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# Incomplete Contracts, Intellectual Property and Institutional Complementarities

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## *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, suggesting a direction of causation going from technology to property rights, 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

The New Property Rights approach provides an analytical framework that emphasizes the incentive effect following from the allocation of residual rights of control over physical or nonhuman assets in circumstances characterized by contractual incompleteness. In many respects, this framework is better suited to address issues concerning the optimal allocation of assets subject to intellectual property protection than of (physical) assets that do not enjoy the same kind of protection. However, we argue that the peculiar nature of intellectual assets is not without consequences for the theory because of the very high level of transaction costs in the market for the exchange of intellectual assets. Relaxing the GHM assumption of zero transaction costs in the market for non-human capital (including IPRs) leads to an inversion of the GHM logic, running from technology (including the distribution of abilities) to (efficient) ownership of (material as well as intellectual) assets. 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). We argue that this double-way relation can be better framed as a situation of institutional complementarity between the technological domain and the property rights domain characterized by multiple organizational equilibria that possess rather strong self-reinforcing properties.

The paper is structured in four sections.

In the first section we summarize the basic aspects of the New Property Rights approach and we consider the insights that it provides when it is interpreted as a theory of the allocation of intellectual property rights. We argue that the model makes more sense as a theory of intellectual ownership for several reasons, and principally because human capital is more likely to be specific to intellectual assets that cannot be legally reproduced without the owner's consent because of IP protection 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) suggest valuable contributions to the theory of the allocation of intellectual property.

In Section 2 we remove the assumption of zero transaction costs in the exchange of non-human 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.

In the third section we consider a very simple model sketching the situation of institutional complementarity between development of individual capabilities and intellectual property. There we argue that multiple organizational equilibria characterize the choices made in the domain of technology (including the distribution of individual capabilities) and in the domain of property rights. 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 4 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 simply directly relevant to introduce new products. However, such "optimal mix" of incentives holds only for a single-country world and may well be very 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 New Property Rights approach as a theory of intellectual ownership

The idea that IPRs can be interpreted as residual rights of control is indeed not novel. Aghion and Tirole (1994) are the first to point out the incentive effect the allocation of IPRs may provide in a context characterized by contractual incompleteness. The notion of IPRs as residual rights of control is also taken as a starting point by Merges (1999), and by Arora and Merges (2001).

Differently from the mentioned papers, we would like to argue that the interpretation of the New Property Rights approach as a theory of the allocation of intellectual capital is not only one possible interpretation, but it is actually the most appropriate one. As a consequence, it is worth considering to the full extent the insights such a theory may provide, rather that restricting the analysis to the case of single contractual relationships as in the previous contributions. However, the peculiar nature of intellectual assets is not without consequences for the theory. We will therefore stress in this paragraph the implications of the non-rival and non-excludable attributes of intellectual assets for the efficacy of the "correct" property rights allocation the theory predicts, whereas the following paragraph will suggest that the evident existence of strictly positive transaction costs in the market for intellectual capital renders at least questionable the conclusion that economic agents will be able to achieve spontaneously the optimal ownership structure.

The New Property Rights School emphasizes the important economic function of an efficient allocation of property rights over physical or nonhuman 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.

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. 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. 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] 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. 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. The logic of the New Property Rights approach thus implies the optimality of assigning 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 solution envisaged by the theory represents, however, only a second-best solution. The owner's investment will be below the "first-best" level, since she cannot be secured against the possibility of hold up of the agents who have invested in specific human capital. At the same time, 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.

In our view three observations make the interpretation of the New Property Rights approach as a theory of intellectual ownership more appropriate than its traditional formulation. First, the New Property Rights theory provides an analytical framework relevant in circumstances characterized by contractual incompleteness. Every contract is—to some extent, at least—incomplete, but contractual incompleteness is certainly a matter of degree. The harder it is to specify in a contract the details of the relationship, the more relevant the role performed by the allocation of residual rights of control as an incentive mechanism. 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.[2]

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."[3]

Third, and most important, the notion of asset specificity, that is another building block of the GHM framework, has a clear-cut content when the specific investments at stake concern intellectual assets, whereas it is indeed difficult to spell out the special attributes that may confer to a physical asset a low degree of substitutability,[4] absent a prohibition

enforceable by law to reproduce it. To simplify things to the extreme, the essence of IPRs is the prohibition to replicate the object of the right without the owner's authorization. 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 and, indeed, unique resources, whose control represents a source of bargaining power in a trading relationship.[5]

Conventional ownership of a physical asset 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. Even when the physical asset is presently unique, the specificity of human capital may only last a relatively short time if the asset can be reproduced.[6] In presence of intellectual property protection, by contrast, the ban on unauthorized reproduction of the assets at stake implies that 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.

