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SHOULD WE CONSIDER ALTERNATIVE INCENTIVES FOR BASIC RESEARCH? PATENTS VS. PRIZES

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ABSTRACT

The widespread patenting of research results, the decline in freely available public knowledge, and their implications for innovation, have renewed interest in finding ways to reform the patent system and/or supplement it with other R&D incentives to preserve its benefits while mitigating its costs. This paper explores the advantages and disadvantages of one such alternative: a reinvigorated *ex ante* R&D "grand prize" system. While prizes have historically provided key incentives to basic research, they have fallen out of such use today. A modern R&D prize system could focus innovative efforts on important societal problems where the answers are not obvious, and which does not rely on a proprietary approach to knowledge. But since a prize system involves an administrative replacement of the market, it also imposes costs: the risk of favoritism, difficulties in picking the most qualified contestant, and duplication of innovative resources. We analyze how prizes might function as incentives to R&D, the associated benefits and costs, and the problem of contest design. Finally, we discuss the degree to which there might be a place in the new economy for the kind of "created," innovation-enhancing competition implied by an R&D prize system.

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"Prizes help to focus unfocused energy… They provide a spirit of competition which has been one of the most important driving forces since the dawn of humanity."
- www.xprize.org

1. Introduction

Over the past two decades, concerns have grown that the widespread patenting of research results has reduced the amount of freely available knowledge in the public domain. Governments have cut funding for basic research, patent laws have been strengthened, firms increasingly view patents as integral to business strategy, and university researchers have increasingly resorted to patents and licensing. Some warn that this trend might ultimately impede progress in science itself (Mowery *et al.,* 2001).

Yet the patent system has served for centuries as a key incentive to R&D. This raises the question: is it possible to maintain the benefits of the patent system while reducing its costs – here, in particular, the decline in public knowledge? Proposals for reform include restricting patent scope (Merges & Nelson, 1994), differentiated patent terms (e.g. Thurow, 1997), patent buy-outs (e.g. Kremer, 1997), and supplementing patents with other incentives (e.g. Von Hippel, 1983, Shavell and Van Ypersele, 1999). This paper investigates the advantages and disadvantages of one such alternative: a reinvigorated *ex ante* R&D "grand prize" system. We ask: *To what degree might a modern R&D prize system provide a valuable supplement the patent system, preserving its benefits while mitigating its costs?*

The growing importance of patents means, *ceteris paribus,* that innovative resources will increasingly be allocated to *patentable* ideas. Patents give inventors the legal right to exclude others from making, selling or using their new product or process for a limited period (normally twenty years). In return, the inventor agrees to disclose the details of the invention in the patent document. The patent system serves as an incentive to R&D by initially restricting competition in the invention; it contributes to the accumulation of public knowledge both via the disclosure requirement, and by providing the legal basis for licensing. Yet neither disclosure nor licensing are the same as placing new knowledge in the public domain, since other economic agents cannot freely use it as they wish.

In a "grand prize" R&D incentive system, one party (typically a government agency, but also a firm, a foundation, even a wealthy individual) defines a problem to be solved, and posts a reward for the best solution, typically a large monetary reward. While prizes have historically led to valuable inventions like the chronometer, synthetic chemical alkali, and food canning – their role today is mainly confined to architectural competitions, "best slogan" contests, and so forth. Large awards are also given *ex post* for outstanding scientific achievement (like the Nobel Prize). A reinvigorated *ex ante* R&D prize system could conceivably do more (e.g. Horrobin, 1986). Only a scattering of articles have systematically investigated the incentive effects of prizes (Polanvyi, 1943, Wright, 1983, and Shavell and Van Ypersele, 1999). This paper builds on and extends the findings of this and related work.

With prizes, it is the promise of a cash reward that provides the incentive to invest in R&D. Prizes can help focus innovative efforts on important societal problems where the answers are not obvious, and where the incentive effects do not rely on a proprietary approach to knowledge. Nevertheless, a prize system also imposes costs. Rewards may be arbitrary. It can be extremely difficult to set the appropriate size of the reward, and/or to pick the most qualified contestant. Finally, there may be an inefficient duplication of innovative resources.

We start by discussing the nature and implications of the decline in public knowledge, and some of the reform proposals. Section 3 explores how "grand prizes" can function as incentives to R&D, and how a modern prize system might be applied. The following sections consider the benefits and costs of prizes, and the problem of contest design. Section 6 speculates on the degree to which there might be a place in the new economy for the kind of "created," innovation-enhancing competition implied by an R&D prize system. The conclusions are presented in Section 7.

2. The decline in public knowledge

2.1. An increasingly proprietary approach to knowledge creation and exploitation

Knowledge goods are different from physical goods in that they have some of the characteristics of public goods (Nelson, 1959, Arrow, 1962). Information does not diminish with use. But once a new idea is disclosed, it is difficult to prevent others from using it as they wish, creating a disincentive to generate new knowledge. But this logic applies to innovating firms – not to publicly funded research. Arrow concluded that to ensure optimal allocation to basic research, the government or another agency not ruled by profit and loss criteria should also be brought in to finance this. Similarly, Nelson (1959) argued that when the marginal value of a good for society exceeds its marginal value for the innovator, society will spend fewer resources on scientific research “than it should”. Thus it might be necessary to accept that only large firms perform basic research, with the attendant social costs. Alternatively, society could finance university scientists, or companies could form cooperative research institutions. Both scholars saw the patent system as one way to address this problem, but not the only one.

Traditionally, the fruits of government-funded research were largely placed in the public domain. For example, from the early twentieth century, the U.S. government financed agricultural research (mainly applied research); later, funding was extended to research in engineering, physics and chemistry (Rosenberg & Nelson, 1994), and in the 1960s, to basic biomedical university research. After World War II, the U.S. government encouraged the global diffusion of this research (except for certain military aspects); the rationale was that firms in other countries could implement and further develop these results, while U.S. firms remained world leaders by continuing to make new innovations (Thurow, 1997). While university scientists often cooperated with private firms, they sometimes made socially valuable inventions freely available, the classic example being penicillin.

