PATENT BUY-OUTS: A MECHANISM FOR ENCOURAGING INNOVATION

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ABSTRACT

In 1839, the French government purchased the patent on the Daguerreotype process and placed it in the public domain. This paper examines a mechanism under which governments would use an auction to estimate the private value of patents and then offer to buy out patents at this private value, times a fixed markup. The markup would correspond to the estimated typical ratio of the social and private values of inventions -- perhaps two. Most patents purchased would be placed in the public domain, but in order to induce bidders to reveal their valuations, a few patents would be sold to the highest bidder. Such patent buy-outs could eliminate monopoly price distortions and incentives for wasteful reverse engineering, while raising private incentives for original research closer to their social value. However, patent buy-outs are potentially vulnerable to collusion. Patent buy-outs may be particularly appropriate for pharmaceuticals.

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Economic growth ultimately depends on the production of new ideas, but competitive markets do not provide appropriate incentives for the production of ideas [Arrow, 1962; Romer, 1990]. If consumers pay only the marginal cost of transmitting ideas, revenues will not be sufficient to cover the cost of producing ideas. Societies have historically used a wide variety of mechanisms to encourage production of ideas. Some of these mechanisms, such as patents and copyrights, provide inventors with monopolies over goods produced using their ideas. Others, such as the National Science Foundation and the synthetic fuels program, directly subsidize research. The United States uses both types of mechanisms: for example, government and industry each spent about $13 billion on health research in 1992 [National Science Board, 1993].

Creating monopolies in ideas and directly subsidizing research both lead to serious problems. Patents and copyrights create insufficient incentives for original inventions, since inventors cannot fully capture consumer surplus or the spillovers of their ideas to other researchers. Patents and copyrights also create static distortions from monopoly pricing and encourage socially wasteful expenditures on reverse engineering to invent around patents. The empirical evidence suggests these distortions are large.

As Spence [1984] has argued, the first-best solution to underprovision of ideas is subsidizing research, not creating a new set of monopoly price distortions through the patent system. In practice, however, rent-seeking and information asymmetries between researchers and government officials often lead to inefficiency in government funding of research.

In 1839, the government of France purchased the patent for the Daguerreotype process and made the technique freely available. Such patent buy-outs combine some of the advantages of direct funding of research and of the patent system. Like direct funding of research, patent buy-outs correct under-provision of research while eliminating monopoly pricing, and with it the incentive for wastefully duplicative inventions. However, patent buy-outs allow private firms to largely determine the direction of research, as under the current patent system. Patent buy-outs require somewhat more government discretion than the current patent system, but substantially less discretion than say, the National Institutes of Health.

A major challenge for any system of patent buy-outs is determining the price. This paper examines a mechanism through which the private value of patents and copyrights would be determined using an auction.[2] The government would then offer to buy out patents at this private value times a fixed markup that would roughly cover the difference between the social and private values of inventions. Inventors could decide whether to sell or retain their patents. Patents purchased by the government would typically be placed in the public domain. However, in order to provide auction participants with an incentive to truthfully reveal their valuations, the government would randomly select a few patents that would be sold to the highest bidder.

The paper is organized as follows. Section I reviews several methods that societies have used to encourage innovation, and argues that all are subject to serious shortcomings. It also discusses the historical experience of patent buy-outs. Section II explains how an auction could be used to estimate the private and social value of patents, and thus determine the buy-out price. Section III discusses equilibrium behavior in the auction when inventors have private

[2]Both patents and copyrights could be bought out, but for convenience, the remainder of the paper will refer to patents, rather than to patents and copyrights.

information about the value of patents, or cost-advantages in producing the patented good. Section IV discusses incentives for marketing and development of inventions under patent buy-outs.

Section V outlines rules that would be necessary to deal with substituting and complementary patents. To prevent research from being discouraged by the prospect that future, substituting patents would be placed in the public domain, patent holders could request that their patent be re-auctioned at the same time as the new patent. After the auctions, a joint randomization would be conducted to determine whether both patents would be placed in the public domain or whether each patent would be transferred to the highest bidder for that patent. Complementary patents would also be jointly randomized.

Patent buy-outs are potentially vulnerable to collusion, since inventors could bribe auction participants to submit high bids. Section VI discusses several ways the government could control collusion; such as estimating the value of patents based on the entire distribution of bids rather than just the highest bid; buying out patents at just above their estimated private value and then selling to suspected over-bidders at their bid, and establishing ceilings on buy-out prices based on sales of the patented goods.

Patent buy-outs are likely to be particularly appropriate for pharmaceuticals, since pharmaceuticals are an industry in which distortions from patents are severe; patents provide significant protection for innovations; markets would be fairly competitive in the absence of patents; government institutions and social norms are strong enough that corruption can be kept under control; and goods are non-durable. Moreover, the Food and Drug Administration (FDA) approval process provides information on the potential value of new inventions that should lower bidding costs and reduce problems of asymmetric information.

Section VII suggests that a private foundation could conduct a trial patent buy-out to explore the potential of this system. The Rockefeller Foundation has offered a prize for a diagnostic test for sexually transmitted diseases that would be appropriate for use in developing countries. The Foundation could announce that if no one had met the stringent prize conditions by the expiration date of the prize, it would consider buying out patents on diagnostic tests that came close to meeting these conditions. If the patent buy-out is a failure, little will have been lost. If the patent buy-out was successful, the government could establish a fund to buy out other pharmaceutical patents, and perhaps eventually patents in other industries.

This paper follows independent work by Guell and Fischbaum [1995], who suggest that the government use its power of eminent domain to purchase pharmaceutical patents.[3] One danger of their proposal is that it might degenerate into a process through which the government would expropriate inventors. This mechanism is much more favorable to inventors than Guell and Fischbaum's proposal -- patent holders could choose whether to sell their patents, and they would receive a markup over the private value of the patents, so as to bring incentives for invention closer to the social value. This proposal also differs from Guell and Fischbaum's because it uses a market mechanism to value patents, rather than relying on the judge's discretion. Finally, this paper differs from that of Guell and Fischbaum in

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[3]Paul Romer has suggested that the government buy out the patent to polymerase chain-reaction, a process used in government funded health research, rather than providing grants to researchers who then buy the rights to the process.

addressing the problem of creating proper incentives for the development of complementary and substituting inventions. More generally, this paper is related to a broader literature on the potential of new mechanisms to encourage innovation [Johnston and Zeckhauser, 1991; Romer, 1993; Taylor, 1995; Baker, 1996].

I. Mechanisms for Encouraging Innovation

This section examines mechanisms that have been used to encourage innovation, arguing that all are subject to serious shortcomings. Sub-section I.A. briefly reviews the historical experience of direct government support of research through prizes and contracts. Sub-section I.B. examines patents. Sub-section I.C. discusses two cases in which governments bought out patents.

I.A. Direct Government Support of Research

Until the early 19th century, prizes were widely used to encourage inventions. For example, Napoleon established a prize for the development of a food storage technology usable by the military, which was awarded in 1810 to Nicholas Appert for the invention of food canning [Wright, 1983]. Unfortunately, it is difficult to write complete contracts covering all aspects of all potential inventions. On the other hand, if the authority awarding prizes has discretion about whether to award the prize, it may expropriate the inventor *ex post*. Mokyr [1990] cites Finley [1973] as relating a (possibly apocryphal) story that the inventor of an improved glass-making method asked the Emperor Tiberius for a reward. Tiberius made sure that no one else knew about the invention, and then executed the inventor. Perhaps more reliably, Sobel [1996] relates the difficulties the inventor of the chronometer encountered in claiming the British government's £20,000 prize for a method of determining longitude at sea.[4]

Today, much of the $55 billion federal research budget is spent through research contracts and grants or through in-house research by federal agencies. These methods seem to work well when researchers are motivated by the non-pecuniary rewards available in basic science, but they have been less successful for more applied projects, such as the synthetic fuel program or the development of commercial supersonic transport. This may be because information asymmetries make it difficult for research administrators to prevent researchers from shirking research on the applied problem of interest to the research funder, either by applying little effort or by focusing on areas of purely scientific interest. Another problem with direct government support of research is that small groups that are strongly affected by particular government decisions distort political decisions, reducing the effectiveness of government research [Romer, 1993]. Nadiri [1993] finds that the rate of return on privately financed R&D is much higher than that on publicly financed R&D. Lichtenberg [1992] estimates that the within-country social return to private research and development is seven times as large as the return to investment in equipment and structures, but that the social return to government-funded research and development is insignificantly different from zero.[5] Nadiri and Manuneas [1994] find that the

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[4]However, others are more sympathetic to the prize administrators [Paul David, personal communication].

[5]However, see Toole [1997] for an alternative view.

social rate of return on public investment in research and development is just under ten percent -- substantially less than the rate of return on private R & D investment found by Bernstein and Nadiri [1988, 1991].

I.B. Patents

From the 17th to 19th century, patents evolved from a discretionary grant of monopoly power by the sovereign (often given as a reward to favorites) to a reasonably systematic and effective way of rewarding inventors [Dutton, 1984; Kaufer, 1989]. By the mid-19th century, patents had replaced prizes as the dominant form of reward for invention. As Wright [1983] points out, patents may provide more appropriate research incentives than prizes if researchers have private information about the value of inventions and if prizes must be set *ex ante*.

However, patents also create important distortions. Monopoly pricing creates static distortions, as people who value the good above the marginal cost of production do not consume it. To take a particularly dramatic example, millions of people will die of AIDS in developing countries because they cannot afford protease inhibitors. This will remain the case even if the cost of producing protease inhibitors falls dramatically, because pharmaceutical firms price above marginal cost to recover R&D expenditures. Monopoly pricing also creates a major dynamic distortion since potential inventors will not take consumer surplus into account when deciding whether to undertake research projects. Since pharmaceutical companies cannot price discriminate well enough to extract the full consumer surplus that millionaires with HIV would obtain from a cure for AIDS, the companies do not have sufficient incentives to develop a cure. Under the crude assumption that willingness to pay for drugs is proportional to income, it is possible to use data on the U.S. income distribution to calculate the monopoly price and the percentage of the social value of drugs that would be extracted by the monopolist. Such calculations suggest that the social value of new pharmaceuticals is 2.6 times the profits extracted by a monopolist who could not price discriminate.[6] The deadweight loss due to monopoly pricing would be one-quarter of the sum of profits and consumer surplus, although in practice some of this is probably recovered through price discrimination.

