organisational opportunities as well as to increase competitiveness. In this case, the firm is not a follower but a proactive actor of change.

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[4] *Cf.* F. Pollock, *Automazione*, Einaudi, Torino 1956.

[5] H. Kern e M. Schumann, *Des Ende der Arbeitsteilung?*, Werlag Bech'sche, Munchen 1984; Italian translation: *La fine della divisione del lavoro?*, Einaudi, Torino 1991.

[6] *Cf.* Sergio Mariotti, *Il paradigma tecnologico emergente*, in P. Ciocca, (ed.), *Disoccupazione di fine secolo. Studi e proposte per l'Europa*. Boringhieri, Torino 1997, p. 117.

[7] Stiglitz, J., "Learning to Learn, Localised Learning and Technolo gical Progress" in Dasgupta P. and P. Stoneman (eds.) *Economic Policy and Technological Performance*, Cambridge, Cambridge University Press, 1987.

The range of situations in reality is far more articulated and complex. When the knowledge capital of firms is static, firms may implement none of these two functions. Static knowledge is repetitive, as the case of a certain type subcontractors show. When the dynamism of economies augments due to the speed at which innovation evolves, to capital mobility and decentralisation of activities, subcontractors whose knowledge leaves space only to repetitive tasks are at risk. They are threatened by price competition, which sustains those firms that are able to reduce costs and which are often located in so-called less developed countries, where the cost of labour is kept at very low levels. Conversely, we may find firms that, because of a well-developed adaptive function, succeed in re-interpreting their knowledge, thus keeping their position on the market. The risk in this case is that firms do not make the hidden quality and the knowledge incorporated inside their products explicit. Another situation is provided by firms operating inside market niches or producing very high quality goods. Continuous innovation is crucial for these firms, which are usually leaders producing high value-added products, and growing at very high rates. Finally, there may be firms that make use of both functions. These are, for instance, multi-product firms that follow market evolutions with respect to one product, whilst proactively innovating on another.
During their evolution and consolidation, firms may go through different phases. For some of them knowledge can grow year after year, for others knowledge can be obscured by time, or it can rapidly grow, but then stops and quickly decays. This continuous tension between adaptive and innovative function creates "layers of knowledge" inside the firm. These pieces of knowledge can be kept active and functional or, in some cases, they can be forgotten because unfruitful in the light of new competitive dynamics. Over time, some of these layers of knowledge have reproduced, others have refined and grown, others have been lost because reckoned as unproductive and not useful or because difficult to transfer or reproduce. In any case, whatever its story is, the firm can be seen as an accumulation of tacit and codified knowledge. This stratification varies according to the nature of the firm, the industrial sector and the local systems in which the firm operates.

2. TACIT AND CODIFIED KNOWLEDGE

Most of our actions depend, for their achievement, on our knowledge that is made by a sub-group of knowledge of which the individual is aware when acting, and on a vast sub-group of knowledge of which individuals are not conscious. This second set is tacit knowledge[8]. By doing things the individual acquires practical knowledge and through a process of trials, errors and adjustments he/she memorises the sequence of actions that steered him/her successfully to his/her objective. This sedimentation of "memory" forms tacit knowledge.
Codified knowledge represents an extrapolation of tacit knowledge which occurs when the latter is "translated" and fixed inside manuals or incorporated by machineries. Codified knowledge is the language through which knowledge transfer occurs. Craft

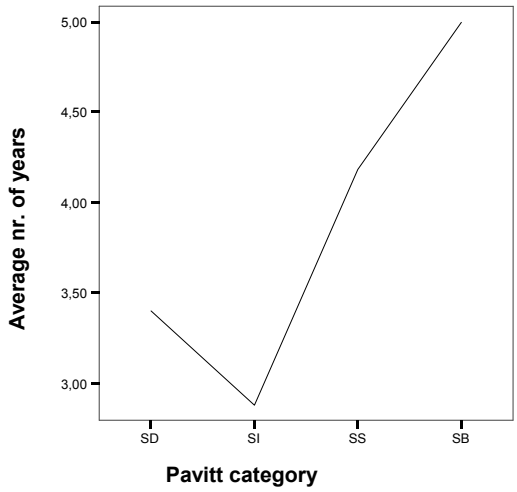
[8] For deeper treatment Cf. Michael Polanyi, *Personal Knowledge. Toward a Post-Critical Philosophy*, Routledge & Kegan Paul, London 1958.

enterprises and more generally small firms are principally built on tacit knowledge, whilst as size increases firms transfer mainly codified and standardised knowledge.
Both tacit and codified knowledge include advantages and limitations. If tacit knowledge allows to transfer large amounts of subsidiary knowledge, on the other side this process requires time. Being a tacit process, knowledge is transferred when the apprentice observes the master. Scholars will succeed in learning the master's knowledge at different levels, according to their abilities and only after a long period of training. A second limitation has to be linked to the subjective characteristic of transfer: the transmission of tacit knowledge depends on the ability of the master to teach in the same manner as it depends on the talent of the scholar to learn. Being the result of the combination of two subjective elements (the ability of the master and the scholar) the resulting amount of knowledge that has been transferred and the length of the process are very much variable. The third limitation is spatial. Tacit knowledge cannot be transferred at a distance. Transfer requires synchrony of time and space between the master and the scholar. When a system opens to external dynamics this third limitation may become problematic as processes of change increase their speed. Tacit knowledge must therefore be extrapolated and converted into a language that is suitable to be rapidly transferred over time and space.
Codified knowledge can be transmitted more rapidly. Its main limitation is that it does not allow to transfer all the capital that is included inside tacit knowledge. Large firms, by virtue of their scale and standardisation of production need to rapidly instruct labour and therefore they will mainly transfer codified knowledge. Oppositely, small firms and craft firms rely essentially on tacit knowledge. Although with different intensity, we can find both the components of knowledge, tacit and codified , in the large as well in the small firm.
The results of a recent research undertaken in the Italian province of Reggio Emilia (Emilia-Romagna) seem to support some of the above mentioned hypotheses. Firms have been classified according to the R&D intensity that characterises sectors. In particular, Pavitt (1984) provides criteria to classify firms on the basis of the attitude of a sector to produce innovation. Inside certain sectors firms ask for the technology produced by other sectors. Others, conversely, mainly rely on their internal R&D. According to this criteria, together with Pavitt, we classify our firms using the following four categories: "supplier dominated" (SD), "scale intensive" (SI), "specialised suppliers" (SS) e "science based" (SB).[9]
We found out that firms belonging to SS sectors are particularly oriented towards hiring managers with a university degree. Therefore, sectors such as those producing control equipment or specific high-tech components to other firms favour the introduction of individuals with a strong codified knowledge base, provided in this case by education. In parallel, a corresponding amount of firms hires managers without a university degree. This result suggests the existence of industrial realities for which the degree of complexity that characterises a sector does not require high levels of codified knowledge (as a university degree can be), but encourage individual learning inside the firm, in some cases with the help of training programmes.

