THE REMARKABLE PROPERTIES OF KNOWLEDGE AS AN ECONOMIC GOOD: A NOTE[1]

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In this paper we review the three properties that qualify knowledge as an economic good and determine the main dilemma of the economics of knowledge, i.e. the conflict between the social goal of efficient use of knowledge once it has been produced, and the goal of providing ideal motivation to the private producer. In order to fully grasp the implications of each property, we consider in the first section the extreme case of codified knowledge (appearing in the form of a manual of codified instructions) for which those properties are very strong. Such a case generates a kind of very "pure" world in which we can see very clearly the economic problems of public good and knowledge dilemma (section 2). In section 3 we will progressively qualify this fiction to show to what extent the economic problems are reduced as we get away from the extreme case of knowledge defined as "codified instructions". In our conclusion, however, we note that a twofold phenomenon that is characterizing the emergence and development of the knowledge-based economy (i.e. the long-term trend relating to the huge increase in resources devoted to the production, transmission, and management of knowledge, on the one hand, and the advent of new information and communication technologies, on the other hand) makes that we are getting closer to the hypothetical world; a world in which the marginal cost of learning, formatting and transmitting knowledge constantly decreases, giving rise to a massive growth of knowledge externalities.

SECTION 1 - THREE PROPERTIES OF KNOWLEDGE AS AN ECONOMIC GOOD

Knowledge is a strange good, with remarkable properties that differ from those characterising conventional tangible goods. These properties are ambiguous, for while on the one hand activities concerning knowledge production generally have a very high "social return" and are therefore a powerful mechanism in economic growth, they also pose daunting problems of resource allocation and economic coordination.

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1 - A good that is difficult to control and generates externalities

Knowledge is a non-excludable good; in other words, it is difficult to make it exclusive or to control it privately. It is a fluid and portable good. A firm finds it far more difficult to control its knowledge than its machines, for numerous opportunities for leaks and spillovers arise. Information and knowledge continuously escape from the entities producing them, and can thus be used freely by rivals. The literature uses the generic term "positive externalities" to denote this positive impact on third parties, from whom it is technically difficult to obtain compensation. Knowledge or information externalities, of interest to us here, are said to be "non-pecuniary". They denote the fact that knowledge produced by an agent benefits other agents without financial or any other kind of compensation. They are different from so-called "pecuniary" externalities that relate to cases in which inventors are unable to recover from buyers the full value derived from the innovation in terms of lower costs or better quality[2].

2 - Knowledge is a non-rival good

The notion of non-excludability of an economic good is a fairly general property that economists encounter in many situations. For example, a fruit farmer provides a positive externality to his neighbour the beekeeper, whose bees gather pollen in the orchard; a musician does the same thing for her neighbour who loves music. In all such cases the characteristic of a total lack of control enables one to account for situations in which services are accidentally provided to third parties, without any financial compensation. The fact remains, however, that in the cases described above the externality is limited since the resource concerned is either exhaustible or difficult to access (congestion). The beekeeper can set up a dozen hives to take full advantage of the orchard, but if he set up a thousand hives most of the bees would not have access to it. The music-lover on her own can enjoy her neighbour's music, but a thousand people wanting to listen to it would hear nothing.

This is where knowledge differs from situations in which positive externalities are limited. As a resource, knowledge can be characterised by its inexhaustibility. Why? Because unlike bees in the orchard, economic agents are not rival users of a resource when that resource is knowledge. The use of existing knowledge by an additional agent does not imply the production of an additional copy of that knowledge (the author does not have to produce an additional unit of knowledge every time its use is extended).

To explain this strange property to economics students, the example of "giving a watch and giving the hour" is often used. A teacher gives his watch to a student in the class. This operation changes nothing as regards the aggregate: there are still n watches in the classroom. It is a rival good in so far as the students are rivals for its consumption. If now the teacher just gives the hour (assuming that only the teacher has a watch and there is no clock hung on the wall), we immediately see that transmission has a completely different meaning: the aggregate changes completely. Whereas only one person had the information in the beginning, the entire class now has it and the fact of having transmitted it does not deprive the teacher of anything. It is a non-rival good in so far as people do not have to compete for its use.

