Intellectual property, dissemination of innovation and sustainable development

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1. Introduction

One doesn't need to be an expert to understand that the development path on which we are globally drifting is unsustainable. We now understand that the growth path in the United States based on the real estate bubble was not sustainable. As the aphorism puts it, that which is not sustainable won't be sustained, and so it should not have come as a surprise that growth based on a bubble was not sustained. But the problem of environmental sustainability is even worse. It is apparent that the world cannot sustain the patterns of consumption that prevail in the U.S. It will not be easy, to say the least, to switch from the present path to a significantly more sustainable one. Success will require a determined mobilization of all relevant scientific and technical resources, as well as a transformation of behaviors and institutions.

Revolutionary advances since the 1920s in physics, chemistry, and life sciences have made available many more scientific and technical resources than are currently being utilized. Even among those that are still not available, some of the most critical ones (like efficient electricity storage and workable carbon capture and sequestration from both concentrated and diffuse sources) *could* be developed in time to make a difference (assuming that proper management and sufficient finance are provided).

However, if they are to have the impact on sustainability that they could and should, there has to be fast and broad dissemination of these innovations. This paper asks the question: do intellectual property rights—which nowadays have more of a global reach than ever before—further or hinder dissemination of those innovations and hence affect the prospects of sustainable development? The evidence so far is mixed: under certain circumstances, intellectual property rights indeed further the dissemination of important innovations; under different circumstances, they do the opposite. More generally, we show that there are reforms in the intellectual property regime that hold out the promise of simultaneously increasing the pace of innovation and the utilization of the knowledge produced. Indeed, the history of innovations for genetically modified organisms clearly shows that a model markedly different from the currently prevalent one is far more likely to bring wider social benefits, *both in the short run and the long.*

2. Contrasting effects: Two examples

A particular case involving genetic engineering provides an example of contrasting effects. In 1973, Herbert Boyer of the University of California at San Francisco and Stanley Cohen of Stanford University were the first scientists to devise a method for inserting into a bacterium a DNA fragment from a

different organism in such a way that the bacterium becomes able to produce proteins normally produced in that organism (human insulin, for example).

Both scientists' universities insisted that this fundamental technique of genetic engineering be patented. The scientists agreed, provided there would be no exclusivity in the offer of licenses: any interested party should be able to buy a license at a reasonable price.[1] Moreover, a provision was made for the free use of the technique in not-for-profit research. Since then, dissemination of the method has indeed been fast and broad, and the total amount of collected royalties has been high enough to satisfy both the universities and the scientists.[2]

This story seems to illustrate how traditional IPRs may be an instrument for disseminating important innovations; however, the aftermath of the story also illustrates the limits of this assessment.

It is well known that the US firm Monsanto has a strong grip on the production and commercialization of genetically modified plants. This is in part due to the fact that the patents it owns, which were first granted in the United States and then in all countries where Monsanto operates, control the use of a bacterium called *Agrobacterium tumefaciens*, the role of which is crucial in the chain of gene transfers.[3] The gene transfers unfold in the following way: a gene controlling a valuable trait (for instance, a gene in a wild plant that makes it drought-resistant) is introduced by the Boyer-Cohen method into the genome of *Agrobacterium tumefaciens*. In a second stage, the genetically modified bacterium is led to transfer the gene to a cultivated plant—rice, for example—that in this way becomes endowed with the valuable trait possessed by the wild plant at the origin of the process.

Mostly concerned by its profitability, Monsanto was interested not in using this technique for the benefit of developing countries, but rather for tinkering with pest control in developed countries.

From an empirical investigation into the development of genetically modified seeds, economists Dietmar Harhoff, Pierre Regibeau, and Katharine Rockett have concluded that firms like Monsanto or Syngenta have given priority to

[1] This is reminiscent of the "licenses of right" in UK law, by which anybody is entitled to buy a license at a price that is partly regulated.

[2] Herbert Boyer invested his share in the creation of a biotechnology start-up that became the giant Genentech.

[3] Experts warn that similar problems might arise in the bio fuels industry. At stake are second generation biofuels (produced from wood by-products, straw, some varieties of grass) that are energetically and ecologically much more attractive than first generation biofuels (themselves often in competition with foodstuffs) to a large extent because they are produced in catalytic reactions, with natural enzymes as catalysts. Steve Suppan (2007), from the Institute for Agriculture and Trade Policy, Minneapolis (MN), indicates that each year patents related to biofuels are granted by the thousands to the likes of Monsanto, Dupont, Syngenta and various oil groups. Among the most strategic ones are the patents on the enzymes themselves.

traits (for example, resistance to an insecticide or herbicide) that are linked to a product they already sell. They do not currently offer any seed modified in such a way that the plant might have an increased resistance to drought or salinity, though they say they intend to produce the first ones within three years for the American market and another two or three years for the African market. Given the incentives provided by the "rules of the game," Monsanto's behavior is understandable. But it should be clear: the presumption that profit maximizing behavior is socially optimal is not always right. It may be true, for instance, in the production of conventional goods like steel and chairs, but it does not hold for the production of knowledge and information.[4]

Subsequent events proved this to be the case. In February 2005, a team of Australian and Belgian scientists led by Dr Richard Jefferson, head of Cambia, an independent nonprofit Australian institute, reported a remarkable achievement: they had succeeded in performing the same kind of transfer with bacteria sufficiently different from *Agrobacterium tumefaciens* that they did not infringe Monsanto's patents.[5] They might have applied for patents of their own, eventually transforming a monopoly into a duopoly. Instead, they preferred to protect their discovery in the spirit of open source, which Cambia has consistently promoted so that it may be used freely, provided any improvement is also made freely available (see the discussion later in this paper). This appears to have significant potential for enhancing sustainability in tropical agriculture.

On the basis of this contrasting evidence, we are led to the second central question of this paper: in order to promote fast and broad dissemination of sustainability-enhancing innovations, should we only rely on making the most of traditional IPRs, or should we also consider far-reaching reforms in the current Intellectual Property regimes and put greater reliance on alternative ways of incentivizing and financing R & D?

Dealing in a meaningful way with our two questions requires first considering how IPRs have evolved during the last 30 years, a period of considerable change, first at the national level and then at the global level. We will then examine reforms to IPR and alternatives to IPR that might be helpful in promoting innovations, especially those that might benefit developing countries. In so doing, we intend to give operational content to demands from developing countries within the UN agency WIPO (World Intellectual Property Organization) for a *Development Oriented Intellectual Property Regime*. The proposal of the Group of Friends of Development (a group of 15 African and Latin-American countries led by Brazil and Chile) succeeded in getting the

[4] This is a corollary of the earlier observation that knowledge is like a public good, and that there can be large externalities associated with innovation.
[5] W. Broothaerts et al (2005).