It is therefore the very essence of intellectual property protection that it may give self-evident substance to the notion of asset specificity. Given this premise, it is immediate to understand why we deem more appropriate to interpret the New Property Rights approach as a theory of the allocation of intellectual property assets. Thus, the insights of the New Property Rights approach are particularly useful when considering the conditions for an efficient allocation of intellectual property rights. More specifically, by simple analogy with Hart's (1995) argument we can maintain that:

> Ownership 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" entails that intellectual assets are moved to these people.

Moreover, in a way that is again 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. 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. Thus:

> The second best allocation of intellectual assets implies underinvestment of human capital.

This underinvestment will be particularly severe for the case of complementary intellectual assets where no one can be sure that his human capital is properly safeguarded without the ownership of all the complementary intellectual assets. Indeed, again in a way similar to standard physical assets, we have that:

Complementary intellectual assets should be under common ownership.

Indeed, 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."[7] 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.

By contrast:

Independent intellectual 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. Again, the New Property Rights approach offers an intuitive and efficient way to understand the nature of the allocation of intellectual property.

Up to this stage of the analysis it has been our contention to demonstrate that—mainly because of the nature of the rights protecting intellectual assets—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 peculiar nature of the object of IP-rights suggests that the efficacy of their "correct" allocation (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 ownership of physical assets.

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.

The specific limitations of the IPRs second-best allocation will depend on several factors.

A first limitation is related to 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.

Other factors, setting the limits of second best efficiency, are due to the nature of the intellectual asset itself. In particular, they are related to its characteristics of being defined on "more or less upstream knowledge" and its degree of "non-excludability".

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.[8]

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 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.

## 2. 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.

As for the other costs normally associated to the exchange of assets—research, negotiation and enforcement costs—they are also most acute in IP-related transactions. Uncertainty, imperfect and asymmetric information, strategic behavior but also valuation biases are all likely to be magnified when intangible assets are concerned.[9] 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 a high probability of error.

Non-verifiability and therefore contractual incompleteness characterize the market for the exchange of intangibles to a significant extent and cannot be limited to the market for the human capital of the individuals using these assets. In this respect a shortcoming of the New Property Rights approach is that it assumes the existence of 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 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 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.[10] 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".[11] The metaphor indicates a situation in which "multiple owners each have a right to exclude others from a scarce resource and no one has an effective privilege of use".[12] 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 has followed 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".[13]

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.[14]

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 favour 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.

## 3. 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[15] by way of a very simple model.

Consider two different (sets of) agents $i$ and $j$ and consider two different domains of choice:

(1) the property rights domain (P);
(2) the technology domain (T).

In domain P, ownership of the intellectual and material assets A available at the beginning of the period is attributed to the individuals with the most relevant investment in human capital specific to the assets, taking the distribution of investments among agents as given. By contrast, in the domain of technology T, individuals choose the level of their specific investments taking the distribution of property rights as given.

We will indicate by $P^i$ the case in which the assets A are attributed to the individuals i at the beginning of the period and by $P^j$ the case in which the assets A are attributed to the individuals $j$ at the beginning of the period. Moreover, we will denote by $T^i$ and $T^j$ two different technologies that are characterized by the fact that the intensity of the specific investment of agents $i$ with respect to agents $j$ is relatively higher in $T^i$ than in $T^j$.

We thus assume that both agents $i$ and agents $j$ are able to realize investments (denoted respectively by $I_i$ and $I_j$) specific to the assets A. Denote by $c_i$ and $c_j$ respectively the cost of one unit of specific investment by agents $i$ and one unit of specific investment by agents $j$. Assume that, when agents $i$ own A, they sustain an additional cost $x$ to induce the realization of one unit of specific investment $I_j$ by agents $j$. Similarly, assume that when agents $j$ own A, they sustain an additional cost $y$ to induce the realization of one unit of specific investment by agents $i$. Those additional costs can be interpreted as transaction costs arising from the unverifiable nature of the investments at stake and they are saved by the agents when they own the asset A.

