Via Po, 53 – 10124 Torino (Italy)
Tel. (+39) 011 6702704 - Fax (+39) 011 6702762
URL: http//www.de.unito.it

WORKING PAPER SERIES

TECHNOLOGICAL KNOWLEDGE AS AN ESSENTIAL FACILITY

Cristiano Antonelli

Dipartimento di Economia “S. Cognetti de Martiis”

Laboratorio di Economia dell’Innovazione “Franco Momigliano”

Working paper No. 04/2005

Università di Torino

TECHNOLOGICAL KNOWLEDGE AS AN ESSENTIAL FACILITY[1]

CRISTIANO ANTONELLI

UNIVERSITA' DI TORINO
LABORATORIO DI ECONOMIA DELL'INNOVAZIONE
DIPARTIMENTO DI ECONOMIA

ABSTRACT. The economics of regulation has articulated the notions of essential facility and mandated interconnection Their application to the governance of technological knowledge can be fruitful especially when implemented by the adoption of the liability rule and the parallel reduction in the exclusivity of patents. Because knowledge is at the same time an output and an input in the production of new knowledge, exclusivity, traditionally associated to patents, is the cause of actual knowledge rationing with major drawbacks in terms of both static and dynamic efficiency. This institutional innovation can improve the governance of technological knowledge and increase both its rates of dissemination and generation.

KEY-WORDS: KNOWLEDGE GOVERNANCE, INTELLECTUAL PROPERTY RIGHT REGIMES, ESSENTIAL FACILITY, LIABILITY RULE,

JEL CLASSIFICATION: O31

1. INTRODUCTION

[1] I acknowledge the funding of the Italian National Research Project (PRIN) "Economia della generazione, valorizzazione e disseminazione della conoscenza tecnologica" and of the European Union Directorate for Research within the context of the Integrated Project EURODITE, contract n. 006187 in progress at the Fondazione Rosselli. Preliminary versions have been presented at the International Workshop Evolutionary Macroeconomics: Building Micro and Meso Foundations from Studies of Systems of Innovation, Self-Organization, Competitive Processes, Knowledge Networks and Complex Adaptive Economic Systems at the University of Queensland, Brisbane, July 2005; the workshop organized by the CEPN (Centre d'Économie de Paris Nord) of the University of Paris XIII in June 2005; the Plenary Session of the 5th Triple Helix Conference "The capitalization of knowledge: Cognitive, economic, social & cultural aspects" Turin, May 2005; the 5th EPIP (European Policy for Intellectual Property) Conference on "European policy on patents and intellectual property: What direction should it go?" Copenhagen, March 2005 and at the Centre Auguste et Léon Walras de l'Université Lumière-Lyon 2, in Lyon, in November 2004. The comments of many, including two anonymous referees are acknowledged.

The basic notion of essential facility, and its implications in terms of mandated interconnection, introduced in regulation economics, has a wide scope of application, well beyond network industries. The economics of knowledge stresses the role of indivisibility and cumulability. Knowledge is not only an output, but also an input in the generation of further knowledge. Hence knowledge can be considered an essential facility itself. The analysis of the direction of localized technological change suggests that there are strong incentives to innovate and make an intensive use of idiosyncratic production factors that are locally abundant and specific to innovators. Hence innovators enjoy a far stronger appropriability of the stream of rents generated by the applications of knowledge than currently assumed. From a normative viewpoint, this analysis has major implications for a re-assessment of the intellectual property right regime, a new understanding of knowledge as an essential facility and the introduction of the liability rule in the governance of patents.

The rest of the paper is structured as follows. Paragraph 2 introduces the notion of essential facility, as it has been first elaborated in telecommunication economics and shows how it can be applied to the economics of knowledge. Paragraph 3 elaborates the analysis of the informational role of patents and presents the opportunity for a drastic reduction of exclusivity of patents. Paragraph 4 elaborates the parallel application of the liability rule to fix ex-post the proper rewards for innovations that have been used. The conclusions summarize the main findings.

2. ESSENTIAL FACILITY: ECONOMIES OF DENSITY AND MANDATED INTERCONNECTION. FROM THE ECONOMICS OF TELECOMMUNICATIONS TO THE ECONOMICS OF KNOWLEDGE

The notion of essential facility has been elaborated in the economics of telecommunications to regulate the problems raised by complementarity and cumulability. A production factor is an essential facility when its use in the production process is characterized by substantial indivisibility. Relevant economics of density take place when the repeated use of the same input is possible. Increasing returns take place because output increases with the increase of variable factors only. When long-term duration, excess capacity and little wearing characterize fixed inputs, marginal costs remain below average costs. Moreover incremental costs, i.e. the costs of additional production units, display low average costs, lower than total average costs. The social use of essential facilities requires strong regulation as the rights of exclusive use have significant asymmetric effects on competition in the market place, which favor the exclusive users. When a piece of property acquires the characteristics of an essential facility, the rights to use, access and interconnection cannot be exclusive. A separation between the rights of ownership and the rights of use is necessary in order for actual and workable competition to be implemented and eventually made possible (Baumol and Sydak, 1994).

As it is well known, privatization of networks and competition in the telecommunication industry has been made possible by mandated interconnection. Mandated interconnection has been a major factor of change and evolution in the definition of property rights. The ownership rights on the one hand and the rights of exclusive use on the other, traditionally associated in one single right, have been separated and rights of use of the network have been separated from the ownership

rights. Firms do and can own telecommunication networks and can claim their property on all the segments of the network, but cannot claim any longer the right to the exclusive usage. Other firms have the right to access the network and make a selective use of it. Dedicated authorities have been established since the late 1980s in most advanced countries in order to implement the right to interconnection, to regulate it and to fix the prices of interconnection (Fransman, 2002).