[2] Knowledge leaks out in multiple ways. The main ways in which it does so has been the subject of an abundant literature. Von Hippel (1988), in particular, analysed the role of informal networks of cooperation and exchange of experiences between engineers in different – sometimes even rival – companies. But simply the marketing of high-tech products that competitors can disassemble is an important source of technological knowledge.The significance of these spillovers has been evaluated by Mansfield (1985) who shows that information on R&D decisions is known to rivals within six months, while technical details are known within a year. As we know, however, the harnessing of knowledge by other firms also depends on their learning capacity.

We thus see that transmitting knowledge is a positive sum game which multiplies the owners of that knowledge indefinitely (as opposed to transmitting a watch which is a zero-sum game).

Instead of the term "non-rivalry", some authors prefer "infinite expansibility" (David, 1993; Keely & Quah, 1998). They justify their choice with the idea of describing this property by means of a positive term, and also with the following reference to a great thinker, T.Jefferson, who, in 1813, wrote: "That ideas should freely spread from one to another over the globe, for the moral and mutual instruction of man, and improvement of his condition, seems to have been peculiarly and benevolently designed by nature, when she made them, like fire expansible over all space, without lessening their density in any point, and like the air in which we breathe, move, and have our physical being, incapable of confinement or exclusive appropriation" (quoted by David, 1993; our emphasis). We note, moreover, that Jefferson thus highlighted the two characteristics underlying the power of positive externalities in the case of knowledge production: the difficulty of private control and non-rivalry.

It is important to note that the codified knowledge received by each party or individual is not a copy of the original good (as one can possess a copy of a work of art). It is not a copy of Pythagoras' theorem that you use but the theorem itself. The implications of the property of non-rivalry as regards costs and prices are important. Since the marginal cost of use is nil, knowledge cannot comply with the economic rules of cost-based pricing. According to those rules, the use of existing knowledge would be free and it would be impossible to compensate financially for the fact that a piece of knowledge is used many times. This problem concerns more than scientific and technological knowledge only; it affects all knowledge expressed in the form of texts, books, journals, music scores, drawings and graphs. Television and radio programmes also belong to this category of goods.

3 - Knowledge is a cumulative good

In the field of science and technology, knowledge is cumulative and progressive. Existing knowledge is the prime factor in the production of new knowledge and new ideas. This means that externalities enhance not only consumers' enjoyment but also, and above all, the accumulation of knowledge and collective progress; it is the possibility for some to "stand on the shoulders of giants". In other words, what spreads and can be used an infinite number of times is not only a consumer good (say, a poem or piece of music) but essentially an investment good likely to spawn new goods that will also be usable an infinite number of times. Jefferson, a particularly insightful thinker, wrote: "The fact is, that one new idea leads to another, that to a third, and so on through a course of time until someone, with whom no one of these ideas was original, combines all together, and produces what is justly called an new invention" (quoted by David, 1993). It is this cumulativeness that distinguishes "small talk and pass time", as Machlup (1984) puts it, from scientific and technological knowledge.

SECTION 2 – PUBLIC GOOD AND THE KNOWLEDGE DILEMMA

The main implication of the three properties is the creation of a difference between the private and the social return in the domain of the production of knowledge. The simple property of non-excludability (or difficulty to control knowledge) is sufficient to produce that difference: assuming the production of knowledge generates profits, the recovery of all those profits is in itself a problem because of the difficulty of completely controlling knowledge. A share of the profits is harnessed by others; in other words, they are externalised. The two additional properties (non-rival and cumulative good) play a role of amplification of that difference between private and social return, opening the possibility of huge social returns.

It is basically the uncontrollability, non-rivalry and cumulativeness threesome that is at the origin of the importance of social returns to research and innovation, and that makes these activities an essential basis for growth. Measurements of social returns to research generally give extremely good results[3].

1 - Externalities and lack of incentives

In the presence of externalities, inventors must expect to receive less than the social returns of their invention. Private agents therefore tend to "under-invest" in the production of knowledge since they cease their efforts devoted to innovation at the point where the marginal costs of those efforts meet the private marginal value of their investment. From society's point of view, it would be preferable for them to cease their efforts only at the point where the marginal costs curve meets the curve representing the sum of marginal values, that is, the social return. This is a typical situation of a lack of incentives, which leads to a level of insufficient private investments, for society. The problem thus formulated is qualified as a "public good problem". It is a general problem described by Pigou (1932) and studied by Arrow (1962) in the case of research and innovation. In Pigou's own terms, there is a large number of situations in which the net private marginal gain is less than the net social marginal gain because services are accidentally offered to a third party from whom it is technically difficult to obtain payment (Pigou cites scientific research as an example of this type of situation).