Patents create additional distortions because they provide no incentive for potential researchers to consider the externalities they create for other researchers -- either positively through knowledge spillovers, or negatively through patent races. The available empirical evidence suggests that on balance, researchers usually create positive externalities for other researchers. Jaffe [1986] finds that, controlling for technological opportunities, firms whose neighbors invest more in research and development have more patents per dollar of R&D and a higher return to R&D in terms of both accounting profits and market value. Cockburn and Henderson [1993, 1994] obtain similar results in a study of the pharmaceutical industry, even after controlling for measures of technical opportunity. They conclude that, "far from 'mining out' opportunities, competitors' research appears to be a complementary activity to own R&D."

Patents also distort the direction of research by creating too much incentive to develop substitutes for patented goods and too little to create complements. By developing substitute

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[6]I thank Atif Mian for these calculations, which are available from the author.

inventions, firms can steal rents from existing patent holders. The limited available evidence suggests that this problem may be severe. Mansfield [1981] finds that 60 percent of a sample of patented innovations were imitated within four years, and that the average imitation cost was two thirds the original cost of invention. Green and Skotchmer [1982] show that if potential developers of complementary inventions cannot make licensing agreements with patent holders before sinking any costs into developing these complementary inventions, they will have too little incentive to develop complementary inventions, because the owners of the original patent will be able to hold up the inventors of the new inventions and demand a share of the return on these sunk costs. If developers of complementary inventions and the owner of the original patent cannot reach agreement, for example due to asymmetric information, then society may be denied the benefit of the new inventions. Mokyr [1990] notes that the development of the high pressure steam engine was blocked by Watt's patent covering all steam engines; that Watt's steam engine was blocked by a previous patent until he found a way to invent around it; and that Edison's improved version of the telegraph was blocked by Bell's prior patent for many years.

An extensive empirical literature suggests that social returns to innovation far exceed the private returns. Nadiri [1993] summarizes this literature and finds that social rates of return to R&D vary from 20 percent to over 100 percent among industries, with an average close to 50 percent. Mansfield [1977] examines 17 innovations in detail, and finds an average social rate of return to research and development of 56 percent, compared to a 25 percent private rate of return. In his exhaustive study of the CT scanner industry, Trajtenberg [1990] finds a 270 percent social rate of return to R&D. He states that even under the assumption that 50 percent of the revenues to manufacturing were profits, this figure exceeds the private returns by several orders of magnitude. Jones and Williams [1995] find that these studies all provide a lower bound on the true social returns to innovation.

The available evidence thus suggests that the social rate of return on research and development is at least twice the private rate of return, *given the quantities consumed under monopolistic pricing*. The social rate of return would be even greater if inventions were priced at marginal cost, so that the deadweight loss due to monopoly pricing was avoided. Moreover, since a substantial fraction of research funds are spent on wasteful duplication of existing products, the social rate of return on *original* research is substantially higher than the overall rate of return to research. Based on Mansfield's [1984] estimates, one might guess that one-quarter of research funds are spent on socially wasteful duplication and that three-quarters are spent on original research.[7] In this case, the social return to original inventions will be 4/3 as large as the social return to overall research. If deadweight loss due to monopoly pricing is one-quarter of the profits and consumer surplus that are realized under monopoly pricing, the social return to non-duplicative research under marginal cost pricing would be 2 * 4/3 * 5/4 = 3.33 times the current private rate of return on research. In the analysis below, I will generally make the conservative assumption that the social value of patents is on average twice the private value.

Research should be financed out of general revenue even if the government can only raise revenue through distortionary taxation. One way to see why it is better to finance research with

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[7] Mansfield [1985] suggests that even if inventions were only copied once, almost 30% of research effort would go to me-too inventions. In fact, many inventions are copied multiple times. On the other hand, most "me-too" inventions do have at least some incremental value -- for example, some people may respond to one drug, but not another.

tax revenue, rather than with monopoly profits, is to consider the problem of a social planner choosing a tax to finance research. The principles of Ramsey or Mirrlees taxation should clearly guide the planner's decision, and it is highly unlikely that the optimal tax will be a several thousand percent tax on the patented good. Yet this tax is equivalent to the system of financing research through giving monopoly rights to inventors.

I.C. Patent Buy-Outs

During the early nineteenth century, both the patent and prize system were in widespread use. There were at least two cases in which governments combined the two systems by buying out patents.[8] Such patent buy-outs offer the opportunity to eliminate the monopoly pricing distortions associated with patents, avoid excessive incentives for research designed to duplicate existing inventions, improve incentives for the development of complementary inventions, and, if the patent buy-out price is a better approximation of the social value of the invention than the monopoly price, provide more appropriate incentives for the original invention. Reviewing these cases suggests some general lessons about patent buy-outs.

In 1837, Louis Jacques Mande Daguerre invented photography by developing the Daguerreotype process.[9] He exhibited images produced with the process, and offered to sell

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[8]I thank Zvi Grilliches and Ken Sokoloff for informing me about the buy-outs of the Daguerreotype and cotton gin patents, respectively.

[9]The information on the Daguerreotype is taken from Barger and White [1991] and Nelson [1996].

detailed instructions to a single buyer for 200,000 francs or to 100 to 400 subscribers at 1,000 francs each. Daguerre was not able to find a buyer, but obtained the backing of Francois Arago, a politician and member of the Acadamie des Sciences, who argued that it was "...indispensable that the government should compensate M. Daguerre direct, and that France should then nobly give to the whole world this discovery which could contribute so much to the progress of art and science."[10] In July 1839, the French government purchased the patent in exchange for pensions of 6000 francs per year to Daguerre, 4000 francs to his partner, and half that amount to their widows upon their death.[11] The French government then put the rights to Daguerre's patent in the public domain (except in England, where the French government allowed Daguerre's original patent to remain in force.) The invention was adopted rapidly. Within months, Daguerre's instruction manual was translated into a dozen languages. A multitude of improvements were quickly made to the chemistry and lenses used in Daguerre's process.

In England, William Fox Talbot had developed the calotype process independently, and when he heard of Daguerre's process, he patented his own system in 1841. The Daguerre process became the standard, while the English process was abandoned, perhaps in part because Talbot charged high fees for use of his process. However, twenty years later, a new process was developed, which also involved making prints from negatives, as had Talbot's process. The subsequent development of photography followed this colloidotype process.

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[10]Cited in Nelson [1996].

[11]6,000 francs in 1839 corresponds approximately to $1.8 million in 1988 based on cost-of-living figures in Mitchell [1992].

Like Daguerre, Eli Whitney was unable to make much money from his patent.[12] The cotton gin could be easily replicated by local carpenters and blacksmiths, and Southern juries were expert at finding technicalities on which to rule against Whitney in the many patent infringement suits that he filed. Facing bankruptcy, in 1802 Whitney sold the South Carolina rights to the cotton gin to the state government for $50,000, payable in installments. In 1803, on rather flimsy pretexts, South Carolina suspended payment on the unpaid balance of its debt to Whitney, sued to recover the money Whitney had already been paid, and even had him arrested! However, the legislature of 1804 reversed the annulment of 1803. Later, Whitney sold the rights to the cotton gin in North Carolina and Tennessee to the state governments in exchange for an agreement that the states would tax cotton gins and pay the proceeds to Whitney.

It is only possible to guess why these particular patents were bought out. The social surplus from patent buy-outs may have been particularly great for the Daguerreotype process and the cotton gin. Daguerre planned to keep the details of his process secret until he reached agreement with a buyer, and in the meantime society was denied the benefits of photography. , Since Whitney was very dogged in pursuing court battles, engaging in sixty suits in Georgia alone, Whitney's imitators wasted a lot of resources in litigation and other costs associated with violating Whitney's patent on the cotton gin -- according to Whitney's partner, planters would go so far as to install cotton gins in buildings to which only their slaves were admitted because slaves could not testify in court [Green, 1956].

It is worth trying to draw a few lessons from the experience of the cotton gin and

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[12]The information on Whitney is taken from Green [1956] and Olmstead [1972].

Daguerreotype patent buy-outs. In both cases the government purchased important patents. The political economy problem with patent buy-outs does not seem to be that unscrupulous rent-seekers bribe government officials to purchase patents for useless inventions, but rather, as Whitney's experience suggests, that once a good is invented, there is a temptation for the government to expropriate the inventor.[13] (This suggests that any system of patent buy-outs should be voluntary, so as to protect the rights of inventors.)

Both the Daguerreotype and the cotton gin were adopted rapidly after the patents were bought out, and were subject to further technological development afterwards. Although we do not have evidence on the counterfactual, it seems plausible that the free availability of the inventions led to wider adoption, and that this wide adoption created incentives and opportunity for the development of technological improvements.

The Daguerreotype example indicates that buying patents at a price greater than the private value of the patent increases inventors' incentive to patent discoveries, rather than relying on trade secrecy. The release of the information on Daguerre's techniques led to positive externalities for other researchers, helping create scientific advances in chemical reactivity and solar spectrum analysis [Barger and White, 1991].

A final, cautionary, lesson from the historical experience of patent buy-outs is that it is important to consider the effect on other patent holders. It seems possible that the Daguerreotype process was too widely adopted because it was free, whereas the Talbot process was costly.

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[13]It is possible, however, that less important patents were bought out, but that these more obscure patents did not come to my attention.