[9] See Appendix A) for details on the classification of industrial sectors.

The learning process which brings managers to knowledge maturity takes, on average, three years for SD and SI sectors, whilst it takes more time for SS e SB sectors (four and five years, respectively). Therefore, in those sectors where knowledge and complexity evolve more rapidly, managers need to improve their individual knowledge through a learning process which is based also on experience and on the skills acquired inside the firm.

Figure 1: Average number of years that are necessary for the training of a manager by Pavitt categories



The presence of people with university degrees is important for the industrial development of a territory because it increases the possibility for firms to catch new technological or market opportunities. Inside the local system of Reggio Emilia, however, we find a paradox which is indeed not so peculiar for the Italian industrial situation: on the one side there is abundance of people with a university degree and, on the other, a lack of specialised technicians. 43 per cent of firms that have hired workers during the last five years, hired white-collar employees with a university degree for functions that until fifteen years ago characterised the job of workers with secondary education. In parallel, 79 per cent of firms has experienced difficulties in finding specialised workers and technicians. On the face of these results, firms seem to confront with a bottle neck which is not caused by the impossibility to access workers with the highest education, but individuals with specific technical competences or, in other words, people who are able to use technologies.

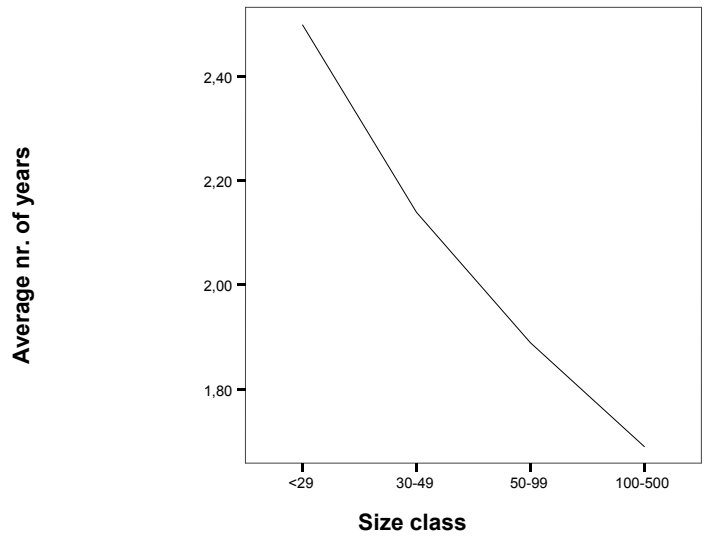
The length of the training period of workers with specific technical competences, in particular, varies according to the size of firms. We observe that firms invest in the training of skilled blue collars a period which goes, on average, from a bit less than two years to two years and half.

Table 1: Average number of years to reach knowledge maturity for a skilled blue collar by size class

Size class (number of workers)	Number of years
<29	2,5
30-49	2,1
50-99	1,9
100-500	1,7
over 500	2,0
Average	**2,0**

In particular, if we consider the first four dimensional classes, those including firms up to 500 workers, we observe a strong inverse correlation (-0.88) between the learning period and the size of the firm. The difference between small firms (<29 employees) and larger firms (100-500) is remarkable: the learning period for a specialised blue collar in firms with less than 29 employees lasts 50 per cent more than the learning period required inside firms with 100-500 employees.

Figure 2: Relation between firm's size class and the average number of years to reach knowledge maturity for a skilled blue collar



We read these results on the face of the smithian principle of the division of labour: as the size of the firm increases, individuals adapt to an increasingly focused functional specialisation, which requires, as the division of labour augments, shorter learning periods.
At the same time, what we have observed so far has to be linked to the different degrees of complexity and to the different levels of ability and skills that characterise various sectors and functions. In Table 2 we relate the length of the learning period of a skilled worker with the nature of the sector. Results support the hypothesis that we have advanced: firms operating in SI sectors require shorter learning periods. In parallel, in labour intensive sectors (those defined as SD) the maturation of a skilled blue collar takes longer. The highest number of years is needed, on average, for specialised suppliers (SS) where we find firms producing technologies and products which requires internal competences in design and development.

Table 2: Average number of years to reach knowledge maturity for a skilled blue collar by Pavitt category

Pavitt category	Number of years
SD	2,4
SI	1,6
SS	3,0
SB	2,3
Average	**2,3**

These results emphasises the tacit and codified nature of the knowledge that belongs to a skilled worker. The incidence of longer learning periods inside smaller firms, which are mainly labour intensive firms belonging to SD sectors, may be linked to what we were arguing before: tacit knowledge characterises especially small firms. But the tacit dimension is an important component for all dimensional classes: learning lasts for two years on average.

These results support what theory has already emphasised: consistent levels of tacit knowledge may be acquired only by accumulating experience and specific learning. This process requires time. The analysis by size class and Pavitt categories contributes to add a further point: the time required to transfer knowledge, here meant as transmission of *skills*, *dexterity* and *judgment*, is linked to the degree of division of labour and to the innovative characterisation of the sector.
Evidences of the relationship between codification of knowledge and the size of the firm come also from data on R&D centres (Table 3). Our empirical work has shown a

strong correlation (0.94) between the size of the firm and R&D centres inside firms. The frequency of firms with an internal R&D centre increases as size augments. From 8.5 per cent of firms with less than 30 employees, frequencies shifts to 48 per cent for firms with 100-500 employees and to 100 per cent for firms with more than 500 employees.