WIPO General Assembly to endorse the move in 2005, though it has yet to result in significant concrete reforms, e.g. to prevailing practices and agreements, such as TRIPS.[6]

But before turning to these tasks, we need to understand the economic and legal foundations of intellectual property rights, particularly as viewed within the context of a country's innovation system, the set of institutional arrangements designed to promote research and innovation and to ensure that the benefits of that research and innovation are widely shared.

3. Innovation and intellectual property rights: legal and economic foundations

Intellectual property is a legal construct, and different countries have constructed different intellectual property regimes. These different IP regimes can affect both the extent of the utilization of knowledge and the pace of innovation.[7] IP law defines what can be patented, how patents are granted, what the scope of the patent is, what the rights of the owners of the patent are, and how long those rights persist. Answering each of these questions is contentious. The answers are often provided not through legislation but through a series of court decisions.

There are a limited number of basic legal principles that have traditionally provided answers to these questions, which may be summarized as follows. To be patentable, an innovation should be new; that is, it should not merely reproduce something that is already known and must entail an actual "inventive step." It should not be obvious. It should also have practical uses. A discovery is not an invention and thus is not patentable according to this legal tradition.[8] The breadth of a patent must correspond to the actual scope of the invention. The patent gives the owner the exclusive right to the use of the patent for 20 years, but property rights are always circumscribed (just as the owner of land may have to provide a right-of-way to walkers). However, the patent holder cannot use his monopoly power to engage in abusive anti-competitive practices (as Microsoft was judged to have done).

[6] For a discussion of some of the implications of a "development oriented intellectual property régime," see Stiglitz (forthcoming). See also chapter 5 of Stiglitz (2006). Some of the worst practices have been incorporated into bilateral trade agreements—and some of these have even occurred after the 2005 WIPO agreement.

[7] For a more extensive discussion of the "law and economics" of intellectual property, see Stiglitz (2008); Maskus and Reichman (2004); and Reichman (2005).

[8] To distinguish between the two, innovations are manmade, and discoveries are structured observations of natural phenomena.

An essential quid pro quo in the granting of patents is *disclosure:* while the owner of the patent can restrict the use of the knowledge, there has to be full disclosure of the knowledge so that subsequent researchers can build upon the knowledge that has been produced and patented.

Many of the terms of IP have been the subject of litigation. Moreover, property rights—including intellectual property rights—are not unfettered: public interest may override intellectual "property rights" through compulsory licenses. The United States used a compulsory license to manufacture Cipro during the anthrax scare following 9/11. The Rio Convention on Biological Diversity gives governments the right to use compulsory licenses for purposes of global warming. When intellectual property rights threatened the development of the airplane in World War II, the government overrode traditional rights and forced the formation of patent pools.

Among the most difficult issues is the breadth of the patent: should, for instance, the government issue a patent on all four-wheel, self-propelled vehicles (as the government did to Ransom, a patent that, had it been upheld, might have impeded the development of an affordable automobile)?

Details of the legal process matter—they affect how patents can be challenged and the rights of those who hold a patent while it is being challenged.

Economic principles help us answer each of these questions. The specific answers (the laws and regulations defining, say, "novelty," or the appropriate breadth of a patent) need, of course, to be constantly modified, to keep them updated with changes in, say, technology and institutional arrangements.

The question that must be asked is: how to update the IPR regime to reflect today's technical and economic circumstances? In the end, intellectual property law is a social "convention," designed to promote societal well-being, assessed both in terms of access to the benefits of the knowledge and the level of production of knowledge.

As Aghion and Howitt have put it, "Economic growth involves a two-way interaction between technology and economic life: technological progress transforms the very economic system that creates it." [9]

Schumpeter argued that the true virtue of a market economy lies in its ability to stimulate innovation. But research over the past thirty years made it clear that, in general, there are no "optimality" properties of Schumpeterian competition.

[9] Aghion and Howitt (1998), p.1.

There may, for instance, be too much research in some directions and too little in others. While Schumpeter may be right that competition provides an important incentive for innovation, it is not the case that "competition for the market" is a perfect substitute for "competition in the market."[10] Schumpeter was wrong in his claim that the monopolies would inevitably be temporary.[11] Firms have the incentive—and the ability—to preempt rivals. While in some cases, preemption may have a social value (e.g. when the incumbent is induced to innovate at a faster pace), in others it can be socially destructive. Sleeping patents are an example; more generally, the dominant firm has an incentive to get just far enough ahead of rivals so that the rivals are discouraged from competing.[12]

Much of innovation is incentivized by the "patent race": the first firm to make a discovery gets the entire surplus associated with the innovation. But there is a marked discrepancy between social and private returns. Social returns are related to the extent to which the innovation was available earlier than it otherwise would have been. Dasgupta and Stiglitz (1980) show that there is a complex relationship between private and social returns—with some presumption that social returns may exceed the private returns. This is especially true in the case of patents, like that of Myriad's patents on BRCA genes related to the risk of breast cancer. There were few social benefits associated with that patent race, since it was clear that the human genome would have been fully decoded through the global human genome project.

But some innovation is incentivized by capturing rents—e.g., by differentiating products, as firms try to escape "neck-and-neck" competition by transforming a quasi-homogenous market into a highly differentiated one.[13] This gives rise to me-too inventions; for these, the presumption is again that private rewards exceed social returns.[14] More generally, the objective of innovation is to create a product sufficiently differentiated from existing products that there is some degree (hopefully a high degree) of monopoly power. It should be obvious: the prospect of a protected market is more attractive for the innovator than the prospect of a competitive one. Monopolization not only results in an inefficient utilization of knowledge but also introduces a distortion in production.

[10] For a discussion of Schumpeter's contributions in light of modern economic theory, see Stiglitz (2010b).
[11] See Dasgupta and Stiglitz (1980).
[12] See Dasgupta and Stiglitz (1980).
[13] The effects of "neck-and-neck" competition on innovation are considered in Nickell (1996); Aghion, Harris, Howitt and Vickers (2001); and Aghion (2003).
[14] For an equilibrium theory, see Dasgupta and Stiglitz (1980). This problem has been particularly important in the area of medicine. See Jayadev and Stiglitz (forthcoming).

Knowledge, once produced, is a public good; any restriction on its utilization is therefore inefficient.[15] The justification for any restriction is that there is a dynamic benefit, as a spur to innovation. But in fact, there is increasing concern that intellectual property rights, especially if they are not carefully designed, will impede the production of knowledge. The main reason is that the most important input into the production of knowledge is knowledge.[16]

As Isaac Newton put it, "If I have seen further, it is by standing on the shoulders of giants."[17] Knowledge is a public good and, as such, should ideally be freely available: do not privatize the giants' shoulders.