II. A Mechanism for Buying Out Patents

It is worth stepping back from the details of various historical mechanisms for encouraging innovation to consider the abstract problem of a government deciding whether to undertake a public good -- in this case, a research project. If citizens' preferences are quasi-linear and if the government does not face any participation constraints, a Groves [1973] mechanism can be used to attain efficiency [d'Aspremont and Gérard-Varet, 1979]. Two considerations restrict the choice of mechanism, however. First, given the temptation for governments to expropriate investors *ex post*, I will restrict attention to mechanisms that do not violate the property rights of inventors under the patent system. Formally, this means the mechanism designer is subject to a participation constraint.

A second constraint on mechanism design arises because it is costly for people to gather information on the value of inventions. Determining the social value of an invention requires determining the value of the invention to each person in the economy. This is difficult because most people are not well informed about the value they would obtain from potential new inventions. However, given the institutions that have arisen under the current patent system, a few people or firms are likely to be able to obtain at least some information on the monopoly value of patents at reasonable cost. I therefore restrict attention to mechanisms in which agents reveal their estimate of the monopoly value of the patent, as opposed to mechanisms in which agents reveal either their own valuation of the services of the invention, or their estimates of the social value of the invention. Note that the patent system is in this class of mechanisms, because the reward to the inventor is exactly equal to the monopoly value of the invention. The evidence reviewed in Section I.B. suggests that this monopoly value systematically tends to be much less than the social value, so an ideal mechanism would typically pay inventors more than the monopoly value of their invention.

A standard way of eliciting information on the private value of indivisible goods, such as patents, is through an auction. Below, I describe how an auction could be used to elicit information on the value of patents. However, many other mechanisms are possible,[14] and there is no particular reason to assume that the one outlined here is the best. The purpose of the paper is not so much to recommend one particular mechanism as to suggest that various mechanisms for buying out patents should be explored.

Figure 1 depicts a mechanism for determining the price at which the government would offer to buy out patents. Under the mechanism, the market value of patents would be determined through a sealed-bid second-price auction,[15] and the government would then offer to buy patents at this private value times some constant markup which would reflect the typical

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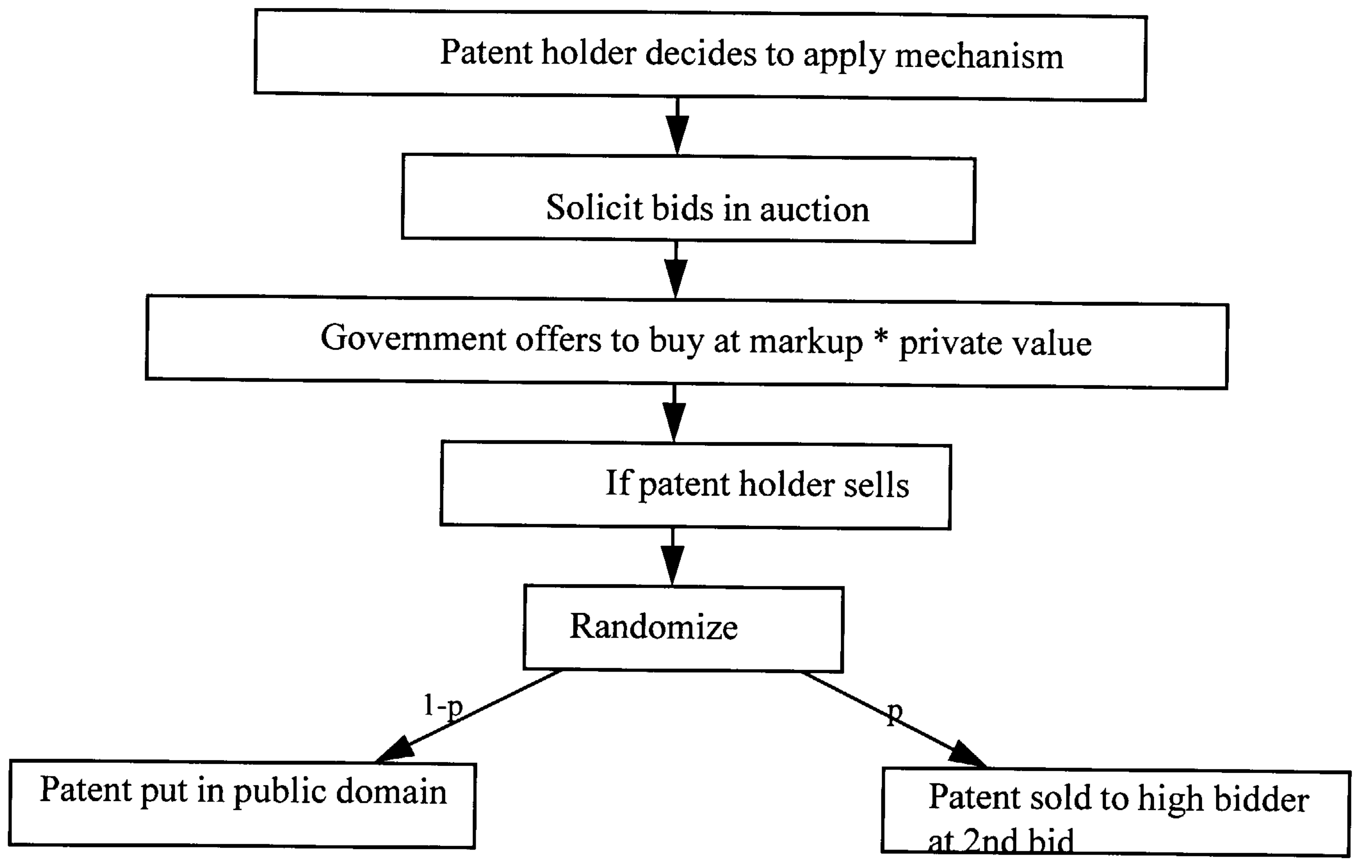
[14]For example, consulting firms could be hired to estimate demand for the product, and the government could pay the firms based on the accuracy of their predictions in those cases in which the good was randomized to the private domain.

[15]The theoretical literature does not provide clear guidance about what form of auction is preferable, especially since the goals of this auction are multiple. The principle goal is to obtain accurate information about the value of the invention, but secondary goals include raising revenue, assigning the patent to the low-cost producer, and avoiding politically unpalatable collusion. Sealing the bids may make collusion more difficult. The disadvantages of sealed-bid second-price auctions discussed by Milgrom [1989] are likely to be manageable in the case of patent buy-outs. Milgrom notes that in such auctions the auctioneer may try to introduce false bids to drive up the price, but presumably the government could credibly commit not to do this. Milgrom also notes that such auctions are vulnerable to rings of bidders who collude to bring down the purchase price. However, as will become clear, the principle danger in the setting examined here is collusion to increase, not reduce the price.

Figure 1: Auction Mechanism for Patent Buy-Outs



ratio of social to private value. Most of the patents that the government bought would be placed in the public domain. However, in order to give auction participants an incentive to reveal their true valuations, a small proportion of patents, chosen randomly, would be sold to the high bidder. Patent holders would have the right to accept or reject the government's offer. The government would set the markup to reflect the typical ratio of the social value of inventions to the private value.[16]

Based on the empirical estimates of the social return to innovation discussed above, it seems likely that the government should offer to buy patents at a markup of at least twice their estimated private value.[17] Clearly, this markup will be too small for some inventions, and too great for others. The appropriate standard for judging mechanisms for encouraging innovations is not whether they attain the social optimum, but whether they would be a useful supplement to imperfect existing mechanisms. In the absence of patent buy-outs, inventions will only be developed if their private value is positive. The social value of inventions is likely to be better

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[16]It is widely believed that public projects should be undertaken only if their net social value exceeds the deadweight loss associated with taxation. Kaplow [1996] argues that, since taxation is distortionary only to the extent it is redistributive, and since public projects can always be financed in a distributionally neutral way, public projects should typically be undertaken if their social value is positive. In any case, standard public finance principles suggest that intermediate goods should not be taxed, since doing so would create productive inefficiency [Diamond and Mirrlees, 1971]. Researchers' income from patent buy-outs would be taxed.

[17] A government that cares only about the welfare of its own citizens would buy out only the domestic patent rights to the good. If the inventor were foreign, the government would not necessarily want to pay the full social value of the invention, but would merely pay enough to buy out the monopoly. If the inventor were domestic, the government would be willing to pay the full domestic social value of the invention. This analysis assumes that all countries are playing non-cooperatively. In practice, the existence of international patents suggests that nations have been able to cooperate.

approximated by twice the private value of inventions than by the private value.

Although the government might require a waiting period following either patenting or FDA approval of the drug before it would buy out patents, patent holders would be free to postpone the patent buy-outs.

Under a sealed-bid, second-price auction, auction participants will bid their expectation of the patent's value, given their information, conditional on their making the winning bid. It will be efficient for the government to use information from the entire distribution of bids, rather than only the highest bid, in estimating the private value: there is no reason to throw away the information provided by the other bids in estimating the private value. If the government knew the prior distribution of valuations, it would be able to aggregate the information of all bidders to estimate the private value of the patent.

In practice, the government does not know the bidders' prior distribution of valuations. Therefore, it might be best for the government could use a simple rule, such as offering the original patent holder some multiple of the third highest bid.[18]

III. Inventor Cost or Informational Advantages

This section argues that if inventors have private information about the value of the patent or have a cost-advantage in producing the patented good, they will be more likely to reject the

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[18] Because this type of rule is robust to outliers, it makes the system less prone to disruption by a few crazy bidders, or, as discussed in Section V, by collusion. For example, if it were thought that the social value of inventions were typically M times the private value, the private value was Y times the value of the highest bid, and the highest bid was typically Z times the third highest bid, then the government would offer MYZ times the third highest bid.

government's offer to buy their patents. However, unless these cost or informational advantages are extreme, the markup will still cause most inventors to sell their patents. In those cases in which inventors do refuse to sell their patents, the system of patent buy-outs would be equivalent to the current patent system. It is useful to consider two polar extremes of auction environments. Sub-section III. A. examines the case of a common value auction in which the original inventor is better informed about the patent's value than other bidders. Sub-section III. B. examines the case of a private value auction in which the inventor has the highest value for the patent and there is some dispersion of valuations among bidders.