During the 1980s, these attitudes and policies changed. Researchers – in universities, government, and private firms – sharpened their efforts to exert proprietary control over new knowledge. Federal funding for university research in the United States fell, and industry-sourced financing rose. In 1970, federal funds accounted for 70.5% of university performed research; industry support was just 2.6%. In 1997, federal funds provided 59.6%, and industry 7.1% (figures cited in Mowery *et al.*, 2001). University scholars increasingly patented their inventions, and licensing income from patents now contributes a substantial portion of university funding in the United States. These trends have been best documented in the United States, but are also felt in Europe, Japan, and other parts of the world.

Moreover, in the U.S., Congress passed a series of laws strengthening intellectual property rights protection, and the courts have adopted a substantially stronger "pro-patent" stance in lawsuits. In 1980, in the case *Diamond vs. Chakrabarty*, the Supreme Court upheld the validity of a broad biotechnology patent, paving the way for the patenting of organisms, molecules and diagnostic methods based on biotechnology (Mowery *et al.,* 2001). A 1984 U.S. law enabled lengthening the patent term for pharmaceuticals for up to five years. As new technologies became commercially important, pressure to extend patent protection into these areas intensified. Patent protection is now available for software technologies and software-implemented business methods (as yet not patentable outside the United States), leading to a surge in new patent applications (see Davis, 2002a,b). In addition, the U.S. government pressed for a stronger, more standardized international system of intellectual property rights, an effort rewarded in 1995 with the adoption of the TRIPS agreement (Trade-Related Intellectual Property Rights), under the World Trade Organization.

Other factors have contributed to this trend. Firms increasingly leverage patents as an integral part of business strategy (Rivette and Kline, 2000, Grandstrand, 1999, Davis, 1998, Grindley & Teece, 1997). Patents not only protect new ideas, but can also signal territorial intent, block and "enclose" rivals, or indicate stock market value. Companies have developed sophisticated patent "mining" and "mapping" techniques to analyze the patent positions of competitors and target acquisitions. The number of patent applications has continued to rise, again most markedly in the United States, but also elsewhere.

Finally, patents have become more prominent in influencing firm R&D priorities *per se*. For the biotech firm Genetics Institute, patents are reportedly a "leading factor" in deciding which research to pursue (Rivette and Kline, 2000, p. 58). New biotechnology firms cannot obtain venture capital without effective patent protection. In electronics and semiconductors, patents serve as negotiating tools in complex cross-licensing agreements. Knowledge is shared among firms in competing and complementary technologies, with participation limited to those with strong patent positions.

These changes can be explained, in part, by the general liberalization of political and economic life. For innovating firms, moreover, the costs and risks of R&D have risen, enhancing the need for strong intellectual property rights. Government subsidies are often viewed as market distorting, allowing companies to perform (dubious) basic research without subjecting products to a rigorous "commercial test." Procurement contracts have been plagued by incompetence, bias and cost overruns.

2.2. Implications for innovation

While the recent strengthening of the patent system has been justified as providing superior R&D investment incentives, we actually know surprisingly little about how patents affect innovation. In the economics literature, arguments have been advanced on both sides of the issue (see for example Wright, 1983). Several recent empirical studies found no relationship between stronger patent protection and innovation (cited in Sakakibara, 2000, p. 217). Sakakibara herself determined that "the expansion of the scope of patent protection in Japan in 1988 increased neither innovative efforts nor innovative output by Japanese firms" (p. 218). The spiraling use of "defensive patenting" in particular can lead to deadweight losses without necessarily any innovation.

The rational for the Bayh-Dole Patent Act, passed by the U.S. Congress in 1980, was the belief that stronger intellectual property protection for inventions resulting from public funding would accelerate their commercialization, providing a higher economic return for taxpayers. University incentive structures were seen, in this sense, as similar to those in private firms (Mowery *et al.,* 2001). The Act gave researchers blanket permission to file for patents based on findings from federally funded research, and to license out research results to other parties. What will happen when this source of freely available knowledge declines?

According to one recent study (cited by Thurow, 1997, p. 98), fully 73% of private patents were based on publicly generated knowledge from university, government and non-profit laboratories. Numerous scholars (e.g. McMillan and Hamilton, 2000, McMillan *et al*., 2000, Blind and Grupp, 1999) have documented the critical role played by public science in innovation. Cohen *et al*. (1999) found that the four most important channels by which firms benefit from university research are publications, conferences, information channels, and publishing. According to Mowery and his colleagues (2001), patent protection is not only not necessary to induce universities to invest in R&D, but permitting university scientists to patent the results of government funded research can have a socially negative effect, since the knowledge is not made freely available in the public domain.[1]

The increasing allocation of innovative resources to patentable inventions has several implications for the *kinds* of inventions encouraged. First, to be patented, an invention must fulfill specified criteria: novelty, non-obviousness, industrial utility. But patent examiners pass no judgment as to whether the invention itself is important or socially beneficial. Second, inventors themselves decide what to patent, and how to develop the invention. Again, patent examiners pass no judgment as to whether the applicant is best suited to do so (or is even able or willing to do so). Third, while basic research is motivated mainly by intellectual curiosity, the incentive effects patents are strongest for inventions promising short-term commercial returns. The patent system also imposes other costs: deadweight losses due to monopoly, "defensive patenting" (where firms patent mainly to keep others out of their area), and "patent races" (where firms compete more to take out patents than to innovate).

At the same time, the patent system has historically provided a key incentive for firms to undertake the R&D that underpins most areas of economic growth. Any weakening of the patent system will (*ceteris paribus)* enhance the use of secrecy. Knowledge which would otherwise have been published in the patent document (and/or made the basis of a patent license) will no longer be available.

2.3. Proposals for reform

Earlier, compulsory licenses were used to mitigate the costs of patent monopolies. In 1956, both AT&T and IBM were required by a U.S. anti-trust consent decree to liberally cross-license the rights to their fundamental patents to qualified applicants at reasonable fees. As a result, a huge range of basic semiconductor and telecommunications technology was made widely available for next to nothing to both domestic and foreign firms, providing a huge boost to global welfare. Write Grindley and Teece: "It remains as one of the most unheralded contributions to economic development – possibly far exceeding the Marshall Plan in terms of the wealth generation capability it established abroad and in the United States" (Grindley & Teece, 1997, p. 13). Today, firms in both semiconductors and electronics take a distinctly more proprietary view of their innovations. Compulsory licensing, while still legally possible, is rarely (if ever) used in the U.S. or Europe.

