QUADERNI

Università degli Studi di Siena
DIPARTIMENTO DI ECONOMIA POLITICA

UGO PAGANO
MARIA ALESSANDRA ROSSI

Incomplete Contracts, Intellectual Property and Institutional Complementarities

n. 355 – Luglio 2002

Abstract - In the New Property Rights model ownership of assets should be assigned to the most capable agents. While, in a world of incomplete contracts, the application of the model to IPRs provides insights on the nature of their second best allocation, also the opposite direction of causation may arise: owners of IPRs tend to develop more capabilities in the production of new IPRs. For some firms and countries, a virtuous complementarity between the development of IPRs and skills arises. For others the disincentive effect of the exclusion from intellectual property has more damaging consequences than the lack of access to material capital.

Keywords: Intellectual Property, Incomplete contracts, Incentives, Efficient Allocation, Institutional Complementarity.

JEL Classification: D23, K11, K12, O34

Introduction

The New Property Rights approach emphasizes the important economic function of an efficient allocation of property rights over physical assets in a situation of incomplete contractibility. Control of residual rights over physical capital increases the owner's bargaining power and therefore constitutes a safeguard against the possibility of opportunistic behaviour by other parties. The asset owner will thus have a greater incentive to make unverifiable specific investments in human capital in comparison to other individuals.

In this paper we argue that, in many respects, the New Property Rights approach can be better interpreted as a theory of the allocation of intellectual property rights. In this case, ownership of intellectual assets can be allocated – similarly to ownership of physical capital – so as to provide incentives to the realization of the asset-specific investments in human capital that contractual incompleteness tends to reduce. Property of an intellectual asset should therefore be assigned to the economic agent who has to make the most relevant and specific investment in human capital and therefore places the highest value on it. However, the instrument of efficient property rights allocation allows to achieve only a second best solution, given that the asset owner is exposed to the possibility of hold up of specific human capital by the other agents and that the parties excluded from ownership are exposed to the risk of hold-up of both human and intellectual capital. The higher the number of agents required to make investments specific to the assets and to other agents, the wider the gap between the first best and the second best outcome.

What is more, in the case of intellectual property even this second best solution is less likely to be spontaneously achieved by economic agents than per standard New Property Rights theory, which assumes that the markets for physical capital operate at zero transaction costs. The existence of strictly positive transaction costs in the market for the allocation of property over intellectual assets is more likely to prevent efficient bargaining. One consequence is that, in contrast with the standard formulation of the New Property Rights approach, real-world allocation of intellectual property rights will often not coincide with the efficient (second best) solution. For example, the theory suggests that strictly complementary assets should be owned by the same economic agent. With positive and significant transaction costs the efficiency gains determined by the "correct" property rights allocation may be outweighed by the costs of exchanging the rights, so that the economic agents may fail to reach such efficient solution. A second, more fundamental consequence is that the existing allocation of property rights over intellectual assets may exert an enduring influence on the direction of technological development. If the exchange of property rights is costly and takes time, the property rights structure will not adjust easily to changes in technology so that the latter will be shaped by the initial allocation of intellectual property. Structurally

misallocated intellectual property assets have therefore negative effects that reach beyond the static dimension and may, for instance, be a cause of the "anti-commons tragedy" that is sometimes associated to the present excessive dispersion of intellectual property rights.

The paper is structured in six sections.

In section 1 we summarize the basic aspects of the New Property Rights approach while in section 2 we interpret the canonic model as a theory of the allocation of intellectual property rights. We argue that the model makes more sense as a theory of intellectual property rights for several reasons, and principally because human capital is more likely to be specific to (unique) intellectual properties than to easily replicable machines. Some of the results of the model (such as second best efficiency with unified ownership of complementary assets and decentralized ownership of independent assets) give valuable insights in the theory of the allocation of intellectual property.

In section 3 we remove the assumption of zero transaction costs in the exchange of (material) assets that characterizes the Grossman-Hart-Moore (GHM) models. We argue that, when the assets are interpreted as intellectual assets, relaxing this assumption becomes even more important than in the original setting of the model. Obviously, the existence of transaction costs may imply that such undesirable phenomena such as the "anti-commons tragedy" can easily arise and that public policies may be necessary to bring about an efficient allocation of property rights. In addition to this, we argue that the introduction of transaction costs in the GHM model should not simply imply the desirability of policies that favor efficiency enhancing exchanges of property rights. In any case intellectual property may be a poor incentive device when many agents have to be motivated and a costly property right to enforce when agents engage in imitation or recur to a strategy of secrecy (that implies wasteful duplication of research efforts) in order not to be imitated.

However, the introduction of positive transaction costs has an even more striking implication: that the logic of the GHM model running from technology (including the distribution of abilities) to (efficient) ownership of (material as well as intellectual) assets can be inverted. If property rights are chosen on the basis of given technologies and abilities, also the opposite is true: abilities and technologies are chosen on the basis of given property rights (IPRs). This implies a situation of institutional complementarity characterized by multiple organizational equilibria that is considered in section 4. There we argue that these equilibria are characterized by self-reinforcing properties. While some agents tend to acquire abilities because they have IPRs and tend to acquire IPRs because they have abilities some other agents may be trapped in equilibria where they do not acquire IPRs because they do not have the specific abilities and they do not acquire the abilities because they do not have IPRs. From an international perspective such a situation may also easily

diversify countries characterized by different initial endowments of IPRs and abilities and by different capacities to enforce IPRs at the international level.

Finally, in section 5 we consider whether the privatization (and monopolization!) of knowledge has gone too far and we consider the relative merits of reward systems. We argue that the relevant merits of reward systems become more evident for "upward knowledge" that may be used for the production of numerous lines of new knowledge and less evident for knowledge that is more relevant to introduce new products than to produce new knowledge. However, the "optimal mix" of incentives for a one-country world may well be different in a world where IPRs may be a better tool to exclude other countries from the benefits of new knowledge. Perhaps, the divergence in the economic perspectives among countries is not only an unintended consequence of IPRs. It may also be one of its purposes, even when a better alternative is available for the world taken as a whole.

1. The Allocation of the Ownership of Material Capital in the New Property Rights Approach

As mentioned, the New Property Rights School – associated with the contributions of Grossman, Hart and Moore (GHM) - emphasizes the important economic function of an efficient allocation of property rights over physical assets in a situation of incomplete contractibility. In this literature, contractual incompleteness arises because it is prohibitively costly to describe ex-ante in a contract the characteristics of what is traded and/or the parties' effort. This holds particularly for investments in "human capital" that – by their very nature – cannot be described as a "list of instructions" (Polanyi, 1958). As a consequence, outsiders, e.g. the courts, will not be able to verify ex-post the efforts or the results obtained by the parties' investment so as to enforce the contractual provisions.

Under such circumstances, the future returns on an individual's current action may bear little relation with his investment effort. Since an incomplete contract will be subject to renegotiation as the future unfolds, the extent to which an individual will be able to appropriate the surplus from his investment in human capital depends on his ex-post bargaining power. Some of the economic agent's increased productivity will thus be dissipated in the ex-post bargaining process. Economic agents will therefore have a much reduced incentive to invest with respect to a situation in which the retributions due for their investments in human capital can be determined ex-ante via the original contract.