But IP may reduce the pace of innovation for another reason: the boundaries of a patent are often ambiguous, giving rise to the risk of litigation from patent suits. Such litigation risk impeded the development of the airplane in the first part of the last century, and patent thickets have had a particularly adverse effect in the software industry.[18]

When capital markets are imperfect, there is another tension between ex ante and ex post competition: less ex post competition generates more revenues to finance research, which can enhance marketplace competition in a broader sense. In a way, *ex post* competition after one round of innovation is *ex ante* competition before the next round. That suggests that there may be an optimal degree of competition.[19] Schumpeter was thus more comfortable with (at least some degree of) monopoly than conventional economists—and anti-trust courts—who saw monopolization as the "supreme evil."[20] But he was too cavalier. Microsoft's anti-competitive behavior not only restricted the use of knowledge but also reduced the incentive of others to engage in research.[21]

Granting patents to innovators is in general a very imperfect way of creating incentives for innovation and of financing the necessary investments.

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[15] See Stiglitz (1987, 1999)

[16] We explain below why restrictions on access to knowledge can be so costly.

[17] Or "The invention makes it possible for other researchers to begin working on the next innovations," Aghion and Howitt (1998), p. 54. See also Scotchmer (1991), for which she has chosen the title, "Standing on the Shoulders of Giants: Cumulative Research and the Patent Law." Newton's quotation is from a letter to his friend Robert Hooke, written in 1676.

[18] The BlackBerry case has become the classic case of a patent abuse. See Stiglitz (2006), pp. 107-112.

[19] See Dasgupta and Stiglitz (1980).

[20] *Verizon Communications v. Law Offices of Curtis V. Trinko*, 540 U.S. 398, 408 (2004).
The famous American jurist, Judge Learned Hand forcefully described the dangers of monopolization in the landmark Alcoa case: "…unchallenged economic power deadens initiative, discourages thrift and depresses energy; …immunity from competition is a narcotic, and rivalry a stimulant, to industrial progress." United States v. Aluminum Co. of Am., 148 F.2d 416, 427 (2d Cir. 1945)

[21] What he meant, however, was monopoly powers on products—that is, on private goods—emanating from new knowledge, and not monopoly powers on knowledge itself, which is a public good.

Intellectual property rights need to be viewed within the perspective of a broader *innovation system*, which includes government supported research, government laboratories, and other ways of financing and incentivizing innovation, alongside the patent system (such as prizes). Each of these has certain advantages and disadvantages.

To maximize the benefits of patents and minimize their social costs, careful attention has to be placed on *design* (both the rules that determine, say, when a patent will be granted and the breadth of the patent when it is granted, and the institutional arrangements for the implementation of those rules), and the extent of the reliance on IPR within a country's innovation system needs to carefully balance benefits and costs, taking into account the *possibilities* to muster other incentives and other sources of finance. Obviously, if we design better IPR frameworks, IPR can play a larger role.

It needs to be recognized that even in the absence of intellectual property rights, there are incentives to innovate. There has been great progress in mathematics and physics, without intellectual property rights. In some industries, such as metallurgy, trade secrets play a more important role. Innovators always have a "first mover" advantage.

It also has to be recognized that making knowledge available as widely and as freely as possible is of paramount importance to the progress of science. As Paul David argues, "Legal and other institutional arrangements may be imposing high costs on research intensive firms, and society more generally, by restricting access to some elements in the streams of creative thought, and thereby making it less likely that the elements will be rapidly rearranged and recombined in new and fruitful ways." [22] It is not possible to determine in advance who will have the creative vision to "rearrange and recombine" elements of knowledge in the most fruitful ways, hence the paramount value of general access to knowledge.

The results of the economic analysis mentioned above vindicate to a large extent the traditional legal principles mentioned at the beginning of the present section. There is no point in creating incentives to reinvent something that already exists. There is a cost to making knowledge "less accessible" without any commensurate benefit. When a patent is granted, there is possibly a high cost in terms of privatizing knowledge--including the burden of all the transactions necessary to access that knowledge.[23] Even when an invention is new—but only insignificantly so—the costs still surpasses the benefits.

[22] David (1993), p. 29.
[23] As is shown in Shapiro (2000), who considers how to "navigate the patent thicket."

What should be patentable? And, if patentable, how broad should the patent be?

Economic analysis also helps us understand why certain things (like "discovery") are unpatentable.[24] One might observe that in the course of research or an inventive process, it is often more difficult to bypass the results of such a discovery than the contents of an invention.[25] This leads to an appeal, when appropriate, to the "essential facility" argument, which will be discussed later in the course of this section, along with results on the appropriate breadth of a patent.

The extent of the monopoly power embedded in a patent depends on the patent's length and breadth. The length of 20 years is becoming more and more uniform around the world. For products like pharmaceuticals that are subject to long regulatory delays, the length may be up to 25 years. The "effective" length of patents is often shorter, as new competing products are often developed without infringing existing patents.

A patent's breadth can often be characterized by the minimum degree of differentiation that a new product must entail with respect to the product covered by the patent, in order to avoid infringing the patent. There is thus a protection zone that competitors must respect in their own efforts to innovate.

Patents can not only have a direct dynamic benefit in spurring innovation, but also an indirect benefit: Other potential innovators are helped in their innovation efforts by the information that must be disclosed when a patent is granted, information that would not be available if, in the absence of patents, innovations were kept secret.

If its breadth is excessive, however, a patent will act more as a roadblock than as a stepping stone to further innovations. In such a case, the benefits of the increased incentives for innovation may be more than offset by costs associated with (a) reduced follow-on innovation; (b) possibly lower utilization of the knowledge; and (c) less competition in relevant markets. The losses in terms of the diminution of research may be particularly significant as Merges and Nelson explain, "When a broad patent is granted, its scope diminishes incentives for others to stay in the invention game, compared with a patent whose claims are

[24] Thus, traditionally, discoveries of mathematical theorems or compounds which exist in nature are not patentable. (Chemical companies could get patents on the processes by which they synthesized compounds existing in nature.)

[25] Such discoveries can be even more important than an ordinary innovation (cf. the critical role of the Turing machine in the development of the modern computer).

trimmed more closely to the inventor's actual results."[26] In this way, economic analysis supports the traditional legal principle pertaining to the appropriate adjustment of a patent's breadth to the actual achievements of the inventor.

Economists have produced more precise results on the subject by specifically investigating what they have called the "optimal" breadth of a patent.

Many contributions in the economic literature provide some elements of an answer to the problem of the optimal breadth.[27] A patent on an invention or a discovery[28] should be the narrower: (a) the fewer close substitutes there are for the products developed from the invention, or the more difficult it is to bypass the invention or the discovery in subsequent research; (b) the lower the cost of completing the invention; and (c) the higher the non-monetary incentives (for example, "academic rewards") available to motivate the inventor.