Table 3: Relationship between internal R&D and firm size – Frequencies within size class (%)

Size class (Nr. of workers)	Firms undertaking internal R&D
<29	8.5
30-49	17,6
50-99	31,6
100-500	48,3
over 500	100,0
Total sample	22,4

3. KNOWLEDGE PRODUCTION

Inside a closed economy the "institutional spaces" of production and exchange tend to overlap. As markets open these two institutional spaces are increasingly diverging. Competition does not occur only through techniques and technologies, but puts side by side and compare different institutional contexts in different countries. This widened competitive environment is one of the factors which has contributed to design a new international division of labour. Advanced economies are experiencing the difficulty to compete on costs against economic and institutional contexts where salaries are kept at the level of subsistence. Therefore, firms in advanced economies are obliged to improve the quality of their production, augmenting the value added and emphasising the "knowledge value" incorporated by goods or services. Physical production is the outcome of the institutional context where knowledge circulates. The tacit element of this knowledge surfaces and flows inside new information and communication technologies.

Knowledge is a collective good that is produced by firms but also by the whole territorial system. The production of knowledge is not a natural and casual event but it is strictly related to the institutional context where knowledge develops and consolidates: knowledge production is part of a "project" that must be stimulated and governed. The capacity of a country, of its regions and local systems to interpret and stimulate knowledge production determines the conditions and the modalities of competition, as well as the position of these territorial systems inside new production dynamics.

The internationalisation of markets has introduced new complexity in national economic spheres. Local economies are engaged into a wider system, which includes at various degrees most of the world countries. The intensity of inclusion seems to be extremely different: absolute for transnational and multinational corporations, almost

total for the financial sector, progressing for those territorial systems that have opened to external exchanges[10], still far for closed local systems which do not relate with other economic systems. National economic policies, local policies and firms' strategies can be more or less influenced by what happens outside, in other territorial systems or organisations. This is part of globalisation, which however appears as a multiform, contradictory, and in many aspects uncertain phenomenon.

Therefore, we need to be able to interpret this economic complexity. Interpretation, however, can be driven nor by machineries, nor by technological innovation: it is the entrepreneur, the individual, who keeps these possibilities and capacities. A new role for knowledge appears. Knowledge is not a complementary element incorporated by the skills, it is not reduced to learning by doing or learning by using, but it is the engine of development. It is the creation of knowledge which provides the tools to interpret economic complexity and uncertainty. Schumpeter was the first to entrust the entrepreneur with this role when he says that success depends on intuition, on the ability to see things in a way that will prove to be right afterwards, even when the actual choice is not justifiable, keeping the essential and neglecting the unessential[11]. According to this perspective, knowledge tends to "reveal" rather than to create directly, as the following words emphasise "[New possibilities] are always present, abundantly accumulated by all sorts of people"[12]. The use of knowledge can be seen as sensemaking capacity. The invention is "institutionalised" by the entrepreneur's actions. This has induced advanced economies to a transition from physical production, which implicitly wells up from knowledge, typical of Fordism and partly of post-Fordism, to the explicit production of knowledge.

[10] For an analysis of the impact of different forms linkages amongst firms Cf. Sacchetti, Silvia. and Roger Sugden, "The governance of networks and economic power: the nature and impact of subcontracting relationships", *Journal of Economic Surveys* (forthcoming).

[11] J. A. Schumpeter, *Theorie der wirtschaftlichen Entwicklung*, Duncker & Humblot, Leipzig 1912; English translation: *The Theory of Economic Development*, Harvard University Press, Cambridge Mass. 1934; reprinted by Transaction Publisher, New Brunswick 1996, p. 85.

[12] *Ibidem*, p. 88.

Table 4: Percentage of actual investments on expected investments, Province of Reggio Emilia 1994-2000

Type of Investment	1994	1995	1996	1997	1998	1999	2000
Research and product innovation	103%	49%	**203%**	117%	59%	139%	89%
Computer and software systems for business	117%	103%	**236%**	169%	105%	**206%**	125%
Computer and software systems for production	100%	63%	179%	161%	88%	182%	93%
Enlargment of sites	107%	82%	**205%**	**205%**	116%	169%	
Enlargment of production lines	151%	76%	195%	138%	107%	175%	88%
Restructuring/conversion of production lines	91%	80%	134%	126%	106%	3%	95%
New production lines	89%	45%	131%	163%	90%	0%	83%
Total investments	98%	65%	180%	129%	84%	131%	102%

Source: authors' elaboration on data Assindustria Reggio Emilia (Industrial Association of Reggio Emilia)

Interpretative capacity is reflected by the entrepreneur's expectations. Table 4 shows the evolution of entrepreneurs' investment expectations in the province of Reggio Emilia. In particular, the first three typologies of investments (research and product innovation, computer and software systems for business, computer and software systems for production activities) identify investments in intangibles, whilst the remaining typologies refer to physical capital. Data indicates the ratio between investments at time *t* (actual investments) and investments planned by firms the year before, at time *t-1*. The ratio shows which typologies have been over-estimated (percentage is below 100) and which, on the contrary, have required a larger commitment with respect to expectations (percentage is over 100). As far as intangibles are concerned, we observe important under-estimations since 1996. Investments in research and product innovation, in particular, is the more rising and falling typology. This stresses the delicate equilibriums of research outputs: planned investments for the realisation of specific projects could be interrupted before end when, for instance, unexpected difficulties arise during the research process. Differently, we observe that investments in ICTs (computer and software systems for business and production) are constantly under-estimated.

3.1 Information and Communication Technologies (ICTs)and knowledge production

The actual strategy of the European Union expressed by Agenda 2000 strongly emphasises the role of knowledge production. In its introductory section it states that the development of internal policies should happen according to four main directions: to promote economic growth together with employment opportunities, to stress the relevance of *knowledge and new technologies*, to modernise occupational systems, to

improve the living standard of people[13]. The specific section on knowledge, in particular, emphasises the role of *information and communication technologies* for the competitiveness of all economic sectors[14]. As a consequence, ICTs have been perceived as a possible instrument to increase the opportunities and competitiveness of SMEs, with positive effects on employment rates.