As we have seen, scientific or technological knowledge is not only a good that is difficult to control, it is also a non-rival and cumulative good. These different characteristics enhance the strength of positive externalities and thus increase the difference between private and social returns. Thus, social returns may be so substantial that remunerating the inventor accordingly is unthinkable. What is the social return of the demonstration of the Fermat theorem by A.Wiles and how can it be rewarded "fairly"? Of course it is only in an economy which is not reduced to monetary values alone and which also has "honorary rewards" – to use Montaigne's expression – that mechanisms for rewarding knowledge creation can be conceived.

2 - Knowledge: a public good

Saying that knowledge is a public good, when we are living in an historical period of accelerated privatisation of knowledge bases, can be a source of misunderstanding. It is an interesting subject for debate and even controversy with those who maintain that no good is essentially public – and who inappropriately illustrate their argument with Coase's famous article on lighthouses, a service that was once provided by the private sector in the UK. It therefore seems relevant to recall that, saying a good (e.g. knowledge) is a public good, on the basis of the properties of non-excludability and non-rivalry, does not mean that this good must

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[3] Griliches (1995) conducted a survey of the econometric literature on this subject, showing that the social return varies between 20 and 100% (for one $ spent). Another survey by Mairesse and Mohnen (1995) also shows the same order of magnitude for social returns from R&D. Mentioning some typical studies, based on particular methods, Mansfield (1977) examined in detail 17 innovations and estimated an average social return of 56% compared to a 25% private return. Trajtenberg (1990) calculated a social return of 270% in the case of scanners. In a discussion of this literature, Mairesse (1998) recognises the extreme sensitivity of the results to the choice of econometric methods and the quality of the data used. He concludes, however, that even though each of these studies seems fragile and open to criticism on many counts when taken on its own, the overall convergence of the results is quite convincing.

necessarily be produced by the state, that markets for it do not exist or that its private production is impossible. It simply means that, considering the properties of the good, it is not possible to rely exclusively on a system of competitive markets to efficiently guarantee production (David, 1993). Indeed, if we take the example of the lighthouse again we see that the private market functions because an agent is granted local monopoly on the right to collect a tax in exchange for the service provided. In the same way, the creation of a private monopoly on new knowledge (a patent) enables the market to produce that good. But in both cases the remedy is imperfect, for the owner of the monopoly will not supply the "light" (of the lighthouse or knowledge) at a price (harbour tax or royalties) equivalent to the negligible cost of making these goods available to additional users (we have seen that the marginal cost of use of existing knowledge is nil, as it is in the case of using the harbour’s lighthouse).

3 - The knowledge dilemma

Since the marginal cost of use of knowledge is nil, maximum efficiency in its use implies that there is no restriction to access and that the price of use is equal to 0. Knowledge should be a "free" good; that is the condition for optimum use of a non-rival good. From a concrete point of view, rapid distribution of knowledge facilitates coordination between agents and reduces risks of duplication between research projects. Above all, by propagating knowledge within a heterogeneous population of researchers and entrepreneurs, it increases the probability of later discoveries and inventions and decreases the risk of this knowledge falling into the hands of agents incapable of exploiting its potential (David & Foray, 1995).

But whereas maximum efficiency in the use of knowledge supposes rapid and complete distribution and hence requires that its price be nil, the same does not apply to its production. Producing knowledge is costly, very much so in some cases. As a result, maximum efficiency in the use of resources to create new knowledge requires that the costs of all necessary resources be covered by the economic value of the knowledge created. Private agents therefore need to be given the means to capture or requisition financial benefits derived from the use of knowledge. A price must be paid for such use, but that is possible only if it is restricted. It follows that the solution is to create a control mechanism. Such mechanisms can concern the actual use of knowledge (copyright or patent), the transmission medium (pay-TV or tax on the recording) or the formatting of the knowledge (coding to prevent copying or free recording).

Thus, if the problem facing creators is to be solved, they must be allowed to install a "fence" around the new knowledge. In this way the private value is raised and investment encouraged. However, in the field of scientific and technological knowledge it is not only the individual enjoyment of a few "consumers" that is curbed by limiting the use of knowledge but, above all, accumulation and collective progress, the thousand opportunities afforded by new combinations between diverse elements of knowledge.