Communication Authorities have been established to monitor the effective separation between the right of ownership and the rights of usage of telecommunication networks. Their activity here is most necessary because of the ever changing conditions of the technology and hence the ever changing conditions of the separation between ownership and usage. Second and most important, Communications Authorities have been established in order to fix ex-ante the levels of interconnection tariffs. Interconnection tariffs must reflect properly the costs of the network and must make possible both appropriate returns on the investments for the owners and viable conditions of entry to new competitors. In order to avoid suboptimal provision of communication infrastructure, investors need to receive appropriate rewards and hence incentives for future investments. At the same time however, newcomers must be put in conditions of actual cost symmetry in downstream markets with respect to incumbents and other competitors in the telecommunications industry (Madden, 2003). The evolution of property rights in the telecommunications industries has been the result of the understanding of the role of sunk costs and complementarities and their effects in terms economies of density and incremental costs on the actual costs of both incumbents and new competitors in the industry. Mandated interconnection is indeed a significant departure from a full fledged and traditional definition of property rights.

A process of widespread generalization of the application of the notion of essential facility has been taking place since the last decade of the XX century. The separation between ownership and rights of exclusive use and the introduction of mandated interconnection is now regarded as a necessary regulation within economic and physical systems where and when complementarities and indivisibilities matter, in order to restore and enforce the conditions for the viability of competitive markets. Such evolution of the property rights regime has been spreading from the original application in the telecommunications industry to all the network industries from electricity to gas and railway.

There are today strong reasons to believe that the notion of essential facility and mandated interconnection is directly relevant for the governance of technological knowledge.

According to the results of much economics of knowledge, knowledge shares all the relevant characteristics of an essential facility. Knowledge is characterized by intrinsic indivisibility and yet it is dispersed and fragmented in a variety of uses and possessed by a variety of owners. Each bit of knowledge is complementary to each other along chains of weak and strong indivisibilities, which act both synchronically and diachronically. The exclusive access to each bit of knowledge can prevent others from cumulative undertakings (Antonelli, 2001 and 2003).

Since the path breaking contribution of Kenneth Arrow (1962), the economics of knowledge builds upon the analysis of knowledge as a good per se and explores all the limitations to its production and dissemination in the market place that are engendered by its limited appropriability, non divisibility and non-rival use. Intellectual property rights regimes have been built mainly to increase the appropriability of the benefits generated by the introduction of new technological knowledge. The basic claim has been that the natural appropriability of knowledge is too low to induce investors to fund appropriate levels or research activities.

Following the resource-based theory of the firm, however, technological knowledge cannot be separated from the firm. Technological knowledge can be considered both the primary input of the firm and its basic output. The firm exists because it is the institution that, by means of the valorization and direction of learning processes, makes it possible the accumulation of technological knowledge. At the same time the firm can be considered the basic tool of exploitation of new knowledge that cannot be sold as a good itself. The choice whether to sell technological knowledge or to use it and make with it, is especially relevant for the analysis of the firm.

This approach can contribute the debate on the governance of knowledge. A new appreciation of the role of intellectual property rights can now be found in the assessment of their positive effects from an informational viewpoint in terms of higher levels of specialization and division of labor, rather than in terms of the assignment of exclusive property rights. From this viewpoint the so called knowledge trade-off, that is the balanced assessment of both the positive effects of the monopolistic control of patents in terms of increased incentive to the supply of knowledge and the negative effects in terms of the reduced distribution of knowledge, needs to be reconsidered (Machlup and Penrose, 1950; David, 1993).

3. THE INFORMATIONAL ROLE OF PATENTS: SIGNALING AND LICENSING

The economic analysis has much debated the positive and negative consequences of intellectual property rights. Two well distinct knowledge trade offs have been identified.

The first knowledge trade-off has emerged from the cost-benefit analysis in terms of the balance between the positive effects in terms of dynamic efficiency and the negative effects in term of static efficiency. Increased dynamic efficiency stems from the assignment of intellectual property rights as they increase the incentives to invest resources in the creation of new technological knowledge because of the positive effects in terms of appropriability and hence tradability of technological knowledge. The negative effects on competition stemming from exclusive property rights however diminish static efficiency. Monopolistic market power, engendered by intellectual property rights, makes it possible the extraction of consumer surplus by patents holders and induces them to technical inefficiency.

The second knowledge trade-off has been identified by the dynamic cost-benefit analysis in terms of the balance between the positive and negative effects on the dynamic efficiency of an economic system. As soon as the joint character of

knowledge as an input and an output is acknowledged, in fact, the positive effects in terms of the increased incentives to invest resources in the generation of new technological knowledge stemming from intellectual property rights are now confronted with their negative effects in terms of reduced dissemination and access for third parties. Reduced dissemination in turn limits the use the knowledge for the production of new knowledge with clear negative effects in terms of decreasing efficiency in the production of further knowledge.

Combining the two knowledge trade-offs it seems that intellectual property rights risk to reduce both static and dynamic efficiency at the system level. These results are reflected in the recent renewed interest in alternative solution to existing intellectual property rights, especially patenting regime, like the awarding of prizes. The risks of a major state-failure as opposed to market-failure seem to limit the applicability of the prize mechanism beyond the scope of well-identified problems especially in the case of diseases and epidemics (Shavell and Van Ypersele, 2001; Davis, 2004).

An attempt to highlight the positive elements of intellectual property rights so as to select the features that are more conducive to foster the rates of generation and dissemination of new knowledge, and, possibly to limit the effects of the most negative ones, seems more promising than venturing in the design of new institutional devices.

It is clear, in fact, that the debates about the twin knowledge trade-off has been concentrated upon the positive and negative effects of the creation of intellectual property rights in terms of exclusivity. Little attention had been paid to the informational role of intellectual property rights. From the viewpoint of welfare analysis, at the system level, intellectual property rights have an important role from an informational viewpoint and as such exert relevant consequences. According to the localized technological change approach, technological change is the emergent property of an economic system, if, when and where the latent complementarities among the fragmented bits of indivisible knowledge possessed by a myriad of agents dispersed and isolated, are valorized and exploited. From this viewpoint the role of patents as signaling mechanisms, that provide information about new inventions and relevant technological applications, seems far more relevant than their traditional role of appropriability mechanisms based upon the enforcement of excludability.