III.A. Inventor Informational Advantage

If the inventor has private information about the value of the patent, the winner's curse will lead bidders to make low bids (Milgrom and Webber, 1982; Hendricks and Porter, 1988; Hendricks, Porter and Wilson, 1994). However, the winner's curse may be greatly mitigated by the markup.

Consider an example in which the patent has a common value, the inventor knows this value, and conditional on the information revealed by the FDA approval process, potential bidders know only that the value is distributed uniformly in (L, U). The bidders will know that if a bid of B leads to the good being sold by the inventor, then the true private value of the patent is uniformly distributed in (L, min(U, MB)), where M is the mark up. In equilibrium, auction participants will bid the expected value of the patent, conditional on their bid being accepted, or (L + min (U, MB)) / 2. This implies that

$$B = \min\left(\frac{L+U}{2},\ \max\left[0, \frac{L}{2-M}\right]\right) . \qquad \textbf{(1)}$$

The mark-up mitigates an adverse selection problem that could otherwise shut down the market for patents. If M=1, so there were no government markup, auction participants would bid L, and patent owners would never sell their patents. For a markup of 2, auction participants will bid (L+U)/2, the government will offer to buy out patents for L+U, and patents will always be sold. (This extreme result depends on the assumption that the value of the patent is uniformly distributed, but more generally, adverse selection will be reduced by the markup.[19]) Note that inventors will have an incentive to reveal as much information as possible about the invention, so as to reduce adverse selection in bidding. In the case of pharmaceuticals, the efficacy and side effects of the drug will be documented through FDA trials. For drugs treating well-defined diseases, the size of the potential market will often be well-known.

Despite the markup, there will be cases in which the bids are so low that the original inventor refuses to sell the patent. In such cases, the existing patent rules will remain in force, and (abstracting from administrative costs) nothing will have been gained or lost by the procedure. To avoid frivolous auctions, patent holders who wished to sell their patents would be required to pay a fee to cover the administrative costs of the auction.

III.B. Inventor Cost-Advantages

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[19]Although the unconditional distribution of the value of patents is extremely skewed, the distribution conditional on the information revealed during the FDA approval process is likely to be much less skewed.

Inventors are often the low-cost producers of their inventions, because they own assets complementary to their patents, such as marketing networks or unpatented intangible information on production techniques. However, even inventors with cost-advantages will typically sell their patents, because the government will offer a markup and because the inventor will still be able to produce the good if the patent is placed in the public domain.

To understand the effect of cost-differences among inventors, it is useful to consider the case of a private-value auction. In this case, it is well known that under a sealed-bid second-price auction, the optimal strategy is for bidders to bid their valuations. To see why inventors will typically sell, suppose the inventor can produce at a cost c_0, that the ith lowest cost producer can produce at cost c_i, and that demand for the good is given by $Q = P^{\alpha}$, where $\alpha < -1$. For a patent holder with cost c_i, the optimal price is $c_i\, \alpha/(\alpha+1)$, which yields profits of

$$\pi_i = c_i^{1+\alpha}\left(\frac{\alpha}{\alpha+1}\right)^{\alpha}\left(\frac{-1}{\alpha+1}\right) \tag{2}$$

Under a second-price sealed bid auction, each auction participant will bid π_i[20]. If, based on this, the government offered to buy out the patent at $MZ\pi_j$, where π_j denotes the value of the jth highest bid, Z is some multiplier, such as the historical ratio of the jth highest bid to the highest bid, and M>1 is the markup, inventors will sell their patents to the government if

$$\pi_0 < MZ\pi_j + (1-p)\,\pi_{COMP}, \tag{3}$$

[20]I normalize time so that the interest rate is one, and hence the present discounted value of a profit stream of π per period is π.

where π_0 is the value to the inventor of a monopoly on the good, p is the probability that patents purchased by the government will be transferred to the high bidder, and π_{COMP} is the value to the original inventor of producing the good in competition with other firms. If the patent is placed in the public domain, and if $c'/c < \alpha/(\alpha +1)$, so the inventor's cost advantage is not too large relative to the monopoly markup, then under Bertrand competition, the inventor will limit price and obtain profits

$$\pi_{COMP} = c_1^{\alpha}(c_1 - c_0) \ . \qquad \textbf{(4)}$$

Given the drastic markups in pharmaceuticals, and the ease of manufacturing most pharmaceuticals, this condition for limit pricing is likely to be fulfilled. However, if $c_1 / c_0 > \alpha/(\alpha +1)$, so the inventor's cost advantage is drastic, and if the patent is placed in the public domain, the inventor will sell the good at the monopoly price, and obtain profits π_0. In this case, patent buy-outs will not ameliorate monopoly price distortions. This suggests that patent buy-outs are likely to be most desirable in industries in which prices would be considerably lower in the absence of patents, such as the pharmaceutical industry.[21] Patent buy-outs are also more desirable in industries where cost differences are small, since they would occasionally entail transferring the patent to higher-cost producers. (As discussed in Section VI, patent buyers

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[21] Patent buy-outs may be desirable even if they do not eliminate monopoly price distortions, because they increase the private value of patents closer to the social value of inventions. However, there is some danger of increasing the private value of inventions above the social value, since patent owners will receive M times the expected value of the invention from the government buy-out, and with probability (1-p) they will also be able to produce the good and earn π without a patent. Since the social value of inventions may often be three or four times the private value, it is likely that even with a markup of 2, patent buy-outs will bring the private value of inventions closer to the social value, even if they do not eliminate monopoly price distortions.

would not be allowed to resell the patent to the original owner because this could facilitate collusion.)

Condition (3), under which the inventor will sell the patent, can be rewritten as

$$c_0^{1+\alpha}\left(\frac{\alpha}{\alpha+1}\right)^{\alpha}\left(\frac{-1}{\alpha+1}\right) < MZc_j^{/1+\alpha}\left(\frac{\alpha}{\alpha+1}\right)^{\alpha}\left(\frac{-1}{\alpha+1}\right) + (1-p)\pi_{comp} \tag{5}$$

where

$$\pi_{comp} = \begin{cases} c_1^{\alpha}(c_1 - c_0) & \text{if } c_1 \le c_0\dfrac{\alpha}{1+\alpha} \\ c_0^{1+\alpha}\left(\dfrac{\alpha}{1+\alpha}\right)^{\alpha}\left(-\dfrac{1}{1+\alpha}\right) & \text{otherwise.} \end{cases} \tag{6}$$

Thus if $c_j/c_0 < (MZ)^{-1/(1+\alpha)}$, so the cost-advantage is not too great relative to the markup, the condition will be satisfied because $Mz\pi_j > \pi_0$. On the other hand, if $c_1/c_0 > \alpha/(\alpha+1)$, inventors will sell the patent for sufficiently small p, because their monopoly price will not be constrained by competition, and hence π_0 will equal π_{COMP}.

In a model in which potential bidders differ in their valuations, but must spend some resources to learn their valuation, the costs of processing information are likely to reduce entry into the auction, and hence reduce the average winning bid in equilibrium. Assuming free entry into the auction and symmetry among bidders, on average, the cost of bidding should just be covered by bidders's profits. By monitoring bidders' administrative costs, the government could figure out the proportion of the true private value that the high bidder typically paid, and then adjust its estimate of the private value of patents accordingly. Presumably, bidding costs will be smaller relative to the value of the patent for more valuable patents, so this problem is more likely to be manageable for patents on pharmaceuticals which have already undergone FDA approval, and thus are likely to be valuable.

IV. Incentives for Product Development

Incentives for marketing and development are likely to be enhanced by patent buy-outs. Suppose that the private value of a patent is $\pi(E)$, where E denotes expenditures on development and marketing. In the absence of patent buy-outs, patent owners will invest in development until $\partial\pi/\partial E=1$. Patent owners who expect to sell their patent at a markup of M will invest until $\partial\pi/\partial E = 1/M$.[22] Inventors would be able to delay patent sales to undertake development and marketing. For example, they might want to introduce the invention into the market and advertise for several years before selling the patent.[23]

Although patent owners will be more inclined to conduct development and marketing if they expect that patents will be bought out at a markup, some opportunities for further development may appear only after patents have been sold. For example, technological advances

[22]Whether it is efficient to encourage this much development depends on how much of the social value of the marginal development or marketing dollar is captured by the patent holder. If the patent holder captures the same fraction of the marginal development cost as of the cost of the invention as a whole, then the increased incentives for development are appropriate.

[23]If the original inventor did not have the resources to undertake development fully, it could privately sell the patent to a second company, which could in turn submit the patent to the government for auction after undertaking the development.

in related fields may open up new opportunities for development after the patent has been bought out. Patent buy-outs are likely to substantially strengthen incentives for this further development if the further development can itself be patented or appropriated in some other way. Since the original invention will be sold at marginal cost, the market for the complementary invention will be larger. Moreover, the developer of the complementary invention will not have to split its value with the original inventor. Patent buy-outs will also prevent new versions of a product from being blocked by unresolved disputes with previous patent holders.

Although patent buy-outs increase inventors' incentive to conduct development prior to the buy-out, and increase others' incentives to conduct development after the buy-out, they reduce inventors' incentives to conduct unpatentable development after patent buy-outs. For example, pharmaceutical firms have much less incentive to test for new uses for generic drugs than for patented drugs. In practice, there may be other ways of appropriating investment in marketing and development. For example, some aspirin manufacturers have sufficient market power that even without patent protection they advertise aspirin's effectiveness in preventing heart attacks. It is an empirical question whether patent buy-outs would stimulate or retard product development on average, but it is worth noting that both the Daguerreotype process and the cotton gin were subject to substantial improvement after the patents were bought out. In any case, pharmaceuticals typically need little new development after they have been approved by the FDA.