Indicate now by $R_i$ and $R_j$ the profits obtainable respectively under ownership of assets A by agents $i$ and agents $j$:

$$R_i = Q(I_i, I_j) - [c_i I_i + (x + c_j) I_j] \tag{1}$$

$$R_j = Q(I_i, I_j) - [(y + c_i) I_i + c_j I_j] \tag{2}$$

According to the logic of the New Property Rights theory, given the prevailing technology T defined in terms of the relative intensity of specific investments by $i$ and $j$, the optimal ownership structure will be the one that allows to achieve the highest level of profits. This means that property rights over assets A will be attributed to agents i when the benefit $U(P^i)$ of having the property rights structure $P^i$ exceeds the benefit $U(P^j)$ of having the property rights structure $P^j$, that is when $R_i \geq R_j$, implying[16]:

$$x I_j \leq y I_i \tag{3}$$

That can be rewritten in terms of the relative intensity of the investments by agents $i$ and $j$ as:

$$I_i / I_j \geq x / y \tag{3'}$$

Similarly, assets A will be attributed to agents $j$ if the benefit $U(P^j)$ of implementing the property rights structure $P^j$ is greater that the benefit deriving from implementing the

property rights structure $\mathrm{P}^i$ , i.e. when $R_j \geq R_i$, that implies:

$$y I_i \leq x I_j \tag{4}$$

or

$$I_i / I_j \leq x / y \tag{4'}$$

From (3′) it is straightforward to derive the following proposition:

**Proposition 1.** *In the domain of property rights P, the benefit from choosing the property rights structure $P^i$ (instead of choosing $P^j$) increases when a technology characterized by a relatively higher intensity of investment by agents i is selected in domain T, that is when $T^i$ is selected instead of $T^j$.*

Proposition 1 can be summarized by the following relation:

$$U(\mathrm{P}^i, \mathrm{T}^i) - U(\mathrm{P}^j, \mathrm{T}^i) \geq U(\mathrm{P}^i, \mathrm{T}^j) - U(\mathrm{P}^j, \mathrm{T}^j)$$

As already mentioned, the New Property Rights logic can be meaningfully inverted, so as to consider the direction of causation that runs from a given property rights structure to the choice of technology. In order to do so, denote by $I_i^i$ and $I_j^i$ the level of investment respectively by agents $i$ and agents $j$ that maximizes profits $\mathrm{R}_i$ when property rights are attributed to agents $i$ and, similarly, denote by $I_i^j$ and $I_j^j$ the level of investment respectively by agents $i$ and $j$ that maximizes profits $\mathrm{R}_j$ when property rights over assets A are attributed to agents $j$.

From a simple inspection of eqs. (1) and (2) it is straightforward to derive the following relation:

$$I_j^j / I_i^j \geq I_j^i / I_i^i \tag{5}$$

In words, the preceding relation suggests the very simple intuition that, in presence of transaction costs, the relative intensity of specific investments by agents $i$ with respect to agents $j$ will be higher if the former own the assets than if assets A are in the hands of agents $j$.

Relation (5) implies the following proposition:

**Proposition 2.** *In the domain of technology T, the benefit from choosing technology $T^j$, characterized by a relatively higher intensity of investment by agents j increases when the property rights structure selected in domain P is $P^j$ instead of $P^i$.*

Proposition 2 can be summarized by the following relation:

$$U(\mathrm{T}^j, \mathrm{P}^j) - U(\mathrm{T}^i, \mathrm{P}^j) \geq U(\mathrm{T}^j, \mathrm{P}^i) - U(\mathrm{T}^i, \mathrm{P}^i)$$

The combination of Propositions 1 and 2 implies that the choices made in the property rights domain P and the choices made in the technological domain T satisfy the standard supermodularity conditions. Under the supermodularity conditions there can be two pure Nash equilibria in the system comprised in domains P and T. When such equilibria are possible, we say that domains P and T and $P^i$ and $T^i$ as well as $P^j$ and $T^j$ are institutional complements of each other.