Secrecy is the alternative to intellectual property rights, to secure exclusive ownership and reduce non-appropriability. Secrecy, however, can have dramatic effects upon the amount of knowledge externalities and knowledge complementarities, which can be effectively activated (Arundel, 2001). The systematic use of secrecy would limit drastically the information and access to external knowledge for each firm with dramatic consequences in terms of the general efficiency in the production of new knowledge. The exploration of external knowledge, the searching and screening of relevant bits of complementary knowledge would become much more expensive with an increase in the costs of new knowledge. As a matter of fact, and beyond the intentions of each patent holder, patents play a major role as signaling devices: patents help the social identification of the advances of knowledge and hence help locating the available bits of complementary knowledge and their owners so as to reduce search and exploration costs.

Intellectual property rights are a remedy to tight vertical integration between the generation of new technological knowledge and its application to the production of new goods or to new production processes, rather than to its undersupply. This analysis contrasts the traditional argument according to which the market supply of technological knowledge is deemed to undersupply because of its public good nature. The public good nature of technological knowledge, as a matter of fact, does not necessarily lead to undersupply but rather pushes the knowledge-creating firm to use it as an intermediary input for the sequential production of economic goods. The markets for the products that are manufactured and delivered by means of the technological knowledge they embody can generate the incentives to generation of appropriate quantities of knowledge.

Effective property right systems favor the creation of markets for disembodied technological knowledge where the firms can specialize in the production of knowledge as a good per se. With a weak intellectual property right regime and low appropriability, in fact, the holders of each bit of knowledge have much a stronger incentive to integrate vertically into the production of new goods and processes based upon the novel ideas and to rely upon industrial secrets as a way to reduce the informational leakage with the radical reduction of the circulation of the relevant bits of disembodied knowledge. The embodiment effect can be especially negative when the scope of application is wide and reverse engineering is complex, at least for unrelated perspective users. An effective intellectual property right regime, able to secure appropriate returns to inventors, reduce the incentive to internalize the valorization of technological knowledge by means of downward vertical integration, and favor the creation of markets for technological knowledge, as a good per se, and hence favor the division of labor with the well-know positive effects in terms of specialization and dissemination of fungible technological knowledge to a wider range of economic activities. The assignment of intellectual property rights seems by now a necessary condition not only to increase appropriability, but also as an institutional device which can improve the viability of the markets for knowledge and facilitate the interactions among holders of bits of complementary knowledge. Patents in fact can help transactions in the markets for knowledge because they make it easier for demand and supply to meet (Arora, Gambardella and Fosfuri, 2001).

The systematic use of patents, because it helps the identification of bits of relevant knowledge for perspective users, is essential to reducing the waste of duplication due to lack of information and to make it easier the working of social cumulability in the production of new knowledge, provided the use of knowledge by third parties is not restricted. Patents make knowledge interactions easier, provided the exclusivity of ownership is properly tuned. The basic problems of the knowledge trade-off emerge can be tackled in a different way, if the excludability of patents is reconsidered (Kingston, 2001).

4. THE LIABILITY RULE AS A MECHANISM FOR THE GOVERNANCE OF TECHNOLOGICAL KNOWLEDGE

The separation between ownership and usage conditions and the extension of the notion of essential facility to technological knowledge experienced in the case of the telecommunications industry can apply with success to intellectual property rights.

The application of the notion of essential facility and mandated interconnection to the governance of technological knowledge can be implemented by the adoption of the liability rule and the parallel reduction in the exclusivity of patents. Because knowledge is at the same time an output and an input in the production of new knowledge, exclusivity, traditionally associated to patents, is the cause of actual knowledge rationing with major drawbacks in terms of both static and dynamic efficiency. This institutional innovation can improve the governance of technological knowledge and increase both its rates of dissemination and generation.

The present intellectual property right regime, based upon exclusive rights suffers from at least four main problems: a) exclusive intellectual rights delivered to inventors reduce the allocative and technical efficiency in the product markets and favor their strategic use in a oligopolistic rivalry (McDonald, 2004; Calderini, Scellato, 2005); b) exclusive intellectual rights delivered to inventors reduce dissemination of proprietary knowledge and hence limit the dynamic efficiency of the system. Such effects are especially negative when knowledge complementarities apply and bits of knowledge can have important effects for the production of other knowledge in other fields of applications, often remote from those of original invention and introduction (Nelson, 2004); c) litigation costs and generally transaction costs, typically associated to the delivery and defense of exclusive intellectual property rights, have been growing with a dangerous pace, actually faster than investment in R&D (Barton, 2000); d) duplication of efforts and major coordination problems limit the general efficiency of the system in the production and use of knowledge.

In this context, the present intellectual property right regime can be improved substantially with the reduction of the levels of exclusivity Here the guidance provided by the evolution of property rights with the application of the notion of essential facility to technological knowledge and the related institutional innovations introduced in telecommunications provides basic guidance. The separation between the ownership of intellectual property and the right of exclusive use, already experienced with success in the telecommunications industry with the notion of mandated interconnection, can apply in this central and strategic area as well.

