On Copyright and Patent Protection for Software and Databases: A Tale of Two Worlds

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Abstract

The paper considers the impact of increased copyright and patent protection for software and databases (that is, for "pure" information goods) on research communities. The central issue discussed is the tension between the two worlds of commercial innovation and scientific research with respect to the twin goals of appropriating and diffusing knowledge. These two worlds have developed very different incentive systems for rewarding the production of information, and problems develop when the two worlds move closer together, as they have recently in much of the world. Examples of this tension from university patenting in the United States and from increases in database protection are given. The paper argues that a useful distinction between the necessary incentives for the production of pure information goods (which require little complementary investment to make them useful) and industrial innovations (which require a great deal) might lead to a lesser need for intellectual property protection in the former case.

1. Intellectual Property Protection and Open Science

At least since the work of Nelson (1959) and Arrow (1962), economists have understood that the production of knowledge and information may be at an insufficient level from the point of view of society due to the relative ease and lower cost of using rather than producing knowledge, which leads to free-riding by others in its provision. In the absence of intellectual property protection, not only is the producer unable to cover his production costs in the presence of free entry of imitators, but he is also typically unable to charge for the benefits that his product (knowledge or information) confers on other producers whose knowledge production builds on his.

Intellectual property (IP) protection is often introduced as a second-best solution to the incentive problem; the obvious cost of this solution is that such protection creates at least a temporary monopoly and may lead to higher prices for the good that embodies the information in question. When the product itself is intangible "information," as in the case of scientific output, software, or databases, the tension between the benefits of IP protection to guarantee appropriability and the costs of restricted access to the product by those who wish to build on it is particularly acute. This is because the costs of imitation (and the marginal cost of production) in the case of pure information goods are quite low and therefore the IP protection required to prevent entry creates a larger deadweight loss, ceteris paribus. For the same reason, these types of goods are more likely to generate the spillovers that we would

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like to encourage, and we would therefore prefer not to have them subject to monopoly pricing.

With respect to the decision to undertake research and/or development, economists generally argue that the incentive problem creates a gap between the private and social returns to research that will vary depending on imitation costs and on the generality of application of the results of the R&D, with the gap being smaller for R&D leading to commercial products and larger for basic scientific research. For this reason, the "optimal" tradeoff between policies designed to ensure appropriability of research and those designed to promote spillovers will necessarily be different in the two arenas. In fact, since in reality R&D environments display a continuum between the most extreme private industry settings to the "open science" community, there ought to be a wide variety of policies, institutions and informal arrangements for both ensuring appropriability and facilitating the diffusion and sharing of research results.

When considering how the desire of the economic agents to encourage the spillovers from which they benefit plays out in a setting where there are also appropriability mechanisms in place, it is useful to distinguish between conventional R&D that is embodied in commercialized products and the production of such items as scientific knowledge, research tools, software, and databases. In the former case, diffusion of the "knowledge" created by the R&D can often be achieved separately from the sale of the product in which it is embedded, via information disclosed on the patent or reverse engineering. In the latter case, the "product" itself is the knowledge that will be used as an input to the creation of future products. In this case, there is nothing else to sell besides the output of the R&D, and therefore private provision of the knowledge will inevitably mean that its use is restricted or limited in some way if the knowledge is subject to strong IP protection.[2]

A second characteristic distinguishes many, but not all, pure information goods: they are often produced by creative individuals using few inputs other than "sweat of the brow." Such products include software of various kinds, books, musical compositions, games, some types of research discoveries, and some video and audio productions. For such goods, very little in the way of complementary investment is required to make a fairly attractive and useful product. For many of these producers, the utility and fame from invention and/or creation is its own reward, and requires little incentive of the conventional IP type. Because such goods do not require large financial outlays to others to produce, they are likely to be produced even in the absence of strong IP protection, although in many cases incentives in the form of priority or fame to the first mover may be important. For these types of goods alternative systems that both ensure knowledge spillovers and provide appropriate (but not necessarily financial) incentives have often developed.