More precisely, to assess the conditions supporting the existence of multiple equilibria consider the following definitions:

*Definition 1.* The set of choices ($P^i$, $T^i$) constitutes an equilibrium for the set of values for which the property rights structure $P^i$ maximizes profits under the prevailing technology $T^i$ and, in turn, the choice of technology $T^i$ maximizes profits given the property rights structure $P^i$. This occurs when the values of the arguments ($I_i^i$, $I_j^i$) that maximize (1) satisfy also (3′), i.e. when:

$$I_i^i / I_j^i \geq x/y \tag{6}$$

*Definition 2.* The set of choices ($P^j$, $T^j$) constitutes an equilibrium for the set of values for which the property rights structure $P^j$ maximizes profits under the prevailing technology $T^j$ and, in turn, the choice of technology $T^j$ maximizes profits given the property rights structure $P^j$. This occurs when the values of the arguments ($I_i^j$, $I_j^j$) that maximize (2) satisfy also (4′), i.e. when:

$$I_i^j / I_j^j \leq x/y \tag{7}$$

From definitions 1 and 2 it is easy to notice the self-reinforcing properties of equilibria ($P^i$, $T^i$) and ($P^j$, $T^j$): once a given property rights structure is in place, the choice of technology, defined again in terms of the relative intensity of the specific investments by the two sets of agents, will not upset it. Rather, it will be such as to reinforce the convenience of keeping the initial ownership system in place.

On the basis of Propositions 1 and 2 and of relation (7), we can now state the following proposition:

**Proposition 3.**

(a) *Multiple property rights-technology equilibria* ($P^i$, $T^i$) *and* ($P^j$, $T^j$) *exist when the following condition is satisfied*:

$$I_i^j / I_j^j \leq x/y \leq I_i^i / I_j^i$$

*i.e. when both condition* (6) *and* (7) *are satisfied.*

(b) *A unique equilibrium* ($P^i$, $T^i$) *exists when*:

$$x/y \leq I_i^j / I_j^j$$

*i.e. when condition* (6) *is satisfied but condition* (7) *is not satisfied.*

(c) *A unique equilibrium* ($P^j$, $T^j$) *exists when*:

$$I_i^i / I_j^i \leq x/y$$

*i.e. when condition* (7) *is satisfied but condition* (6) *is not satisfied.*

There are two interesting observations concerning multiple equilibria that are worth recalling. The first is that the existence of multiple organizational equilibria implies the existence of an inefficient equilibrium.[17] This observation is particularly relevant in light of the self-reinforcing properties of organizational equilibria that have just been mentioned. Indeed, these self-reinforcing properties imply that an equilibrium may be sustained in spite of its inefficiency. Secondly, it is interesting to note that the set of values for which multiple equilibria exist increases as the elasticity of substitution between the investments by agents $i$ and agents $j$ increases.[18] The two preceding observations thus imply that the set of values for which inefficient equilibria exist increases as the elasticity of substitution between $I_i$ and $I_j$ increases, i.e. as the possibility of varying the relative intensity of investment by agents $i$ and $j$ increases.

A consequence of the argument we have briefly sketched out is that some individuals may enjoy situations where an initial distribution of rights over initial assets favors the realization of specific investments and in turn reinforces their convenience to keep that ownership system. By contrast, because of the same argument, other individuals can be trapped in vicious circles where the lack of property rights diminishes the convenience to make specific investments and the lack of investments 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 thus 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.

## 4. IPRs vs. reward systems: Has the privatization of knowledge gone too far?

If the hypothesis of the existence of a self-reinforcing interaction between IPRs and technology is correct, present-day conflicts about the privatization of knowledge should come at no surprise. One aspect of this phenomenon is the move "upward" of patents, i.e. the tendency to recur to patent protection for innovations ever more distant from commercial application and close to the domain of pure science. Such a move can bring some countries to a virtuous self-reinforcing circle between accumulation of IPR and increasingly skill-intensive technology and exclude other countries from the activities of production of new knowledge.

For any single country, there will be in general an optimum choice in the continuum set of choices that goes from "downstream" patents near to commercial application to "upstream patents" over the outcomes of basic research. The determination of the optimum will however differ in a setting where a plurality of countries is considered. To see why, consider that the "upstreaming" of patentability may have two different distributional effects. On the one hand, it makes better off all the countries that have the skills to produce knowledge that can be patented with respect to those countries that do not have these skills. On the other hand, it makes better off those countries that have a comparative advantage in carrying out more science based research with respect to those that have a comparative advantage in producing "more downstream patents" based on "upstream knowledge" and "bottom-up" production experience. In this respect, industrialised countries can be classified according to the positions that they occupy in the production of innovations (See Estevez-Abe, Inversen and Soskice 2001, pp. 174–175). These positions may imply that they may have divergent interests with regard to an "upstreaming" of patentability. Thus, countries enjoying the benefits of virtuous interactions between accumulation of IPRs and development of specific skills will favour a move "upward" of patents and will expend resources in strengthening the effectiveness of the international IP regime.