The last two conditions reflect the desirability of minimizing the effects of the deeply rooted imperfections associated with using patents as incentives to further innovation. The first condition implies that it is not appropriate to grant a broad patent to an invention or a discovery that in turn commands access to lines of research that cannot be pursued without the results covered by the patent. Under such circumstances, the invention or discovery is an "essential facility," that is, it is essential for working on further research. This is where the Economics of the Protection of Intellectual Property and the Economics of the Protection of Competition (including the competition for innovation and the access to knowledge) meet; as argued by Tom and Newberg, both members of the US Federal Trade Commission, put it: "If market power in an antitrust sense is not to be presumed, then, as with any other form of property, the existence of such power must be determined by evaluating the availability of close substitutes."[29] Still, there is a longstanding presumption: even if the granting of a patent might generate a market structure in which a firm has market power, the patent does not grant the owner of the patent the right to engage in an anti-competitive manner. (As one commentator put it, simply owning a baseball bat does not give the owner any rights to use the bat to injure someone else.)

[26] Merges and Nelson (1990), p. 916. The reason for this is obvious: a broad patent reduces access to knowledge, and if the follow-on innovation is successful, increases the likelihood of patent litigation and/or the payment to the holder of the broad patent—in either case, diminishing the returns to the follow on innovation.

[27] Among the most significant ones are: Merges and Nelson (1990); Chang (1995); Scotchmer (1999); Gallini and Scotchmer (2002); and Denicolo (2002).

[28] According to the traditional principles, a discovery is not patentable; only an invention is. Nevertheless, for about the last 30 years, the distinction has been ignored by the main patent offices and by the courts.

[29] Tom and Newberg (1998), p. 346. That "market power is not to be presumed" means that not all patents automatically create problems from the point of view of competition protection; however, problems, possibly serious ones, derive from the absence of close substitutes, and thus need remedies. See also Barton (1995). For an extremely well-documented report on the relationships between competition policy and the protection of intellectual property rights, see Federal Trade Commission (2003).

Applying the principles: should genes be patentable?

Consider, for example, elements in the living world like genes, proteins, or enzymes. This is an extreme case of the situation discussed above, because there are no substitutes. Regarding such elements, which incidentally are discovered and not invented, even the caution urged by Merges and Nelson in the quotation above might not be sufficient; from the viewpoint of economic efficiency, it might be necessary to reduce a patent's breadth further, even below what might seem the inventor's marginal contribution in expanding the frontier of knowledge. In antitrust terms, these elements are "essential facilities." (In addition, there is an argument that today, the process of isolating, sequencing, and characterizing has become almost routinized, with costs contained. Perhaps not even the "obviousness" criterion is satisfied.)

For all these reasons—and the essential facility character is paramount—no *broad* patent should be granted on them, and possibly no patent should be granted at all. For instance, in the context of genetically modified food, Dr. Harhoff, using the tools of industrial organization analysis, concludes that "granting patents on gene themselves [*sic*] (or even on gene functions), is not necessary to promote innovation. It is likely even to delay the development of socially useful applications." [30]

4. Recent trends in the approach to intellectual property rights

Today's global IPR system has been greatly affected by the historical evolution of IPR in the United States. And unfortunately, some of the changes in IPR that have occurred in recent years have increased the costs of the system without commensurate increases in benefit.[31] The result is that today, our IPR regime may, on net, actually impede innovation. Whether or not one agrees with such an assessment, it is clear that the IPR system is badly in need of reform: there are changes that would almost surely both increase static efficiency (better usage of existing knowledge) *and* promote innovation. Even many in the innovation sector have come to that conclusion.

In 1982, in an atmosphere of pessimism concerning the technical capabilities and relative productivity of the US economy, Congress created the Court of Appeals for the Federal Circuit (CAFC) within the framework of the Federal Courts Improvement Act. This federal court specializes in intellectual property matters, and it is the only court that handles appeals on such matters. The

[30] Harhoff et al (2001), 289.

[31] This includes, for instance, extending patent protection to "innovations" that should not be patentable. In the past couple of years, the U.S. Supreme Court has expressed some skepticism about recent practices of the Patent Office.

objectives in creating the court were to ensure greater consistency in dealing with appeals and to support an approach that would be systematically sympathetic to the defense and promotion of intellectual property. The judges chosen to sit on the CAFC are selected according to their supposed willingness to further the latter objective. The statistics of the decisions made by the CAFC since its inception—including a dramatic increase in the number of rulings on patent infringements in favor of patent holders, as well as skyrocketing damages granted by the judges—reveal a pro-patent bias that is certainly not disappointing to the founders of the CAFC.[32]

It appears that Congress consciously promoted easier access to patenting. As controller of public receipts and expenses, it appears that it also did the same unconsciously: by starving the US Patent and Trademark Office of adequate funds, it created a situation where overloaded and underpaid examiners are not able to properly assess the submissions for patents. Within a system of incentives geared towards granting patents, it is only natural that examiners tend to grant patents easily on the basis of generally superficial investigations.

The result has been a remarkable increase in the number of patent requests submitted and accepted. Of course, the scientific and technical breakthroughs that occurred during the 1980s and the 1990s contributed to that increase, but most of it can be attributed to a reversion of the de facto patenting system to the role it had at the time of its origin in the 19th century: simply a registration system. Patents are routinely granted to submissions devoid of any novelty or with insignificant original contributions. There are even allegations that patents are granted to parties that are not the real innovators.[33] Overlapping patents are granted, which is a sure recipe for igniting inextricable conflicts, exacerbating the already oppressive problem of the patent thicket.[34] Patents that are broader than they should be are routinely granted. The scope of what can be patented has been widely expanded, without a rational, balanced assessment of the benefits and costs in each case. This is particularly true in areas such as applied mathematics, computing, and business methods, which have produced patents like the Amazon one-click or portfolio choice methods that boil down to the inversion of a matrix. More sinister was the effort by a collaborator of Microsoft to get a patent on computer formulations of some Darwinian methods to testing the laws of evolution.[35] The patent office's willingness to grant patents to traditional knowledge, like basmati rice, neem oil, and the healing properties of turmeric—allowing for the continuation of such patents, sometimes even after

[32] See Jaffe and Lerner (2004), pp. 104-107.
[33] See Merges and Duffy (2007)
[34] For a discussion of the problem of the patent thicket, set Stiglitz (2006).
[35] Pennisi (2009).

European patent offices or courts have rejected these patents—has increased opposition to intellectual property rights in developing countries.[36]

Dealing with patents, in or out of court, uses up as much or more effort and money than working on genuine innovations. As Robert Barr put it at a Federal Trade Commission Roundtable in 2002:

> "An innovator asks two questions: Can I get a patent? Do I infringe the patents of others? The answer to the first is usually too easy: yes. The answer to the second is much more difficult and, as a practical matter, impossible."[37]

He could have added: if the innovator acts on the basis of a "yes" (or even a "maybe") to the second question, it may be indeed very costly in time and money to disentangle the web of dependencies on existing patents. The patent system has made research an even riskier business: to the uncertainty about the success of the research effort is added that of litigation risk. This risk more than offsets any benefit from the fact that it may be easier for an innovator to get a patent. Small and medium-sized firms do not have enough resources to stand a legal battle against large firms. In the current system, the small and medium-sized firms that could be particularly innovative are thus deterred from fulfilling their potential. The outcome is the worst of all possible worlds: not only is free access to knowledge reduced, but also the very function of patents—to act as incentives to innovation—is stifled by the proliferation of bad patents.