In recent years, various proposals for reform have been advanced. Some involve the weakening of patent rights. Merges and Nelson (1994), for example, maintain that technical change proceeds best when innovators compete vigorously for success, and where "second generation" innovators can effectively build on earlier knowledge. The authors suggest that within the bounds of existing patent law, patent scope should be restricted in situations where an invention opens up a relatively broad area of exploration for the future.

Thurow (1997) proposes differentiating patent terms, distinguishing between fundamental new inventions which should be strongly protected (or bought out and put directly into the public domain, see below), and extensions of existing knowledge, which merit less protection. Industry dynamics are also different. In electronics, what matters are speed and short-term protection; in pharmaceuticals, firms need long-term protection due to the long period of testing prior to commercialization. A range of patent types could be established, with different costs, terms, and dispute-settlement parameters. Individual inventors could be treated differently from large firms. Thurow does not discuss the potential problems of such a system. One serious objection, however, is that it would place enormous administrative burdens on patent authorities. It would also reverse the trend towards international patent standardization considered important to trade and economic growth.

A somewhat different approach is patent buy-outs, where governments purchase the patent rights to important inventions and place them in the public domain (Kremer, 1997, Thurow, 1997). The French government purchased the Daguerreotype process in 1839 and made it available to all. In this system, inventors are rewarded for original research at a price approximating the social value of the innovation. This eliminates monopoly price distortions, reduces wasteful expenditures on reverse engineering to invent around patents, and the duplication of existing work. By enabling private firms to determine the direction of research, patent buy-outs preserve a major advantage of the current patent system. The problems are difficulties in determining the private value of a patent,[2] and vulnerability to bidding collusion. These could be minimized (though not eliminated) through proper auction design.

Finally, alternative R&D incentive systems might be considered (e.g. Von Hippel, 1983). These include procurement contracts (often for military purposes, but also for large civilian projects like public transport systems), publicly funded research grants to university scientists, subsidies to companies for certain types of basic research (like the EU programs ESPRIT and EUREKA), tax deductions for R&D investments – and prizes. It is to this last that we will now turn.

3. Grand prizes as incentives to R&D

3.1. Different types of prizes

There are many types of prizes. Prizes may be given to individuals for internationally-recognized scientific or artistic excellence, such as the Nobel Prizes for outstanding academic work, the Pulitzer prize for journalistic excellence, the Hollywood Oscars, and so forth.[3] The U.S. Atomic Energy Act of 1946 set up a Patent Compensation Board to bestow monetary rewards on militarily valuable innovations in atomic energy, since such innovations were not permitted to be sold commercially. The former Soviet Union often rewarded individual innovators for valuable ideas, sometimes in the form of a percentage of the cost savings achieved (see Shavell & Ypersele, 1999, note 9). But these are all examples of *ex post* prizes, as opposed to the kinds of *ex ante* prizes proposed in this paper.

The topic of prizes is not well researched. A review of the economics literature indicates that while prizes are often mentioned, few studies focus on their economic effects *per se*. The value of rewards as incentives is briefly described by economists like Arrow and Tirole (cited in Shavell & Ypersele, 1999, note 10), but not investigated in depth. There is a lack of precision as to the distinction between prizes, awards and rewards, which are typically used interchangeably. Adding to the confusion, the term "prize" is applied in different contexts. Thus in work on patent races, the first firm to take out a patent is seen as winning a "prize" (e.g. Grishagin *et al*., 2001). An analysis of buyer-supplier contracts discusses bidding "contests" for competing suppliers hoping to win the contract (Seshadri, 1995).

In the economic literature, three basic forms of prize systems may be distinguished: (1) intra-firm incentives, (2) pre-bidding signaling devices in procurement and other contracting systems, and (3) "grand prizes" to stimulate R&D. As regards the first two (briefly discussed below), the use of prizes is well-recognized, but prizes are not (necessarily) used to motivate invention and innovation. The third, (forming the focus of our analysis), while practiced historically, are not utilized much today.

The establishment of prizes within a firm – such as awards promised for cost-saving ideas from the shop floor – are often an important means by which firms can reward creative engineers and "signal" the direction in which management wishes to go. Prizes can also be awarded to individual employees and/or in connection with intra-organizational competitions. Bognanno (2001) and Rosen (1985), for example, discuss prizes in relation to corporate promotion and pay competitions; Fullerton *et al.* (1999) develop this logic with regard to R&D.[4]

As regards the second form of prizes, firms compete in the pre-contractual bidding round for a procurement contract (or other type of contract), several "winners" get a "prize," consisting of money for the further development of their proposals, and the final contract is awarded the most successful winner. This, it has been argued, is less a function of altruism than a means by which the government, as a future contractor, can determine which firms might qualify for a major future contract. Such contests allow firms to "signal" their abilities, and thereby to qualify for serious consideration. The "prize" conveys otherwise unavailable information about a firm's capacity to perform R&D.[5]

A more recent, non-military, instance of such a prize was arranged by the U.S. Department of Energy and the American Institute of Architects. Inventors were asked to create a solar architectural and technological landmark to cover the south wall of the Energy Department's building (nearly 3,000 square meters) in Washington, D.C. The Department received more than one hundred entries, which were evaluated on the basis of aesthetics, energy production and cost effectiveness. The top prize of $20,000 was awarded to a design involving both hydronic and photovoltaic solar panels to maximize the use of the sun's energy throughout the year (Aveni, 2001).

3.2. Grand prizes: background

In 1714, the British government, responding to a petition from the Royal Navy, "Merchants of London" and "Commanders of Merchantman," and dismayed at the losses of men, ships and battles through navigational disasters, announced a series of prizes to the inventor who could design a system to measure longitude accurately. There would be a prize of 10,000 pounds for a method reliably measuring longitude to within 1 degree; a prize of 15,000 pounds for a method accurate to within 40 minutes; and a prize of 20,000 pounds for a method accurate to within 5 tenths of one degree. In terms of 1714 currency, anyone winning the prize would be really and truly rich.