SMEs localised inside a specific territory can be seen as the nodes of a thick network of relationship that represents the territory as a system. The production of knowledge implies collective interaction amongst territorial actors. The distinction between physical production and its external context, which is the facilitator of activities, must therefore be combined with the collective production of knowledge. Therefore, we abandon the view according to which production and its environment are separated. We see, instead, two indissoluble dimensions, one is visible and includes physical production, the other is invisible and relates to the production of knowledge.
However, interaction is increasingly expanding beyond localities. The development of linkages which enable actors to benefit of complementary competences represents a possible way to overcome major obstacles that may jeopardise access to individual or collective opportunities. The space of these interactions may be local, or it may go beyond regional and national borders. ICTs, with respect to the speed and flexibility of exchange, may facilitate co-operation. This increases information flows and improves the possibility to share information with remote actors. Therefore, ICTs have opened new opportunities for the creation of long-distance networks, for example in the case of subcontracting networks ICTs are useful instruments to manage just-in-time systems or to co-design products at the distance.
Results from our empirical research in Reggio Emilia shows that 52 per cent of firms uses ICTs to interact with other firms.[15] However, the innovative potential of ICTs is not fully exploited. ICTs are perceived and used as accelerators of old production and organisational modalities rather than as radical technological changes that redefine production and the organisational context. In particular we have observed that firms in Reggio Emilia do not exploit the communication potential (knowledge circulation) of ICTs, nor their project making potential (knowledge production). This is shown by data on the motivations that have supported the introduction of these technologies. 95 per cent of users relies on ICTs to communicate, 78 per cent to transfer files. Both these two functions could be substituted by traditional technologies, such as the telephone or mail. Only one quarter of ICTs users apply ICTs to co-design products in partnership with other firms. ICTs seem therefore to be a useful instrument to enhance the circulation of codified knowledge amongst firms, whilst the creation and design of products are undertaken according to traditional ways.

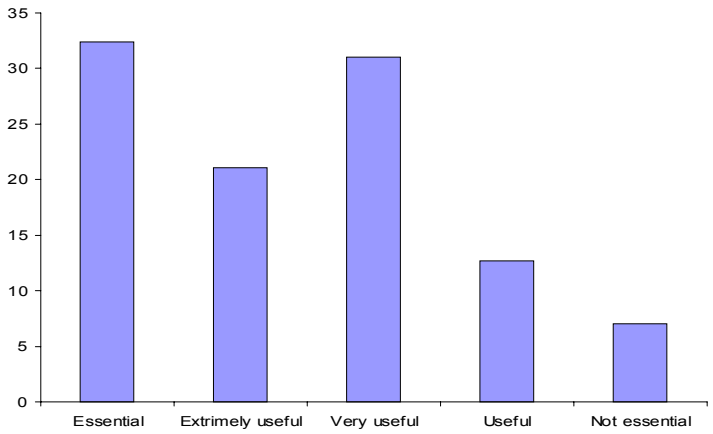
[13] *Agenda 2000*, July 1997, p. 17.
[14] *Ibidem*, p. 19.
[15] 42 per cent of users utilizes EDI, whilst 16 per cent rely on ERP.

Table 5: Objectives that are pursued with the use of ICTs

Motivation	% of user firms
Communication	95,1
File transfer	80,3
To manage integrated process information	36,1
Co-design products	26,2
To accelerate post-sale services	23,0
To delegate customer services	13,1
To create new products in partnership	8,2
Other	4,0

ICTs brake with previous technological paradigms and imply a new codification of competences and knowledge. In terms of industrial organisation, the small firm owner has generally a deep knowledge of its machineries; he/she is able to adapt them to the productive process introducing incremental innovation as a distinctive action of SME's. Moreover, he/she is also able to estimate the productivity of the machinery and assess the convenience of a new purchase. Technology dissemination policies focus, in this case, on information. The entrepreneur/owner has sufficient knowledge to assess production technologies and, in order to undertake a process of technological change he/she only needs to acquire the necessary information. The introduction of ICTs breaks down this mechanism. Knowledge must be codified anew. This can be done more easily by large enterprises where most of the knowledge is codified, rather than by small firms which are more used to tacit forms of knowledge. In the latter case, the entrepreneur may not have the capability to adapt his knowledge to the new paradigm.
Our territorial analysis has considered the entrepreneurs' perception of the magnitude of change introduced by ICTs. 32 per cent of user firms reckons the essentiality of ICTs.

Figure 3: Entrepreneurs' judgment on ICTs



The declared essentiality of ICTs for inter-firm production relations suggests that for one third of firms these technologies are not juxtaposed to traditional communication technologies as an alternative, but they are conceived as opening new opportunities.
When the technological change induced by ICTs is followed by organisational change we can assume that firms will increase their productivity. 64 per cent of user firms has indeed declared to have modified its structure as a consequence of ICTs. Amongst these, we observe a neat predominance of firms that have enlarged their structure. This suggests some considerations about the implications of technological change on labour. Knowledge is a form of capital[16] which deteriorates over years. Lately, the cycle that includes learning, the creation and use of knowledge has become shorter (the "lead time of knowledge"). The life cycle of technologies, where technologies represent the application of scientific knowledge, has become shorter and this is particularly evident when thinking about the frequency with which ICTs renew themselves. Rapid changes may create a demand for specific competences. In this case, it seems that the technological change introduced by ICTs has not induced the substitution of labour for technologies. Rather, ICTs have created the space for new competences. Amongst the firms which have restructured their organisation by virtue of ICTs, 84 per cent has enlarged their structure by hiring new personnel.

4. THE KNOWLEDGE LIFE CYCLE INSIDE THE FIRM

Our analysis of the mechanisms that characterise the production of knowledge introduces a concern about the relationship between knowledge dynamics and local economic systems, and knowledge dynamics inside firms. The answers to our questions – what are the mechanisms and factors that make knowledge capital either grow, consolidate, or decay – require the introduction of a new concept, that of *knowledge life cycles*, which aims at capturing declining and ascending flows of knowledge within firms and local economic systems.
Resources continuously combine and in so doing they create new value which is a cause of the wealth of nations. Knowledge is one of these resources. Better still it is knowledge that enables the process of bringing resources together.
More generally we can say that all resources are subject to a process of obsolescence which, over time, diminishes their value. Positional goods[17] represent an exception because, by virtue of their uniqueness, they increase their value as time goes on (for instance diamonds, gold, Carrara's marbles). Over time, other raw materials have diminished, for various reasons, their value, until they were unused. This has been the case for coal, PVC, asbestos, or iron which is often substituted by alloys of different materials. Wool, the raw material which characterised the industrial revolution, is more and more substituted by synthetics. Raw materials are changing also in the food

[16] Cf. Sacchetti, Silvia (2003) "Knowledge as capital. How the organisation of production impacts on local development", Working Paper Nr. 2, University of Ferrara, Dep. of Economics.
[17] That of "positional good" is the main concept of Fred Hirsch's work, *The Social Limits to Growth*, Cambridge Mass., Harvard University Press 1976.

industry with the introduction of genetically modified seeds. Technologies are changing as well: their equipments, their power engines, and their technique. Transistors have substituted valves, plastic is used instead of steel, silicon has become a precious construction material. Machines, which were manual at their earlier stages, turned to automation and finally to numeric control, thus improving their precision and reducing production times. Besides, technologies have reduced their impact on the environment, becoming less polluting. The revolution introduced by computer science and by its application to machines, as we have mentioned earlier, has further contributed to modify the knowledge of people. Raw materials, technologies and machines are changing, therefore the individual knowledge of those who produce technologies and of those who will use them are becoming more and more different.