Barr's is a businessman's assessment. It has its parallel in science, as the biologist David Maddison puts it: "As patents enter this field, there is a very great danger that we will get bogged down in a legal morass." [38]

Economists point out that there is an asymmetry: everyone has an incentive to "privatize knowledge." By converting knowledge which is in the public domain into a private asset, they increase their own income, albeit at the expense of others. But the incentive to *oppose* such privatization efforts are limited, since making public what otherwise would be private creates a public good. Everyone benefits from such opposition—which means that any private party will have captured but a fraction of the returns from doing so.

Patents inevitably "enclose" the commons of public knowledge[39], supposedly in the hope that in doing so incentives for innovation will be enhanced. Inevitably,

[36] See Stiglitz (2006).
[37] Federal Trade Commission (2003).
[38] Pennisi (2009).
[39] James Boyle of Duke University has made the analogy between the enclosure of the commons in seventeenth and eighteenth century England and Scotland and the patent system, e.g., Boyle (2003). But there is one

there is also fuzziness in the boundaries of what should and should not be privatized. The argument above suggests that there is a natural bias toward excessive patenting. The manner in which the United States' patent court system has worked has exacerbated that bias. Below, we describe one way that the bias might be partially corrected.

Given the systemic bias in the granting of patents, it is even more important that there are protections against the abuses of intellectual property rights, made so evident by the attempt to shut down BlackBerry. (Most of the patents involved have subsequently been called into question.) This has led many legal experts, such as Duke University's Jerry Reichman, to argue for the substitution of a "liability" system for the current system.[40] Under the current system, the owner of a patent—even a patent whose validity is dubious and likely to shortly be proved invalid—is unfettered in his ability to stop others from using his patent. By contrast, under the liability system, anyone "trespassing" on the property can only be made to pay appropriate fees for using the property in question.

More recently, the U.S. Supreme Court has shown concern for the lack of balance in the U.S. intellectual property regime.[41] But meanwhile, the United States has been active in exporting its unbalanced IPR regime around the world. Similarly, as those in the U.S. software industry—one of the most innovative in the world—worried especially about how patent thickets might suppress innovation and were calling for reforms in the IPR regime, the Office of the U.S. Trade Representative was doing all it could to spread an even "stronger" IPR regime.

5. Going global

As a result, the United States' dysfunctional approach to patenting (involving granting to many patents and patents that are too broad) has spread globally. To understand the United States' forceful push in this direction, it is again useful to

important difference: knowledge is a public good. Hence, the problem of "overgrazing," given as the efficiency justification of the enclosures, does not apply to knowledge. (Its relevance even to the problem of overgrazing has been questioned. There are other effective social mechanisms of preventing overutilization of commons, as Elinor Ostrom, recipient of the 2009 Nobel Memorial Prize in economics, has pointed out.)

[40] See Lewis and Reichman (2005).

[41] See, for example, *KSR International Co. v. Teleflex. Inc. et al*, 550 U.S. 398 (2007). In the case, the Supreme Court reversed a lower court's ruling that KSR had infringed on a Teleflex patent by combining two different car parts into a single system, an idea Teleflex said it had patented. The Supreme Court said that the combination was obvious – and thus not patentable – and that the lower court's application of the test of obviousness had been narrow and rigid. "Granting patent protection to advances that would occur in the ordinary course without real innovation retards progress and may, for patents combining previously known elements, deprive prior inventions of their value or utility," the opinion stated. Jaffe and Lerner (2004) have claimed that the expansion in patentability has created a broken system: the United States "converted the weapon that a patent represents from something like a handgun or a pocket knife into a bazooka, and then started handing out the bazookas to pretty much anyone who asked me for one, despite the legal tests of novelty and non-obviousness."

remember the atmosphere of technical and economic pessimism of the 1970s. The United States was seen as losing its competitive advantage in manufacturing (at the time, especially to Japan), but at least U.S. universities and technological innovation were preeminent. Still, the United States needed to somehow appropriate the returns to its technological prowess. Japan had expertise in adaptation, but the United States should get returns from its technological leadership. There was a general feeling in the United States that the absence of a proper *global* system of protection of intellectual property rights was interfering with the country's ability to appropriate its returns to these investments in intellectual capital, and the result was seriously distorting competition, to the detriment of the United States. The idea emerged that the best remedy would be to introduce *compulsory* global rules on the protection of intellectual property into the mechanisms regulating free trade among nations.

For more than a hundred years, the World Intellectual Property Organization had worked to create global rules, but there was no enforcement mechanism. The only way to have an enforcement mechanism was to link intellectual property with the trade agenda. Intellectual property thus became an item on the broad agenda of the Uruguay Round[42] under the General Agreement on Tariffs and Trade (GATT). While "linkage" was opposed by many of the most ardent advocates of trade liberalization,[43] the politics was compelling. A grand bargain was struck between developed and developing countries, whereby there would be reductions in agricultural subsidies and a lowering of tariffs and quotas, especially on textiles, in developed countries in return for liberalization of financial services (desired by Western banks) and enforceable global rules on intellectual property. In the end, the West reneged on its side of the bargain: the agricultural subsidies remain little changed (even after a WTO appeal panel ruled U.S. cotton subsidies to be illegal), and full liberalization of textiles was postponed by more than a decade.[44] But the advanced industrial countries did succeed in forcing the TRIPS (Trade-Related Aspects of Intellectual Property Rights) agreement on a reluctant developing world. The reference to trade was a farce—nomenclature designed to shoe-horn intellectual property into a trade agreement.

Thus it was that a small group of mainly American lawyers and chief executives of large firms, active mostly in the entertainment industry (for whom copyright law was important), electronics (software), and life sciences, elaborated a doctrine concerning intellectual property rights and a strategy of action. They recruited more firms and convinced key legislators, the Department of Commerce, and the US Trade Representative to insert into the Uruguay Round

[42] The Uruguay Round started in 1982 and was not concluded until 1994.
[43] See Bhagwati (2004).
[44] See Charlton and Stiglitz (2005).

mechanisms for protecting intellectual property. Making the most of their connections with European and Japanese Business Associations, they were able to secure the backing, albeit somewhat reluctant, of Japan and the main European countries. Even within the White House, within the Office of Science and Technology Policy and the Council of Economic Advisers, there was deep skepticism whether TRIPS was good for the advancement of science and overall economic performance.[45]

The attitude among emerging countries has been less cooperative. Many among them resisted the idea of a global, uniform system for protecting intellectual property, and for good reason. Access to knowledge was essential if they were to be successful in their development strategies.[46] Any intellectual property régime must balance out the static inefficiencies associated with restricting the use of knowledge and the creation of monopoly power with the dynamic benefits. How that balance is struck will obviously differ between developed and developing countries.[47] The developing countries had to be pressured into agreement, and then into compliance.