Thus, by moving on from the property of externality to those of non-rivalry and cumulativeness, we see how the contradiction worsens between the aim of increasing the private value of knowledge (implying restrictions on its use) and that of preserving its social value (implying free use). The more cumulative the use, the more control mechanisms – locks, tickets and patents – will tend to generate social losses. That is the dilemma: only the anticipation of a positive price on use will guarantee the allocation of resources for creation; but only a price that is nil will guarantee efficient use of knowledge, once it has been produced. It is a dilemma between the social objective of ensuring efficient use of knowledge, once its has been produced, and the objective of providing ideal motivation to the private producer. It imposes itself only with the notion of cumulativeness of knowledge which shifts knowledge from the world of consumer goods to that of production.

If, in principle, it is possible to treat positive and negative externalities symmetrically (subsidising one who is producing knowledge and taxing one who is producing carbon emission), the problem is that monitoring and preventing opportunistic behaviour is likely to be much more difficult in the case of positive externalities. For instance, it is easy to provide 'too much' subsidy, encouraging those with a very low chance of finding the invention to engage in search.[4]

SECTION 3 – ON A FEW PHENOMENA WHICH REDUCE THE KNOWLEDGE DILEMMA

There is a whole series of phenomena which lessen the knowledge dilemma either by reducing the public good problem at its source (for instance the tacit dimension of knowledge makes it more easily to control) or by reducing the dimension of externalities (there are conditions and factors that degrade the non-rival and cumulative aspects of knowledge). Yet technological developments underway seem rather to compound the problem.

1 - Qualifying the argument of uncontrollability

Until now we have treated only one extreme case, knowledge, expressed in an appropriate form for its diffusion (writing, computer programme, digital image, film). But a knowledge base – that of a firm, institution or even sector – is not reducible to pure "codified" knowledge. It is composed of tacit knowledge, know-how and practical experiences (knowing how to conduct an experiment) as well as research materials, instruments and tools, all of which are more easily controllable goods.

Thus, very few research results, inventions or new technological practices are formalised from the start to the point of being a "simple" set of codified instructions so that experiments and results can be reproduced by scrupulously following the codified instructions (in the way that anyone, by reading the manual, can get their new washing machine going). When knowledge is expressed completely in this form of codified instructions (of which software is the most interesting example), it is indeed practically impossible to control it, at least in the community of specialists and practitioners able to understand and interpret the instructions. In reality, however, knowledge and results are far more often presented as a combination of formalised instructions and tacit knowledge, based on practical experiences that can be acquired only in the laboratory where the discovery was made (Cowan and Foray, 1997, Cowan, David and Foray, 2000). An excellent example has just been provided in the scientific world, where about thirty teams from different countries competed in the race for 0 Kelvin degrees. To date only one of them has managed, and reproduction of the experiment requires know-how that is kept largely secret. Thus, the tacit dimension of knowledge affords those who have it a degree of control, since only voluntary demonstration and learning on site allow its acquisition.

Hence, there is a sort of natural excludability that this tacit dimension bestows on knowledge. This represents a transitory source of intellectual capital, producing rents for companies who have the know-how. They benefit from it until the new knowledge is sufficiently codified, articulated, clarified and hence diffused so that the rents are dissipated.

[4] We thank Ed Steinmueller for this particular comment.

This transitory tacit dimension is therefore a way of controlling access to new knowledge, but it is not a solution that can be used systematically by firms. Many technological and organisational issues today – such as transfer, communication and learning between scattered sites; capitalisation and memorisation of skills; effective use of new information technologies; acquisition of a quality label – demand a degree of formalisation and codification of knowledge.

A related aspect of the argument of uncontrollability relates to the role of complementary assets. Very often the exploitation of new knowledge requires specific capacities that only the inventor has, such as technological capacities needed to implement the innovation. Even if the idea is harnessed by others, only the one who has these capacities is able to exploit it. Moreover, apart from highly advanced technological capacities that have to be mastered in order to exploit the new knowledge, control of a particular market is a kind of complementary asset essential to the exploitation of an innovation. In all these cases, the externality is artificial. Although knowledge is diffused, the profits associated with its implementation remain internal.