An important example of such a system is the "republic of science." Obviously the scientific research community primarily produces pure information goods, where the tension between appropriability considerations and the need for the sharing of information to increase researcher productivity and secure scientific advance is the greatest. As others have argued (David 1998; Dasgupta and David 1992; David 1992), this community has evolved a rather

[2] Once again, this is a question of degree, not absolutes. Clearly firms that produce software and databases have devised a variety of ways to ensure that their products are not "merely" information, by providing attendant services, publishing in a convenient physical format, etc.

different approach to rewards for and spillovers from the production of information goods than that suggested by a conventional economic property rights analysis, one based on rapid publication and dissemination in order to achieve a prior claim as the inventor.[3] "Priority" thus acquired is an important input to the career and sometimes the financial reward structure faced by scientists, but because there is no direct sale of the information, there is no attempt to restrict its diffusion. The cultural and institutional norm in this sector is therefore to maximize the dissemination of research results, in order to establish priority in as wide an arena as possible. As Liebeskind and Oliver (1997) argue, because the quality of "new" information is frequently difficult to judge, exposing it early and often via publication serves an additional purpose: by allowing replication and verification, it increases the "trust" placed in new results from the same researchers. If the norm were secrecy instead (at least for a limited time), the progress of science would be substantially impeded.

Of course it is possible that the free diffusion of the "public goods" knowledge created by R&D might also be industry welfare-enhancing in some private industry settings, provided that there remain sufficient avenues to capture the returns to the investment via the production of private goods for sale.[4] That is, one can imagine an equilibrium with weak IP rights where firms were willing to allow diffusion of their own knowledge in exchange for low cost absorption of the knowledge of others. Such an equilibrium might have transactions costs enough lower than those incurred in a setting with strong IP rights, large amounts of cross-licensing, and aggressive patent enforcement strategies that aggregate innovative effort would not suffer even though incentives of the conventional economic kind were weakened. It is possible to argue that this was the situation in the U.S. semi-conductor and electronic computing industries prior to the strengthening of patent protection both statutorily and via legal precedent in the early 1980s.[5] Certainly it appears to be the model underlying the open source software movement.[6]

The difficulty is that such an equilibrium in the private (profit-maximizing) sector is unstable if IP protection is in fact available to the participants and also that an equilibrium based on a tacit *quid pro quo* may discriminate against new entrants who are not part of the "club." For an example of the first difficulty, consider the aggressive litigation strategies of Texas Instruments in the 1980s, which appear to have been destabilizing in the case of the semiconductor industry. For the second, Hall and Ziedonis (2001) found that one of the primary arguments given in favor of strong IP protection in the semiconductor industry by the participants was that the possession of key patents helped start-ups to obtain financing for entry into the industry. Because external finance is essential to entry in industries that require high upfront investments, and because investors require an *ex ante* signal that the firm has an

[3] Also see Arora, David, and Gambardella (1999) for empirical evidence on the "increasing returns" nature of the reward system in science, sometimes known as the "Matthew" effect.

[4] For example, Hicks (1995) finds that researchers in private firms often publish scientific articles in an effort to link to the scientific community and to signal the possession of tacit knowledge that will enable these researchers to participate in the "open science" community. The same idea is suggested by Cockburn and Henderson (1996, 1998) using evidence on research productivity in the pharmaceutical industry.

[5] See Grindley and Teece (1997) and Hall and Ziedonis (2001), *inter alia*, for a discussion of changing IP protection in this industry.

[6] See Lerner and Tirole (2002) for a discussion of the role of "signaling" programming competence in the production of open source software and Kuan (2002) for an argument that open source represents the backward integration of consumers into production.

potentially rent-generating asset, obtaining IP protection becomes important when the only thing an entrepreneur possesses is a good idea. Once again, it is the need for *complementary* investment that suggests the importance of IP rights.

A couple of implications follow from this brief review of the "two worlds" of research and development: First, we might expect particular tensions to arise in settings where the conventions of one world (private industry) come up against the conventions of another (public R&D and university science). The design of appropriate incentives at the boundary is difficult but important. Second, as highlighted above, the area where we might want to be particularly careful to ensure that the policies we adopt to secure appropriability do not discourage spillovers is in the production of "pure" information goods and research tools. The remainder of this brief paper discusses these two aspects of IP protection in the scientific research setting in somewhat more detail and suggests avenues for future research on the management of IP policy to ensure continued co-existence of multiple reward systems.