For those countries that hesitated in providing intellectual property protection for American firms, the United States Congress provided an incentive. In 1984 it passed an amendment to Section 301 of the US Trade Act that allowed the US Trade Representative to impose trade restrictions on countries that were deemed lacking a proper system of protection of intellectual property, a lack that allegedly made them unfair competitors for the United States. The threat of Section 301 was swiftly exercised on numerous countries, among them Brazil, Korea and Thailand, to help create a climate conducive to accepting the United States' position at the GATT negotiations.

The efforts of this special group of American businesses proved successful: As a result, TRIPS was part of the Uruguay Round agreement of 1994 (which simultaneously created the World Trade Organization (WTO). The WTO was granted specific powers to arbitrate disputes and to allow those hurt by unfair trade practices to impose sanctions on the offending parties. This included violations of TRIPS.

The characteristics of the system of intellectual property prevalent in the developed world (and especially the U.S.) have thus to a large extent been globalized, and so the individual patenting systems of developing countries have inherited most of the defects discussed above.

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[45] Stiglitz was at the time a member of the Council of Economic Advisers, responsible for developing policy towards intellectual property. See the discussion in chapter 5 of Stiglitz (2006).

[46] Indeed, the World Bank itself emphasized that what separated developing from developed countries was not so much a gap in resources as a gap in knowledge. See World Bank (1998)

[47] See Stiglitz (forthcoming). The implication is tht there should not be a uniform intellectual property régime.

The question is, has there been any benefit for the developing countries? Are there more commercial investments from developed countries, as TRIPS allegedly made such investments more secure? Answering such a question is difficult: There is always the problem of the counterfactual, what would have happened if TRIPS had not been adopted. What seems clear is that if there has been any increase in the flow of investment, it has been relatively modest and mainly by subsidiaries of multinationals.[48] In what might at first glance appear to be a paradox, the largest flow by far of commercial investments has been going to China, the country that has most consistently been accused of cheating on TRIPS, even after it formally endorsed the agreement when it became a member of the WTO.

Even from the outset, it was recognized that the TRIPS agreement was unbalanced, with costs imposed on developing countries almost surely greater than the benefits, and with intellectual property protection concerns of developing countries being given short shrift. While developing countries would have to pay more for drugs, the drug companies invested little in the diseases that afflicted the poor, especially the poor in developing countries. There was little protection afforded to the traditional knowledge of developing countries, and drug company opposition to paying for the value of the knowledge associated with the genetic material obtained from developing countries led to the refusal of the United States and other advanced industrial countries to sign the Convention on Biological Diversity.

Access to health

In 2003, the international Commission on the Social Dimensions of Globalization, recognizing the severe potential adverse impact of TRIPS on health conditions in developing countries, and how lack of access to knowledge could impair their development, called for a rethinking of TRIPS.[49] The problems were rightly anticipated to get worse as developing countries rewrote their intellectual property laws to conform to TRIPS. Generic drug producers, so critical to the provision of low-cost medicines, might be forced out of business.

Meanwhile, there were worries that even the "flexibilities" built into the Uruguay Round agreement would be undermined, as the U.S. and Europe might

[48] Some critics worry that TRIPS has thus encouraged the concentration of research within the developed countries (the headquarters of most of the multinationals), and may thereby be further impeding the development of poor countries. These concerns have become particularly pronounced as economists focus on developmental transformation, on how to convert static societies into learning economies. See, e.g. Greenwald and Stiglitz (2006, forthcoming).

[49] See World Commission on the Social Dimensions of Globalization (2003).

subtly threaten developing countries who exercised their rights to issue compulsory licenses. All of these fears have proven justified.[50]

Rather than the rebalancing of intellectual property regimes (toward something called TRIPS minus) that the Commission on the Human Dimensions of Globalization called for, these obligations have been extended as part of bilateral agreements imposed upon weak countries in Africa or Latin America; their regimes are dubbed TRIPS+. For these countries, the globalization of intellectual property has had two main consequences: increasing havoc in their public health systems and a draining of royalties toward rich countries.[51]

This global state of affairs is not satisfactory. Neither development nor health has been promoted.

Global warming

In the past 15 years, a new concern has risen to the top of the global agenda: global warming. Reducing global carbon emissions to prevent global warming will require an agreement between developed and developing countries. The global intellectual property regime that was imposed on developing countries has made reaching such an agreement even more difficult. The current flow of funds from developing to developed countries in royalties obviously undermines their ability to bear the costs; but even more important, it makes developing countries wary about signing another agreement that might increase such payments. That might happen if they sign on to obligations to reduce emissions that could only be obtained through usage of American (or European) technology. Of course, the 1992 Rio Convention had a provision for the issuance of compulsory licenses. But, again, the way the "flexibilities" in the Uruguay Round agreement have been implemented has undermined trust: developing countries believe that in practice they will be subject to enormous pressures not to issue such compulsory licenses, similar to the pressures not to issue compulsory licenses for generic drugs. And the fact that the United States has been unwilling to recommit itself to the terms of the Rio Convention reinforces these suspicions.

Reforms

The current global intellectual property regime, as well as serving the interests of the international electronic and pharmaceutical companies, is an impediment

[50] Critics of India's new intellectual property law argue that it went beyond what was required by the TRIPS agreement. Court decisions, e.g. against Novartis's attempt to "evergreen" its patents have maintained some balance.
[51] See World Bank (2001).

to the kind of global cooperation necessary in so many arenas, especially in development, global health, and even addressing the problems of global warming. Neither is it good for global science. This raises the question: what are possible reforms?

First, as long as the IPR system is burdened with the dispositions and practices accumulated during the last 30 years—including unwarranted patents and too-broad patents—some form of corrective action will be necessary, in particular in the form of compulsory licenses. But how do we make sure that it does not drift again? The forces that have led to the current distorted intellectual property regime are still present.

One of the surest ways is to open the process within which a patent is examined to all interested parties.

Second, important benefits could be derived from introducing more competitive mechanisms and concerns within the fabric of IPRs.

Finally, it is also possible to give more weight to other ways of stimulating innovation. Among them (besides direct public support of research) are guaranteed sales, prizes, and open-source mechanisms.

We will explore these perspectives in turn.

6. Cutting Gordian knots

Public utilities (such as electricity, rail, or telecommunications) depend on essential infrastructures (grid, track, or local networks). Without access to these natural monopolies at fair prices, firms are excluded from the corresponding businesses. Regulating access and the price of access by specialized public authorities (the regulators) is now the almost universal approach to the problems posed by natural monopolies in essential facilities.[52]

Living organisms or elements of knowledge in physics constitute examples of essential infrastructure of critical importance for public health, "green" energy, and, more broadly, for furtherance of research generally. If owners of patents do not offer licenses at reasonable prices when, for instance, these "green" energy imperatives require it, then regulating them is no less economically justified than it is to do so for electricity, rail, or telecommunications networks.