The result was a boom in research on longitude measurement. The prizes were so spectacular that they excited wide interest. They were mentioned in Swift's Gulliver's Travels and featured in a Hogarth illustration. It was known that one solution involved the design of precise timepieces that, through accurately telling the time at Greenwich, would enable comparison with local time, and thus the location of the ship. No expert believed this solution was technically possible. But John Harrison, an amateur, self-educated clockmaker, persisted. Over time, he developed a series of timepieces of increasing accuracy, "chronometers" sufficient robust to withstand battering at sea, yet exact enough eventually to qualify for the 20,000 pound prize, according to tests carried out by the Royal Navy. Yet the Royal Society would not recognize Harrison's achievement, and attempted to block his award. It took the intervention of King George to secure the award to Harrison in 1773, when the inventor, at the age of 80, finally received the prize money (Horrobin, p. 221).

This somewhat apocryphal story provides a good introduction to the benefits – and problems – of prizes. The incentive was a large cash award. The inventor's genius lay in the accurate designing of timepieces, a known technology. It is not certain whether an invention of this type would have been forthcoming under the patent system alone, given the need to demonstrate the criteria of novelty and non-obviousness. At the same time, Harrison very nearly missed getting the prize at all!

In addition to the chronometer, other significant innovations induced by a prize system include the first process to make synthetic alkali, which led to the establishment of the nineteenth century inorganic chemical industry, and the use of canning in food preservation.

In 1775, the French Academy of Sciences had offered a 12,000 franc award to anybody who developed a form of artificial alkali in the laboratory. Alkali, produced from natural vegetables, was at that time in heavy demand by both the soap and glass industries. Nicholas Leblanc developed a process using the known reaction of sulfuric acid on common salt. The genius in the process lay in making it economic and allowing for scale production. Leblanc was granted a patent to produce alkali and built a factory. Sponsored by his patron the duke of Orleans, his factory began to turn out commercial supplies of alkali in 1791. But events turned against him. The duke of Orleans was sent to guillotine, and Leblanc's factory was nationalized. Although the facility was restored by Napoleon, Leblanc lack capital to restart production. Throughout this period, the French Academy categorically refused Leblanc his reward, judging that none of the processes submitted to it (Leblanc's included) was worthy. Leblanc, despondent, committed suicide in 1806 – an ending rather different to that of Harrison and the chronometer in England (Davis, 1988).

Twenty years later, in 1795, a prize of 12,000 francs was offered by Napoleon's Society for the Encouragement of Industry for a method of food preservation usable by the French military. It was awarded in 1810 to Nicolas Appert, the inventor of food canning. The process utilized heat treatment of food in sealed champagne bottles (Wright, 1983, p. 704).

A more recent example led to the successful flight of the bicycle-driven Gossamer Albatross across the

English Channel in 1979. The British industrialist, Henry Kremer, had sponsored a series of awards to encourage the development of human-powered flight. The winner of the prize to cross the 22-mile Channel was not a British amateur group, as Henry Kremer had apparently hoped, but a project in part sponsored by the American chemical firm Du Pont (www.achievement.org).

Probably the most well-known modern prize system is the “X Prize”, established in 1996 to stimulate the development of a new generation of launch vehicles to carry passengers into space. The $10 million prize will be awarded to the first privately funded team to build and fly a spacecraft that can carry three persons into sub-orbital space (100 km) and back, and that is also reusable within two weeks. As of this writing, over twenty contestants from five countries have entered the competition (www.xprize.org).

In the academic literature, the use of prizes as “grand incentives” is occasionally suggested or discussed. One proposal of note was made in the well-reputed *Nature* magazine in late 1986, by D.F. Horrobin, for the establishment of “glittering prizes” to solve industrial/political problems that are commonly recognized as important. His proposal assumes an enormous prize. He writes: “The solution need not be brilliant or sophisticated, nor need it meet with the intellectual approval of experts. The only condition is that it must work” (Horrobin, 1986, p. 221). Horrobin continues:

> The government should decide what problems it wants solving. In my field of medicine, obvious problems whose solutions would save a great deal of money include schizophrenia, eczema… People from other fields should be able to produce long and comparable lists. Economists could then work out what each particular problem costs the nation, and a prize would be offered for a practical approach which would either eliminate the problem or reduce the cost of solution. The prize should be the value of the savings made during one full year.”

Horrobin points out that depending on the problem, the prizes could reach tens or hundreds of millions of pounds. The costs of such a system, all things considered, would be small. Its significance for research could be fundamental.

3.3. How a modern R&D prize system might be applied

At present, *ex ante* prizes are used largely for trivial purposes (best recipe contests and the like), or for glamorous but socially unimportant problems (such as the "x.prize"). A modern prize system, inspired by historical example, could aim higher.

In the pharmaceutical industry, for example, patents are essential to innovation, due to the high costs and risks or R&D combined with the low production costs of the drug once developed.[6] As a result, firms restrict their basic research to patentable inventions for large markets where they can charge a high price. There is little motivation to develop medicines for serious diseases affecting small groups of patients, or drugs with large markets where people are too poor to pay the monopoly price. For example, malaria rages in the Third World. Several drugs for are available, but expensive. The drug companies have little incentive to develop new malaria drugs, because the price – again reflecting the costs and risks of both failed and successful R&D – would be even higher. A prize system for a new malaria drug might break the deadlock.

But a prize system could do more than this. With regard to malaria, the prize-giver could specify a problem: the need for a new, effective, safe, affordable cure. This might be a drug – but it might be something completely different, like a combination of known and commonly available herbs (which cannot be patented). Possibly the solution would lie in another technology altogether. The same logic could be applied to other major health problems afflicting the Third World, such as AIDS. Contests could conceivably be open to all kinds of contestants, from large multinationals to single entrepreneurs, from high-tech engineers to "garage" tinkerers to high-school physics classes.

A putative R&D prize system could also be applied to a range of other socially important problems that have so far resisted solution. One might be the seepage of agricultural chemicals into groundwater. Current solutions focus on reducing the amount of chemicals used, physically blocking the downward flow of chemicals, and developing new ways to clean the water. But are these the best way to address this problem? Perhaps other, better solutions exist, but due to failures in the markets for basic research in this area, have not been forthcoming. A related problem is the long-term, safe disposal of nuclear waste. Existing containers are not fully effective. Solutions involve building better storage containers. Is this approach the only – or best – way of dealing with this problem?