On technological trajectories we can count a number of contributions, coming from different disciplines: economic history, industrial economics, economics of innovation, business studies. Economists have been flanked by labour sociologists and psychologists who have enriched literature with contributions on the obsolescence of specific capabilities and of human resources. Less relevance has been instead given to the obsolescence of knowledge *per se* and to its production context, where by context we refer to the firm or to the territory.

The idea of introducing time in the analysis of firms and industrial sectors is not new. Vernon's idea of the product life cycle[18] proposes four distinct phases to which correspond different firm's strategies (entrants and incumbents strategies, for instance). The main theme that underlines these studies is physical production. Indeed, the four phases of birth, growth, maturity and decline are linked to consumers' demand for goods. The idea of the product cycle, therefore, projects us onto the final stage of production.

Differently, our perspective builds on the idea of knowledge production, which precedes the stage of physical production. Shifting from physical to knowledge production, we radically change the subject of the analysis. Because we refer to knowledge inside the firm as a complex system which cannot be identified with a single product or machine, there is not a correspondence between the two cycles, the cycle of a product and the cycle of knowledge[19]. Some stages of physical production could correspond to different phases of the knowledge life cycle or more generally the two cycles could relate according to irregular patterns.

The knowledge capital of a firm needs to be constantly renewed. Therefore, it requires continuous inward flows of new knowledge. The most precious source of knowledge is learning, which is stimulated by educational and training programmes, by communication[20] and interaction (especially for complex activities that require the combination of complementary pieces of knowledge), by participation,[21] and by R&D activities. Knowledge flows allow a firm to renew its competences when otherwise competences would reach, at first, the stage of maturity and then they would start a

[18] Vernon, R. (1966), "International Investment and International Trade in the Product Cycle" *Quarterly Journal of Economics*, 80(2): 190-207.

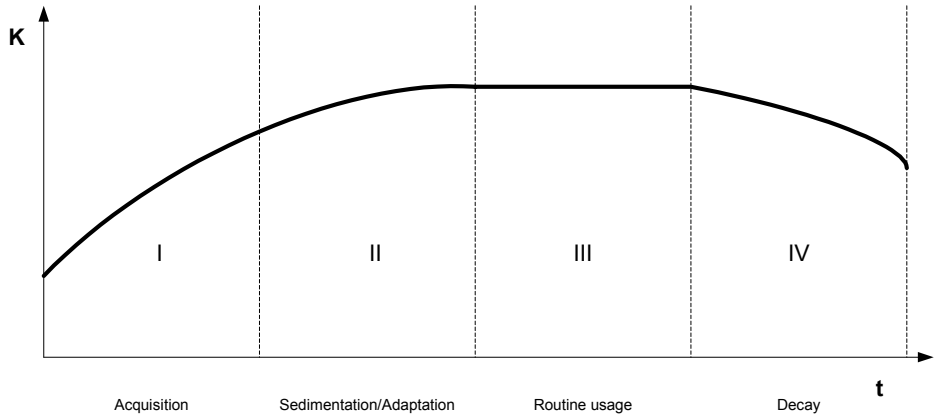
[19] To compare the two perspectives is not amongst the objectives of this work.

[20] Cf. Habermas, J., *The Theory of Communicative Action*, vol. I, Boston, Beacon, 1984.

[21] Cf. Sacchetti, S. and R. Sugden (forthcoming), *op. cit.*

declining phase that would weaken the value added produced by the firm. This would therefore decrease the firm's contribution to the knowledge capital and wealth of its local system.
We build on two main hypothesis. The first is that although knowledge represents a form of capital which accumulates over time, such capital could not be economically relevant or, in some cases, it could produce distorting effects. The second hypothesis is that, inside the firm or the territory, the accumulation of knowledge does not proceed along a straight trajectory and indistinctively, but it is articulated along different phases, which allow us to advance the hypothesis of a knowledge life cycle.
Figure 4 graphically shows our hypothesis with respect to the knowledge life cycle of firms. It develops along four stages: 1) knowledge acquisition, 2) knowledge sedimentation and adaptation, 3) routine usage of knowledge, 4) knowledge decay.

Figure 4: Knowledge life cycles inside firms and territories



In the first stage, *knowledge acquisition*, the firm acquires the knowledge which is then incorporated inside physical production in an innovative or differentiated manner. Knowledge acquisition may occur from the outside or the inside. In the first case knowledge can be obtained from three main channels: technology and machineries, human resources, linkages with other firms.
When a firm buys a new machine it appropriates the knowledge incorporated by the machine itself. The firm can then implicitly use this knowledge through physical production. The firm can interact with the knowledge incorporated inside the machinery, causing continuous incremental adjustments which reveal new productive potential. This, for instance, is typical inside industrial districts.
External knowledge can be obtained also from labour, especially when hiring skilled personnel. In this case the firm appropriates both codified and/or tacit knowledge. An employee without any previous working experience will bring to the firm the codified knowledge that he/she has learned during his/her education. The highest the level of workers' education, the highest the level of the knowledge incorporated by the firm. When the educational level of the worker is not very high but the worker has