[52] See Henry and Matheu (2001).

There is in fact a simple and proven regulatory tool: Compulsory licenses. Canada and the United States have a long experience with compulsory licenses. Canada used them for dealing mainly with health requirements. The United States used them in health (in response to the anthrax scare, as mentioned above) and as antitrust remedies;[53] they have also been used in defense procurement to overcome deadlocks between private firms (in aeronautics and in electronics) deemed detrimental to national security. What the war against Germany or Japan required, the war against climate change might as well.

There are familiar objections against compulsory licenses, for instance, that they weaken the incentives to innovation.[54] But good public policy has always balanced incentives to innovate with concerns for competition. A monopolist who derives his monopoly power from a patent is no more entitled to engage in anticompetitive practices than a monopolist who has attained his monopoly power in any other way, even if such a monopoly power would lead to greater investment in innovation. In network utilities, the parallel concern is that capped prices for access to essential infrastructures could lead to lower investment in these infrastructures.

A more general critique is that, the asymmetry of information between regulator and regulated firms would make it impossible for the regulator to set appropriate access conditions (to essential patents or to essential infrastructures). These problems are serious and deserve serious consideration, which is precisely what they get in the regulation of network utilities. In particular, both academic research and regulators' learning-by-doing have produced dynamic procedures, converging to reasonable access conditions. This has been done in such a way that information useful to the regulator is revealed during the course of the procedure, thanks to built-in incentive devices.[55] What has been possible for

[53] See Barton (1995) and Scherer (1998).

[54] Interestingly, from the large set of data he has gathered, Scherer (1998) concludes that, statistically, the imposition of compulsory licenses on the firms considered had no effect on their subsequent propensity to innovate.

[55] See Henry and Matheu (2001), and Armstrong, Cowan and Vickers (1994). Here is a simple example. British Telecom (BT) was privatized in 1983. At the same time, a second operator called Mercury was created from scratch, in order to introduce a measure of competition on the market for public telecommunications. This new operator quickly built, using brand new technology, new long-distance lines on links with high expected traffic (like London-Birmingham). It was, however, obviously impossible for Mercury to duplicate BT local networks. Hence, Mercury had to rely on the local networks (essential facilities) of the firm with which it had to compete (BT) for its long-distance services.

The regulator, also put in place in 1983, had to sort out the consequences of that awkward situation. The law had it that he should first try to mediate between the two firms. This led nowhere; asymmetries of information posed particular problems: according to BT, the interconnection between its own local networks and Mercury's long-distance lines was technically very difficult; Mercury would therefore have to pay interconnection charges that were so high that its business would not be profitable. However, BT did not provide any precise figures on its costs, and without that information the regulator could not have an accurate idea of BT's interconnection costs. He and his staff of engineers and economists could, however, estimate a lower and an upper bound for these costs. BT pretended that its costs were above the upper bound, which the regulator knew was not true but was unable to provide proof acceptable to a judge in the event the conflict had to be adjudicated. The regulator, still

network utilities regulation is attainable for intellectual property regulation. Indeed, the information requirements associated with running an efficient compulsory license system are likely to be far less demanding than those associated with network utilities regulation.

7. Eliciting information: opening examination processes

One of the key problems noted earlier is the granting of patents that should not have been granted. Not only is there excessive "privatization" of knowledge as a result, there are also excessive litigation costs and, as we have seen, innovation is stymied.[56]

The European Patent Office (EPO) has a procedure for evaluating the validity of patents that seems preferable to those employed elsewhere: when a patent is granted, parties that are unhappy with the decision and that think they have robust arguments to prove that the patent is unwarranted may demand an "opposition" procedure before an appellate body within the EPO. Such a procedure is quicker and far less costly than going to court. Above all, it considers all significant evidence that is submitted. The opposition procedure functions as a device that elicits and examines relevant information that the opposing parties possess and have every interest to communicate. This is particularly important in a situation where the quality of direct information gathered by the examiners in patent offices has seriously deteriorated, particularly because of budget constraints that lead to understaffing. (Because there are still some costs borne by those standing in opposition, there still may be an undersupply of "opposition," as noted earlier.)

This function of the opposition procedures is so important that economist Jean Tirole suggests that it should be integrated within the examination process itself.[57] Jaffe and Lerner concur: "For those patent applications that really matter, parties should have [...] opportunities to bring the information in their possession before the US Patent and Trademark Office." [58] So does Robert C. Pozen (chairman of MFS Investment Management, after having been vice-chairman of Fidelity Investments). He urges Congress to reform the way patents are examined: "Patent examiners, many of whom are young or lack practical experience, are not qualified to evaluate whether complex claims in biotech or

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acting according to the law, then published a "draft determination," that is, he proposed a level for the interconnection charges. He deliberately chose a level near the lower bound. In so doing, he radically changed the conditions of the exchange of information with BT: henceforth, it was in BT's best interest to provide cost figures based on credible data in order to obtain somewhat better interconnection charges than those set in the draft determination. Thus, in the matter of the exchange of information, the regulator had reversed the situation.

[56] The problems would be mitigated under the liability system described elsewhere in this paper.

[57] Tirole (2002).

[58] This is a natural consequence of the analysis in their book, Jaffe and Lerner (2004). For the point of view of the specialist in patent law at GW Law School, see Duffy (2009).

physics meet the most critical tests: whether the claim is novel relative to prior art, and whether this would be obvious to a person skilled in the art. To help fix this, Congress should pass an amendment allowing experts in the field to submit explanatory or critical comments on patent applications."[59]

Such reforms would reduce if not erase the mountain of bad patents that are now granted and would dramatically reduce the excessive breadths of many patents. It would be a good example of a revelation mechanism within which the parties involved have strong incentives to reveal the information they possess, information that is of paramount importance to reach an appropriate decision.[60]

8. The power of competition

Traditionally, advocates of intellectual property have argued that the economic distortion associated with the underutilization of knowledge—and even the potential reduction in competition—is more than offset by the benefits of greater innovation. But more recently, this perspective has come under two criticisms. First, innovation itself may be hampered (see our earlier discussion). Secondly, there are better ways of providing incentives for innovation without the adverse affects associated with the patent system.

John Bartonhas chaired a Commission appointed by the UK Government (DFID) with the objective of integrating intellectual property rights and development policy (2002). The Commission devoted a great deal of attention to health and agriculture issues, pointing out serious difficulties in integrating scientific and technical innovations into development policy due to the monopolization of genes and other elementary constituents of life by current intellectual property law and practices. Five years later, Barton completed another report on intellectual property and development in the field of clean technologies, where he identified no roadblock similar to genes, with the possible exception of enzymes, for the production of bio fuels; at least photons and electrons have not yet been considered for patenting.[61] Moreover, "there is competition between a number of patented products," i.e. between techniques and devices to produce clean energy.