If complete patent buy-outs prevented development, the mechanism could be modified to allow some market power in newly invented goods. For example, the government could offer to buy out the last ten years of a patent after it had been in private hands for seven years.

Alternatively, rather than placing patents in the public domain, the government could sell a limited number of licenses to produce the good, converting what would have been a monopoly to an oligopoly.

V. Substitute and Complementary Patents

Anticipation that future substitute patents will be bought out will reduce current research incentives in two ways. First, patent buy-outs act as a subsidy to research, increasing the chance that future substitutes will be developed quickly. Sub-section V.A. shows that in order to attain the socially optimal level of research, the markup must therefore be greater than the ratio of the social value of inventions to their private value given the current level of research. Sub-section V.B. shows that anticipated buy-outs of substitute patents also deter current research by causing future patents to be placed in the public domain, and thus to be more formidable competitors. In order to preserve incentives for current research, patent buy-outs would incorporate a rule that if a patent remains in private hands and a patent for a substitute good is put up for auction, the holder of the original patent could have it jointly randomized with the new patent. Either both patents would be placed in the public domain, or both patents would be transferred to their respective high bidders. Sub-section V.C. discusses some special issues that arise in the case of non-rentable durable goods. Complementary patents would also be jointly randomized, as discussed in Sub-section V.D.

V. A. Patent Buy-Outs as Research Subsidies

To understand the "research subsidy" effect of patent buy-outs on steady-state research, consider models of creative destruction such as Aghion and Howitt [1992] or Grossman-Helpman [1991] in which each invention is eventually subject to competition from future inventions. Under models of creative destruction, research at time t, x_t, can be written as $x_t(M_t, x_{t+1})$ where M_t is the subsidy to research at time t (here, the markup), $\partial x_t/\partial M_t > 0$, and $\partial x_t/\partial x_{t+1} < 0$. Suppose that there is a constant markup M. Denote the steady-state level of research as x^*. Then

$$\frac{dx^*}{dM} = \frac{\partial x_t}{\partial M_t} + \frac{\partial x_t}{\partial x_{t+1}} \frac{dx^*}{dM}, \qquad (7)$$

This implies that

$$\frac{dx^*}{dM} = \frac{\dfrac{\partial x_t}{\partial M_t}}{1 - \dfrac{\partial x_t}{\partial x_{t+1}}} \qquad (8)$$

Note that the total derivative of research with respect to the mark-up is positive, but less than the partial derivative.

Although equilibrium research effort may be either greater or less than optimal in models of creative destruction, the empirical evidence suggests that the current patent system produces too little research and development [Jones and Williams, 1995].[24] Denote the research effort that

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[24]If the current incentive to conduct research was too great, it might be possible to approximate the correct incentives by simultaneously reducing patent length and instituting a program of patent buy-outs.

would be chosen by a social planner as x^s. The optimal markup, M^s, solves $x^s = \phi(M^s, x^s)$. The optimal markup will be the typical ratio of the social value of inventions to their private value, given that the socially optimal amount of research will be conducted in the future. Note that under quality ladder models the expected lifetime of patents, and hence their private value, will be lower if more research is expected in the future.[25] Hence the ratio of social to private value under patent buy-outs will be greater than the current ratio of social to private value. This implies that the optimal markup is even larger than suggested by Section II.

V.B. Joint Randomization for Substitute Patents

Future patent buy-outs may reduce incentives for current research not only by encouraging future research, but also by causing future inventions to be placed in the public domain and sold at marginal cost, and thus to be more formidable competitors for current inventions.[26] As explained below, incentives for current research can be preserved by holding a joint randomization to determine whether substitute patents would each be put into the public domain, or each be transferred to their respective high bidders.

To see why anticipated patent buy-outs with separate randomization weaken current

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[25]Under the Aghion-Howitt model, an increase in future research intensity reduces the commercial lifetime of patents, but does not reduce their social value, because the knowledge developed for each invention is incorporated in all future inventions. More generally, at least some of the knowledge developed for inventions is incorporated into future inventions.

[26]Note that this effect does not arise in Aghion and Howitt [1992], or Grossman and Helpman [1991] because new inventions always completely replace old varieties in these models. This in turn is either because inventions are drastic, or because competition is Bertrand, and owners of new patents limit price.

research incentives, consider a case of two drugs which are perfect substitutes and Cournot competitors. Denote the cost of inventing the first drug, which I will call Leader, as I, the cost of copying as C < I, the value of being the sole producer as S, and the value of producing as a duopolist as D. In this section, I will abstract from the asymmetries considered in section II, and assume that these amounts are known to all bidders, and are equal for all bidders. Figure 2 depicts the game tree without patent buy-outs. V_F denotes the value to the inventor of Follower, and V_L denotes the value to the inventor of Leader. Solving backwards, given that Leader is invented, Follower will be invented if D > C. Given this, Leader will be developed either if I < D, or if C > D and I < S.

Figure 3 shows the game tree for patent buy-outs with separate randomization, and a markup of M. I assume that bidders play their equilibrium strategy, but do not depict this on the game tree, because the bidders have a continuum of possible moves. B(F) and B(L) denote the amounts bid for Follower and Leader respectively. Again, solve backwards, first considering the subgame in which the government has randomized the Leader patent to the highest bidder, and Follower has been put up for auction. If the patent is randomized to the highest bidder it is worth D. Auction participants therefore bid D and the government offers MD for Follower. It is will be profitable to invent Follower if MD > C. To determine the value of the Leader patent in this case, note that if the Follower patent is randomized to the high bidder, the Leader patent will be worth D, and if the Follower patent is randomized to the public domain, the Leader patent will be worth nothing. Thus, if MD > C, so Follower is invented, the expected payoff to the holder of the Leader patent is the probability that Follower will be randomized to the high bidder, p, times the value of Leader in this case, D. Assuming that MD > C, risk-neutral bidders will therefore

Figure 2: No Patent Buyouts

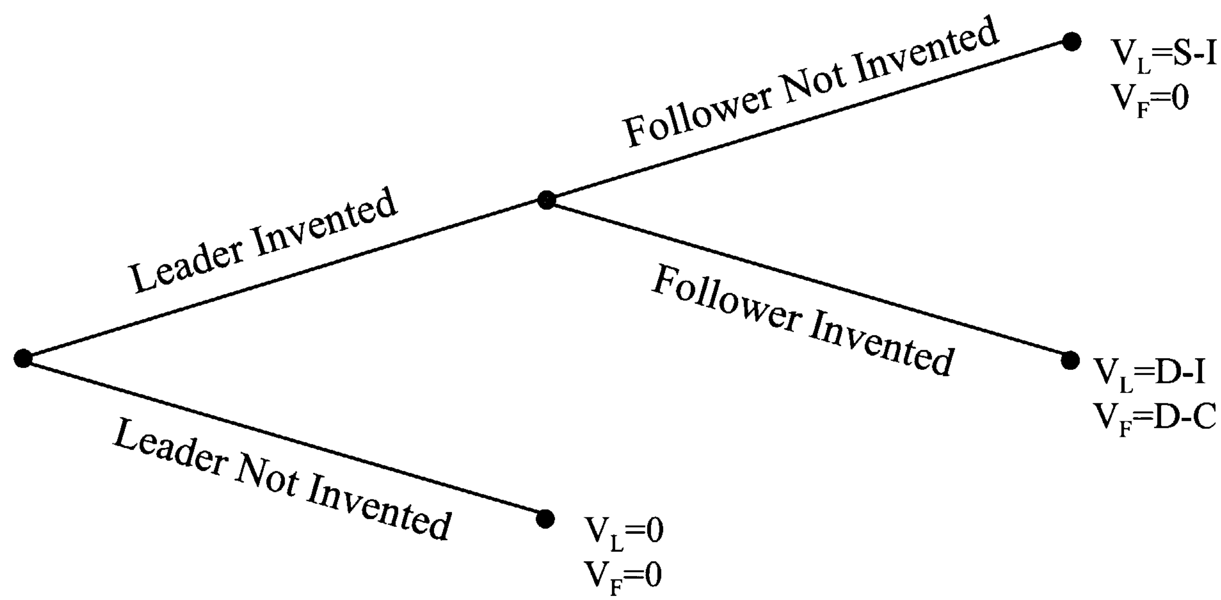
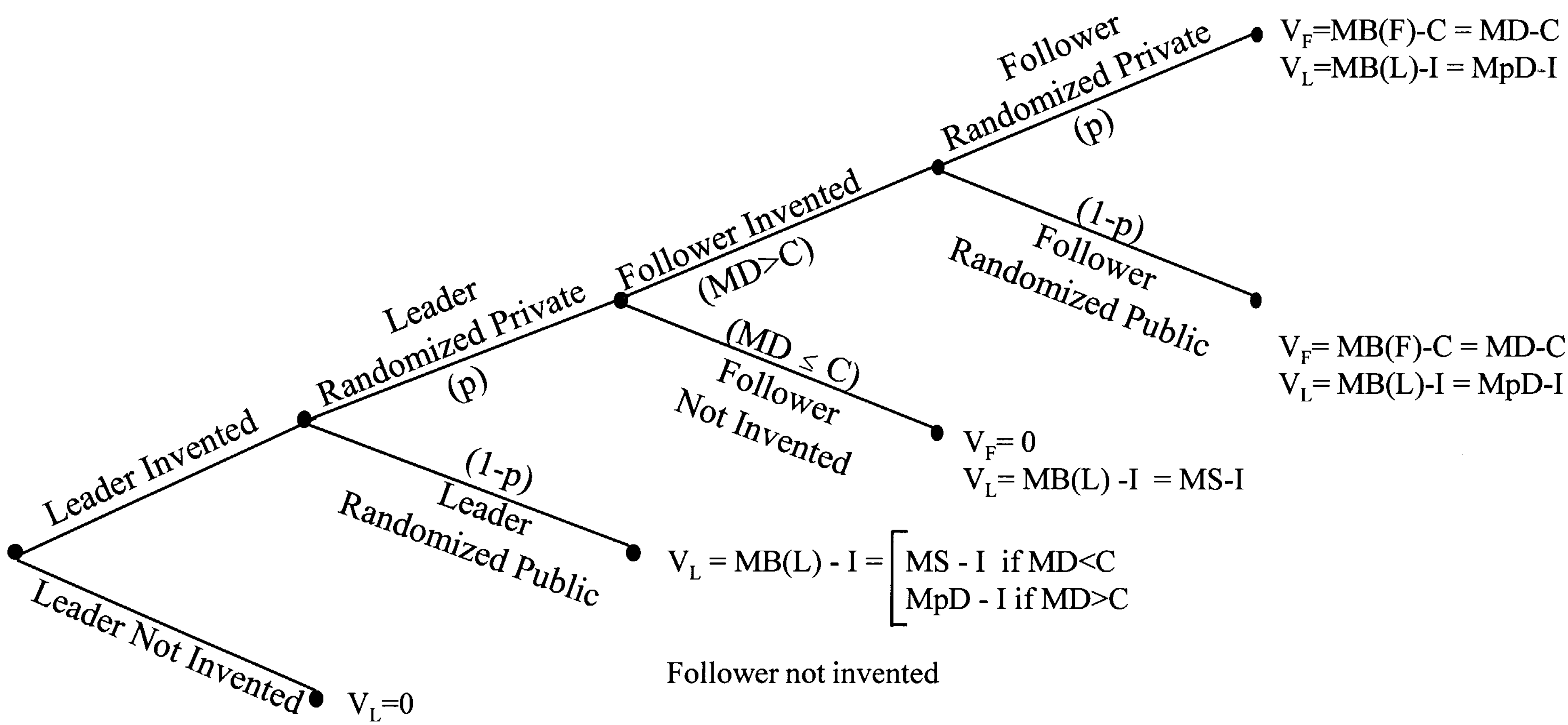