The disincentive effect is most acute when incomplete contracts involve investments specific to a particular set of individuals or assets. Once specific investments have been incurred, the contractual parties become to some extent locked into each other. This is because, outside the relevant transaction, the ex-post value of specific assets or investments is much lower than their ex-

ante next best alternatives. In order to realize the surplus from his investment in human capital each agent needs the cooperation of other agents and requires access to a particular set of assets. Agents who make specific investments are therefore exposed to the risk of counterparts' opportunistic behavior. In order to appropriate a greater share of the surplus from the transaction, individuals may threaten to hold up their human capital and/or the assets they control. The threat of non-cooperation of other agents thus constitutes a deterrent to the realization of unverifiable specific investments in human capital.

In the contractual environment just described, ownership of physical or nonhuman assets is important because it affects the distribution of ex-post bargaining power and the division of ex-post surplus. This is because "the owner of an asset has residual control rights over that asset: the right to decide all usages of the asset in any way not inconsistent with a prior contract, custom or law."[1] In other words, it will be the asset owner that will have the power to decide about the use of the asset in question in every contingency not specified by the incomplete contract. Ownership ensures ex-ante the owner that he will be able to dispose ex-post of the asset and will not be excluded from its use. In case of break up of cooperation with the other agents, owners can at least count on the access to physical capital. The increased bargaining power at the renegotiation stage provides the owner with a greater incentive to invest in human capital in comparison to the other individuals. It makes therefore sense to assign ownership rights over nonhuman assets to the agents who value them the most, i.e. to the parties who have to make the most relevant and specific investment in human capital.

The owner's investment will however be below the "first-best" level. Since human assets cannot be bought or sold, there is no way in which the asset owner can be secured against the possibility of hold up of the agents who have invested in specific human capital. Moreover, the parties excluded from ownership are exposed to the possibility of hold up of both physical and human capital. The allocation of property rights will therefore be efficient if the incentive effect that operates with respect to the parties that have ownership rights outweighs the reduction in the level of the specific investment of the parties excluded from ownership. It goes without saying that when the number of agents required to make specific investments is high, the gap between the first-best and the second-best solution will be particularly wide, and the allocation of ownership rights will therefore display a limited efficacy as an incentive mechanism.

2. The New Property Rights Approach as a Theory of Intellectual Ownership.

IPRs can fruitfully be interpreted as residual rights of control, relevant in a situation of incomplete contractibility. Such an interpretation hints at the fact that intellectual property –

[1] Hart (1995, p.30)

similarly to private property of physical assets – can be allocated so as to provide incentives to the realization of the asset-specific investments in human capital that contractual incompleteness tends to reduce. Thus, if our contention is correct, the main conclusions that the New Property Rights approach derives as regards the characterization of the optimal ownership structure will have to be considered relevant for intellectual assets as well.

In our view three observations make this interpretation more appropriate than the traditional formulations of the models of Grossman Hart and Moore. First, as extensively remarked, the role residual rights of control play in the New Property Rights theory is to promote the realization of unverifiable investments in circumstances in which contracts are incomplete. Every contract is – to some extent, at least – incomplete, given that the tacit nature of human knowledge impedes to write out in a "blueprint" form the details of each agent's contribution to the productive process. However, contractual incompleteness is certainly a matter of degree and the importance of the role residual rights of control perform will vary directly with the amount of incompleteness. When technological knowledge is involved to some significant extent, as it is for contracts in which the specific investments at stake concern intellectual assets, one might reasonably expect the degree of incompleteness to be high not least because of the large amount of context-specific information courts need to gather in order to ensure enforcement. It follows that residual rights of control will be particularly relevant exactly under the circumstances we are considering. For instance, in an empirical study Lerner and Merges (1998) find that the allocation of control rights between small research firms and larger corporations plays a crucial role in biotechnology alliances, where the contribution of the contractual parties is not verifiable, and the uncertainty of the technology combines with asymmetric information in enhancing the likelihood of contractual breakdown.

Second, it is interesting to note that interpreting intellectual property rights as residual rights of control is congruent with legal theory and practice. As Merges (1999a) remarks: "the details of IPR law reflect this core idea of controlling residual uses. Licensees infringe an IPR, for example, when they operate even slightly outside the scope of their license; residual uses are by default controlled by the IPR owner. Control of residual uses is also evident in the remedy for breach of an IPR: injunctions issue virtually automatically in cases of licensee breach."[2]

Third, and most important, in GHM models the level of investment in human capital is sensitive to the allocation of property rights because, in presence of asset-specific investments, the acquisition of some skills and capabilities "pays off" in the future only if agents have access to particular assets. The implicit assumption here is that assets possess distinctive characteristics that render them difficult to be substituted for. Otherwise, it would always be possible for any agent to

[2] Merges (1999a, p.7).

find a suitable alternative to the asset on the spot market and the very notion of asset specificity would be meaningless. In the New Property Rights literature the assets at stake are usually described as physical assets, such as machines, buildings and other tangible goods. However, someone interested in spelling out the special attributes that may confer to a physical asset a low degree of substitutability would indeed face a hard task. In the end, machines are easy to replace with other machines of a similar kind available on the spot market. Similarly, it is difficult to describe the exact nature of asset-specific investments in human capital. The effort an economic agent may spend to enhance his productivity in the use of a particular machine and the skills acquired as a result of such an effort will in general be valuable also in different contexts, i.e. in a productive process utilizing a slightly different machine.

It is easier to grasp the notion of asset specificity if the asset considered is an intellectual one. Intellectual assets, such as pharmaceutical and chemical compounds, new product designs, algorithms, basic software programs and other "inventions" liable to IP protection, may present features that confer them a degree of "uniqueness" that is unknown to physical assets. In some instances, particular inventions will have no substitutes available on the market. This is especially the case of assets represented by patented "inventions" that cover elements or phenomena found in nature (DNA fragments, genetic materials, etc.). In other cases, the asset will have to be considered "unique" because it would be too costly to find a substitute for it by "inventing around" it. Under both circumstances, given the special characteristics intellectual assets have, an agent who has made an asset-specific investment would loose completely (or almost completely) the value of his investment should the asset owner hold up his asset. Thus, it is the "uniqueness" characterizing intellectual assets that may give substance to the idea – crucial to GHM models – that being excluded from control of an asset depresses agents' investment effort and, conversely, that attributing control positively affects agents' investment incentives.

In addition to this, the nature of the right granted to an IP-owner makes it even easier to understand why ownership of an (intellectual) asset matters. Although we use a terminology that evokes the category of conventional property to refer to the legal right conferred over intellectual assets, what ownership of an intellectual asset does in effect is according to the right-holder a temporary monopoly over the use of the asset. In fact, intellectual property seeks to reward inventors with the gains obtainable from establishing exclusivity of possession over ideas and inventions that – exactly because of legal protection – become in effect scarce resources, whose control represents a source of bargaining power in a trading relationship. By contrast, ownership of a machine certainly grants exclusivity of control to the right-holder but, to the extent that similar assets are available on the spot market, it is not straightforward to understand why the possibility of

exercising such control matters. It follows not only that the incentive mechanism the New Property Rights theory identifies in the allocation of ownership over physical assets operates with respect to intellectual assets as well, but also that the interpretation of the standard model as a theory of the allocation of intellectual property rights seems more "convincing" because of the peculiar nature of the assets and because of the monopoly component intrinsic in the notion of IPR.