Such competition may be promoted at all levels, including the process through which patents are granted, which currently only gives gold medals; why not grant silver medals as well, or ever bronze ones, etc., so that inventions applying within a sufficiently short period of time after the winner of the race (especially

[59] See Pozen (2009)
[60] Revelation mechanisms play a central role in contemporary economic analysis, as shown in Eric Maskin's Nobel Lecture (2007).
[61] Barton (2007).

since a claim takes years to be examined) would share the patent? One strong objection is that it would weaken the incentives to invent. This is not necessarily the case, as the perspective of several lesser prizes might compensate for the absence of a jackpot, especially when, as is often the case, there is some degree of differentiation between the proposed inventions. Indeed, if those engaged in the patent race are identical and risk averse, spreading the risk increases investment in innovation.[62]

Moreover, in general, a winner-take-all reward structure is not optimal, and there are further market benefits from competition that arise from the existence of multiple holders of IPR. However the main motivation behind this multi-patentees mechanism is the following : the public authority in charge may use the length of the period, within which claims are considered, as an incentive device with respect to the inventors in such a way that under broad conditions social welfare is greater than with the traditional one-takes-all approach: the incentives to invent are not seriously, if at all, weakened, and the benefits from competition induced on the product market are significant.[63]

In the reform just described, patents do get issued, albeit shared, in ways that better balance incentives to invent and benefits from competition. As James Bessen and Eric Maskin have shown, there are economic activities and structures where the proper balance altogether dispenses with patents. They introduce their findings in the following way:

> "How could such industries as software, semiconductors, and computers, have been so innovative despite historically weak patent protection? We argue that if innovation is both sequential and complementary – as it certainly has been in those industries – competition can increase firms' future profits thus offsetting short-term dissipation of rents. A simple model also shows that in such a dynamic industry, patent protections may reduce overall innovation and social welfare." [64]

There are here "natural market forces"[65] that call for innovations and protect innovators from imitators.

9. Other logics: prizes and open source

The open source movement has radically transformed the production of software over the last two decades. The "success of open source," to use the title of

[62] More generally, Nalebuff and Stiglitz (1983) consider the design of optimal races.
[63] See Henry (forthcoming).
[64] Bessen and Maskin (2009). See also Boldrin and Levine (2004)
[65] Gallini and Scotchmer (2001) p.52; see also Henry and Ponce (2009).

Steven Weber's book, is undeniable and supported by numerous figures. Linux, one of the most prominent open source projects, was estimated in 2007 to hold 12.7% of the server market, and 60% of all web servers ran Linux. Apache, an open source web server software, now serves more than 50% of all websites. However, the success is not limited to a few prominent examples. Sourceforge, the largest open source software development website that provides tools and services for developers, is currently hosting more than 230,000 projects and has more than 2 million registered users. Many of these projects are small, but these numbers nevertheless reflect the vibrancy of the movement.

The open source model of production challenges the more traditional models based on protection of intellectual property. What motivates people to contribute when they can't directly appropriate the returns from their work? How can a decentralized system produce software of undeniably high quality? Many have pictured the movement as marginal and non-replicable: the common image is one of a group of programming fanatics getting together and producing code in semi anarchy with no possibility of making a profit. This perception is flawed in several respects.

First, the motivations of participants in the movement are complex, as survey evidence suggests.[66] Several categories seem to emerge: Some are motivated purely by the fun of programming, others by a particular computing need that is not satisfied by existing software. Still others are motivated by the sense of belonging to a common culture, where participants share a common ideology, often characterized by reciprocity (some also claim that the ideology is defined in opposition to Microsoft). Finally, Lerner and Tirole (2002) suggest that some programmers might be motivated to make high quality contributions to signal their ability to potential employers (although survey evidence appears to indicate that this motivation is not of first-order importance). This gives a much richer set of motivations than suggested by the common representation, some of them not particularly specific to software production.

Second, the system relies heavily on contracts. The software is generally licensed under "copyleft" licenses, the most prominent example being the General Public License (GPL). The idea is that the licensee can use the software for any purpose he wants, including modifying it and redistributing it, possibly for a fee. The unique restriction placed on the licensee is that modified versions also need to be licensed under copyleft licenses. Several variations exist around this initial idea, depending on, for instance, whether the open source software can be combined with a proprietary one or whether a fee can be charged for redistribution.

[66] See Haruvy, Wu, and Chakravarty (2003); and Hertel, Krishnan, and Slaughter (2003).

Third, firms can make profits in this environment. A prominent example is the case of Red Hat, a Linux distributor. This firm, introduced on the stock market in 1999, heavily finances innovation: it pays programmers to contribute to the Linux project. Given that Linux is licensed under GPL, the modifications are made public, so returns cannot be appropriated directly. The sources of indirect profits are, however, numerous. Linux sells pre-compiled versions of the software, support, and assistance for large companies. It also proposes services for firms that want specific features developed. All these channels are quite characteristic of how firms make profits in open source.

Right now, only the software industry has seen the penetration of open source contracts on a large scale. However there are significant examples in other sectors.[67] The case of the open source contracts on the bacteria identified by the Cambia scientists (see Section 2) provides an important example in the biological sciences and techniques where the innovations may have enormous potential in terms of sustainable development.

10. Conclusion: how to promote dissemination of sustainability-enhancing innovations.

Intellectual property, it has been argued, is essential for promoting innovation. While it is recognized that there are high costs—both in terms of restrictions in the dissemination of the benefits of knowledge and in potential risks of monopolization—the advocates of strong intellectual property laws contend that these costs are worth the benefits. But in this paper, we have questioned that premise in two ways. First, we have shown how poorly designed intellectual property regimes—and America's is not well designed—can actually impede innovation. Secondly, we have contended that there are alternative ways of organizing research—of providing finance and incentives—that may be better both in promoting innovation and in disseminating the fruits of research.

More generally, we need to think of intellectual property as *only one aspect* of a country's (and the world's) innovation system. Part of the problem today is that this one aspect has come to dominate the other aspects. We need to rebalance, giving more weight to other instruments that further innovation. But another part of the problem is that our intellectual property system is not well designed. There are reforms in its design—simple reforms, such as the processes governing how and when patents are granted or the breadth and standards for issuing patents—that would increase the benefits from the patent system and

[67] As illustrated in von Hippel (2005).

reduce its costs. There are more fundamental reforms, such as moving to a pro-innovation competition mechanism or a "liability system", which might yield even higher benefits.

Unfortunately, a few special interests, especially in the United States, have played a disproportionate role in the design of the current system. The result is a system which does not work well for the United States but works even more poorly for the rest of the world. The United States is in the process of changing the design of its IPR system, as the Supreme Court comes to recognize its weaknesses. The worry is that the rest of the world will be mired in the legacy of a flawed intellectual property system, embraced by many countries in their response to TRIPS. That would be a tragedy both for the health and well-being of the citizens of these countries and for the prospects of their sustainable development.

This article shows that there are alternatives.

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