2 - Qualifying the argument of non-rivalry

The capacity of knowledge to be used infinitely – which strengthens positive externalities and therefore compounds the problem of under-investment – is limited when costs of accessing, formatting and transmitting knowledge are high. Even if the cost of using existing knowledge is nil, this does not mean that there are no costs for formatting, transmitting and learning such knowledge.

We use the term *learning costs* for the costs of intellectual investments needed to form a community capable of understanding and exploiting knowledge. Without these investments the value of non-rivalry of knowledge is nil, as Callon (1994) suggests in his critical analysis of the economics of science. For the property of non-rivalry to actually be exploited, there has to be a collective capable of understanding and using that knowledge. This collective may be tiny, as in the case of using the last theorem in an extremely specialised branch of mathematics, for example. In that instance the economic value of non-rivalry is fairly weak. On the other hand, the collective may be almost universal when the knowledge in question concerns an elementary technique or know-how. The bigger the community of agents with the "intellectual equipment" to understand the knowledge, the greater the economic value attached to the property of non-rivalry will be and, consequently, the greater the social return of the knowledge. By taking into account learning costs it is possible to distinguish between a fairly specific or specialised non-rival good and a more general or universal non-rival good. This distinction, which must of course be represented on a continuum, depends on the investments that communities of agents make to enable them to use and exploit a particular type of knowledge.

Apart from these learning costs (training and maintenance of "intellectual equipment"), we also identify costs for *formatting* knowledge which relate essentially to costs for codifying and formalising knowledge and for *physical transmission*.

It is therefore very important to think about the structure of these costs, for it can change not the nature but the degree of the problem of externality. Take a very basic example: extremely specialised knowledge in an almost esoteric branch of astronomy (high learning costs), developed by a lone scientist at a time when only manual writing exists and communication is difficult (high formatting and transmission costs), is non-rival knowledge but has a very small potential audience (one or two colleagues in the world) and no actual audience. The externalities produced will be very weak. But when learning, transmission and formatting costs fall – e.g. new medical knowledge on the feeding of babies, immediately printed in all languages and disseminated by all possible media – the externality becomes very large.

We can consider that, as a rule, formatting and transmission costs drop steeply with time, depending on the dynamics of information and communication technologies. By contrast, the development of learning costs is far less predictable. They remain very high for specialised knowledge but the increase in education and training investments makes them declining over time. Learning costs must however include search costs which can increase due to the problem of attention (Simon, 1982). In an information-rich world, processes of research, screening and selection of relevant knowledge can require use of more and more "intellectual equipment", which reduces the size of the community of potential users.

The structure of marginal costs of knowledge, as an economic good, is presented in the following table.

Activity	Old situation	New situation	Driver
Production of knowledge	High costs	High costs	
Reproduction of knowledge	0 cost (non rival good)	0 cost (non rival good)	
Codification of knowledge	Very high	Rapidly declining	ICT developments
Transmission of knowledge	Very high	Rapidly declining	ICT developments
Learning of knowledge (including search costs)	Very high	Declining	Education/training

Structure of marginal costs of production and use of knowledge

If we relate this table to the essential characteristics of knowledge-based economies we see that the ICT revolution causes knowledge formatting and transmission costs to drop, while the tendency for spending on training and education to increase, leads to some decrease in acquisition costs. The knowledge-based economy is therefore clearly an economy in which knowledge externalities are more powerful than ever, consecutive to this double trend of ICT development and increasing investments in education.

3 - Qualifying the argument of cumulativeness

Limits and obstacles to cumulativeness are obvious: if knowledge is kept secret or if the costs of formatting, transmission and acquisition are high, cumulativeness will be reduced or even nil. But there are also specific obstacles that hinder cognitive processes underlying the cumulativeness of knowledge.

First, the cumulativeness of knowledge implies the adoption of systematic codes and forms of expression as well as procedures of verification and evaluation of knowledge, agreed by all. It appears, however that these conditions are far from being self-evident. In the Middle Ages the alchemist was symbolic of the absence of progressiveness of knowledge. Books written by alchemists used allusive, obscure terminology so that, as Eamon put it so well (1985): "Alchemy was a science that never progressed. One had to redo alone what others did throughout the centuries". The difference is of course very slight between the notion of a secret that allows control and that of allusive terminology that is an obstacle to progress. Yet it enables us to show that disclosure itself is nothing; it must be accompanied by an effort to systematise and clarify. It was after a long time only that awareness grew of the importance of technical names and systematic classifications used by all. People protested against the (deliberate) lack of clarity, the instability of terminology, the "play on words" of alchemists. During the Renaissance engineers started to codify technical processes and develop a systematic technical vocabulary in order to reduce the imprecision and ambiguity of existing vocabulary (Long, 1991). A basic factor was also the adoption of a single standard of scientific reliability, based on observation, reason, experience and the possibility of replicating experimental work. This standard enables scientists to use the results of other laboratories and even other disciplines.