"Upstream" patenting may have some undesirable consequences. We will focus on two of them and consider the relative merits of one form of incentive mechanism based on disclosure: the reward system.[19]

The first set of remarks relates to 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 of exercising 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 thus 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.

By contrast, 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.[20] 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. Finally, it is worth noting that, although under a reward system the payoff from being the first-comer does not include claims on subsequent and/or related inventions, reward payments represent 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.

A second set of observations concerns the ex-post use of inventions. "Upstream" patenting may exacerbate the problems posed by the dispersion of complementary assets—the so-called "Tragedy of the anticommons". 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. One consequence is that some inventions may never be realized. A more serious consequence is the distortion of the pattern of technological change associated to the presence of "hidden" transaction costs. Indeed, some transaction costs related to the combination of complementary assets may never be sustained because the choice of technology may be congruent with the aim of avoiding the possibility of contractual stalemates.[21] In other words, when technological assets are highly dispersed, the prospect of incurring high transaction costs may bias the choice of technology towards research paths deliberately independent one from the other.[22] This may, in turn, induce an excessive duplication of research efforts, as the benefits of the pursuit of potentially complementary lines of research are foregone.

To this respect, reward systems enjoy an advantage relative to IP-based incentives as they imply that inventions immediately pass into the public domain. This circumstance may facilitate the aggregation of complementary assets to the extent that efficient mechanisms for the diffusion of innovations are put in place.

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.[23] One 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 in principle it cannot be excluded that systems based on disclosure could ensure not only greater equality, but also greater efficiency.

A second aspect of the phenomenon of extreme privatization of knowledge is the possibility that countries display a tendency towards underinvestment in basic research. Basic research is pursued in both private and public laboratories. The motivation for public funding of basic research is widely acknowledged and relates to externalities. The benefits from investments in basic research do not entirely accrue to its funder for a variety of reasons, and principally because a substantial fraction of the value of basic research results resides in its contribution to further research. The wedge existing between the private and social value of basic research implies that some (socially) valuable research results may not be funded, and public funding aims at avoiding this undesirable result.

However, States may perceive the rationale for public funding of basic research as less compelling if considered in an international perspective. The pursuit of basic research is often characterized by adherence to the rule of disclosure prevailing in the domain of "open science", given the recognition that the payoffs from basic research results do hinge on their widespread diffusion. In any case, the outcomes of basic research may not be fully appropriable through patents and other formal instruments of intellectual property protection. Public funding of scientific research will thus generate substantial cross-border spillovers, with the consequence that States might be reluctant to invest resources in the generation of knowledge "public" in nature, whose economic benefits cannot be entirely reaped by its creator.[24]

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.[25] 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.

## 5. 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 assets that, because of IP protection, cannot be legally replicated without the owner's consent than for the case of physical assets that do not enjoy the same kind of protection. 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 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.

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## Notes

1. Hart (1995, p. 30).
2. 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 contractual parties is not verifiable, and the uncertainty of the technology combines with asymmetric information in enhancing the likelihood of contractual breakdown.
3. Merges (1999a, p. 7).
4. Besides, of course, the case of assets characterized by site specificity.
5. Of course, to qualify IPRs as monopolistic rights, it is necessary that assets' technological characteristics warrant, i.e. there must be technological obstacles to reproducing the asset without infringing the legal right protecting it. The bottom line of our observations on the notion of asset specificity is however unaffected by this last remark.
6. On the relation between reproducibility and specificity of assets see Battistini (2002).
7. Hart and Moore (1990, p. 1135).
8. 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.
9. 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.