2. IP Issues on the Boundary

The tension between IP protection and the desire for the promotion of spillovers can be seen in a couple of examples from the recent U.S. experience with policy efforts to increase the ties between academic science and industry, and to speed the commercialization of inventions made in the university.[7] These efforts have been somewhat successful: Table 1 shows a tripling of the share of university research funding that is paid for by private industry in the United States between 1970 and 2000 (although the fraction is still fairly low, just above six percent). Yet a number of problems and potential problems have arisen, which are mainly due to the collision between the reward structures of academic science and those of private industry.

The first example is that of university-industry research centers in the United States. Cohen, Florida, and Goe (1994) conducted a survey of 437 universities that covered more than 1000 University-Industry Research Centers (UIRCs) in 1991. These centers are the principal vehicle for industry support of academic science and engineering in the United States. One of the findings from their survey was that industrial participants were often able to restrict information flow and delay publication of the results from the academic research that they were supporting, suggesting a conflict between the university's open science goals and those of industry. Whether we should be concerned about this deviation from the cultural norm of science depends somewhat on whether the research conducted in these centers was "additional" to that normally conducted by the university. On this question, the study is fairly silent. However, more recent survey evidence due to Hertzfeld, Link, and Vonortas (2001), based on a small sample of firms involved in university research partnerships, suggests that companies are now beginning to find ways to accommodate the open science need to publish early.

The second example concerns the effects of attempts to increase university commercialization by granting them rights to their discoveries. In the United States, most

[7] The examples in this paper are largely drawn from the U.S. experience, with which I am more familiar and for which there have been a number of policy experiments and attendant studies in the recent past. See Cassier and Foray (1999a,b) for a discussion of this issue in Europe.

basic scientific research is conducted within universities or within federal laboratories managed by universities. The Bayh-Dole Act of 1980 was one of several measures adopted in response to a perceived threat of Japanese technological competition that were designed to accelerate and enhance the commercialization of research results from the university community. This act allowed universities to obtain patents on technology developed using federal research funds so that the technology could be licensed to private firms for development.[8]

One might expect that adding such a goal to the university agenda would have an impact on university behavior and there is some evidence that it did. University patenting, which had been growing prior to 1980, accelerated after 1980 from a 0.7% share in domestic U.S. patents in 1979 to 3.6% by 1999.[9] The share of new invention disclosures in universities that are patented rose from 26 percent in 1991 to 49 percent in 2000.[10] Henderson, Jaffe, and Trajtenberg (1998) found that universities increased their overall patenting per R&D dollar rate, with an apparent drop in patent quality, suggesting the harvesting of lower quality outputs of their research.

Mowery and Ziedonis (2001, 2002) provide more nuanced evidence on this point, finding little decline in importance or generality of the patents taken out by the University of California and Stanford University following the passage of Bayh-Dole. These two universities were two of the heaviest patenters both before and after the passage of this act and therefore dominate the statistics on "incumbent" universities. Entrant universities, those who began patenting in response to Bayh-Dole, account for the overall decline in patent quality observed by Henderson, Jaffe, and Trajtenberg. Mowery and Ziedonis conclude that the primary effects of Bayh-Dole are increases in the marketing of innovations by incumbent universities and the entry of universities new to patenting, rather than an actual change in research strategy.[11] However, along with Mowery et al (2001), they caution that other trends in scientific research and patenting, particularly the rise in biomedical research and the 1980 U.S. Supreme Court decision in *Diamond v. Chakrabarty*, which upheld the validity of a broad patent in biotechnology, make it difficult to attribute the entire effect to the Bayh-Dole Act.

In contrast, Argyres and Liebeskind (1996) found that university efforts to commercialize biotechnology innovations following the Bayh-Dole Act of 1980 were impeded by the academic institution's traditional commitment to the "intellectual commons" and absence of secrecy, suggesting that the tension goes both ways. Yet Mowery and Ziedonis (2002) do report that the majority of technology licenses granted by UC Berkeley and Stanford are exclusive, suggesting that those agreements that are reached are structured to satisfy the desires of industry. In a survey of university-industry partnerships that were partly funded by the U.S. Advanced Technology Program (ATP), Hall, Link, and Scott (2001) found that

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[8] Universities had been patenting some inventions before this time, but the Bayh-Dole Act replaced a series of individually negotiated agreements between particular universities and federal agencies.

[9] Mowery and Ziedonis (2001, 2002).

[10] Association of University Technology Managers (AUTM) Survey data, as reported in Graff (2002).