When our interpretation is accepted, one of the main results of the New Property Rights approach gains a novel and fruitful meaning. A first immediate consequence of our interpretation is that, in this framework, also the property of intellectual assets should be given to the agents that are going to make the most relevant investment in human capital specific to these assets. The "second best solution" should entail that intellectual assets are moved to these people. In a way that is perfectly analogous to that of material capital, there will be a gap between the first best solution that can be achieved under a complete contract and the second best solution. Again the gap may be very wide when many agents should make investments that are specific to the same piece of intellectual property and intellectual ownership can protect only one of them by giving her the availability of the asset in case of non co-operation. In any case ownership can guarantee access to intellectual assets but it cannot ensure the co-operation of the other individuals. Thus, as it is for owners of physical capital, also the owner of the intellectual asset underinvests with respect to the first-best solution entailed by complete contracts.

A second consequence of our approach relates to the fact that the New Property Rights theory predicts that complementary assets should be under common ownership. Such a proposition follows directly from the very definition of complementarity. "Two assets are (strictly) complementary if they are unproductive unless they are used together"[3]. In other words, access to both sets of (complementary) assets is the *conditio sine qua non* for any agent to benefit from increases in her marginal productivity. Starting from a situation of separate ownership, any form of integration enhances efficiency because transferring ownership rights over one of the assets to either party increases the latter's marginal returns without decreasing the returns to the party excluded from ownership. This is because control of one of the assets alone has no effect on an agent's marginal productivity absent an agreement with the agent controlling the complementary asset. Conversely, attributing ownership rights to different agents negatively affects actors' incentives since it increases the number of possible hold-ups. An analogous line of reasoning suggests that attribution of ownership rights over complementary assets to the same right-holder may have a positive impact on efficiency also because under common ownership outside agents have to negotiate with only one agent rather than two in order to use the assets.

[3] Hart and Moore (1990, p. 1135).

A third consequence stems from another result of the GHM models: that independent assets should be owned separately. When assets are independent their concentration in the hands of one individual decreases the incentive to invest of one of the individuals without increasing the incentive to invest of the other. Thus, intellectual assets that are independent should be owned separately and the decentralization of intellectual ownership can be a means to provide greater incentives to invest in human capital.

Up to this stage of the analysis it has been our contention to demonstrate that – mainly because of the peculiar characteristics of knowledge as a commodity – the allocation of ownership rights appears to be a more effective incentive mechanism in the case of intellectual assets than in the case of ordinary tangible assets. However, the very fact that knowledge is not a commodity as any other commodity suggests that the efficacy of the "correct" allocation of private property rights (measured as a means of narrowing the gap between the "first" and the "second" best solutions) may be limited as compared to the standard case of physical assets. This conclusion depends, on one side, on acknowledgment of the fact that ideas, inventions and other intellectual objects liable to intellectual property protection possess the attributes of (impure) public goods, i.e. non-rivalness and non-exclusiveness; on the other side it depends on the fact that the evident existence of strictly positive transaction costs in the market for intellectual capital renders at least questionable the GHM conclusion that economic agents will be able to achieve spontaneously the proper allocation the theory predicts. To the first issue is dedicated the remaining of this section, whereas the implications of removing the zero-transaction-costs assumption will be treated in the next section.

Knowledge assets have two critical properties: nonrivalrous consumption and nonexcludability. Both of them have strong implications for a theory of the allocation of intellectual ownership. The first leads to question whether the very act of establishing exclusive rights over newly created pieces of knowledge can be motivated at all on efficiency grounds. The property of non-rivalness refers to the fact that the use of information made by someone does not diminish the potential or actual use of the same piece of information made by someone else. In other words, the marginal cost stemming from an additional individual enjoying the benefits of the knowledge is zero. Static efficiency would therefore require granting access to the intellectual asset to as many as care of making use of it.

Given that the first-best solution would involve simultaneous access by many agents, the efficiency gap between first-best solutions and the second-best solutions entailed by the New Property Rights approach will be particularly wide. The size of the gap will depend not only on the restriction to the use of the knowledge asset, but also on the reduction of the amount of asset-specific investments. Indeed – differently from the case of physical assets – were exclusive rights

over a certain intellectual asset absent, many agents could have (simultaneously) invested in human capital specific to the asset.

Whether the latter effect will have a negative impact on overall efficiency will depend on at least two factors. The first is the intensity of the incentive effect that ownership generates. The responsiveness of agents' investment effort to the availability of control of residual rights will typically vary across industries and sectors, depending on the degree of appropriability that IPRs afford. It might well be the case that in industries where the incentive effect that follows from ownership is slight because – for instance – lead time or secrecy are more effective appropriability mechanisms, the efficiency loss due to the restriction to the use of "public" knowledge outweighs the gains from the correct property rights allocation. The second factor likely to affect overall efficiency is the nature of the intellectual asset. The more upstream is the knowledge that is subjected to the exclusive right, the higher is the potential loss in efficiency that stems from the reduction in the number of individuals that make investments specific to it. This is because a single individual will not in general be able to exploit all the potential theoretical and practical applications of an asset that – by definition – is suited for a wide-ranging set of uses. Moreover, investment by different people (with heterogeneous skills, research interests and objectives) would increase the likelihood that many diverse lines of research stemming from the original "upstream" invention will be pursued and would therefore favour additions to the stock of knowledge available to society.[4]

The property of nonexcludability refers to the fact that it is inherently difficult to prevent someone from accessing or using information created by others. Once an invention, a formula or an idea is disclosed it is virtually impossible to avoid its unauthorized use in the absence of a legally enforceable claim over it. But even legal protection of intellectual assets (in the form of patent rights) may well be insufficient to grant to the right-holder a secure and complete ability to exclude others from access to the protected information. Imperfect excludability implies that the incentives an efficient allocation of ownership provides may not display the full effects the theory predicts. Indeed, essential to the notion of residual right of control over an asset is the possibility to deny others access to the asset – to "hold-up" the asset – that allows the owner to appropriate a greater share of the surplus in comparison to the individuals excluded from ownership. If legal protection results ineffective, economic agents will tend to integrate formal patent rights with other

[4] Note that this last remark would not make sense in a strictly interpreted GHM framework. The GHM theory assumes the stock of (physical) capital to be fixed and considers the issue of the allocation of the assets as distinct from that of their production. However, in the case of intellectual assets this distinction is blurred and the two issues necessarily interlinked, not least because the very act of investing in human capital specific to intellectual assets generates additions to the stock of (intellectual) capital. Thus, in the intellectual property domain one must necessarily be concerned with the influence that a given allocation of property rights exerts on the rate of growth of (intellectual) capital.

complementary devices. One of such devices is secrecy, and secrecy may be a source of additional inefficiencies not least because of the duplication of research efforts it contributes to create.

3. Anti-Commons Tragedies and IPRs Transaction Costs.

Ever since Arrow published his landmark 1962 paper recognition of the difficulty of creating a market for information has become a commonplace. In principle, intellectual property rights are apt to solve at least some of the transactional problems envisaged by Arrow's analysis. At a minimum, they create the possibility of exchange of intangible assets. They enable the buyer to assess the value of his purchase and protect the seller from the risk of loosing the entirety of his asset, thus overcoming the Arrowian "fundamental paradox". Even with that problem solved, however, exchange of intangible assets is scattered with substantial transactional difficulties.