Such a reduction of the exclusivity of intellectual property rights can be realized by means of the liability rule. The extension of the liability rule in this field seems to be able to provide important positive effects. The application of the liability rule in intellectual property rights can be considered a useful device to implement ‘mandated interconnection’ in intellectual property rights. Liability rule consists in the right of the owner of intellectual property to claim for appropriate payments for the usage of her rights. In this context, the right of exclusive use is no longer associated to the rights of ownership of any intellectual property. Like in telecommunications networks, mandated interconnection combines the provision of a fee to the owners of the communication channel for all uses of their infrastructure with the right of third parties to access all existing communication infrastructure, a non-exclusive ownership of intellectual property rights can be identified. The separation of ownership rights from exclusivity rights means that the rights of ownership to receive a payment for the use of proprietary knowledge is recognized as well as the right of other parties to take advantage of it.

The application of the liability rule seems to make progress with respect to the well-known hypothesis of compulsory licensing. The major problem with compulsory licensing in fact lies in the definition of the correct levels of the royalties associated with the use of proprietary knowledge. Too high royalties become an effective impediment to the actual dissemination of the knowledge.

In the case of intellectual property rights, the ex-ante definition of the value of a patent and hence of the royalties, the equivalent of interconnection tariffs, seems difficult on many counts. First of all research activities are characterized by high levels of risk and intrinsic uncertainty, in terms of the chances of generating an output so that the allocation to each novelty of the effective costs is most difficult. Second, because of the role of cumulability in the production of knowledge, the identification of the actual levels of incremental costs, that is the identification of the specific costs for the last bit of knowledge as distinct from the sunk costs is problematic. Thirdly, technological knowledge is very much the result of the valorization of bottom-up processes built upon learning processes and accumulated competence: it is difficult if not impossible to disentangle the specific cost items that can be charged: major issue of indivisibility applies. Fourthly and consequently, it seems that sheer cost-pricing cannot apply when technological knowledge is concerned. The role of creativity and ingenuity here is a key factor and its costs impossible to assess. Moreover creative talent is a scarce and rare resource, which needs to be valorized and used in the social applications, which are more valuable[2]. The correct price for technological knowledge is necessarily influenced by its value. A divide between the fair price for knowledge and its cost emerges. Here, regulation economics provides us with the valuable support of Ramsey pricing.

Here the analogy between the new institutional arrangements put in place in network industries and intellectual property rights fails to apply. Communication Authorities have been successfully put in place and performed quite well their task to fix the fair value of interconnection. The creation of an independent authority charged with the task of assessing the ex-ante value of a new piece of technological knowledge seems far less credible for the amount of ingenuity and Olympic, far-sighted rationality required. Ramsey pricing can provide basic guidance.

The combined substitution of the property rule with the liability rule and the use of Ramsey pricing can overcome the traditional problems associated with compulsory licensing. With the liability rule in fact the definition of the payments for the owner of the intellectual property right used by third parties can be defined ex-post, that is after its use has been experienced. The ex-post identification of the economic value stemming from the application of a given specific piece of new knowledge is much less difficult than the ex-ante assessment. Only an ex-post approach, to defining the levels of the rents due to inventors, which builds upon the notion of knowledge as an essential facility and hence on the notion of non-exclusive intellectual property rights implemented by the liability rule, can grasp the specific levels of markups which are likely to actually implement the overall levels of research activities in a system. The ex-post definition of a value for the unrestricted use of proprietary technological knowledge by third parties, based upon the actual evidence about its economic effects,

[2] See, for a parallel analysis on the value of artistic talent, Swann (2005).

and hence the basic reference to the derived demand for the knowledge considered, seem the proper solution.

By means of negotiations the parties involved can try and find an agreement about the share of the value stemming from the use of the technological knowledge that the owner should receive from the user. As soon as a patent holder realizes that her proprietary, albeit no longer exclusive, knowledge has been put in place by a third party, a litigation procedure can be activated. The patent holder will claim a share of the actual economic value generated by the applications of the proprietary knowledge. The evidence about the effects of the use of the new knowledge can be gathered and an economic assessment elaborated. A formal litigation will be the extreme context into which the parties involved will solve the problem (Reichman, 2000). The judiciary system will enforce the procedure and define the correct share of the revenue stemming from the use of the new knowledge, which should be paid by the user to the original owner.

A simple application of welfare analysis can help to identify the correct level of the share of the revenue stemming from the use of proprietary knowledge. From a system viewpoint the allocation of the shares between the owner and the user(s) is most important.