[11] This view is also supported by Thursby and Thursby (2000), using survey evidence from 65 universities that license innovations for commercial use and the businesses that license from them.

intellectual property issues were one of the main areas of conflict between the universities and industry partners, although in this case the dispute was over the allocation of rights rather than the diffusion of the information.[12] For their subsample of 25 ATP projects where there was no university partner, over half reported that IP issues had been an insurmountable obstacle to reaching agreement with a university partner. Hertzfeld, Link, and Vonortas (2001) surveyed a range of industry Research Joint Venture (RJV) participants and found that the most problematic area for RJV negotiations was those with universities, especially university technology transfer officers, who were perceived by industry participants as being overly aggressive and "greedy" in approaching IP issues.

The conclusion from this brief survey of the effects of changes in IP protection during the past 15-20 years on the university-industry research relationship in the United States is that "harvesting" of patents from inventions has increased greatly in the university, but with relatively little effect on actual research (this is similar to the trends in industry, see Ziedonis and Hall 2002). At the same time, the growth in partnerships with industry has led to increased tension over IP rights and the ability to publish freely. However, it is likely that the current trends in patenting (especially in software and genomics) and in database protection are probably more threatening to the university research environment than the effects of 1980s policy changes in joint venturing and university patenting.

3. IP Protection for Software and Databases

Recent trends in biotechnology (gene sequencing) and information technology (the internet) have brought to the forefront a set of issues in the law and economics of intellectual property that were first brought to the attention of economists by Scotchmer (Green and Scotchmer 1996; Scotchmer 1996). These issues have to do with the problem of rewarding multiple inventors in a setting with cumulative innovation. That is, is it possible to provide optimal incentives for innovation simultaneously to the producer of a first generation product and a second-generation product that builds on it? The answer in general is no. At least two problems arise:

1. The first invention creates an externality for the second inventor and therefore may be worth developing even if the expected cost exceeds its value as a stand-alone product. However, broad patent rights for the first inventor to ensure innovation do not leave enough profit for the second inventor. One solution to this problem is "internalizing the externality" via licensing. Scotchmer (1996) shows the following:
    - *Ex post licensing agreements*, entered into after the cost of first innovation is sunk can increase the profits available for the two innovators, but cannot achieve the first best, because it is impossible to give the total surplus to each party separately using this (or any other) mechanism, as would be required to incent each of the innovators separately.
    - *Ex ante cooperative R&D investment (RJVs),* entered into before the R&D cost is sunk generally will achieve a more efficient outcome (in terms of total welfare), but it is very difficult to identify potential partners *ex ante* in practice.[13]

[12] See also Hall, Link, and Scott (2002).

[13] See Headley (1995) for an interesting discussion of the political/legal history of the idea of extending *droit de suite* to cover scientific inventions during the earlier part of the twentieth century. This idea essentially

2. Where the first invention is the pure outcome of scientific research, that is, where the value is only the information, it cannot be sold without revealing it, which makes a sale moot, unless strong IP protection or legally enforceable non-disclosure agreements (NDAs) are in place. In the case where such measures (IPR or NDAs) are only partially effective, Anton and Yao (1998) show that a signaling equilibrium exists with partial disclosure of the idea that gives an indication of its quality. This essentially means that the inventor will receive a "lemons" discount for his innovation, because he gives away some of it as a signal. The discount, which can be large, will clearly reduce the provision of ideas unless non-financial motivations come to the fore (such as priority of the open science kind).

As discussed earlier, a characteristic of information goods such as software that differentiates them from industrial R&D products is that once the invention exists very little complementary investment is necessary to make it useful, so that without some form of IP protection, conventional economic incentives for their production would essentially not exist. Unlike physical products that merely embody the results of R&D, in the case of information goods, the R&D itself is what is for sale. It is this feature that makes the tension between IP protection, which gives incentives for production but restricts the subsequent use of the information, and measures to promote spillovers from the current generations to those which build on them particularly acute.

The insights of Scotchmer and Anton and Yao suggest the difficulty of contract design for optimal cumulative innovation in a setting where each innovation builds on the last, and where subsequent innovators are many, geographically diffuse, and hard to identify. This description characterizes the production of both software and databases in the scientific research community. The origins of database and software packages in common use are often "lost in the mists of time."[14] See Maurer (1999) for some examples. In other cases, they are public and non-protected, but have been developed and augmented by private researchers or research firms.