Figure 3: Patent Buy-Outs Without Joint Randomization



offer pD for the Leader patent, and hence the government will offer MpD for the Leader patent. Therefore, if MpD < I and MD>C, Leader will not be invented. This implies that some inventions that would be developed under the current patent system would not be developed under patent buy-outs with separate randomization.

Joint randomization could preserve incentives for current research. It would work as follows: if the patent on Leader was in private hands, and Follower was invented and put up for auction, the holder of the Leader patent could ask for the Leader patent to be re-auctioned at the same time as the Follower patent.[27] Prospective buyers would bid on each patent separately, but the government would conduct a single randomization to determine if the Leader and Follower patents would both be put in the public domain or both be sold to the high bidders in their respective auctions. (If the original inventor had not previously sold the Leader patent to the government, then the government would pay a markup on the Leader patent, but if Leader had been through a previous patent buy-out, the government would not pay a second markup.)

Note that joint randomization does not require a bureaucracy to judge whether goods are substitutes. Any patent holder could claim that his or her patent was a substitute for a new patent, and request that it be jointly randomized with the new patent. Even if the new patent was not in fact a substitute for the old patent, jointly randomizing the old patent together with an unrelated new patent would create no harm and would have the advantage of possibly transferring another patent to the public domain.

Under joint randomization, Leader will be valued based on the contingency in which

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[27]Current anti-trust regulations would determine whether a single entity could buy both patents.

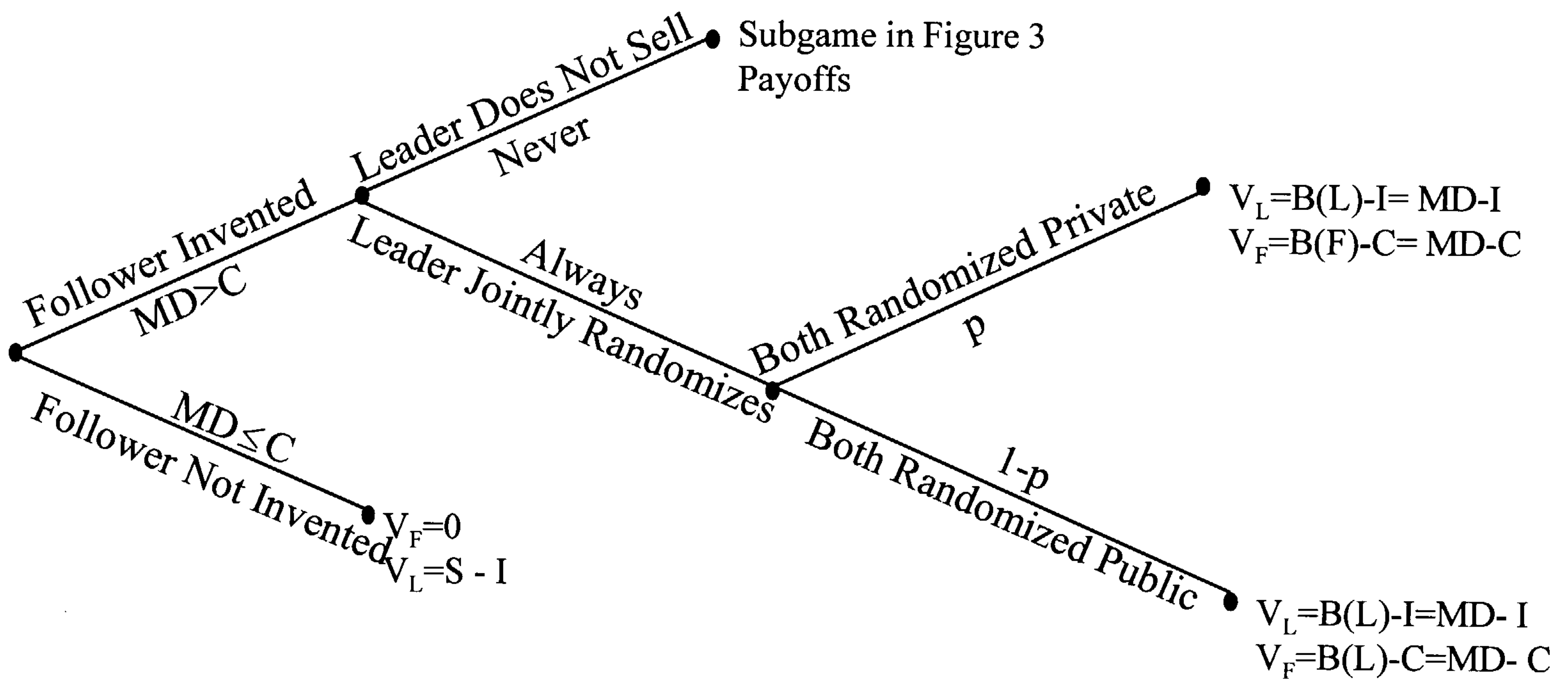
both Leader and Follower stay in private hands. Figure 4 depicts the sub-game under joint randomization in which Leader was invented, but not sold to the government.[28] To solve this game, work backwards, starting with the case in which both patents are randomized to their respective high bidders. The equilibrium bid for each patent will be D and the government will offer to buy out each patent at a price of MD. Follower will be developed if MD>C. If this condition is fulfilled, it will be worthwhile to develop Leader if MD>I.

Consider the case in which D>C, so Follower will be developed if Leader is invented. In the absence of patent buy-outs, Leader would be invented if D > I, whereas under patent buy-outs with joint randomization, Leader would be invented under the weaker condition that MD > I. Similarly, if MD<C, so Follower will not be developed, then Leader will be invented if S>I in the absence of patent buy-outs, whereas under patent buy-outs, Leader would be invented under the weaker condition that MS>I. In both cases, patent buy-outs increase research incentives.

There is a case in which incentives for developing Leader might be smaller under patent buy-outs, but this case is somewhat artificial, because it depends on the assumption that there are only two possible drugs for the condition. If D<C<MD, so that Follower would be invented only under patent buy-outs, the return to developing Leader will be S-I without patent buy-outs and MD-I with patent buy-outs. Incentives for developing Leader will be greater under patent buy-outs if and only if MD>S. In this example, anticipated patent buy-outs with joint randomization reduce the incentive to invent the first good not because the second patent is put in the public

[28]In order to avoid cluttering up the game tree, I do not show the branches in which patent holders refuse to sell their patents, since selling patents to the government once they are invented is always a dominant strategy.

Figure 4: Patent Buy-Outs With Joint Randomization: Subgame with Leader in Private Hands



domain, but because they increase the incentive for inventing the second patent. In the notation of the previous sub-section, $\partial x_t/\partial x_{t+1}$ is sufficiently negative that the indirect effect of the markup for the second patent outweighs the direct effect of the markup in the first period. However, this effect depends on there being only two patents in the chain, because it does not allow for the possibility that incentives for developing Follower would be reduced by the markup applied to future Follower substitutes. As shown in Section V.A., markups increase steady-state research if there is an infinite sequence of potential substitute goods, (or a fixed probability that each invention would be the last in a quality-ladder.)

Joint randomization or reversion to the existing patent system would occur only if the original patent remained in private hands. Presumably, these cases would be rare, because most patents would be sold to the government and placed in the public domain.

V.C. Durable Goods

The analysis above assumes that demand for Leader is affected only by the contemporaneous price of Follower, not the expected future price. This assumption seems appropriate for non-durable goods -- that is, goods which are destroyed when they are consumed, such as most pharmaceuticals. However, demand for durable, non-rentable goods will be reduced by anticipated buy-outs of future substitute patents, even under joint randomization.

Consider the example of Intel and Advanced Micro Devices. Under the current patent system, if Intel develops a new chip, customers will foresee that Advanced Micro Devices is likely to develop a similar chip. They will be willing to pay Intel some premium over the duopoly price to avoid waiting until the AMD chip is ready for sale. If customers expected that AMD's chip would eventually be placed in the public domain and sold at its production cost, they would be willing to pay Intel a premium not over the duopoly price, but over the marginal cost of production. This would reduce Intel's incentive to develop the original chip. If this effect were strong enough to outweigh the markup, research incentives for durable goods could actually be smaller under patent buy-outs.