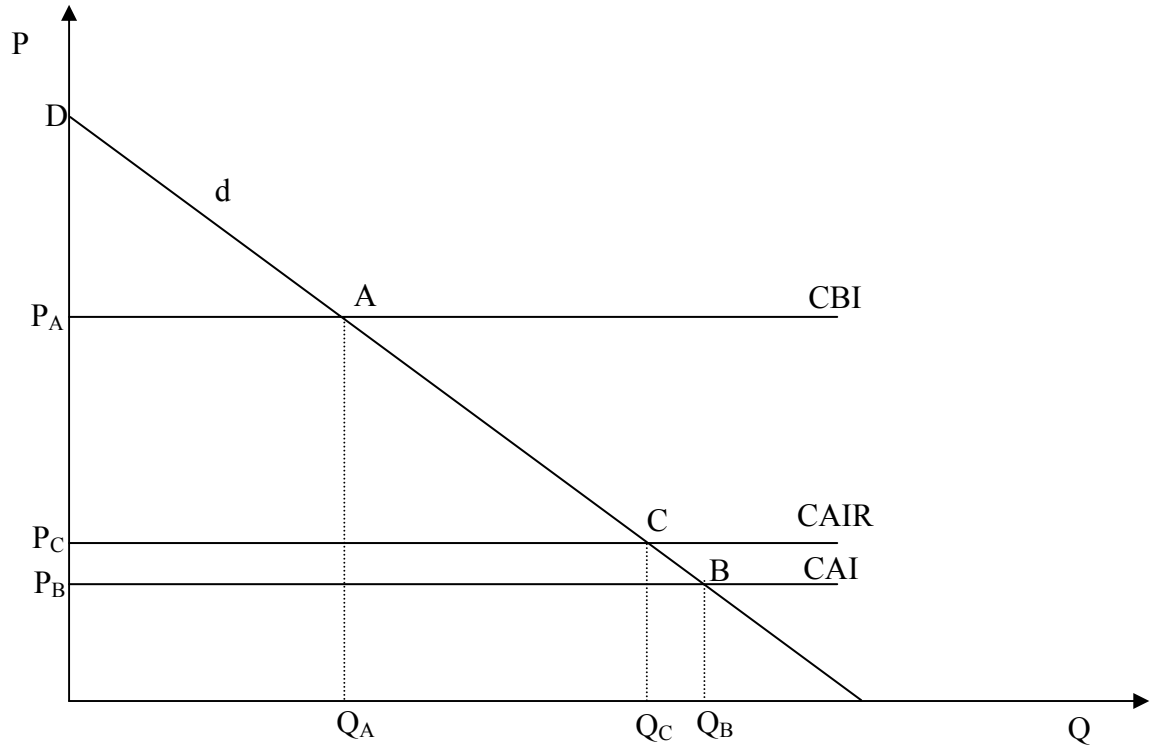
The traditional arrovian setting (Arrow, 1962) can be used to assess the definition of the correct level of the royalties and generally the criteria for the allocation of the revenue stemming from the use of the new knowledge. With the present intellectual property right regime, the monopolistic owner has the right to take all the benefits stemming from the use of the new knowledge. In the context elaborated here the owners of technological knowledge should receive only a portion of the total benefits stemming from the application of their proprietary knowledge: as we have seen knowledge dissemination has a key role in securing appropriate levels of generation of new knowledge. On the other hand, fair incentives to the generation of new knowledge are necessary to avoid the well-known risks of undersupply of such a key input for economic activity. Appropriate incentives can be measured with respect to the costs of generation: the identification of the costs of the technological knowledge enters into the context. The definition of the share of the profits stemming from the application of the knowledge should take into account a rough estimate of the direct, incremental costs incurred by the owner to generate it. The size of the royalty paid to the knowledge by the knowledge user is set to be influenced by the size of the total surplus generated by the use of the knowledge.

The size of the total surplus engendered by the introduction of an innovation of course is very much influenced by the kind of market forms, before and after the introduction of the innovation. Let us consider first the extreme case that competitive pricing applies before and after. Following Arrow (1962) diagram 2 shows how that the introduction of an innovation measured by a reduction in production costs from the levels of the costs before innovation (CBI) to the level of the costs after innovation (CAI) yields positive effects in terms of total surplus (TS) measured by the size of the difference between the area of the triangle DPB and the triangle DPA. This case can be confronted with the possibility that monopolistic pricing applies before and after the introduction of the innovation: in this latter case the amount of total surplus shrinks. Finally and consistently with the results of the analysis on the dynamics of

localized technological change we shall also assume that the downstream markets for the products that use knowledge as a production factor, are characterized by monopolistic competition with relevant barriers to entry and mobility. For this reason relevant extra profits are likely to persist in the long-term[3]

INSERT DIAGRAM 2 ABOUT HERE

THE EFFECTS OF INNOVATION



Specifically the relative markup, that is the difference between the amount of the costs incurred in the generation of the new knowledge (CK) and the royalties (R) paid to the inventor, weighted by the knowledge costs, can be set to be a function of the total surplus stemming from the introduction of the new knowledge in the markets for the products that use it:

(8) (R-CK/CK) = f (TS)

A maximum level or the relative markup needs to be identified. The rationale behind such a ceiling is clear: excess profitability for inventors would easily become an

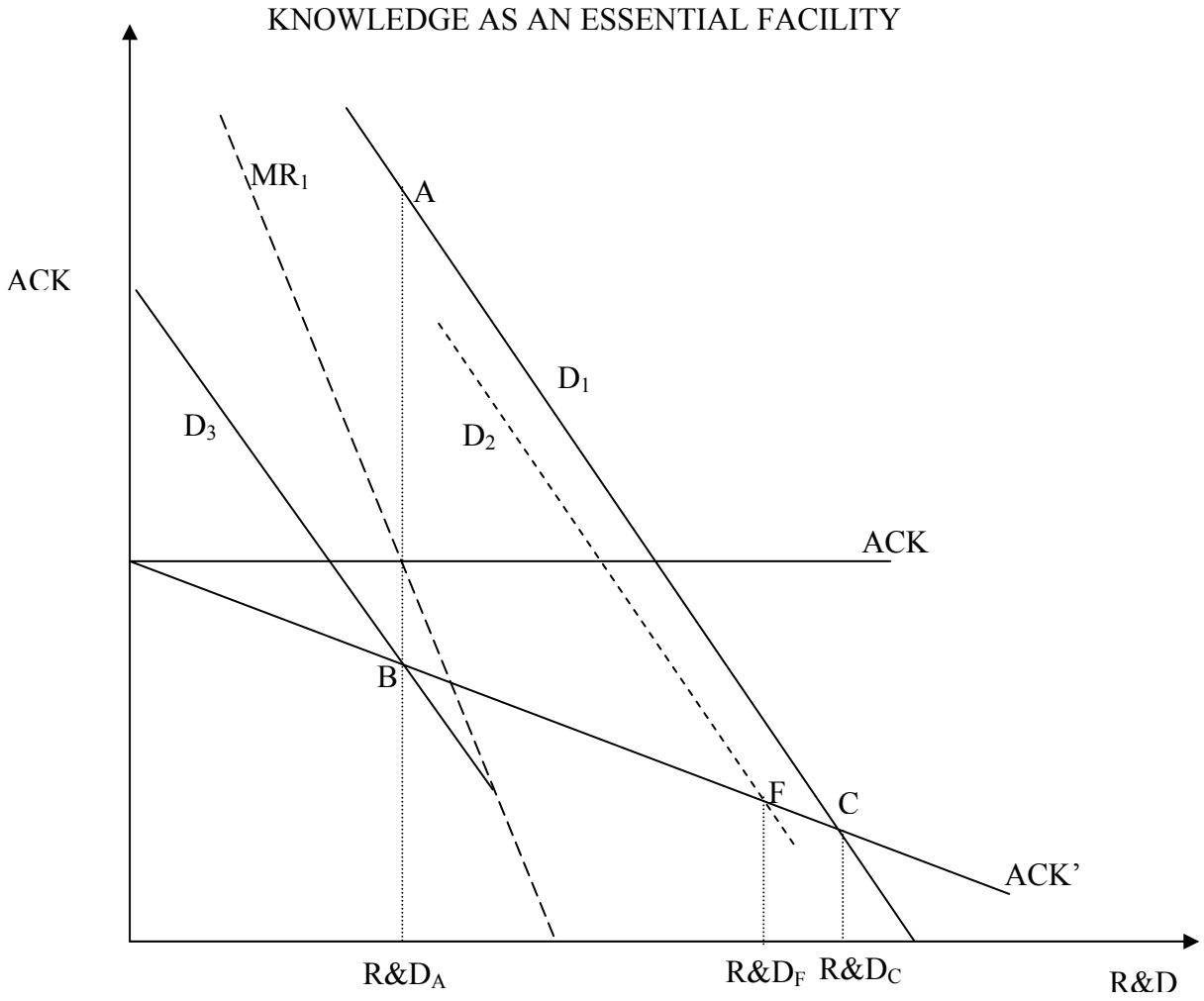
[3] Following our argument it can be claimed that the introduction of the notion of knowledge as an essential facility and the related substitution of the liability rule to the property rule is likely to change the market structure and hence to increase the actual levels of the total surplus stemming from the introduction of an innovation. With exclusive intellectual property rights in fact the exclusive owner of the knowledge can take advantage of monopoly power in the markets of the product that use and benefit from the application of the proprietary knowledge. With monopolistic pricing the welfare effects of the introduction of the new knowledge are clearly lower that the effects of the use of the new knowledge with competitive pricing. Competitive pricing is clearly made possible by the application of non-exclusive intellectual property rights.