These two examples have several things in common. First, the problems are widely recognized as important, and the known solutions imperfect and expensive to implement. Second, they involve externalities, which are difficult to resolve through the normal market mechanism. Third, the costs and risks of R&D in developing alternative solutions are enormous. Fourth, solutions require considerable creative thinking, but once the result is known, it may well not be patentable. Fifth, should effective alternatives be found, governments around the world would want to implement them as quickly as possible, at affordable prices. Thus they could not be commercialized in the normal manner.

4. Economic effects of grand prizes

4.1. Prizes vs. patents

The comparative economic effects of patents and prizes are illustrated in Figure 1.

(Figure 1 about here)

Patents. The patent system is an indirect stimulation to invention and innovation. The innovator identifies the relevant need, bears the costs and risks of R&D, and controls the timing of the development process. The innovation is subject to the discipline of the market; if commercially unsuccessful, no money can be earned from the idea itself (no matter how socially valuable it is).

Prizes. By contrast, the prize system specifically encourages inventive activity in relation to salient problems. The prize-giver identifies a need to be fulfilled. The innovator bears the initial costs and risks of R&D and controls the timing of the development process (within the deadlines imposed by the prize). The award is not based on a commercial test.

4.2. Benefits of the prize system

As illustrated in Figure 1, prizes – like other forms of government intervention in private markets for basic research – may be seen as a response to market failure. First, due to the “public good” character of information, inventors may lack the incentive to invest in R&D. The prize system provides an alternative incentive that does not rely on appropriability. Moreover, winning inventions do not have to be technical, they might also be organizational (and thus normally not patentable – unless they otherwise fulfill the criteria of patentability)

Second, the market pricing of externalities is notoriously difficult. Given a lack of accurate market pricing and difficulties of appropriability, it is unlikely that the patent system can sufficiently encourage solutions to pollution and other classic welfare problems. In such instances, prizes could furnish the needed stimulus.

Third, other uncertainties of innovation can lead to under-investment in basic research. Since the market for the new product does not exist, it is unclear how and when it should be introduced, or when the technology will be outdated. Many inventions cannot be commercialized until complementary products become available at attractive prices. Competitor actions cannot fully be predicted. For all of these reasons, firms may remain with the “tried and true.” Further, the short-term opportunity cost of capital may not reflect long-term societal interests. If interest rates are too high to encourage investment in innovative but highly uncertain projects, prizes might be a solution.

A fourth major advantage of a grand prize system is that it permits governments (or private parties) to signal the importance of particular problems that need to be solved but for some reason aren’t. The promise of a “glittering prize” enables society to redirect inventive resources to these ends, attracting and encouraging inventors who otherwise might not be heard, while still preserving a “market” dimension (in contrast, for example, to government subsidies). A prize-winning firm can also “signal” its competence to solve important problems.

Finally, the prize system can contribute significantly to knowledge development. It encourages investment in unconventional approaches and “lateral thinking.” It stimulates an awareness of different types of solutions, and can generate a plethora of valuable spill-over effects. The successful flight of the Gossamer Albatross, as mentioned above, which won one of Kremer prizes for human-powered aircraft, for example, graphically demonstrated the merits – strength, and durability, combined with minimal weight – of three of Du Pont's new synthetic products, Mylar, Delrin and Kevlar. These composites were later extensively used in the commercial aircraft industry.

4.3. Costs of the prize system

In the literature (e.g. Polanvyi, 1943, Wright, 1983, and Shavell and Van Ypersele, 1999), the main difficulty of a government prize system is felt to be the informational problems officials face in determining who should receive the reward, and how much it should be. Yet the problem is not insoluble. Shavell and Van Ypersele (1999), for example, propose the establishment of an optional reward system that innovators could choose as an alternative to intellectual property rights. A government agency would pay innovators directly for new products or processes, after which the innovations would pass immediately into the public domain. Informational problems in calculating the appropriate size of such rewards could be addressed by basing the amount awarded on sales volume.

Like Kremer's patent buy-out proposal mentioned earlier, this scheme involves an *ex post* payment to the innovator, after the value of the innovation has become apparent. In the *ex ante* reward system discussed here, the size of the award would have to be calculated differently, perhaps on the basis of the cost savings made possible by the solution. Informational problems in deciding who should get the award could, to a certain extent, be addressed by the contest design (see Section 5, below). Even so, as illustrated in Figure 1, information problems of this type are more serious than the corresponding information problems faced by patent authorities in deciding whether or not to grant the patent, which solely concern whether or not the invention fulfills the criteria of patentability.

The second important cost of the prize system arises because it involves administrative intervention in the market, replacing market competition with artificial, constructed competition. This might well divert inventive resources from more productive uses. Or the prize might be awarded to a firm more on the basis of its political connections than the feasibility and cost of its proposal – or perhaps not awarded at all. There is also a real danger of bias and incompetence in the selection process, including (as has occurred historically) the refusal to grant the prize to brilliant but unconventional solutions, a tendency inevitably exacerbated by rent-seeking among established players.

A third category of costs has to do with resource utilization. Since entrants cannot be (fully) aware of each other's efforts, or are convinced that their solution (whether similar to the others or not) will win, duplication of resources will occur. This cannot be avoided without requiring contestants to publish progress reports, which may serve as so much of a disincentive to invest in R&D so as to discourage contest entry in the first place. Administrative vagaries might also delay the commercial realization of valuable inventions. Finally, the winning solution might have been invented anyway – with or without the prize system – and perhaps patented. An advantage of the prize system over the patent system is that it avoids the problem that the patentee is not necessarily the best to develop the innovation.

5. The problem of contest design

The crucial importance of contest design is amply illustrated by the contrasting examples of Harrison and Leblanc. Both had claims to the prizes concerned. Yet Harrison received his prize only upon the intervention of George III, and Leblanc never received his 12,000 francs. Horrobin, aware of this problem, stresses that the qualification for winning prize must be both "crystal clear" and "suitable for verification by non-experts." This was true of the chronometer competition. Qualification for the 20,000 pound prize was so precise that a non-expert, King George (advised undoubtedly by his captains) could intervene, knowing that Harrison deserved the prize. By contrast, the problem for Leblanc was that the rules of the contest left it to the jury alone to decide what was a "good solution."

Prizes can be designed in different manners, depending on the nature of the problem to be solved and the reasons for the prize. Several key issues must be confronted and resolved, given that the design of the system will critically affect the likelihood of success.