accumulated experience, skills and specific competences, the firm will acquire mainly tacit knowledge. Finally, if an individual has a high educational level and working experience, the firm obtains both forms of knowledge.
Linkages with other firms may represent a third source of external knowledge. One of the objectives that can motivate networking is the circulation or creation of knowledge. Literature has explored equilibriums and risks associated with co-operation and competition when firms transfer knowledge and information[22].
Besides external sources, a firm can get new knowledge by creating it internally. As we have mentioned, a characteristic of firms inside industrial districts is the ability to introduce incremental innovations and to continuously adjust their machineries to the needs of production activities. Sometimes larger firms may internalise the production of exclusive machineries to be used in specific production processes. Some have patented their own machineries and sold them to other firms, even to competitors in the event that the firm has decided to change its core business to focus on the production and sell of machines which are intended for the production of consumption goods. Finally there are firms whose original activity is the production of machineries.
Furthermore, a firm can internally increase knowledge with respect to human resources. It is the case when the firm organises internal training courses or groupware for managers, or when the tacit transfer of knowledge from the master to the apprentice leads to innovative adjustments.
To end with, firms can rely on internal R&D centres. Small firms that cannot support a specific internal structure dedicated to research can, nonetheless, assign part of their resources to the development of a new product or process.
After acquisition, the firm moves to the second stage (*sedimentation and adaptation*) during which knowledge deposits and adapts. At this stage the firm starts to select the knowledge previously acquired on the basis of its strategy and of its expected market positioning. Cognitive layers of knowledge overlap and consolidate to form the intangible capital of the firm. That part of tacit knowledge which is considered strategic is codified. Knowledge is socialised[23] inside the firm. Moreover, the firm increases the intensity with which it moulds external knowledge according to its specific activities, through machineries, capital, and linkages with other firms. This adaptive function is the most interesting leverage of innovative dynamics. The combination of internal and external knowledge, tacit and codified, may generate new knowledge that is injected in the physical production of goods. At this second stage, knowledge still follows a raising trend which increases the firm's knowledge capital.
At the third stage, *routine usage*, the firm concentrates on the production process of goods rather than on the production process of knowledge. Knowledge is completely transformed into the physical production of goods. The knowledge that was previously acquired, accumulated and adapted by the firm is now totally consolidated. Tacit knowledge, which has been arranged in the form of codified knowledge, is now part of routines and, consequently, a number of knowledge dimensions are taken for granted.

[22] Cf. Bettis, R. A., S. P. Bradley and G. Hamel (1992), "Outsourcing and industrial decline," *Academy of Management Executive*, Vol. 6, No. 1, 7-22.
[23] On the process of knowledge socialisation Cf. Nonaka I. and Takeuchi H. (1995), *The Knowledge-Creating Company*, Oxford University Press, Oxford 1995.

Knowledge routines are then transformed into production routines. The firm exploits the knowledge that has been accumulated during the previous two phases by transferring that knowledge to goods. Usually, during this third stage firms concentrate on process innovation or on a frenetic activity aimed at the reduction of production costs. Knowledge production ceases and the knowledge capital of the firm is temporarily stable. In Figure 4 the curve representing the cycle becomes flatter, physical production prevails over the production of knowledge.

As we mentioned at the beginning of this Section, one of the premises of our theoretical model was that the function of the knowledge accumulated inside the firm could not be an increasing function. In the fourth stage, *decay*, the knowledge that was accumulated during the first two phases and that was not nourished all through the third stage, becomes obsolete and looses part of its validity. The value added incorporated by the good diminishes and sometimes disappears. In this case the knowledge capital accumulated over years does not represent a convincing barrier and a distinguishing competitive characteristic with respect to potential entrants. Past does not matter anymore. In this situation, changes in competitive dynamics are reflected in the inadequacy of the knowledge capital. Firms facing this phase have two possibilities. They can parch their knowledge capital to focus on cost reduction or they can start producing knowledge again. This means that during the third stage the firm should launch its process of knowledge production either by accessing external knowledge or by increasing the resources dedicated to internal production of knowledge.

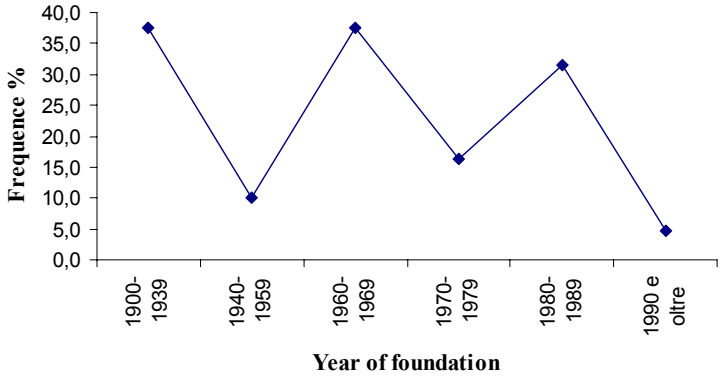
These four stages describe a hypothetical sequence of situations. Evidences shows that there are firms that, given their age, are still travelling along the first or the second stage at most. There are firms that have been on the declining phase for years but still can keep their market share intact. There are firms that have a long history behind them and that launch continuously the first and the second stage: some amongst these succeed in translating knowledge in physical production, other firms fail, or do not meet consumers' demand with their products. Growing firms suit the first situation in which physical production successfully incorporates the firm's knowledge, whilst the last two situations include firms which are experiencing some difficulties and some of them are closing down.

In the course of our empirical work we have related the age of firms to the presence of an internal R&D centre. We have then observed that whilst young firms do not include a structure specific for R&D, one quarter of firms born before 1990 undertakes R&D inside an internal centre.

Table 6: Firms' age and internal R&D

Age		Firms with R&D centre	Firms without R&D centre	Total
Firms born before 1990	Nr. of cases	33	99	132
	%	25,0	75,0	100,0
Firms born after 1990	Nr. of cases	1	20	21
	%	17,6	82,4	100,0
Total	Nr. of cases	34	119	153
	%	22,2	77,8	100,0

Figure 5: Relationship between firms'age and R&D



Within these two groups of firms, whose distinguishing feature is the year of foundation, firms born in 1900-1939, 1960-1969, and 1980-1989 have the highest frequencies of R&D centres.

We observe a sort of cycle that describes the presence of firms for which, today, the actual knowledge capital is enriched also by internal R&D activities. Inside the first class (1900-1939) firms are mainly identifiable with SS and, in particular, with mechanical industry. Amongst firms born within 1960-1969 there are SI and SS sectors with chemical and mechanical firms sized between 100 and 500 employees. The same sectoral characteristics illustrate the type of firms born between 1970-1979, which at present are not so oriented towards organising R&D within a proper internal structure. Between 1980 and 1989 we principally find firms belonging to SI sectors but also firms from SD sectors, which are market leaders in textiles and clothing. More recent firms (from 1990) can be associated with SD sectors (mainly textiles and clothing without leadership roles) or with traditional sectors. Coherently with Pavitt's assumptions, these firms do not rely on internal R&D.