incentive to duplication efforts and inventing around activities with clear costs in terms of social welfare. Such a maximum level can be empirically defined with specific reference to the industrial context of application.

The royalties paid to the knowledge owner will enter the costs of the firm and increase the market cost for the product and hence the price: see in diagram 2 the new costs after the introduction of the innovation now including the royalties (CAIR). In a competitive market firms should account for the royalties to be paid. In a market characterized by monopolistic competition with barriers to entry and to mobility, royalties can be charged on the profits of the firm.

Let us now try and show how the proposed extension of the liability rule affects the generation of knowledge in an economic system. A simple geometric exercise helps defining how non-exclusive intellectual property rights increase the amount of knowledge an economic system is able to generate. Unlike Arrow (1962) we now frame the analysis in a derived demand context, where the costs of generating new knowledge are affected by the access conditions to prior knowledge as a basic input. For given costs of knowledge, the firms decide, on the base of the marginal productivity of knowledge how much knowledge to use. We shall assume that all the firms can generate the same knowledge with the traditional dynamics of multiple inventions. If firms can access knowledge at costs that are below internal generation ones, they shall use it rather than duplicating it.

INSERT DIAGRAM 3 ABOUT HERE



As diagram 3 presents, D_1 identifies the derived demand for knowledge and the average costs of knowledge (ACK). The latter decline significantly if and when all potential users can take advantage of it: the working of economics of density in fact makes it possible to share the same fixed costs, necessary to generate a given piece of knowledge, among all eventual users. If, instead, exclusive intellectual property rights apply, all eventual users need to reinvent the piece of knowledge and average costs remain at a constant level. From the viewpoint of sheer costs, non-exclusivity of intellectual property rights seems to yield a clear social benefit. When the reduction of the incentives to generate new knowledge stemming from such a reduction in exclusivity is considered however, the picture is can be worsened. Now agents are reluctant to fund research activities when the knowledge generated cannot be appropriated. Reduction in exclusivity engenders a reduction in appropriability. The schedule of the derived demand for knowledge is likely to shift on the left, because of the exit of a number of perspective investors and the general reduction in the levels of knowledge generating activities.

At the system level it is clear that the area between the ACK' (with a negative slope because of the effects of economies of scope) and the ACK parallel to the horizontal axis (when exclusive property rights apply) defines the social benefit of the non-exclusive access to proprietary knowledge from the supply side[4].

With exclusive intellectual property rights the traditional monopolistic equilibrium is found in A. In A the profitability for inventors is very high and hence the incentives to fund R&D activities. When the equilibrium in A however the costs of R&D activities are much higher, as well. If non-exclusivity applies and the ACK' is relevant, the new equilibrium, on the same demand curve, would be found in C. Clearly if the derived demand for knowledge were not affected by the reduction in exclusivity the system would benefit from the increased level of research activity $R\&D_C$.

The reduction in exclusivity however has a negative effect on the demand side. As the knowledge trade-off teaches, the reduction in exclusivity is likely to reduce the profitability of the knowledge generated: hence the derived demand for knowledge is expected to bunch back. If and when such a leftward movement from D_1 towards D_3 goes beyond the point B, it is clear that the amount of knowledge generated in the system shrinks, yet its costs also decrease. At the same time however, the reduction in the costs for knowledge should engender a positive shift in the overall demand for research activities fueled by both output and substitution effects. The goods manufactured with cheaper knowledge cost less in the final markets and their demand is larger. Moreover firms are now induced to substitute more knowledge to other production factors. In sum the new position of the derived demand for knowledge is likely to be affected by both a negative shift due to a reduction in monopolistic rents and a positive one, stemming from output and substitution dynamics.