The contest can be open or closed. The question as to who can enter a prize contest is one of the first decisions to be taken. The contest can be open to the members of a single firm but not to members of competing firms. Or it can be open to all within a given industrial association (also among and within competing firms), but closed to non-members of such an association, and so forth. While for reasons of economics these contests should be as open as possible, it is conceivable that for reasons of appropriability, eligibility in such contests – and access to using the solutions – should be limited.

"First past the post" versus "best on simultaneous submission": The chronometer contest was a "first past the post" system; the first person with the winning solution took the prize, there being no deadlines for submissions and consequently no panel decision at a specified time as to which of various submissions should get the prize. The pre-bidding contractual rounds, described in Section 3.1, represent a different kind of competition: firms send in their submissions, which are evaluated by a panel, which chooses the best entries to continue to compete for the actual procurement contract. The Leblanc alkali contest is a hybrid. Evidently designed as a "first past the post" contest, it seems to have been brought to an end by a meeting of the French Academy of Sciences, which evaluated various solutions and decided that none were worthy of the prize. (In as much as the Leblanc process had in fact solved the problem commercially, and received a patent, there was in fact very little incentive to proceed with the contest after this decision).

The contest may involve a large or a small monetary reward, or some other kind of reward. As mentioned earlier, determining the size of the "grand prize" presents considerable obstacles. How is it possible to establish the right value *ex ante*? If the amount is too low, then firms would not be willing to undertake the necessary R&D. If the amount is too high, it would exacerbate the costs of the prize system, as noted above (particularly favoritism and resource duplication).

The costs of an incentive system seldom reflect the social or private value of the solution. Arguably, few prizes in practice reflect the actual value of the winning solution. In theory, however, they can. As Horrobin points out, every prize for medicine has a social value that can be calculated economically. A prize for a cheap, effective cure for malaria could conceivably be calculated along these lines. It should also be noted that the same type of problem is true of the patent system. The actual value of the monopoly right to the patent holder is unknown. What is known is that it is related to the patent holder's ability to market the invention concerned and enforce the patent, and the length of the patent term. The value of the prize will depend on contest design and the criteria on which the ultimate winners are chosen and rewarded.

Prizes can be awarded on the basis of absolute or relative criteria: The terms of the contract defining the nature of the contest may exclude relational achievement: "XX dollars to the first heavier than air manpowered aircraft which can fly across the channel." Conversely, prizes can be awarded on the basis of relative criteria: "XX dollars to the heavier than air manpowered craft which exceeds the current distance record either on the ground or over water, etc." Another mode of introducing relative criteria is to give lesser awards for solutions which are not ideal, but still valuable, while retaining a grand prize for the "perfect solution," much as in the case of Harrison's chronometer competition. Another problem concerns defining what is preferable. A solution might fulfill the prize criteria but imply other problems; for example, a potential winner might be technically superior but pollutes more.

Prizes can be awarded on a design/idea basis or on the basis of performance: Clearly, to stimulate innovation and product development, a performance basis is to be preferred. It gives freer play to unconventional solutions, and to the degree that the performance criteria are specified precisely, can also reduce the uncertainties of the various contestants. But would this restrict from consideration highly unconventional solutions whose commercial potential is not immediately obvious?

Prizes awarded for novelty versus prizes awarded for non-novel achievement: We contended earlier that one of the values of prizes lies in their signaling function, enabling rewards for ideas which are not patentable but still have considerable economic value, such as a unique combination of existing technologies. The sponsors of any prize contest must be aware of these nuances if the prize is to have the proper incentive effect. Thus the French Academy, in looking for a particular kind of novelty, and thereby depriving Leblanc of his prize, did not conform to the concept behind the award. Furthermore, it deprived the use of such prizes of any future incentive effect. (Whether prize-awarding committees are capable of making such distinctions, however, as with the case of Harrison, may be dubious.)

Prizes can be awarded as isolated ends in themselves or as ends within a greater motivational context. Participants in an intra-firm contest may be motivated as much by how winning might further their careers as by the cash value of the award. Similarly, in pre-bidding contractual rounds, firms will be stimulated more by the prospect of the procurement contract than the monetary amount. These are contests within highly motivated contexts which in turn lead to a greater than normal incentive to "win." In contrast to this are the three eighteenth century prizes described above. For Harrison, the issue was winning the prize, which provided sufficient incentive in and of itself.

6. Is there a role for R&D prizes in the new economy to "create" competition for innovation?

A central theme of the literature on the "new economy" is that innovation is *enhanced* by competition, not reduced (Baker, 2001). This theme has been echoed in theoretical work on industrial organization (e.g. Boone, 2000), in empirical studies (e.g. Porter, 1990, Roberts, 1999), and in studies of the impact of patents on innovation (e.g. Merges & Nelson, 1994). Intense rivalry among competing solutions, it is argued, will quickly weed out non-commercial ideas, generate pressures for cost efficiencies, and is also better suited to the "cumulative" process of innovation. Greater competition among innovators can thus be justified both in terms of promoting static efficiency (where competition and imitation increase output and bring prices down), and dynamic efficiency (encouraging continuous innovation).

As Rosenberg (1990) points out, firms have many reasons to invest in basic research. An advanced R&D program is a "ticket" to the information network, enabling firms to keep up with the latest developments and to cooperate with others if they wish. Coming first on the market or achieving cost efficiencies may be central to the commercial success of a new good – regardless of whether patent protection has been obtained. Empirical studies of firm strategies of appropriability have demonstrated that not only patents, but also secrecy, lead time, learning curve, and sales and service efforts are used (Levin *et al*., 1987, Cohen *et al.,* 2000). For these other strategies, competitive success does not hinge primarily on legal restrictions on knowledge use, and duplication of resources may occur to a greater or lesser degree.

A modern R&D prize system, we have contended, provides a way to address the decline in public knowledge because it does not rely on a proprietary approach to innovation. Such a system derives its fundamental strength from marshalling competitive forces to generate solutions to socially important problems. The question then arises: is there a place in modern business life for the kind of "created" competition embodied in the prize system?