Some obstacles to efficient exchange are peculiar to the intangible nature of intellectual assets. In many instances even determining whether a transaction is required at all may result particularly difficult in presence of intellectual assets. For a transaction to occur, parties have first to recognize the need for an exchange of rights. This is not straightforward when the extent of the right one possesses is not exactly defined ex-ante, as it happens with poorly defined patent entitlements. For example, exchange of rights between a patent-owner and an inventor that incorporates the existing invention into a new intellectual creation will take place only if both economic agents recognize that infringement has occurred. In turn, this is very often ascertained only in the context of an infringement suit.

The other costs normally associated to the exchange of assets – research, negotiation and enforcement costs – are also most acute in IP-related transactions. As for research costs, exchange may be hampered by the difficulty of identifying the parties to the transaction, i.e. who are the relevant right holders. On one side, it is well-known that this category of costs increases with the complexity and the specificity of the good to be exchanged. On the other side, transactional impediments stem from the existence of so-called "submarine" patents or more simply from the combination of imperfect information with the dispersed nature of buyers and sellers in the market for intangibles.

Finally, differences in beliefs about the exact value of the asset complicate the picture, thus introducing substantial negotiation costs. In the simple case sketched out above, the cumulative nature of innovation adds some interesting twists to the issue of determining the right "price" for the transaction, given the likely dissent about the contribution of the original invention to the subsequent one. In a more general context, on one side, the "unique" nature of many intellectual objects may make it difficult to assess the value of an asset by way of comparison with similar ones. Moreover, not only the parties will tend to make strategic use of their private information about the

value of the assets in order to secure higher returns from the bargain but also – strategic behavior aside – it has been shown empirically that individuals display self-serving valuation biases in bargaining contexts.[5] On the other side, uncertainty exacerbates valuation problems, thus introducing additional transaction costs. What is more, because of uncertainty, often the immediate costs of obtaining an intellectual asset are balanced against highly speculative gains so that doubts may arise about the worthiness of the effort to be spent in overcoming transactional difficulties. The problem is most acute the more "upstream" is the patented invention and the further is its commercial application.

The previous record of possible transactional problems is not exhaustive but provides a sense of the specificity of the problems the market for intangibles poses as compared to the market for physical assets.[6] Even assuming that a deal falls through – and in many cases indeed it does, as witnessed by the increasing amount of IPRs-related transactions – transactional hurdles may still result as a consequence of monitoring and enforcement problems. The action of a court called to enforce the provisions of a contract regarding an IPRs exchange or to set ex-post the terms of such an exchange, after an alleged infringement has occurred, is restrained by the need to acquire a large amount of context-specific information that – given the parties' incentives to misrepresent their claims – may be extremely difficult to obtain. Of course the above-mentioned "uniqueness" of intellectual assets, together with the multi-faceted nature of the environment in which IPRs transactions take place, add complexity to the task. This circumstance renders the job of such an authority subject to an high probability of error. What is more, it hints at the fact that non-verifiability and therefore contractual incompleteness characterize the market for the exchange of intangibles to a significant extent.

This last remark is particularly interesting because it contributes to elucidate one of the fundamental limits – and the most relevant for the purpose of our paper – of the New Property Rights approach. As one of us has observed elsewhere, the New Property Rights theory "considers a dichotic world where third parties can verify some contracts at zero costs and some other contracts at an infinite cost. The markets for physical capital operate at zero transaction costs and their efficiency is not limited by any wealth or credit constraint. By contrast, the contracts for the results or the efforts of human capital investments are characterized by a total impossibility of third party verification or, in other words, by infinite transaction costs" (Pagano, 2000 p.466). This assumption comes in handy when a stylized representation of the world is deployed to understand the dynamics

[5] see for example Loewenstein et al. (1995) – cited in Somaya and Teece (2001, p.17).
[6] For a more detailed overview of transaction costs in the market for intangibles see for example Somaya and Teece (2001), discussing the combination of inventions in multi-inventions products; Heller and Eisenberg's analysis geared to the biomedical field (1998); Merges (1994) as regards to the application of the Coase Theorem to the IPRs domain.

of the simple incentive mechanism the GHM literature describes. Moreover, in spite of the analytical tensions it generates, in standard GHM models the dichotic assumption recalled above may be given an approximate justification on the basis of the differing degrees of non-verifiability characterizing contracts for the exchange of physical assets, as compared to contracts specifying investments in human capital. By contrast, what the preceding discussion suggests is that such an explanation does not fit with the case of intellectual assets whose exchange – almost by definition – involves substantial transaction/verification costs.

When positive and significant transaction costs are taken into account the efficiency gains determined by the "correct" property rights allocation may be outweighed by the costs of exchanging the rights, so that the economic agents may fail to reach the efficient allocation the theory predicts. Thus, in contrast with the standard formulation of the New Property Rights approach, real-world allocation of intellectual property rights will often not coincide with the efficient (second best) solution.[7] One consequence is that one has to expect that at any point in time it will take a sufficient dose of chance for complementary assets to be owned by the same economic agent. In addition to this, since technological interdependencies may arise unexpectedly as a consequence of breakthroughs in seemingly unrelated areas of research, some applications requiring previously unrelated assets may become feasible with time and unforeseen technological complementarities may become known as time passes. Therefore, even assuming that the existing allocation is the efficient one, the nature of technological innovation suggests that the optimal ownership structure will require frequent modifications not likely to occur at the requested pace.

Moreover, once the existence of transaction costs in the market for the exchange of assets is taken into consideration the GHM logic itself will suggest that those costs will be most relevant exactly in presence of complementary assets. It is when the ownership of complementary assets is attributed to separate agents that the space left to the possibility of opportunistic behaviours is wider and hold-up problems are at their worst.

Thus, when one removes the assumption that the exchange of intellectual and material assets can be carried out at zero costs and their ownership is easily allocated to the most efficient owner, the framework provided by GHM models becomes suited to understand the occurrence of what Heller and Eisenberg have labeled "Tragedy of the Anticommons". The metaphor indicates a situation in which "multiple owners each have a right to exclude others from a scarce resource and

[7] This result is consistent with the findings of Aghion and Tirole (1994). The two authors examine in a GHM perspective a contractual relationship between a customer and a research unit that depends on outside financing to pursue her research and – by relaxing the GHM assumption of absence of "wealth constraints" – show that the efficient allocation would not always take place. Conversely, a number of authors has recognized in the current surge of spin-offs of R&D units from large corporations, "outsourcing" deals, R&D joint ventures and partnerships evidence of GHM-type deductions (see for instance Arora and Fosfuri, 1998; Arora and Merges, 2001; Merges, 1995, 1998, 1999a).

no one has an effective privilege of use"[8]. The excessive fragmentation of property may preclude effective exploitation of the resource because the transactional problems encountered in bundling together a large number of far-flung rights may be so difficult to overcome that economic agents may decide to avoid transactional difficulties by renouncing to the task altogether. Heller and Eisenberg are especially concerned with the effects of this phenomenon in the biomedical field, where research is increasingly becoming "private" in nature and a proliferation of intellectual property rights upstream follows from the surge in patenting of isolated gene fragments. Since commercialisation of a single useful innovation normally requires the combination of many patented fragments, whose property is dispersed among multiple right holders, they warn that "[e]ach upstream patent allows its owner to set up another tollbooth on the road to product development, adding to the cost and slowing the pace of downstream biomedical innovation"[9].