Given the recent trends toward stronger IP protection in the commercial world, it is sensible to ask both whether there is an argument for extending these protections in the scientific community and also what the unintended impact of the changes already made might be on that community. In the case of databases, the issues, particularly those raised by the new European Union Database Directive, have been well discussed by David (1999) and Maurer and Scotchmer (1999). Maurer (1999) also discusses a large number of example databases and reviews the policy options available for ensuring their production.

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foundered on a reluctance to impose compulsory licensing on inventors into the far future and the consequences such a move might have for the publication of the results of scientific research.

[14] One widely diffused statistical package for the social sciences with which the author is familiar was originally developed by a set of graduate students in their spare time in the 1960s. The approximately 50,000 lines of code now contained in the package probably include at most 100 lines of the original code, but the basic design of the syntax has changed little over the years and its origins are clear. Some of the earlier development was financed on research grants, but most of the value added in the past twenty years has been financed by sales of the product. In spite of this, the package retains a strong link to the academic community and is typically sold to them at a substantial discount from the commercial price. This type of situation is very common in the scientific software world, where the primary product being sold back to the academic community from the private sector is service and support rather than programming code. Were the algorithms in the code protected by strong patents, it is likely that these packages would command much higher prices than they do now.

At a practical level, two questions confront us:

1. Are the current incentives for the production of scientific software adequate?

2. How will changes in the patentability of software impact the academic establishment?

The answer to the first question is probably a qualified yes, primarily because the producers of such software have been very creative in funding its production and improvement. Although the priority system ensures that there are rewards for the original ideas that are the product of research activity and their rapid diffusion throughout the science community, it is less good at ensuring the production of "second generation" developments from the original research ideas. That is, the novelty requirement for research output tends to be too high to allow improvements to or even the creation of software or databases to qualify. In some cases, the implication of the scientific reward system has been that it is difficult to induce researchers to support and improve existing software rather than creating it anew. The same argument applies to updating and improving databases. On the other hand, it is difficult to measure and quantify the extent to which there is a real lack here, because scientists and researchers would almost always like updated and improved data and software if they could obtain it at zero cost. The crucial willingness-to-pay test is rarely applied.

For these reasons, there may be good reasons to consider other incentives for their maintenance and improvement such as IP protection. In fact, historically copyright protection has served this function when coupled with limited privatization of the software production. That is, some individuals within or adjacent to scientific communities have chosen to fill the gap between commercial and academic software by supplying packages that incorporate some of the outputs of the research endeavor in their continuing, ongoing development and that are accompanied by improved efforts in both documentation and service.

Simple economic analysis can help us to identify situations where the provision of software to the scientific community might be either insufficient or at a price which researchers are unwilling or unable to pay. The most important characteristic of software or database production is that its cost structure consists of high fixed costs for the first copy coupled with very low marginal costs for subsequent copies. We know that a monopolist faced with this kind of cost structure will find it particularly advantageous to price discriminate if he can, since producing additional units costs so little. If he is able to segment the market into commercial and academic sectors successfully, and *if the demand in the academic sector is more price-sensitive than in the commercial sector,* we will obtain the outcome which prevails in several disciplines: provision of the good at two widely differing prices, often differentiated in a variety of ways to ensure that the markets remain segmented.[15]

The academic disciplines where this strategy is likely to work well and provide a sufficient supply of these types of information goods are those where the commercial sector generates demand for similar goods, such as economics, law, finance, business, computer science, and

[15] For example, the academic product may not have the most recent data, or may be somewhat more difficult to use (less investment may have been made in "user-friendly" characteristics, or support may be minimal). This strategy is very similar to the sale or distribution of "non-professional" versions of certain software products in order to build market share where there are network externalities (see Chen 1998) for a discussion of this strategy in the context of software piracy.

perhaps biotechnology. In some cases, a monopolist who expects to receive related research spillovers from academia in the future may even elect to charge a zero price for the good. This will be particularly true when the software is subject to ongoing development that depends on the latest research results in the field.