If the chip can be rented, rather than sold, Intel's research incentives will be increased by patent buy-outs. In the absence of patent buy-outs, Intel could charge a monopoly rent the first two years, and a duopoly rent thereafter. This would yield the same present discounted value as selling the patent. Under patent buy-outs with joint randomization, a private holder of the Intel patent would charge a monopoly rent for the first two years, and then would randomize the patent together with the AMD patent. Auction participants would bid the present discounted value of duopoly rents for each patent.[29]

In some cases, transaction costs or the difficulty of monitoring maintenance may make it difficult to organize a rental market. Holders of patents on non-rentable durable goods should therefore be able to commit to prevent or delay buy-outs of patents for close substitutes. Clearly, some discretion would be needed to determine whether a new patent is a close substitute for an existing patented durable good. This makes patent buy-outs more attractive for non-durable or

[29]To see why research incentives are preserved only if Intel retains ownership of the chip, think of Intel as selling two products: a one dollar piece of silicon, and a thousand dollar license to use the invention. Joint randomization allows the government to buy back the patent from Intel in the case that placing the AMD patent in the public domain reduces the value of the Intel patent, but it would be hard for the government to compensate all the customers who had bought "licenses" to the invention. If Intel merely rents licenses, rather than selling them, then customers will not need to be reimbursed if the AMD patent is put in the public domain.

rentable goods than for non-rentable durables.

Of course, in reality, durability is continuous rather than dichotomous; no good is completely non-durable or completely durable. For example, restaurant meals are normally considered non-durable, but demand for meals at a restaurant would probably be lower the day before a special promotion. Similarly, although drugs are normally considered non-durable, demand for a new drug such as Prozac would presumably be somewhat reduced by anticipation of the cheap availability of Zoloft two years later. However, the reduction in price for Prozac would presumably be minor, since people in the midst of an episode of depression are likely to want treatment immediately, not two years later. Thus, any reduction in research incentives caused by anticipation of patent buy-outs would likely be outweighed by the increase in research incentives due to the markup.

V.D. Joint Randomization for Complementary Patents

Whereas anticipation that substitute patents will be put in the public domain reduces the price at which patents are bought out, anticipation that complementary patents will be bought out increases the buy-out price -- potentially above the social value of the patent. In the absence of joint randomization, inventors would therefore have an incentive to divide up inventions into multiple complementary patents.[30] To see this, consider the case of two perfectly complementary patents which are worth π together. Since the goods are perfect complements, each patent will be worth π singly if the other is in the public domain. If the two complementary patents were

[30] I thank Paul Romer for pointing this out.

auctioned separately, then each would be bought out for $M[(1-p)\pi + pD]$ where p is the probability that the other patent remains in private hands, and D is the value of owning one patent if the other is in private hands.[31] Assuming that p is small, the government would thus pay close to twice the social value of the pair of patents.

To reduce the possibility that the government pays more than the social value of complementary patents, and to avoid creating incentives for inventors to split up inventions into multiple patents, complementary patents could also be jointly randomized into either the public domain or private hands. Patent owners who do not wish to jointly randomize would not have to sell their patent, but they would not be eligible for future, separate patent buy-outs. Inventors who sell one patent to the government would not be eligible to sell future complementary patents to the government until after a waiting period elapsed. Some discretion would be needed to determine if the goods were complements.

The government would allow auction participants to bid for various bundles of patents. Based on these bids, the government would offer a price at which it would buy all the patents together. If the patent owner refused to sell all the patents, the government would then offer to buy-out subsets of the patents based on the willingness of bidders to pay for these subsets. It is useful to first consider the case in which a single firm owns a group of complementary patents. A mark-up of 2 suffices to ensure that a single owner of an arbitrary number of complementary patents will always find it is worthwhile to sell all the patents to the government. To see this, note that the patent owner will receive $M\pi$ in exchange for all the patents. The owner would

[31] Assuming symmetry in bargaining power, D will be $\pi/2$ if the owners can cooperate in choosing prices that maximize their joint profits, and less if the owners cannot cooperate perfectly.

receive a maximum of $M\pi/2$ in exchange for all but one of the patents. The remaining patent will be worth π with probability 1-p and a maximum of $\pi/2$ with probability p. The owner will therefore prefer to sell all the patents as long as $M\pi > M\pi/2+(1-p)\pi+p\pi/2$, or equivalently, if $2-p < M$.

When complementary patents are held by two different owners, there may be severe distortions under the current patent system, and these would remain under patent buy-outs. The sum of the monopoly prices on the patented goods will typically be greater than the monopoly price that would be charged if there were a single owner, since each patent owner will not take into account the reduction in demand for the other patented goods caused by raising its price. If one patent owner bought out the other, total profits and social welfare would increase. However, hold-up problems may prevent owners from selling their patents to a single buyer, especially if patent owners have private information on the value of their patents. The government could solicit bids both on the entire set of complementary patents, and on those patents belonging to each owner. If the owners could not agree to a joint sale, the government would offer to buy the patents controlled by one owner. This owner could be picked randomly, with the chance of picking an owner proportional to the bid on the owner's patents. The owners will always maximize their joint surplus if they agree to sell jointly.

If the owners do not agree to sell jointly, the owner offered the chance to sell will always be better off doing so. Each owner will prefer to be the one offered the opportunity to sell separately if there are two owners and M=2. If there are more than two owners, and if the goods are strong enough complements, then the government could offer to buy out all but one owner. In this case the owners offered the chance to sell will still wish to do so, although they may be worse off than the other owners.

The government could determine if the patents were very strong complements by looking at the pattern of bids. If the goods are complementary, the sum of the bids for subsets of patents will be less than the bids for the entire set of patents, assuming the bidders anticipate that they will not perfectly cooperate in pricing the goods after buying out the patents. If the government mistakenly classified patents as complements and insisted on joint randomization, patent owners would still be better off than without patent buy-outs. If they reached agreement with other patent owners on a joint sale, they would not be harmed. If not, the government might still offer to buy out their patent.

Note that complementary patents are considerably less common in pharmaceuticals than in other industries. In many fields, a new invention is protected by several new patents. In contrast, pharmaceuticals are much more often based on a single new patent. This is in part because a new drug is often a particular molecule, and in part because the FDA approval process is so expensive that it does not make sense to break a drug into two separate drugs which each have to be approved separately. The main exception is that in some cases, a manufacturer will hold both a product patent on a molecule and process patents on techniques for producing it. The patent buy-out authority could have a policy of not purchasing process patents except in conjunction with associated product patents. This would create an incentive for inventors to sell both patents together. There are also some cases in which drugs themselves are complements: for example, one drug might be used to treat the side effects of another drug, or two drugs may be more effective when used in combination, as in the treatment of HIV with a cocktail of drugs. (Note, however, that any new anti-HIV drugs that are added to the cocktail may be economic substitutes for existing drugs, in the sense that they will lead to reductions in the price of these drugs.)

VI. Preventing Collusion

The system is potentially vulnerable to collusion, since patent holders would have an incentive to bribe auction participants to bid high. The bidder would only have to pay the government with probability p. However, with 100 percent probability, the patent holder would receive an inflated payment. It is impossible to eliminate collusion, but a variety of mechanisms could be used to minimize it. Sub-section VI.A. reviews several methods of reducing collusion. Sub-section VI.B. discusses ways ceiling prices could be established to limit pay outs by the government. Sub-section VI. C. discusses alternative mechanisms that can be used to determine the patent buy-out price if the market were thought to be too thin for auctions.

VI.A. Mechanisms for Preventing Collusion

Standard procedures for preventing collusion in auction could be used. By using a sealed-bid auction, and keeping bids secret after the auction, the government could make collusion more difficult. Companies and individuals found guilty of collusion could be subject to large penalties, and rewards could be established for people who turned in evidence of collusion.

In addition, the following methods could be used to minimize the possibility of collusion:

1. Since the government would base the price it offers the patent holder on the third

highest bid, the original patent holder would have to bribe five companies instead of one to ensure a substantial increase in the buy-out price. This mechanism should significantly raise both the difficulty of collusion and the chance of detection.

2. The government administrator could have the authority to reduce or eliminate the mark-up and cancel the randomization in a set percentage of cases if collusion was suspected. Suppose the administrator suspected a particular bidder of colluding. Suppose that based on the other bids, and any knowledge of the industry, the administrator's best estimate of the patent's value was π, but the suspected colluding bidder offered π+x. The government could offer to buy out the patent at $\pi+\epsilon$ (where ϵ is small), and then require the colluding bidder to purchase the patent at its bid of π+x. The government would make a profit of x-ϵ from the attempted collusion, assuming that the patent owner agreed to sell. Even if the patent owner refused to sell the patent, the patent owner would have to forego the markup of x that it could have received had it not tried to collude. (Collusion could be indicated by an abnormally high variance of bids; entry of companies that had not participated in the past; or high bids by suspected colluders relative to those from a known group of "honest" bidders.)[32]

3. The government could develop lists of suspect bidders by checking whether they made money after buying patents, since companies that systematically over-bid would have big losses.

4. To prevent the original patent holder from forming front companies and having them submit high bids, companies would have to provide information on any ties they had with the

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[32] Allowing the government agency some discretion to reduce the mark-up in cases of suspected collusion could create opportunities for corruption, since colluding companies could bribe regulators for lenient treatment. If necessary, the agency purchasing patents could be structured to reduce the possibility of corruption: two or more departments could recommend offers independently to the original inventor, with the government using the lower figure.

original patent holder. Officers of companies who lied about financial ties with the original patent holder would be subject to prosecution.