Our observations suggest that local specific competences which rely today on R&D were born with producers of specific mechanical components. In parallel, with a more strict focus on products and marketing, sectors such as textiles and clothing that are usually defined as SD but which in this territory are characterised by the presence of leader firms, confer high value added to their production by means of R&D. Internal R&D, undertaken inside specific centres, seems to be linked to the industrial sector of the firm and, within the sector, to the firm's age. This data suggest that firms (mainly leaders) that have consolidated their structure and their knowledge capital tend to renew and enlarge this capital also through intentionally planned R&D.
Further evidences come from an analogous research undertaken in another province (Forli'-Cesena)[24] where it is shown that 50 per cent of firms in the sample assigns an important role to past experience.

Table 7: The importance of past experience (% of firms for which past is important by size class)

Size class	Frequency within size class (%)
20– 49	25
50 – 199	50
200 – 499	71
Average amongst classes	**49**

Medium-large firms are remarkably above the average frequency (71% of cases). This is probably an indicator that larger firms have more remote origins with respect to smaller firms. The same research results emphasise that experience is perceived as an advantage mainly by firms that are at least thirty-year old. In parallel, the crucial role of the past seems to go in the shade when past becomes particularly far, that is for firms created before the Forties. Knowledge, therefore, becomes cyclical and goes through ascending and descending phases. As other forms of capital knowledge necessitates to be nourished and renewed.

5. THE KNOWLEDGE LIFE CYCLE INSIDE LOCAL SYSTEMS

In the previous Section we have hypothesised the existence of ascending and descending flows of knowledge inside firms. We have also considered the firm as an open system that interacts with its territory: the firm both appropriates local knowledge and releases knowledge to the territory. Therefore, beside knowledge life cycles inside firms we can design the knowledge life cycle of a territorial system. Both perspectives are largely related to the fact that production is essentially about knowledge, and that production decisions are mainly taken by firms. Of course, production does not take

[24] See Appendix B) for sample details.

place in a vacuum. Therefore, the knowledge retained by firms may (or may not) have an impact on the knowledge capital of localities and, vice versa local economic systems influence the extent to which local knowledge can be cumulated over time.

The nature of the knowledge accumulated and rooted inside a locality identifies the peculiar competences of a local production system. The relationship between the knowledge retained by firms and local systems can be, for instance, illustrated by the image of a large firm that, at different points in time, absorbs knowledge from a territory (for example, in terms of labour) and then releases it outside when increasing, for instance, the knowledge capital of a territory in the form of spin-off firms and new competencies. In this case, the firm works as a "territorial lung": when the firm first settles down it destroys knowledge by absorbing competences when hiring labour, which is a scarce factor for industry especially when it is enriched by highly qualified skills and competences. After that, when the firm start to interact with the outside system, it can stimulate the establishment of new firms and competencies. For instance, it can encourage education and learning, co-operate with other firms for the introduction of innovation, stimulate knowledge diffusion together with other territorial actors such as Universities.

This (one or two direction) exchange between the firm and its territory is one of the factors that helps the firm to renew its knowledge capital. For the local system to renew its knowledge capital is fundamental because in so doing it follows the evolution of techniques and production modalities. In parallel, it is fundamental also for the firm, which carries on communicating with other actors. Scientific and technological knowledge continuously develops following cyclical patterns. This process decrees the obsolescence of the knowledge capital of firms, from the knowledge incorporated inside technologies, to tacit knowledge that is embodied by individual competences and skills, to the knowledge included into organisational routines.

Figure 6: The "territorial lung"

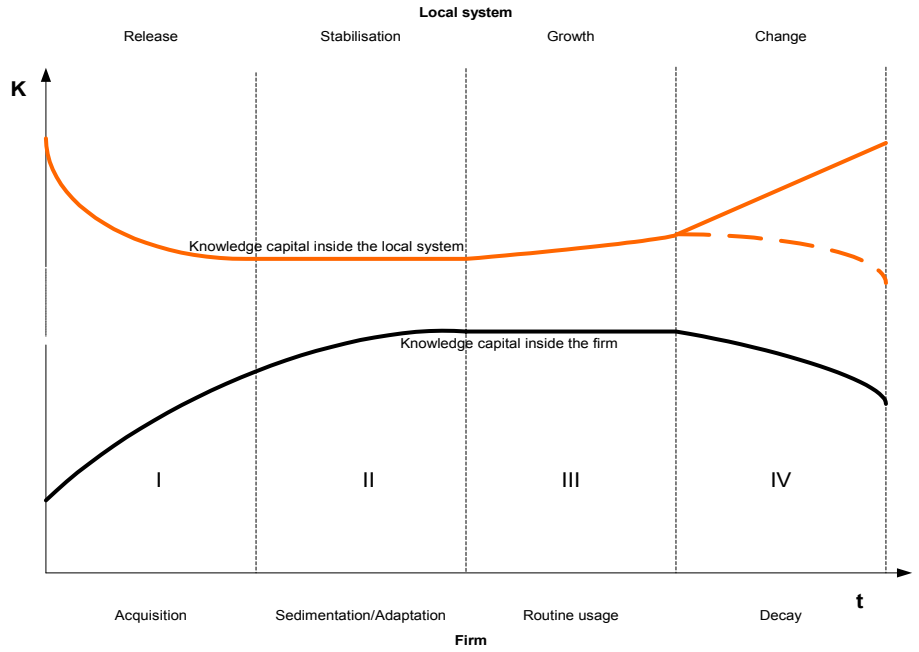


Figure 6 presents, besides the knowledge life cycle of the firm, the knowledge cycle inside the territorial system. We hypothesise, considering a large firm, the existence of an interaction between a firm's dynamics and the local system.[25]

Suppose a situation in which a large firm settles within a territory characterised by a rich knowledge capital. For the large firm a territory may represent a potential of knowledge for three main reasons essentially. A territory is a *potential of tacit knowledge* if a network of small or craft firms already exists as this network can be represent an input of contextual knowledge and of specific learning capacity within a particular industrial sector. Furthermore, a territory is a *potential of codified knowledge* if it includes vocational schools, faculties or university degrees that have contributed over time to diffuse knowledge amongst local people. Finally, a territory is a *potential of tacit and codified knowledge* which is diffused amongst local institutional actors, within their routines, within their policies and development programmes, within their governance capacity to promote the social and economic development of the community. These three factors, which may vary extremely between territories, represent the *whole knowledge potential* that is directly or indirectly appropriable by a large firm when it settles down.