However, problems will arise in at least two situations: first, when the demand of academic researchers for the good is highly price inelastic, as it will be when the good in question is essential to the research endeavor and when the price is not a large share of the overall research budget. In this case, market segmentation will not work, and the monopolist will choose to offer the product at a relatively high price to both markets. Second, the commercial market for some products may fail to exist altogether. In this situation, demand at the price charged may be so low that the producer of the software or database may be unable to cover his or her fixed costs. Of course, this is no different from the difficulty typically faced by basic scientific research and the policy solution is the same: fund the generation of the product as a public good using criteria similar to those used for ordinary research. For the first problem, which may obtain in some scientific disciplines (e.g., satellite data, see David 1999), there is no simple solution. The existence of a private sector solution, even at a high price, makes it difficult politically to fund a public sector solution.

The second question posed above has arisen because of the recent evolution of IP protection for software in the United States, and increasingly in Europe. Up until around twenty years ago, the standard advice given by patent attorneys to their clients was that it was possible to copyright software but not to patent it. The implication of this advice was that the functions of software could be imitated by reverse engineering so long as one did not simply copy the code directly. In general, algorithms themselves were viewed as not protectable.

All this changed during the 1980s as a result of a series of court decisions, beginning with *Diamond v. Diehr* (1981).[16] Today there is a new "land rush" as firms compete to obtain patents on things that were viewed as unpatentable in the early days of computing. Patents are now routinely being issued both on algorithms that may have been available for decades in published works and on "business methods" or "business models" especially when these are incorporated into the Internet. This has naturally lead to an increased fear on the part of scientific researchers that they may be forced to pay for the use of software "concepts" and algorithms that were formerly regarded as free for the taking.[17] Figure 1 contains an example of such a patent (issued to Lucent Technologies). It describes a software and hardware implementation of a method for looking up the sine or cosine of an angle in a table of sines and cosines using an "algorithm" that should be familiar to anyone who has taken elementary trigonometry. Some may question whether this patent passes the nonobviousness test.

[16] Diamond v. Diehr, 450 U.S. 175 (1981).

[17] For an amusing example, see the discussion in Kasdan (2001) of *In re Pardo* [684F.2d 912 (CCPA, 1982)], where Court of Customs and Patent Appeal (the predecessor to the Federal Circuit Court of Appeal) overturned a rejection by the U.S. Patent and Trademark Office Board of Appeals of an application for a patent on a method of solving equations. A reader of the patent would recognize it as the repeated substitution method he or she is familiar with from a first course in algebra, with the equations arranged in the order that would be convenient for a computer. The Court produced an argument claiming that although it was an algorithm, it was not a "mathematical algorithm," and hence could be patented. This particular patent, like so many since, would seem to fail both the "prior art" test and the "nonobviousness" test of patentability.

The validity and enforceability of patents like the one in Figure 1 have yet to be fully tested in the courts, although the principle of patenting the computer implementation of a commonly used process seems to have been upheld in State Street Bank case.[18] Clearly the existence of such patents may make some researchers apprehensive. It could be argued that widespread enforcement of patents on the implementation of common mathematical algorithms might have a chilling effect on the research that uses and builds on them. On the other hand, it is difficult to see a financial motive for the assertion of patents against academic researchers, because there are no product sales on which to collect royalties. Nevertheless, it is clear that this issue is of some concern, especially among university administrators.[19]

4. Concluding Thoughts

The central issue highlighted by this paper is the tension between the two worlds of commercial innovation and scientific research with respect to the twin goals of appropriating and diffusing knowledge. Recent developments in the protection of Intellectual Property, especially in the U.S., together with the increasing closeness of public and university research to commercialization in several major research areas have heightened this tension, causing concern in the academic community and elsewhere that in the race to ensure that the incentives to create new forms of information such as databases and software are in place, we may have also slowed their diffusion in ways that will harm the very enterprise that was responsible for generating the innovations that underlie the IT revolution to begin with (the "digital boomerang," in Paul David's phrase).

Of course, from an economic theory perspective, the policy question and remedy are relatively simple and not new: if society benefits from researchers having access to some forms of information at low cost, and there exists private sector willingness to pay for that information, then subsidies to researchers so that they can acquire the information would be socially beneficial, and at the same time, would leave the incentives to produce the information intact. Because private sector firms would still be charged the "market" price, these subsidies would not have to be as large as they would need to be if the government funded the entire activity.