Secondly, we cannot overlook the temporal dimension which often makes the cumulative aspect of processes almost impossible to grasp (at least on the scale of human life). Rosenberg (1992) has given many historical examples illustrating very long periods of time and the entanglement of relations and affiliation between pure basic research and commercial application. His favourite example is the sequence of discoveries from the phenomenon of electromagnetic induction (Faraday, 1831) to Maxwell's theories (around 1875), Hertz's experimental research (1887) and the use of radio waves for long distance communication (Marconi, 1901).

Finally, the dynamics of knowledge is marked by phenomena of obsolescence. As a consequence of the appearance of new knowledge, older expertise loses its value and the cumulative process is weakened. The extent of this depreciation (the economic consequence of obsolescence) depends on the field in question and of course on the historical period. Mathematical truths and theorems, for example, hardly date; some even last for centuries. By contrast, in other domains frequent changes of paradigm constantly depreciate knowledge.

CONCLUSION

The public good problem and the knowledge dilemma correspond to a fictive world in which knowledge is codified (and not tacit), costs of learning, codification and transmission are low, and knowledge is highly cumulative.

Yet the problem posed by this issue of public goods seems to increase with time. Why? Because we getting closer to the hypothetical world; a world in which the marginal cost of learning, formatting and transmitting knowledge constantly decreases. When knowledge is memorised and transmitted essentially by word of mouth, the circle of actual users is very small. If it widens, oral or written transmission can easily alter the content of the message. Thus, there are physical limits to the expansion of the community of users likely to harness knowledge. The "journey" of knowledge is a process that is so long that ultimately the question of “public good” is not an issue. At the time of manual writing and copyist monks, pirating was certainly possible but nevertheless limited. In fact that was an essential reason for the refusal for so long of the printing press "which puts the fate of texts into mechanical hands and sells them to unknown agents". By means of manuscript copies, often autographs, addressed only to people close to them, authors hoped to retain control of their work. These "scribal communities" greatly reduced the dimension of externalities (Love, 1993).

When, on the other hand, the combination of digital technologies and new networks of electronic transmission made the global and instantaneous transmission of any cultural or scientific programme possible, the problem posed by non-rivalry of knowledge became acute. This was because these technologies allowed the almost infinite expansion of real beneficiaries of knowledge. This type of world – characterised by transmission and formatting costs that are almost nil, and composed of sufficiently large communities of "intelligent" agents – can be seen emerging, for example, in many fields of science. "A simple HP 9000 has radically changed the way scientists work today in the field of high-particle physics. Every day almost 20,000 electronic messages send the abstracts of new academic papers across 60 countries. These messages can then be retrieved by interested readers. Every day, close to 45,000 physicists explore electronic archives to find particular bits of old information" (M. Mulligan, *Financial Times*, 18-04-94).

One should note, however, that without search capabilities, the cost of congestion (information overload) would overcome the benefits. Searching for information and codified knowledge and screening and selecting it are becoming activities of growing economic importance for the performance of the knowledge-based economy. The increase in the productivity of processes used to search for existing information and knowledge (reference standards, artificial agents, transfer science) and the economy of cognitive resources in an information-rich environment ("intelligent" screening devices; new concepts for virtual filing) are the two main requirements for the improvement of both the richness of the knowledge environment and the ability of economic agents to survive and prosper in that environment (Steinmueller, 1992).

We are probably able now to fully grasp the significance, from the point of view of the economics of knowledge, of this long tradition of technical progress, starting with the invention of writing and the development of the book, to the mechanisation and automation of writing and other forms of codifying knowledge. This tradition is itself closely entangled with the development of infrastructures for storing and transmitting information. All this progress allows more effective exploitation of the properties of non-rivalry and cumulativeness of knowledge. In this sense, it gives the economics of knowledge a coherent physical base but also compound problems of protection and compensation for the producers of new knowledge.

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