When a large firm (or a large subsidiary) is established we are in the first stage of the cycle, which corresponds to *knowledge acquisition* for the firm and to a *reduction of knowledge* for the territory. The firm will need specialised competences. It is possible that craftsmen will leave their own activity and accept to become employees, a position that would guarantee a fixed salary to them. Some small firms could orient their production towards the needs of the large firm and become subcontractors producing for a single main prime-contractor. Their incremental innovative capacity will serve the adjustments required by the large firm. People coming from vocational schools and Universities will be absorbed by the large firm, thus jeopardising entrepreneurship forces inside the local system. To sum up, this first stage is characterised by a sort of internalisation of territorial knowledge inside the firm.

In the second stage, the large firm starts to deposit knowledge and transform the tacit knowledge it has acquired into codified knowledge and production routines. Gradually, the appropriation of territorial knowledge slows down. The third stage is characterised by the application of knowledge to physical production. The firm consolidates and grows, the absorption of local knowledge stops.

In the fourth phase, the firm starts to release and diffuses knowledge inside the local system. This is the stage in which the firm externalises its knowledge. This happens, for instance, when spin-off processes (more or less encouraged by the large firm) are activated within the territory, when the firm financially support schools or universities and promotes training courses. Finally, an extreme situation that has been however quite frequent for industrial districts, is when the firm goes bankrupt and releases knowledge on the territory. Specialised workers loose their job and – having access to a sufficient financial capital – may become entrepreneurs and start their own activity, generating a

[25] Our analysis, as it is, is not applicable to the access of small firms or systems of small firms. Nor is it appropriate with respect to the entrance of a large firm inside a system with a poor knowledge capital.

small industrial district. At this stage, the firm releases and therefore looses knowledge, whilst the territory increases its knowledge capital.
These two knowledge cycles last over time, waving in opposite directions with different intensity. The intensity of the osmotic function of knowledge between the firm and the territory is linked to the nature of the firm (whether transnational or multinational), to its industrial sector, to the capacity of territorial actors to manage such a process.

6. CONCLUSIONS

In this paper we have provided some theoretical insights on the production of knowledge and on the role of knowledge in physical production. Our main finding is that knowledge does not always grow following a cumulative process, but it can evolve or stagnate and, if not renewed, it can be subject to a process of decay. This evolutionary perspective relates both to the firm and to its local system, where the two continuously interact by providing or absorbing knowledge the one from the other. Firms' production decisions, in particular, crucially influence ascending and descending flows of knowledge within their organisation and the territory. The territory, in parallel, can accelerate the dynamics of knowledge by proactively favouring interactions and co-operation with outside systems and by supporting a context where knowledge can be transmitted and diffused amongst economic actors.
When economic systems go through phases of structural uncertainty, firms must be able to promptly adapt to new situations at such a speed that the distinction between present and future becomes blurred. On the face of it, according to the way knowledge is organised, created, transferred and diffused inside and amongst firms and between firms and other institutional actors, local economic systems can provide more or less convincing answers to structural uncertainty. Moreover when local actors co-operate and communicate, knowledge is proactively created and diffused also outside firms, thus providing to the local industry the tools to interpret structural uncertainty and, sometimes, to anticipate continuously changing events.
When a new large firm begins a process of interaction with the territory in which knowledge is exchanged territorial knowledge could, over time, either grow or fall down. As we have mentioned, interaction could, for instance, focus on education and training programmes, or diffused processes of technological change. There are, however, other situations that can lead to radically different results. A firm can be opened to knowledge inputs coming from the territory but may be closed with respect to outgoing flows of knowledge. In this situation the local system does not receive knowledge inputs from the firm and thus cannot increase its capital stock. The firm has accumulated new knowledge, whilst at same time destroying pieces of local knowledge.

A) Reggio Emilia empirical data: sample and methodology

Our universe of firms was formed by manufacturing firms with more than 10 employees. 34 per cent of firms in the sample has more than 50 employees and include 87 per cent of employees in the sample. We have collected data between 2000 and 2001 using a structured questionnaire that was sent to almost all firms in our universe (1900 is the number of questionnaires posted). Questionnaires were submitted to the entrepreneurs/owners or to chief directors. 168 questionnaires were returned. Amongst these, 40 questionnaires have been completed with more information obtained with structured interviews with entrepreneurs.

The 168 firms who answered to our questionnaire are mainly belonging to manufacturing, and their average size is above the national average. The average dimension of firms in our sample is 108 employees. 75 per cent of firms have been created between 1960 and 1989 (36 per cent during the Seventies). More than 50 per cent of firms founded between 1970 and 1979 belongs to the mechanical sector.

When using Pavitt's categories, we have used, with minor adaptations, the classification from OECD STAN database for industrial analysis. *SD (supplier dominated)* sectors include: textiles and clothing, food, wood products and furniture, non-metallic mineral products, basic metal industries. *SI (scale intensive)* sectors include: paper products and printing, chemicals excluded drugs, rubber and plastic products, iron and steel, shipbuilding and repairing, motor vehicles. The category of *SS (specialised suppliers)* includes: non-electrical machinery, electrical machines, radio, TV and communication equipment, control equipment. *SB (science based)* sectors include: drugs and medicines, office and computing equipment, aircraft, professional goods.

B) Forli'-Cesena empirical data: sample and methodology

The sample includes 80 firms, of which 47 have more than 50 employees. Data have been collected in the year 2000 through postal questionnaires and direct structured interviews with entrepreneurs.

Table 8: Degree of proportionality and representativeness of sample categories for manufacturing firms

Size Category	Group frequency	Population Proportion*		Sample Proportion**		Category representative level***	
51_100	24	60/97	62%	24/80	30%	24/60	40%
101_500	20	34/97	35%	20/80	25%	20/34	59%
>500	3	3/97	3%	3/80	4%	3/3	100%
Total Cases	47					48%	

* Number of *units* in the population category/Total population units

** Number of *cases* in the sample category/Total sample cases

*** Number of *cases* in the sample category/Number of *units* in the population category