10. 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 does 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).
11. For an interesting formal treatment of the "anticommons" scenario both in the IP setting and in a more general setting see the many papers on the subject by Parisi, Schultz and Depoorter, and especially Parisi and Depoorter (2002) and Parisi, Schultz and Depoorter (2003).
12. Heller and Eisenberg (1998, p. 698).
13. Heller and Eisenberg (1998, p. 699).
14. 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). 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, but it applies to less clear-cut situations as well.
15. 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".
16. Note that $yI_i$ and $xI_j$ denote, respectively, the total ownership rent accruing to agents $i$ and agents $j$.
17. Definitions 1 and 2 imply a "partial" notion of efficiency. Equilibria ($P^i$, $T^i$) and ($P^j$, $T^j$) are efficient in the sense that the choice of property rights minimizes transaction costs *given* the nature of the technology and the choice of technology maximizes profits *given* the ownership structure in place. If we adopt a definition of overall efficiency according to which an equilibrium is said efficient if it involves minimum transaction costs, than equilibrium ($P^i$, $T^i$) will be efficient if $y\ I_i^j = x\ I_j^i$, whereas equilibrium ($P^j$, $T^j$) will be efficient if $y\ I_i^j = xI_j^i$. It is then straightforward to observe that when a unique equilibrium exists it is also efficient, while if multiple equilibria exist one of them must be inefficient, except for the case in which $y\ I_i^j = xI_j^i$.
18. To get a simple intuition of this statement, consider the two polar cases of perfect complementarity (elasticity of substitution equal to zero) of $I_i$ and $I_j$ and the case of perfect substitutability (infinite elasticity of substitution). Under the first case we have that $I_i^i/I_j^i = I_i^j/I_j^j$, so that the only value $(x, y)$ for which multiple equilibria exist is given by $I_i^j\ /\ I_j^j = x/y = I_i^i/I_j^i$. In the second case, for any value of the relative cost of investment (inclusive of transaction costs) by agents $i$ and $j$ different from one there will be investments by only one set of agents, according to the prevailing ownership structure. That is, if property rights are attributed to agents $i$ we will have $I_i^i > 0$ and $I_j^i = 0$, whereas if property rights are attributed to agents $j$ we will have $I_i^j = 0$and $I_j^j > 0$. This implies $I_i^i/I_j^i = \infty$ and $I_i^j/I_j^j = 0$, so that any positive value of $(x, y)$ satisfies the condition $I_i^j/I_j^j = x/y = I_i^i/I_j^i$. For a more detailed proof of the relationship between the elasticity of substitution of factors and the feasibility of multiple organizational equilibria see the appendix in Pagano and Rowthorn (1994).
19. With the expression "reward system" we refer to an incentive mechanism based on (a) direct payment to the innovator by the State and (b) immediate disclosure of the innovation.
20. 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.
21. Walsh, Arora and Cohen (2002) have tested the "anticommons" hypothesis on the basis of interviews conducted in US pharmaceutical and biotech firms as well as universities and trade associations operating in the biomedical field. While they find almost no cases in which IP problems caused valuable research

projects to be stopped, they find evidence of redirection of research towards areas characterized by more IP freedom.

22. The argument is an immediate consequence of the inversion of the GHM logic that we have proposed in Section 3. Given a property rights structure characterized by dispersion of (complementary) intellectual assets, the profit-maximizing choice of technology will imply the minimization of transaction costs and therefore the development of independent assets rather than complementary assets (that generate the possibility of hold-up with separated ownership). In other words, technological choices will be endogenously determined by the prevailing ownership structure.
23. 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).
24. 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).
25. 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.

## References

Aghion, P. & Tirole, J. (1994). "On the Management of Innovation." *Quarterly Journal of Economics.* 109, 1185–1207.

Aoki, M. (2001). *Towards a Comparative Institutional Analysis*, Cambridge, Mass: MIT Press.

Arora, A. & Fosfuri, A. (1998). "Licensing in the Chemical Industry." mimeo, Carnegie Mellon University, Heinz School of Public Policy and Management.

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

Arrow, K. 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, L., Loewenstein, G., Issacharoff, S. & Camerer, C. F. (1995). "Biased Judgments of Fairness in Bargaining." *American Economic Review.* 85(5), 1337–1343.

Battistini, A. (2001) "Competizione tra organizzazioni, specificità degli investimenti ed efficienza." *Economia Politica.* 3, 333–350.

Chang, H.-J. (2001). "Intellectual Property Rights and Economic Development: Historical Lessons and Emerging Issues." *Journal of Human Development.* 2(2), 287–309.