Two objections might be made at this point. First, wouldn't a grand prize system lead to higher taxes and undue government interference in private markets? Yet all incentives – including intellectual property rights – involve government interference in private markets. A prize system would not necessarily involve more government spending on research. In the pharmaceutical industry, for example, corporate research is already heavily financed through tax breaks, or directly through tax-exempt private institutions. Second: are not prizes historical relics? How could a system important hundreds of years ago contribute to modern economic growth? One answer to this question is that the patent system is even older (as an institution, it is over five hundred years old). Further, the concept behind a reinvigorated *ex ante* R&D prize system might be considered quite modern.

When rivalry is seen as enhancing innovation, resource duplication is not necessarily a cost. Firms compete on the basis of the nature of the innovation, not the effectiveness of the juridical protection they can obtain. Ideally, the firm that "wins" is the one with the superior product, not the one with the strongest patent position. Similarly, in the prize system, contestants compete to find the most effective solution, not to come first with the patent application. Entrants are judged not only on the originality of the idea, but also on its effectiveness. On the other hand, competition of this type is not the same as market competition among firms to come first with the new product, or to cut production costs. While all forms of government intervention in private markets lead to distortions, the administrative replacement of the market, central to the prize system, could be especially pernicious. One could also never be sure that the invention would not have been anyway, under normal competitive conditions.

To preserve firm incentives to invest in basic research while reducing the costs imposed by the patent system, the winner should be required to put the invention in the public domain. This could either be done directly (the winner would relinquish all property rights to the invention), or by allowing the inventor to patent the invention but license out the rights to all qualified applicants at reasonable rates. Whatever the case, others would be free to use the knowledge at little or no cost.

For example, as regards AIDS in the Third World, the prize could specify that the invention be patented but licensed out to generic drug producers for a moderate royalty fee. The prize, combined with these fees, would help cover the inventor's R&D costs and risks – perhaps even exceed them. Alternatively, the invention could be made freely available to all. This would permit generic producers to manufacture without paying license fees, and other inventors to utilize the knowledge freely. Here, the original amount of the prize would have to be higher than under the first option.

The costs of the prize system can be reduced, at least to some extent, by contest design. Political favoritism can be mitigated – but not eliminated – by specifying precisely the conditions of winning. Unfortunately, the larger the reward, the more difficult this would be. The possibility of delays in commercializing winning inventions could be addressed by setting clear deadlines for contestant evaluation. This runs into the problem of knowing when to award the prize, and to whom. Asymmetric information can be decreased through strict requirements as regards information disclosure from the contestants. But governments will always lack accurate information as regards what project is best. A related problem concerns prize-giver commitment, amply illustrated by the chronometer case. Harrison didn't solve the problem in the way the committee wanted, so he didn't get the prize. Ideally, prizes should be used to "kick start" desired innovation, not to structure the terms of competition very long.

To be effective, the monetary reward posted for the R&D grand prize would have to be huge. Such an expenditure might be risky in an age where firms, organizations and governments are trying to reduce expenditures. At the same time, it should be remembered that patents on many inventions – such as blockbuster drugs – can also bring in extremely high returns. The costs to consumers, insurance companies and government-financed health care systems in paying for such patented drugs are also high. If the "prize" conferred by the patent is so high, why shouldn't it be possible for, say, a government agency to pay an equivalent amount up front to the winning pharmaceutical company, which would not only enable generic manufacturers to produce the drug a lower price, but also facilitate the efforts of second-generation innovators to build on the knowledge released.

By viewing incentives as a means of encouraging *solutions to specific problems*, rather than as a general motivation to invest in R&D, numerous candidates for a prize system can be identified. For example, unexploded land mines are a hazard in many countries. Might not the prospect of a "glittering prize" tease out a better solution than the painstaking and dangerous methods used today? In the field of medicine, most drugs are tested on adults but later also used for children, even though we lack a precise understanding of how they affect a child's physiology. Or what about the common cold? This widespread, well-known disease, responsible for an enormous number of sick days, has so far eluded a cure. Why? Is it possible that the problem lies with the current research methods used? A prize might call forth a salient new approach to the problem. Other candidates for a prize system include growing insect resistance to pesticides, bacterial resistance to antibiotics, problems of clean water and nutrition in the Third World, perhaps even the rising levels of atmospheric CO2.[7]

Finally, it should be noted that the problem of the decline in public knowledge applies specifically to technologies where patents are important. In other areas, such as music, publishing, and photography, where digitally produced innovations cannot effectively be protected by patents, and where extensive copying occurs, this problem does not exist – quite the contrary (see Davis, 2002a). In such cases, prizes might arguably also serve as valuable incentives, but more for reasons of rewarding innovative work (that is otherwise difficult to protect) than reversing the decline in public knowledge.

7. Conclusion

This paper has investigated how a modern R&D prize system might serve as a supplement to the patent system, to address problems associated with the decline in public knowledge given the increasing allocation of innovative resources to patentable ideas. The prize system encourages innovators to compete to develop new inventions. The incentive is the cash reward. According to the terms of the prize system proposed here, the winner would place the solution in the public domain.

Two interrelated questions for future research can briefly be mentioned. The first concerns contest eligibility and scope. Generally speaking, the more open the contest, the greater the diversity of solutions that can be expected – but also the greater the associated risks of "free riding." Should a prize offered in one country be open only to its own nationals? If so, the field of possible winners would be restricted. If not, one country could end up paying a large sum to a national of another country, which might be politically unacceptable. Information about the entries might also leak out, benefiting foreign firms before the winner was even announced. Firms might also refrain from devoting innovative efforts to the problem at hand, forfeiting the opportunity to win the prize, but reaping the benefits of later access to the knowledge, in that it would be put into the public domain. These problems do not arise under the patent system (to the degree that patent rights can effectively be enforced).

If the prize-giver is a national government, this difficulty could be resolved by stipulating a prize earmarked for a specific national problem. For problems extending across national boundaries, some kind of international cooperation – at the level of the firm, organization, industry, or nation – would probably be best. The contest could also specify that the initial production facility be placed in the country in which the prize was awarded. This would be especially important as regards awards for universal problems, like a remedy for the common cold.

In this connection, the "branding" opportunity afforded by a prize system – another feature of the new economy – should not be underestimated. The prize winner could be required to feature the name of the prize giver prominently in connection with developing and commercializing the invention. Du Pont, for example, which sponsored the Gossamer Albatross (section 3.2), had its name featured prominently on the body of the plane. The image of the graceful bicycle-powered craft, lightly touching down on the shores of the English Channel, was featured in TV specials around the world.