Should one pessimistically conclude that circumstances in which ownership of complementary assets happens to be dispersed at the outset are bound to generate "tragedies" of the kind envisaged by Heller and Eisenberg? A number of real-world phenomena witness what both commonsense and economic theory suggest, i.e. that rational economic agents will tend to pursue transactions when they foresee gains from trade. The relevant question is therefore not as much whether we should expect "anticommons tragedies" to occur, but rather under what circumstances they may prove excessively difficult to overcome in the absence of some form of public intervention. The literature on collective right organizations has attempted to provide an answer to this second question, identifying the circumstances under which agents are able to overcome transactional failures by creating voluntary transactional institutions (e.g. collective copyright licensing organizations, such as ASCAP, and patent pools).[10] One general recommendation that follows from this analysis is that it is sometimes desirable that government intervention takes the form of a stimulus to the formation of pools and other exchange mechanisms. The argument is surely more stringent in cases of technological blockage resulting from standard setting or dispersion of strictly complementary assets[11], but it applies to less clear-cut situations as well. It follows that it is indeed worth paying more attention to the circumstances that may turn transactional problems in the IPRs field into "tragedies" so as to determine the appropriate scope for policies directed at decreasing the costs of exchanging the rights.

---

[8] Heller and Eisenberg (1998, p.698).

[9] Heller and Eisenberg (1998, p.699).

[10] Note that in the dichotic world defined by standard GHM assumptions there would not be room for considerations of this kind because the hypothesis of infinite verification costs rules out the possibility of the constitution of private legal orderings. In fact, in presence of infinite verification costs it cannot be convenient for agents to invest a positive amount of resources in verification capacities.

[11] See Merges (1997, 1999b); Shapiro (2001).

To sum up, if the GHM model assumption of zero enforcement costs on material assets may be problematic, extending it to intellectual property rights is highly unrealistic and this widens the well-known gap existing in that model between first-best and second-best solutions. If IP-related transactions are costly (and often so costly that they may be never carried out by markets) some public policies may well improve the situation by aggregating inefficiently dispersed intellectual property. However, even when State intervention is able to favor efficiency-enhancing transactions, relying only on IPRs may well be insufficient. Indeed – even if transaction costs were negligible – the allocation of ownership might have a limited efficacy as an incentive mechanism for the reasons mentioned in the previous section. Moreover, the introduction of positive transaction costs for the exchange of assets into the analytical framework the New Property Rights theory provides has a consequence that is more serious for public policy than the issues that have been traditionally considered: that (possibly inefficient) intellectual property rights may influence the nature of technology and the distribution of abilities in the economy. The traditional GHM causation mechanism from technology and distribution of abilities to the allocation of property rights is therefore inverted – opening numerous issues to which the following section is dedicated.

5. From IPRs to Technologies (and vice versa): an Extension of the New Property Rights Approach.

According to the standard GHM logic, economic agents with the most important specific investment will obtain ownership of the assets. In other words, it will be the nature of the technology available to a society at any given point of time to determine the efficient property rights structure. However, if transaction costs prevent property rights from being attributed to the "efficient owner" the opposite situation will occur: who is in possession of the rights will invest. Thus, a consequence of taking transaction costs into account is an inversion of the GHM chain of reasoning. Taking this observation as a starting point, we suggest that the existing allocation of property rights over intellectual assets may exert an enduring influence on the direction of technological development and that economic theories as well as public policies should consider both directions of causation: that running from technology to property rights and that running from property rights to technology (whose specification includes intellectual and material resources).

The nature of this double relation of causation suggests that the issue cannot be treated simply as a choice of rights that the individuals make on the basis of the available resources. It should also be treated as a choice of the technology embodying the intellectual and material resources of the society on the basis of the existing definition of property rights. In other words, the problem does necessarily involve choices occurring in two different domains, one where the attribution of rights is made on the basis of a given technology and the other where the technology

is chosen on the basis of existing property rights. The problem can therefore be more aptly treated as a case of institutional complementarity of the choices made in two different domains[12].

In general, a case of institutional complementarity arises when there are two domains *D* and *G* with sets of agents *M* and *N* who do not directly interact, but an institution implemented in one domain might parametrically affect the consequences of the other game by changing the institutional environment. Here technology changes the institutional environment for the choice of property rights and property rights change the institutional environment for the choice of technology.

Assume that the agents in domain *D* face the choice of a rule from either S* or S**, while the agents in domain *G* face the choice of a rule from either L* or L**. Assume also that all the agents in each domain have identical payoff functions $u_i = u$ ($i \in M$) and $v_j = v$ ($j \in N$), defined on binary choices of their own, either (S*, S**) or (L*,L**).

Following Milgrom and Roberts (1990) and Aoki (2001) we can state the following super-modularity (complementarity) conditions:

(1) $u(S^*; L^*) - u(S^{**}; L^*) \geq u(S^*; L^{**}) - u(S^{**};L^{**})$

(2) $v(L^{**}; S^{**}) - v(L^*; S^{**}) \geq v(L^{**};S^*) - v(L^*, S^*)$

The first inequality implies that the "incremental" benefit for the agents in *D* from choosing S* rather than S** increases as their institutional environment in *G* is L* rather than L**.

The second inequality implies that the incremental benefit for the agents in *G* from choosing L** rather than L* increases if their institutional environment in *D* is S** rather than S*.

These conditions are concerned with the property of incremental pay-offs with respect to change in parameter value. They do not exclude the possibility that the level of the pay-off of one rule is strictly higher than that of the other for the agents of one domain or of both domain(s) regardless of the choice of the rule in the other domain. Thus, a unique equilibrium is possible.

However, under the supermodularity conditions, there can be two pure Nash equilibria (institutional arrangements) for the system comprised in *D* and *G,* i.e. (S*,L*) and (S**, L**). When such multiple equilibria are possible, we say that domains *D* and *G* and S* and L* as well as S** and L** are institutional complements of each other.

Consider now two different (sets of) agents i and j and consider two different domains. In the domain P ownership of the intellectual and material assets A available at the beginning of the period is attributed to the most talented individuals taking the distribution of talents as given. By contrast, in

[12] On the concept of Institutional Complementarity see Milgrom and Roberts (1990) and Aoki (2001). According to Aoki (2001, p.396) "[a]lso Pagano (1993) and Pagano and Rowthorn (1994) are two of the earliest analytical contributions to institutional complementarity".

the domain T individuals choose how much to invest in their talents taking the distribution of property rights as given. Define as P^i the case in which the assets A are attributed to the individual i at the beginning of the period and define as P^j the case in which the assets A are attributed to the individual j at the beginning of the period. Consider now two different technologies T^i and T^j that are characterized by the fact that the intensity of the investment in the talents of i with respect to j is relatively higher in T^i than in T^j .