[4] Actually the positive effects of the application of the notion of knowledge as an essential facility and of the liability rule should include the reduction of monopoly power in the downstream markets for the products that use the proprietary knowledge. Now in fact many firms can use it and patents are no longer a cause of downstream monopoly.

The notion of knowledge as an essential facility and the introduction of the right of usage of proprietary knowledge by third parties, provided that the liability rule applies and hence the users of proprietary knowledge generated by third parties can be forced to pay a fee to original inventors is likely to increase the amount of knowledge a system can generate.

Diagram 3 exhibits the working of the twin effects of the knowledge trade-off and shows with clarity the all reduction in exclusive intellectual property rights affects both the supply and the demand side with contradictory effects. Only the fine-tuning of both effects can yield positive aggregate effects in terms of increased levels of knowledge generated at the system level. Diagram 3 shows how the definition of the levels of the mark-up for inventors must take into account both the effects on the supply of knowledge and the effects for its derived demand. The crucial issue is the elasticity of the position of the derived demand, together with the price elasticity on each of the schedules of the derived demand. When the price of proprietary knowledge is larger than average costs, and hence rents are granted to inventors and the totals surplus is now shared between producers and users, the derived demand shifts towards the right. The crucial point is the extent to which the derived demand is elastic to the levels of the markup in defining the equilibrium levels of the research activities, both in terms of slope and position.

It is clear that this procedure can engender significant litigation costs that might diminish the positive impact of the suggested regime in terms of social welfare. Here however the net increase in litigation costs should be considered. The levels of possible litigation costs stemming from the suggested procedure need to be confronted with the huge levels of actual litigation costs. According to Hall (2003) in fact, average, per patent, legal costs for litigation vary in the range of the astonishing level of 400.000-2.500.000 US$ in the US and 50.000-500.000 US$ in the European Union.

5. CONCLUSIONS

Technological knowledge is a collective, highly imperfect and heterogeneous activity. Moreover it is not only an output, but also an input, an essential intermediary production factor that is relevant both in the generation of new technological knowledge and in the generation of other goods. The dynamic efficiency of each firm and of the system at large depends upon the factors affecting the dissemination and the conditions of access to existing knowledge, as a basic essential facility.

This analysis has clear consequences in terms of allocation of knowledge total surplus. In the allocation of the total surplus stemming from knowledge indivisibility, a larger portion, in terms of consumer surplus, should be granted mainly to users, rather than to producers. Lower levels of exclusivity and lower rents for such technological knowledge seem useful also from a competitive advantage. The larger are the effects of the economies of density in knowledge generating activities and the stronger are the asymmetric advantages for incumbents that are for old inventors. Old inventors in fact can retain for themselves and for a long stretch of time larger portions of the competitive advantages stemming from the repeated use and the non-

exhaustibility of the knowledge generated at time t-1 and appropriate all the stream of additional bits of knowledge which build upon the previous ones.

It seems clear that the stronger are the effects of the indivisibility of technological knowledge in terms of cumulability, fungibility and complexity, and the stronger are the incentive to remove the exclusivity of property rights. This is true for many reasons. First from a general 'technical' efficiency viewpoint: the negative slope of the long term cost curve of technological knowledge characterized by high levels of cumulativity, fungibility and complementarity is much steeper that the slope of the costs of technological knowledge with lower levels of divisibility. Hence the larger are the effects of knowledge economies of density and the larger the social waste stemming from exclusive intellectual property rights. Second, from an allocative viewpoint: exclusive intellectual property rights provide to initial inventors the control on the sequence of additional bits of knowledge that build up the previous with clear asymmetric effects. With high levels of knowledge cumulability and knowledge fungibility, strong inventors are likely to be primarily sequential inventors. Thirdly, relevant effects on the demand side can take place when knowledge complexity matters. With high levels of knowledge complexity, increased levels of access to a given bit of knowledge can exert strong widespread effects across the board with typical network externalities. The larger is the number of users of a given piece of technological knowledge and the wider the incentive to increase its usage. In such a case the position of the derived demand for knowledge would not be changed towards the left by the introduction of non-exclusive intellectual property rights, but actually towards the right with significant incremental benefits in terms of the levels of research and development activities undertaken in a given economic system.

Such a new governance of intellectual property rights, based upon the notion of knowledge as an essential facility and hence the extension of the notion of mandated interconnection with the application of the liability rule can balance the defense of intellectual property rights and the rewards stemming from the introduction of an original piece of knowledge with the need to increase the dissemination of relevant knowledge so as to favor its cumulative and competitive applications.

The evolution of the intellectual property rights regime towards the separation between ownership and the exclusive right of access to knowledge can provide important opportunities for the systematic valorization of both the markets for technology and the interactions among holders of complementary bits of knowledge. The mandated right of interconnection to bits of knowledge owned by third parties can take place with the implementation of the liability rule and the ex-post payment of royalties without the preliminary consensus of the patents holders.

The reduction of the rights of exclusive use of intellectual property, the introduction of the mandated right to access intellectual property for third parties, combined with the eventual enforcement of the liability rule such that the judiciary system can help securing ex-post the payment of fair levels of royalties to the effective owners, can become an effective institutional innovation. Intellectual property and hence patents can play a strong role in increasing the quality of the knowledge interactions. Full visibility of intellectual ownership can help locating bits of complementary knowledge and hence reducing the costs of technological communication and networking activities at large. Especially when the parties can agree eventually upon

the payments of appropriate royalties. By means of non-exclusive property rights, implemented by liability rules, knowledge interactions come closer to market transactions and hence increase the scope for the valorization of knowledge complementarities.

The informational role of patents as carriers of relevant information about the actual levels of technological competence of agents and the availability of new bits of knowledge in this context is crucial. Technological signaling becomes relevant as a device to reduce knowledge transaction and networking costs.