The problems with the simple economic solution in this situation are manifold:

1. The politics of government granting organizations usually exhibit considerable reluctance to finance the acquisition of easily reproducible software and/or databases at prices above marginal cost. In practice, there seems to be a bias towards funding the creation of new databases rather than simply purchasing them on the open market.
2. The transactions costs of this kind of solution can be substantial. In the software case, consider the difficulties faced by participant(s) in a small computer science research project with little administrative overhead that might have to license various pieces of software from a series of organizations in order to pursue its research agenda.
3. Imposing administrative and pecuniary costs on researchers who wish to use others' research tools as inputs, even if reimbursement is theoretically possible, tends to discriminate against new and young scientists without grants and also against "outsiders"

[18] State Street Bank and Trust Co., Inc. v. Signature Financial Group, Inc., 149 F.3d 1368(Fed. Cir. 1998).
[19] See the American Association of Universities website, http://www.arl.org/scomm/iptoc.html.

with radical ideas who cannot get past a peer review. It is hard to quantify this idea, but there are repeated historical examples which suggest that the unpredictability of the sources of new ideas means that they are best encouraged when the costs of entry into the research or innovation endeavor are kept as low as is practicable.

Clearly it is beyond the scope of this brief paper to offer definitive solutions to the problem of reconciling the “two worlds” and their varying institutional and cultural approaches to the IP protection of information. I prefer to conclude by suggesting some unanswered questions and avenues for future research on this topic. The first need is empirical: beyond the work of Maurer (1999) on the effects of the European Database Directive, Bessen and Maskin (2002) on the broad effects of introducing software patents, and Kuan (2002) on the productivity of the open source software model, we actually have relatively little evidence on the impact of different forms of IP protection on the incentives to produce databases or software. In particular it would be helpful to know more about the needs of scientific researchers with respect to databases and the costs of filling these needs. What models of database provision have worked in the past and how have they been funded? On software, is there actual evidence of patentholders asserting rights against academic researchers? Or do computer science researchers avoid areas where IP rights are particularly dense, as in Lerner (1995)? If so, should we be concerned?

On the theoretical side, I am unaware of modeling that focuses specifically on the determination of the social welfare outcomes in the two worlds limned here. That is, it would be useful to develop a model of knowledge production in a game theoretic setting with spillovers, but both with and without strong IP protection, for use in welfare analysis. Such a model should take explicit account of the transactions costs incurred under the two systems, as well as the features of the production function for new information goods that I have emphasized here, such as the important role played by the necessity for complementary investment in the choice of which goods to supply when the supplier is not primarily motivated by financial considerations.

Table 1
R&D Performance in U. S. Universities and FFRDCs

Funding for University R&D	**1960**	**1970**	**1980**	**1990**	**2000 (est.)**
% Federal government funded	76.6	77.5	76.7	68.7	64.9
% Industry funded	3.9	2.0	2.8	5.3	6.1
% Self funded	6.2	7.9	9.9	14.2	16.6
% Other (non-profit/state&local)	13.3	12.6	10.6	11.8	12.4
Total spending ($1996B)	**4.61**	**10.45**	**18.76**	**24.46**	**33.75**

Figure 1
Lucent's Patent on Sine/Cosine Table Lookup

5,937,438 -- Sine/cosine lookup table
filed June 1997 -- cites 2 prior patents, and nothing else

1. A lookup table, comprising a complementer adapted to selectively complement a subset of bits of a multibit designation of an angle based on a most significant bit of the multibit designation to produce an address signal; a memory addressed by the address signal and adapted to produce two values; and a switching element adapted to receive the two values from the memory and selectively output the values based on the most significant bit.

2. A lookup table as recited in claim 1, wherein the multibit designation contains n bits, and wherein the memory is an array containing 2^n-1 rows.

3. A lookup table as recited in claim 2, wherein each of the 2^n-1 rows corresponds to an angle between zero degrees and 45 degrees.

4. A lookup table as recited in claim 3, wherein each row contains sine and cosine values associated with the corresponding angle.

5. A lookup table as recited in claim 3, wherein each row contains sine and cosine values associated with an angle between the angle corresponding to the row and an angle corresponding to an adjacent row.

6. A lookup table as recited in claim 5, wherein the sine and cosine values are associated with an angle substantially centered between the angle corresponding to the row and the angle corresponding to the adjacent row.

And 13 more claims of a similar nature…….

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