The logic of the new property rights model can be captured by observing that in the domain P the choice P^i will be marginally better than the choice P^j when in the domain T T^i is selected instead of T^j . In other words, the assets A are more likely to go to agents i than to agents j when agents i have chosen a relatively higher intensity of talents in the domain T. However, in this framework also the opposite direction of causation - that running from property rights to technology – can be easily caught. One can indeed argue that in the domain T the agents j will choose a higher level of investments in their talents and the agents i will choose a lower level of investments in their talents if in the property rights domain the property rights structure P^j has been selected instead of the property rights structure P^i. Thus, in a symmetric manner we can maintain that in the domain T the technology T^j (with a higher intensity of j's talents) does marginally better than the technology T^i (characterized by a higher intensity of i's talents) when in the domain P the assets A are attributed to j rather than to i[13]. The two points can be summarized by the following relations:

(3) $u(P^i,T^i) - u(P^j, T^i) \geq u(P^i,T^j) - u(P^j, T^j)$

(4) $v(T^j,P^j) - v(T^i, P^j) \geq v(T^j,P^i) - v(T^i, P^i)$

(3) and (4) satisfy the supermodularity conditions described by (1) and (2). Thus multiple equilibria are possible and the choice of rights on (intellectual) assets and the choice of the talents defining the technologies chosen by the agents can be seen as interdependent institutional complements that influence each other.

A consequence of this argument is that some individuals may enjoy situations where an initial distribution of rights over initial assets favors the investments in talents and in turn reinforces their convenience to keep that ownership system. By contrast, because of the same argument, other

[13] Thus, the argument is analogous to that developed by Pagano (1993) and Pagano and Rowthorn (1994). Indeed the choices made in the domain P follow the general "New Institutional" efficiency principle that ownership should go to the agents for which this is more valuable (in this particular case the agents that have developed more abilities specific to the assets over which intellectual property rights are defined). The choices made in the domain T are related to the "radical assumption" that ownership can often shape technology. Also this assumption is related to a very general principle of economic theory: that agents tend to invest more in resources that become cheaper. The ownership of intellectual assets decreases the risks of investing in abilities specific to these assets. For this reason agents will choose a technology requiring a higher intensity of these specific abilities when they own the intellectual assets.

individuals can be trapped in vicious circles where the lack of property rights diminishes the convenience to invest in talents and the lack of talents diminishes the convenience to acquire the rights over intellectual and physical assets. While this tendency may characterize different groups of individuals in the same nation, its effects may perhaps be even stronger at the international level. Different countries differ in their capacities to enforce intellectual property rights and the different access to them may - together with different initial ownership rights over them - be a major cause for the divergence in development paths of the different countries. A strong IP system may be both a consequence and a cause of inequality at the international level. If IPRs represent a tool effective in excluding other countries from the benefits of newly-created knowledge a dose of intentionality might be sustaining the perpetuation of a property rights structure that tends to preserve and deepen inequalities. The currently dominant form of international IP regime, shaped by the TRIPS agreement, appears consistent with this observation. By requiring developing countries to adopt the same (high) standards of IP protection implemented in the developed world the TRIPS agreement serves the interests of the countries enjoying the benefits of virtuous interactions between rights and technology and restrains the chances of catching-up through imitation of the countries behind in the technological ladder. Considering that infringement of foreign patents and imitation have been crucial in the early stage of development of the now-industrialized countries, there are reasons to agree with Chang (2001, p.304) that "the imposition of this system amounts to "pulling up the ladder" by these countries against the developing countries". One might well ask if alternative incentive systems that are based on disclosure could not favor more equality as well as greater overall efficiency.

5. IPRs vs. Reward Systems: Has the Privatization of knowledge gone too far?

The same observation spontaneously comes to mind when one considers that – as a consequence of the self-reinforcing interaction between the structure of rights and the nature of technology – countries with a high level of investment in talents and a strong IPRs system will find it convenient to invest resources in keeping the system in place and strengthening its effectiveness and will therefore display a tendency towards an ever increasing reliance on the "privatization of knowledge". This tendency will be likely to take the form both of a move "upward" of patents and of a reduction of the level of investment in basic research with respect to a situation in which only one country exists.

As regards to the first effect, it should be noted that an important aspect of the definition of a property rights structure concerns the requirement of patentability. One may reasonably hypothesize that in a continuum that goes from "downstream" patents over inventions extremely near to commercial application to "upstream" patents over the outcomes of "basic" research, there will be

an optimum choice for each country, depending on the desired level of intellectual property protection and on the nature of technology. The determination of the optimum will however differ in a setting where a plurality of countries is considered. If IPRs are effective in restraining knowledge spillovers at the international level and have therefore a bearing on the pace of a country's technological development relative to other countries, in a multi-countries setting the optimum choice for countries with a high IPRs/investment intensity will lye towards the upward end of the continuum.

Of course the more formal rights are made available for "upstream" research results, the more "privatised" is the nature of research activity likely to be. In the limit, imagine a world whereby all intellectual creations are the object of formal property rights. Because of the self-reinforcing properties of the double relation of causation between rights and technology, the direction of technological development would be exactly determined by the ownership structure that happens to be prevailing at an initial stage. Clearly (and luckily), the scenario we are depicting represents only a thought experiment. However, real-world relevance of the phenomenon of extreme privatisation of research is witnessed by the recent jurisprudence of U.S. and – to a lesser extent – European courts. It therefore makes sense to cast the attention on the drawbacks of "upstream" patenting and to ask whether incentive mechanisms based on disclosure – such as reward systems, for instance – would enjoy some advantages in comparison to "privatised" forms of knowledge creation.

"Upstream" patenting may have some undesirable consequences. On one side, the possibility to obtain formal rights on the outcomes of basic research may increase the incentives to adopt a strategy of secrecy and to reduce the sharing of results and the informal circulation of information essential to the pursuit of science. On the other side, availability of "upstream" patents may exacerbate the problems posed by the dispersion of complementary assets. In fact, the stronger the rights upstream, the higher will be transaction costs – not least because uncertainty is higher when an invention is far from practical application and because potential complementarities have yet to be discovered – and the more acute will therefore be transactional difficulties.

Finally, and most importantly, an increase in the overall inefficiency of the economy may result from the fact that the availability of upstream rights reinforces the "winner-takes-all" nature of the patent system. Upstream patents grant to the right holder the possibility to exercise claims over an indeterminate series of follow-on inventions. As a consequence, the payoff to being the first to achieve a certain research result will disproportionately exceed the payoff to being the second-comer. Inefficiency may emerge at two levels. On one side, individuals may tend to invest above the efficient level in the "scramble for the prize of priority" (David, 1993), as the literature on

patent races has emphasized. On the other side, an ex ante reduction of the investment effort may be the outcome of the fact that individuals anticipate the possibility of their investment being "wasted" in case they do not succeed in being the first to obtain patent rights over an invention. Both kinds of inefficiencies will be more likely to arise in case patent rights cover "upward knowledge" that may be used for the production of numerous lines of new knowledge than in the case of knowledge that is more relevant to introduce new products than to produce new knowledge.