There is clearly also a potential role here for high-profile, wealthy individuals – like Bill Gates, Ted Turner or George Soros – who have previously used their fortunes for broader social purposes. For instance, the Nobel Prizes are financed by a foundation in memory of Alfred Nobel, the 19th century Swedish inventor and entrepreneur. Arguably, Nobel's name would have been long forgotten but for this. Sweden itself enjoys considerable positive publicity in connection with the event – it matters little that the funds are typically awarded to non-Swedes.

The second question for further research concerns how prizes can best serve as a supplement to patents, and how to achieve an effective division of labor between prizes and patents. Which inventions should be made freely available to all, and which should be patented and liberally licensed out at reasonable rates? On what criteria? Who should decide? A further element concerns the patentability of individual elements of prize-winning solutions. For example, while Du Pont did not patent the winning Gossamer Albatross aircraft *per se*, it did patent the synthetic composites that made the winning flight possible.

A prize system might help to clarify the instances under which compulsory licensing is appropriate, particularly in the Third World. The TRIPS agreement on intellectual property rights recognizes the legitimacy of using compulsory licensing to achieve social goals. But it severely restricts their use. Developing countries are concerned that this will exacerbate the social costs of its implementation. A prize for cures for Third World diseases could specify the terms under which licenses would be given, facilitating the wide use of the cure while at the same time compensating firms in the industrialized world for their R&D investments. The contest could be sponsored by an international organization like the United Nations, a coalition of pharmaceutical companies, a coalition of private relief agencies, or some combination. It could even be structured to favor local innovation and production.

There can be little doubt that the kind of R&D prize system suggested here would pose many difficulties. At the same time, if such an approach is not tried, important social problems where solutions are not forthcoming under the patent system will persist – and with the continuing decline in public knowledge, will probably move ever further out of reach.

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Figure 1: Economic effects of prizes and patents

	Prize	Patent
Market identification	Prize-giver	Innovator
Costs and risks	Innovator's costs may be covered by prize, innovator bears *ex ante* risks	Both borne by innovator
Control of timing	Prize-giver	Innovator
"Commercial test"	Not *ex ante*	Yes
BENEFITS		
Appropriability	Enables innovation in both appropriable and non-appropriable technologies	Encourages innovation in appropriable technologies
Externalities	Internalization of externalities can be specified in prize	Existence of externalities not relevant to criteria of patentability
Uncertainties of innovation	Encourages innovation in uncertain technologies by promise of reward	Encourages innovation in uncertain technologies by patent monopoly
Signaling	Prize-giver can signal what is important Contestants can signal what they can do	– Patentees can signal territorial intent
Knowledge development	Focuses innovative efforts on solutions to societally important problems Creates awareness of different types of solutions Spill-overs	Focuses innovative efforts on novel, non-obvious, industrially useful inventions Details of invention published in patent Strong legal basis for knowledge sharing
COSTS		
Information asymmetries	Prize-giver's information in determining who should win the prize may not be accurate	Patent officials' information wrt determining patentability may not be accurate
Nature of competition	Constructed Rewards may be arbitrary Chance of political favoritism	Possible monopoly abuses Patent races
Use of resources	Duplication of resources Possible delays in inventive activity Invention might have been made anyway	Avoids duplication of resources, but patentee not necessarily the best to carry out innovation

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NOTES

[1] The increasingly proprietary approach to knowledge implies other costs. According to press reports, considerable controversy, for example, has arisen over the patent obtained by the American firm Myriad Genetics on a gene which plays a key role in the development of breast cancer. A diagnostic test for this gene can help to determine which women are at risk. This firm – citing the costs and risks of developing new drugs - requires that every doctor who uses the diagnostic test pay a fee of several thousand dollars (CBS News, "60 Minutes," September, 2001). Not only will this mean increased medical costs, but it will also place this kind of treatment beyond the reach of all but the wealthiest patients.

[2] Kremer (1997). recognizing this, suggests that governments could use an auction system to estimate this value, and then offer to buy it out at this value times a fixed markup corresponding to the estimated typical ratio of the social and private value of inventions. To induce bidders to reveal their true valuations, the auction system could be structured so that a few patents would be sold to the highest bidder.

[3] There are also a number of lesser known prizes of this type Examples include the Young Woman Engineer of the Year prize, awarded by the British Royal Society for the Encouragement of the Arts, Manufacturers and Commerce, and the Pritzker Architecture prize, established by the Hyatt Foundation and awarded for architectural excellence.

[4] Yet the economic puzzle explored here only tangentially touches on the role of prizes to spur innovation, focusing instead on the problem of increasing efficiency within the firm in situations where direct observation or monitoring of efficiency is impossible or too costly. In such situations, prizes can provide incentives, obviating the need for productivity monitoring or the like.

[5] A case in point concerns the American Request for Proposals (RFP) system. In 1984, for example, a contest was arranged for a Strategic Defense Initiative, SDI (Star Wars) blueprint. The government announced that it would award five R&D contracts worth $5 million each. As a result, it is not improbable that a private response of between twenty and forth times the amount of this total outlay ($25 million) was elicited by firms "signalling" their respective capabilities (and this excludes the subcontractors involved). Through this process, ideally, the field could be narrowed to the five best proposals, which still had to perform the $5 million research in the respective R&D awards. One of more of these firms could come into consideration in the eventual procurement contracting phase. In the U.S. military and NASA procurement processes, these RFP contests have been estimated to account for half again as much R&D expenditure as reflected in official figures. Clearly, the prize element can have a significant multiplier effect when combined with procurement contracts. In principle, this could apply to other countries, and in fields other than military procurement. See Davis, 1998.

[6] First, the new drug can be described precisely in the patent, reducing the chance it will be disputed in court. Second, while the costs and risks of R&D are extremely high, once the drug is developed, it is relatively cheap to produce – and imitate.

[7] We have restricted our analysis to grand prizes – with one, specified winner – as incentives to R&D. But other versions of the prize system could be used, involving smaller monetary rewards. Prizes could be given *ex post* to important ideas, along the lines of the system proposed by Kremer (1997). Multiple prize systems could also be devised with no limits on the number of winners; the definition of winning would depend on the quality of the solution.