Dasgupta, P. & David, P. A. (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, P. 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, P. A. (1998). "The Political Economy of Public Science." In Helen L. S. (ed.), *The Regulation of Science and Technology*, London: Macmillan Publisher.

David, P. A., Mowery, D. C. & Steinmueller, W. E. (1992). "Analysing the Economic Payoffs from Basic Research." *Economics of Innovation and New Technologies.* 2(3), 73–90.

Estevez-Abe, M., Inversen, T. & Soskice, D. (2001). "Social Protection and the Formation of Skills: A Reinterpretation of the Welfare State." In P. A. Hall & D. Soskice (eds.), *Varieties of Capitalism. The Institutional Advantages of Comparative Advantage*, Oxford: Oxford University Press.

Gallini, N. & Scotchmer, S. (2001). "Intellectual Property: When is it the Best Incentive Mechanism?." In Adam Jaffe, Joshua Lerner & 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, J. R. & Scotchmer, S. (1995). "On the Division of Profit in Sequential Innovation." *Rand Journal of Economics.* 26, 20–33.

Grossman, S. J. & Hart, O. D. (1986). "The Costs ad Benefits of Ownership: A Theory of Vertical and Lateral Integration." *Journal of Political Economy.* 94(4), 691–719.

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

Hart, O. & Moore, J. (1990). "Property Rights and the Nature of the Firm." *Journal of Political Economy*. 98(6), 1119–1158.

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

Heller, M. A. & Eisenberg, R. S. (1998). "Can Patents Deter Innovation? The Anticommons in Biomedical Research." *Science.* 280, 698–701.

Lerner, J. & Merges, R. P. (1998). "The Control of Technological Alliances: An Empirical Analysis of the Biotechnology Industry." *Journal of Industrial Economics.* 46, 125–156.

Loewenstein, G., Issacharoff, S., Camerer, C. F. & Babcock, L. (1993). "Self-Serving Assessments of Fairness and Pretrial Bargaining." *Journal of Legal Studies.* 22(1), 135–159.

Machlup, F. & Penrose, E. (1950). "The Patent Controversy in the Nineteenth Century." *Journal of Economic History.* 10(1), 1–29.

Mazzoleni, R. & Nelson, R. R. (1998). "The Benefits and Costs of Strong Patent Protection: A Contribution to the Current Debate." *Research Policy.* 27, 273–284.

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

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

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

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

Merges, R. P. (1999b) "Institutions for Intellectual Property Transactions: The Case of Patent Pools." Mimeo, U.C. Berkeley.

Merges, R. P. & Nelson, R. R. (1990). "On the Complex Economics of Patent Scope." *Columbia Law Review.* 90(4), 839–916.

Milgrom, P. & Roberts, J. (1990). "Rationalizability, Learning and Equilibrium Games with Strategic Complementarities." *Econometrica.* 59, 511–528.

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

Owen-Smith, J., Riccaboni, M., Pammolli, F. & Powell, W. W. (2001). "A Comparison of U.S. and European University-Industry Relations in the Life-Sciences." *Management Science Informs.* 00(0), 1–19.

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

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

Pagano, U. & Rowthorn, R. (1994). "Ownership, Technology and Institutional Stability." *Structural Change and Economic Dynamics.* 5(2), 221–243.

Parisi, F. & Depoorter, B. (2003). "The Market for Intellectual Property: The Case of Complementary Oligopoly." In W. J. Gordon & R. Watts (eds.), *The Economics of Copyright: Developments in Research and Analysis*, Edward Elgar Publishing.

Parisi, F., Norbert, S. & Depoorter, B. (2003) "Simultaneous and Sequential Anticommons." *European Journal of Law and Economics* (forthcoming).

Polanyi, M. (1958). *Personal Knowledge: Towards a Post-Critical Philosophy*, London: Routledge and Kegan Paul.

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

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

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

Scotchmer, S. & Green, J. (1990). "Novelty and Disclosure in Patent Law." *Rand Journal of Economics.* 21, 131–149.

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

Walsh, J. P., Arora, A. & Cohen, W. M. (2003). "Research Tool Patenting and Licensing and Biomedical Innovation." In W. M. Cohen & S. Merrill (eds.), *Patents in Knowledge-Based Economy*, Washington D.C.: National Academies Press.