It is therefore with respect to the provision of incentives for the production of the first category of knowledge that the relative merits of reward systems become more evident. Under a reward system, although assignment of the reward on the basis of priority of invention confers a "winner takes all" structure to the reward system as well, potential or actual researchers engaged in the same intellectual pursuit will take into account in their investment decision the fact that not being the first in the race to invent does not imply the loss of the entire investment made. In fact, absent formal property rights on the research results of the first-comer, other researchers will be able to "publish" their results even if they overlap to some extent those of the first-comer. Of course in order to presume that the availability of this option positively affects researchers' investment incentives one has necessarily to suppose that under a reward system a fraction of the expected payoff from investing in research is constituted by "scientific notoriety" and other non-monetary benefits relevant in the context of the scientific community. In addition to this, given that under a reward system the rule of disclosure ensures that the research results of the first-comer are brought to the public domain, second-comers will be able to use the results obtained from the first to invent incorporating them into their own research and might therefore "leapfrog" first-comers.

A final remark follows from the observation that under a reward system the payoff from being the first-comer does not include claims on subsequent inventions or on related inventions. Even though it might be argued that this circumstance will render the incentive to invent associated to the reward system lower than that associated to the patent system, it is worth noting that a reward represents a payoff fixed ex ante and therefore associated to a level of uncertainty inferior to that characterizing the economic returns from possession of patent rights. One may thus speculate that agents sufficiently risk-averse may prefer a smaller payoff obtained with a higher probability to a higher but more uncertain payoff and therefore that the overall incentive effect of a patent system would not be stronger – to this respect, at least – than the incentive provided by a reward system.

If there are reasons to think that a reward system is sometimes better than a patent system one is left wondering about the reasons of the present-day neglect of reward systems.[14] One

[14] Both the debate over the relative merits of reward systems and recourse to incentive mechanisms based on disclosure have been much more intense in the second half of the XIXth century than in recent times. See for example Machlup and Penrose (1950).

explanation may be that reward systems have the drawback of requiring the acquisition of a great deal of information relevant to the determination of the exact amount of the reward and are subject to the hazards of discretion. But there is perhaps a more fundamental reason. As already mentioned, given that IPRs may serve the purpose of restraining the benefits of new knowledge within the narrow boundaries of the State in which it was created, a country's choice of the optimal mix of incentive mechanisms might be intentionally biased towards IPRs-based systems, even though systems based on disclosure might ensure not only greater equality, but also greater efficiency.

The possibility that countries display a tendency towards underinvestiment in basic research may be explained on similar grounds. We use the expression "basic research" in opposition to "applied research", i.e. research devoted to the creation of knowledge whose economic benefits are privately appropriable through patents and other formal instruments of intellectual property protection. By contrast, the outcomes of "basic" research are typically not fully appropriable both because establishment of property rights over some of the research results is often unfeasible and because the pursuit of "basic research" is generally governed by the rule of disclosure prevailing in the domain of "open science". Moreover, differently from applied research, basic research may have a non-target-oriented nature, i.e. it often pursues the task of increasing the stock of available scientific knowledge without a previous selection of the number and identity of its beneficiaries.

This is of course a somewhat crude and approximate distinction. However, it allows to capture the complementary nature of the two domains. Basic research is complementary to applied research in that it may be understood as an input for the latter and therefore it gains economic value indirectly through the potential it creates for applied research. The convenience to invest in basic research thus raises with the intensity of a country's applied research. The same conclusion can be reached by considering that in countries characterized by high levels of applied research the self-reinforcing interaction between property rights and technology creates the preconditions for reaping the benefits of basic research through the absorptive capacity the intense investment in talents generates.

Thus, because of the complementarity between basic and applied research one should expect countries in which the relationship of institutional complementarity between rights and technology has virtuous properties to exhibit a high propensity to invest in basic research. However, a shift in perspective from a single-country to a multi-countries setting may dilute this desirable result. Recognition of the fact that the payoffs from basic research results do hinge on their widespread diffusion compels respect of the rule of disclosure. Adherence to the rule of disclosure, in turn, implies that the outcomes of State-financed basic research will be put into the public domain and will therefore easily spill-over outside of the context in which they were created. What makes sense

from the perspective of a single State may therefore be a less compelling argument when existence of a plurality of countries is considered. States may be reluctant to invest resources in the generation of knowledge "public" in nature, whose economic benefits cannot be entirely reaped by its creator[15]. Basic research might be – and indeed it has been – among the "privileged" domains for funding cuts at times of fiscal retrenchment.

The discourse boils down to the question whether it would not be wise to raise the level of investment in basic research pursued by supra-national authorities such as European Union agencies. The shift in perspective beyond the national dimension might make it convenient for states to invest in basic research. By pooling their resources the States financing the supra-national authority would be able to internalise a larger amount of the benefits stemming from their investments. Moreover, efficiency gains might derive from the reduced duplication of research efforts at the international level that follows from the coordination of investment projects[16]. Increased investment in basic research may be a valuable tool in overcoming the "lock-in" effect that follows from the restriction of technological opportunities to the set of choices determined by the technological paradigms shaped by the existing property rights structure. Of course the bureaucratic expenses necessary to the operation of such an authority should be taken into account in assessing its convenience. Coordination is costly, but it might pay off to bear its costs when the alternative is renouncing to the positive payoffs stemming from additions to the stock of knowledge freely available to society at large.

6. Conclusions

This essay combines two somewhat contrasting lines of reasoning. On one side, we argue that the basic logic of the New Property Rights approach is better suited for the case of intellectual assets than for the case of physical assets, mainly because of the "uniqueness" of intellectual objects and of the monopoly component intrinsic in the notion of IPRs. However, in suggesting that the allocation of intellectual ownership may be an effective incentive mechanism, we caution that the peculiar nature of intellectual properties poses limits to the efficacy of the "correct" allocation of ownership. On the other side, we also argue that the evident existence of transaction costs in the market for the exchange of intellectual assets provides a stringent argument (even more stringent than in the standard formulation) for an inversion of the GHM chain of reasoning that casts light on

[15] An argument congruent with the one we present here can be found in a recent paper on the political economy of intellectual property treaties by Scotchmer (2002).

[16] It might be argued that the high levels of investment in basic research characterizing the U.S. may be partially explained on these grounds. For instance, Owen-Smith et al. (2001) observe – with reference to biomedical research – that in the U.S. "generalist regional clusters developed around public research organizations that integrated innovation and development work"(p.18), whereas in Europe the national dimension of clusters and the looser links between basic science and clinical development may have prevented broad exploration of research opportunities and favored a deepening of already narrow competencies.

the fact that the choice of technology and the choice of the property rights structure can be seen as interdependent institutional complements that influence each other.

This apparent paradox is the source of our concerns as regards to the possibility that the self-reinforcing interaction between property rights and technology may have particularly perverse consequences that hinge upon the direction of technological development and contribute to the perpetuation of inequalities. In the scenario we depict both redistributive interventions and the adoption of incentive mechanisms based on disclosure may be justified by the need to avoid excessive monopolization of knowledge and to ensure greater equality as well as greater overall efficiency.

References

Aghion, Philippe and Jean Tirole. (1994). "On the management of innovation," *Quarterly Journal of Economics* 109, 1185-1207.

Aoki, Masahiko. (2001). *Towards a Comparative Institutional Analysis*. MIT Press, forthcoming.

Arora, Ashish and Andrea Fosfuri. (1998). "Licensing in the chemical industry," mimeo, Carnegie Mellon University, Heinz School of Public Policy and Management.