The appreciation of the informational role of patents has significant implications for their characteristics. With respect to the automatic granting of intellectual property rights, as in the case of copyrights, the selective and discretionary assignment of patents seems even more appropriate. The scrutiny of an Authority is in fact most useful as a screening device, which makes it possible to sort out the bits of new knowledge that are actually relevant and useful. For this very same reason patents assigned following the first-to-invent procedure seem more useful than patents assigned with the first-to-file approach: the latter procedure better qualifies the content of the patent in terms of novelty and ingenuity. Second, it seems also clear that a narrow definition of the scope of a patent is more useful, from an informational viewpoint, than a wide one. The identification and location of the relevant bits in the great map of knowledge becomes easier for each perspective user. In such a context of governance of intellectual property rights, it seems clear that the granting of patents should be made easier and the fees charged for renewal should be lowered also so as to increase the role of patents as signals: patentees are now charged with far higher knowledge transactions costs in the form of litigation and judiciary activities. The costs of the identification of the imitations and the activation of the liability rule in fact are now fully shifted to the undertaking of original inventors.

Patents are essential tools to signal the levels and the characteristics of the knowledge embodied in each organization. A new chapter in the economics of intellectual property rights emerges here. Patents are no longer regarded only as tools to increase appropriability, but also as devices to increase transparency in the knowledge markets and hence facilitate markets transactions. The new assessment of the informational role of intellectual property rights in terms of increased incentives to the production and trade of knowledge and hence a remedy to undersupply needs however to be reconsidered, because of the perverse effects of exclusion on the efficiency of the generation of new knowledge, especially when radical innovations are under question. The notion of knowledge as an essential facility becomes relevant. The extension and generalization of the notion of essential facility, elaborated in the telecommunications industry in the last decades of the XX century, is fruitful in the economics of knowledge and hence in the governance of knowledge commons.

6. REFERENCES

Antonelli, C. (2001*), The microeconomics of technological systems,* Oxford University Press, Oxford.

Antonelli, C. (2003), *The economics of innovation, new technologies and structural change*, Routledge, London,

Arora, A., Fosfuri, A. and Gambardella, A. (2001), *Markets for technology*, The MIT Press, Cambridge.

Arrow, K. J. (1962), Economic welfare and the allocation of resources for invention, in Nelson, R. R. (ed.) *The rate and direction of inventive activity: Economic and social factors,* Princeton, Princeton University Press for N.B.E.R. pp.609-625.

Arundel, A. (2001), The relative effectiveness of patents and secrecy for appropriation*, Research Policy* 30, 611-624.

Atkinson, A. B. and Stiglitz, J.E. (1969), A new view of technological change, *Economic Journal* 79, 573-578.

Barton, J. (2000), Reforming the patent system, *Science* 287, 1933-4.

Baumol, W.J. and Sydak, J.G. (1994), *Toward competition in local telephony*, The MIT Press, Cambridge.

Calderini, M. and Scellato, G. (2005), Intellectual property rights as strategic assets: The case of European patent opposition in the telelcommunication industry. Paper presented at the XXXII EARIE Conference, Porto.

David, P.A. (1993), Knowledge property and the system dynamics of technological change, *Proceedings of the World Bank Annual Conference on Development Economics,* The World Bank, Washington.

Davis, L. (2004), Intellectual property rights, strategy and policy, *Economics of Innovation and New Technology* 13, 399-416.

Fransman, M. (2002), *Telecoms in the Internet age: from to boom to bust to ….?,* Oxford, Oxford University Press.

Hall, B., Graham, S.J.H., Harhoff, D. and Mowery, D.C. (2003), Prospects for improving U.S Patent quality via post-grant opposition, Paper prepared for the NBER Conference in Innovation Policy and the Economy, Washington, DC.

Geroski, P. (1995), What do we know about entry? *International Journal of Industrial Organization* 13, 421-440.

Kingston, W. (2001), Innovation needs patents reforms, *Research Policy* 30, 403-423.

Machlup, F. and Penrose, E. (1950), The patent controversy in the nineteenth century, *Journal of Economic History* 10, 1-20.

Madden, G. (ed.) (2003), *Handbook on telecommunications*, Edward Elgar, Cheltenham.

Mansfield, E., Schwartz, M., and Wagner, S. (1981), Imitation costs and patents: An empirical study, *Economic Journal* 91, 907-918.

McDonald, S. (2004), What means become ends: Considering the impact of patent strategy on innovation, *Information Economics and Policy* 16, 135-158.

Mokyr, J. (2002*), The gifts of Athena: Historical origins of the knowledge economy*, Princeton University Press, Princeton.

Nelson, R.R. (2004), The market economy and the scientific commons, *Research Policy* 33, 455-471.

Penrose, E.T. (1959), *The theory of the growth of the firm*, 1st and 3rd editions, Basil Blackwell (1959) and Oxford University Press (1995), Oxford.

Reichman, J. (2000), 'Of green tulips and legal kudzu': Repackaging rights in subpatentable invention, *Vanderbilt Law Review* 53, 17-43. Reprinted in Dreyfuss, R. and Zimmerman, D. (eds.), *Expanding the boundaries of intellectual property*, Oxford University Press (2001) Oxford, pp. 23-54.

Shavell, S. and Van Ypersele, T. (2001), Rewards versus intellectual property rights, *Journal of Law and Economics* 44, 525-47.

Stiglitz, J., (2000), The contributions of the economics of information to twentieth century economics*, Quarterly Journal of Economics* 115, 1441-1478.

Stiglitz, J.E. (2002), Information and the change in the paradigm in economics, *American Economic Review* 92, 460-502.

Swann, G.M.P. (1005), Is the worl flat or round? Mapping changes in the taste for art, in Antonelli, C. et al. (eds.), *New frontiers in the economics of innovation and new technology, Essays in Honour of Paul David*, Edward Elgar, Cheltenham.