Arora, Ashish, Andrea Fosfuri, and Alfonso Gambardella. (1999). "Markets for Technology (Why do we see them, why don't we see more of them, and why we should care)," mimeo, Carnegie Mellon University, Heinz School of Public Policy and Management.

Arora, Ashish and Robert P. Merges. (2001). "Property Rights, Firm Boundaries, and R&D Inputs," mimeo, Carnegie Mellon University, U.C. Berkeley School of Law.

Arrow, Kenneth J.. (1962). "Economic Welfare and the Allocation of Resources for Invention". In Richard R. Nelson (ed.), *The Rate and Direction of Inventive Activity*. Princeton: Princeton University Press.

Babcock, Linda, George Loewenstein, Samuel Issacharoff and Colin F. Camerer. (1995). "Biased judgments of fairness in bargaining," *American Economic Review* 85(5), 1337-1343.

Chang, Ha-Joon. (2001). "Intellectual Property Rights and Economic Development: historical lessons and emerging issues," *Journal of Human Development* 2(2), 287-309.

Dasgupta, Partha and Paul A. David. (1987). "Information Disclosure and the Economics of Science and Technology." In George Feiwel (ed.), *Arrow and the Ascent of Modern Economic Theory*. New York: New York University Press.

David, Paul A. (1993). "Intellectual Property Institutions and the Panda's Thumb: Patents, Copyrights, and Trade Secrets in Economic Theory and History." In Mitchel B. Wallerstein, Mary Ellen Mogee and Roberta A. Schoen (eds.), *Global dimensions of intellectual property rights in science and technology*. Washington D.C.: National Academy Press.

David, Paul A. (1998). "The Political Economy of Public Science." Forthcoming in Helen Lawton Smith, *The Regulation of Science and Technology*. London: Macmillan Publisher.

David, Paul A., David C. Mowery and W.Edward Steinmueller. (1992). "Analysing the Economic Payoffs from Basic Research," *Economics of Innovation and New Technologies* 2(3), 73-90.

Gallini, Nancy and Suzanne Scotchmer. (2001). "Intellectual Property: When is it the Best Incentive Mechanism?." In Adam Jaffe, Joshua Lerner and Scott Stern (eds.), *Innovation Policy and the Economy, Vol 2*. MIT Press. Also forthcoming in Fabrizio Cafaggi, Antonio Nicita and Ugo Pagano (eds.), *Legal Orderings and Economic Institutions*. London: Routledge Studies in Political Economy.

Green, Jerry R., and Suzanne Scotchmer. (1995). "On the Division of Profit in Sequential Innovation," *Rand Journal of Economics* 26, 20-33.

Grossman, Sanford J. and Oliver D. Hart. (1986). "The Costs ad Benefits of Ownership: a Theory of Vertical and Lateral Integration," *Journal of Political Economy* 94(4), 691-719.

Hart, Oliver D. (1995). *Firms, Contracts and Financial Structure*. Oxford: Clarendon Press.

Hart, Oliver and John Moore. (1990). "Property Rights and the Nature of the Firm," *Journal of Political Economy* 98(6), 1119-1158.

Heller, Michael A.. (1998). "The Tragedy of the Anticommons: Property in the Transition from Marx to Markets," *Harvard Law Review* 111, 621-688.

Heller, Michael A. and Rebecca S. Eisenberg. (1998). "Can Patents Deter Innovation? The Anticommons in Biomedical Research," *Science* 280, 698-701.

Lerner, Josh and Robert P. Merges. (1998). "The Control of Technological Alliances: An Empirical Analysis of the Biotechnology Industry," *Journal of Industrial Economics* 46, 125-156.

Loewenstein, George, Samuel Issacharoff, Colin F. Camerer and Linda Babcock . (1993). "Self-Serving Assessments of Fairness and Pretrial Bargaining," *Journal of Legal Studies* 22(1), 135-159.

Machlup, Fritz and Edith Penrose. (1950). "The Patent Controversy in the Nineteenth Century," *Journal of Economic History 10* (1), 1-29.

Mazzoleni, Roberto and Richard R. Nelson. (1998). "The benefits and costs of strong patent protection: a contribution to the current debate," *Research Policy* 27, 273-284.

Merges, Robert P. (1994). "Of Property Rules, Coase, and Intellectual Property, Symposium: Towards a Third Paradigm in Intellectual Property," *Columbia Law Review* 94, 2655-2673.

Merges, Robert P. (1995). "Intellectual Property and the Cost of Commercial Exchange: a Review Essay," *Michigan Law Review* 93, 1570-1615.

Merges, Robert P. (1997). "Contracting into Liability Rules: Intellectual Property Transactions and Collective Rights Organizations," *California Law Review* 84, 1293-1392.

Merges, Robert P. (1999a). "Intellectual Property Rights, Input Markets, and the Value of Intangible Assets," mimeo, U.C. Berkeley School of Law.

Merges, Robert P. (1999b) "Institutions for Intellectual Property Transactions: the case of Patent Pools," mimeo, U.C. Berkeley.

Merges, Robert P. and Richard R. Nelson (1990) "On the complex economics of Patent scope," *Columbia Law Review* 90(4), 839-916.

Milgrom, Paul and John Roberts. (1990). "Rationalizability, Learning and Equilibrium Games with Strategic Complementarities," *Econometrica* 59, 511-528.

Milgrom, Paul and John Roberts. (1990). "The Economics of Modern Manufacturing: Technology, Strategy and Organization," *American Economic Review* 81, 84-88.

Owen-Smith, Jason, Massimo Riccaboni, Fabio Pammolli, and Walter W. Powell. (2001). "A Comparison of U.S. and European University-Industry Relations in the Life-Sciences." *Management Science Informs* 00(0), 1-19.

Pagano, Ugo. (2000). "Public Markets, Private Orderings and Corporate Governance," *International Review of Law and Economics* 20(4), 453-477.

Pagano, Ugo. (1993). "Organizational Equilibria and Institutional Stability." In Bowles, Samuel, Herbert Gintis and Bo Gustafson (eds.) *Markets and Democracy*. Cambridge: Cambridge University Press.

Pagano, Ugo and Robert Rowthorn. (1994). "Ownership, technology and Institutional Stability," *Structural Change and Economic Dynamics* 5(2), 221-243.

Polanyi, Michael. (1958). *Personal Knowledge: towards a post-critical philosophy.* London: Routledge and Kegan Paul.

Shapiro, Carl. (2001). "Navigating the Patent Thicket: Cross Licenses, Patent Pools and Standard Setting." Forthcoming in Adam B. Jaffe, Josh Lerner and Scott Stern (eds), *Innovation Policy and the Economy*, vol.1. MIT Press.

Scotchmer, Suzanne. (1991). "Standing on the Shoulders of Giants: Cumulative Research and the Patent Law," *Journal of Economic Perspectives* 5, 29-41.

Scotchmer, Suzanne. (2002). "The Political Economy of Intellectual Property Treaties," Institute of Economic and Business Research, Working Paper E01-305, UC Berkeley.

Scotchmer, Suzanne and Jerry Green. (1990). "Novelty and Disclosure in Patent Law," *Rand Journal of Economics* 21, 131-149.

Somaya, Deepak and David J. Teece. (2001). "Combining Patented Inventions in Multi-invention Products: Organizational Choices, Patents and Public Policy," mimeo, University of Maryland and U.C. Berkeley.