5. Bidders could be required to pay a licensing fee or deposit allowing them to participate in a number of auctions. This would make it unprofitable for patent holders to set up dummy companies simply to bid on their own patents.

With perfectly competitive markets, excluding bidders with financial ties to patenting companies and requiring deposits would have no social cost. However, with only a limited number of potential bidding firms, there would be a tradeoff between minimizing corruption and encouraging bidding. In the absence of patent protection, there are often many firms producing drugs, in part because it is straightforward to manufacture most drugs. For example, fourteen firms produce oral albuterol sulfate. Any system of patent buy-outs that relies on auctioning patents should focus on drugs that are easy to produce, rather than those which require complicated manufacturing facilities.

6. To prevent inventors from developing a reputation for buying back their patents at inflated prices, the original inventor would be prohibited from buying back the patent from the winning bidder, or making other payments to bidders. Preventing these side payments from the original patent holder to the winning bidder might be one of the most difficult aspects of preventing collusion, since the original patent holder might agree to purchase a completely different good from the winning bidder.

The government agency administering the program would presumably have a budget for patent buy-outs, and would not be able to afford to buy all the patents that were available for purchase. It could presumably pick and choose which patents were the best buy. This would tend to reduce collusion because companies that forced the price up too high would reduce the chance that the government agency would buy their patent.

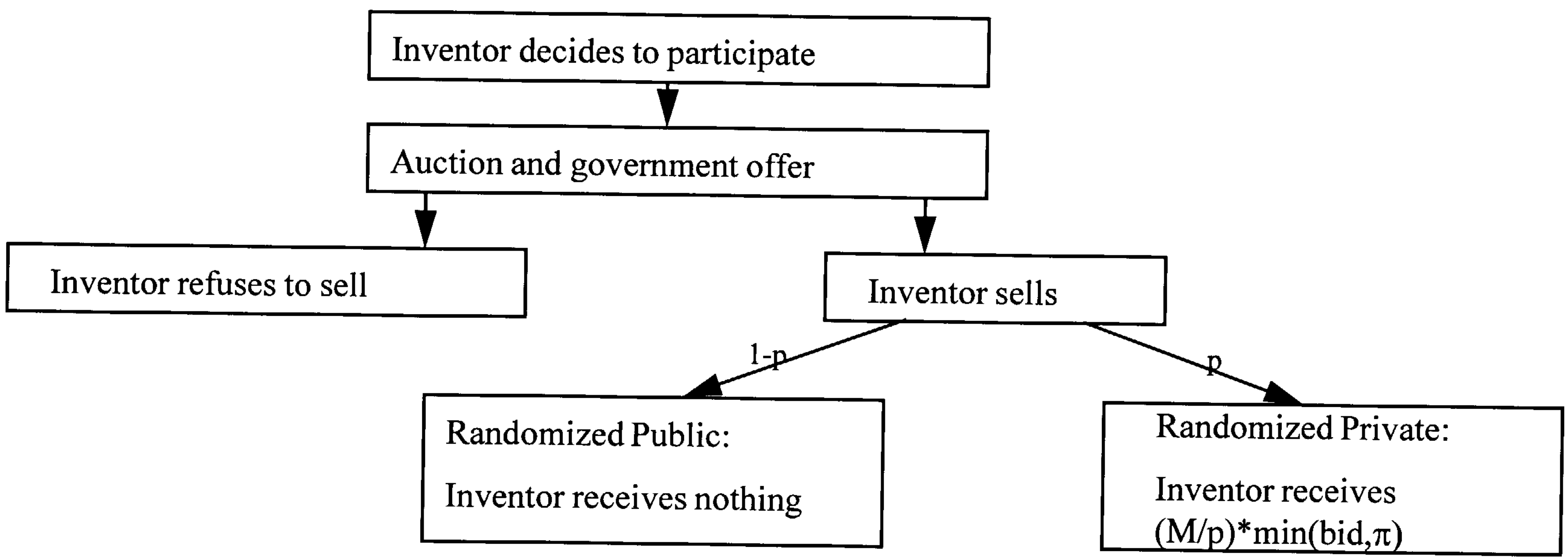
VI.B. Ceiling Prices

The fact that the system is voluntary for the patent holder places a lower bound on the price at which patent sales will take place. There are several ways that the government could establish a ceiling price, and thus avoid the danger of paying vastly inflated sums for patents.

If companies were required to hold a patent for several years before selling it to the government, the government could establish a ceiling price based on a multiple of annual revenues from sales of the good prior to the patent buy-out. Note that this requirement would also make it easier for bidders to assess the value of a patent, and would further guarantee that the inventor would have incentives to develop the invention. Of course, attempts to set an upper bound on the price based on a multiple of revenue would lead firms to artificially boost sales, for example by offering package deals in which customers get discounts on other drugs if they buy the drug for which the firm wanted to sell the patent. Tied sales would have to be prohibited. There could also be a rule that the estimated private value of the patent could never exceed the price before the patent buy-out times consumption after the patent buy-out.

It also might be worth considering a mechanism like that in Figure 5, with a ceiling price based on the actual profits obtained from the new drug. Inventors who wished to participate would have their patents randomized. The patent would be randomized to the high bidder with some probability p, and placed in the public domain with probability 1-p. Owners

Figure 5: Patent Buy-Outs with Ceiling Prices



would be paid only in the state of the world in which the patent was randomized to the high bidder. In this case, they would receive (M/p) min(bid,π) where M is the mark-up, bid is the estimated value of the patent based on the bids, and π is the realized revenue (or ideally profits) from the drug.[33] The expected payment received by the inventor is thus M min (bid, π).

This mechanism does not require the inventor to bear nearly as much risk as it may seem at first glance. Inventors should be able to insure themselves at rates which are close to actuarially fair against the possibility that the patent will be randomized to the high bidder, since this probability is objective and known to all, (unlike the value of the patent, about which the inventor may have private information). The inventor would sign a contract under which it would receive \$x in every state of the world, and pay \$x/p in the state of the world in which the patent is sold to the high bidder. A risk-averse inventor would like to buy enough insurance to receive ME[min (bid,π)] in every state of the world, where the expectation is taken conditional on the information of the inventor.

Large firms selling patents that represent a minor share of the firm's assets would presumably be able to buy as much insurance as they wanted. However, small firms selling

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[33]Whereas Guell and Fischbaum [1995] suggest establishing a price for the patent buy-out by allowing the company to retain patent rights in some limited geographic region, and then estimating the value of the patent based on revenues in this region, this mechanism establishes a price by allowing the company to retain patent rights in a particular state of the world. An advantage of this approach is that geographic regions may differ in income levels, health care systems, or percentage of the population suffering from a particular disease, but the state of the world in which the randomization device causes the patent to be sold to the high bidder is likely to be similar to the state of the world in which the patent is put in the public domain. Moreover, it is more difficult to smuggle drugs across states of the world than to smuggle them across geographic regions.

patents of high and uncertain value might not be able to buy full insurance, because insurers would fear that if the patent turned out to be worth less than expected by the inventor, the inventor might default and go bankrupt. However, even with only partial insurance, patent buy-outs may make inventors better off for any outcome of the randomization.

In order to manipulate the ceiling price, the inventor would have to bribe the high bidder to induce it to boost sales artificially through tie-ins with other products. The government would have to monitor carefully to minimize such tie-ins. Aside from creating transfers from the government to the firm, artificially boosting sales would cause deadweight loss. However, the overall burden of the distortions would not be that serious, since limited subsidies to revenues will actually increase sales closer to their optimal level by counteracting the effects of monopoly pricing, and in any case the subsidies would only be given only in those cases in which the patent is randomized back to the original owner. It is likely to be difficult for firms to greatly increase demand artificially for drugs covering sharply defined diseases, such as cystic fibrosis.

It is easy to come up with scenarios under which people could evade rules designed to discourage collusion, but it is also important to remember that many institutions which are vulnerable to collusion operate relatively well. For example, the peer-review system used to allocate National Science Foundation grants is supremely vulnerable to collusion, yet seems relatively effective. Moreover, a limited amount of collusion will not necessarily be that harmful. Collusion itself is not a problem: deadweight losses due to collusion are a problem, and there is little reason to think that these deadweight losses would exceed the deadweight losses under the current patent system due to insufficient original research, monopoly-price distortions, and the diversion of effort to "me too" research. If implicit collusion were expected to significantly raise the patent prices, then the markup over the private value could be reduced accordingly. For example, if the optimal markup was three (as seems plausible), and if collusion were thought to raise prices by up to 50 percent, then the government could simply offer a mark-up of two. Finally, it is worth noting that even if collusion raises patent prices above their social value, the social value of inventions may be approximated better by the collusive price than by the existing patent system.

VI.C. Alternative Patent Buy-Out Mechanisms

If markets were considered too thin for auctions, other mechanisms could be used that dispense with auctions entirely. For example, patents could be randomized either to the public domain or to the original owner. The inventor would be paid based on a multiple of the realized profits or revenues from the drug in the case in which it was randomized back to the original inventor. One disadvantage of this system relative to the ceiling price mechanism outlined in the previous sub-section is that the owner would have a direct incentive to artificially boost demand through tie-ins with other products.

Under another mechanism, the government would solicit estimates of the value of the patent from independent consulting firms. Participating patent holders would have to agree to disclose information necessary for estimating the profitability of the drug. For example, firms might have to keep track of all revenues generated by sales of the drug, and all production costs. The buy-out price would be based on the consulting firms' prediction of the profits that would be generated by the patent. The consulting firms would then be paid based on the difference between their estimates and the realized value of the drug.

Pharmaceuticals firms might have some incentive to develop a reputation for using accounting tricks to boost recorded drugs profits artificially, (even though this would not gain them anything on that particular drug,) because it might lead consulting firms to bid more on subsequent patents. One difficult issue would therefore be apportioning or marketing expenses between products, and avoiding cross-subsidization in multi-product firms.

There is some danger that the alternative mechanisms will not provide sufficient incentive for inventions to be fully developed before they are sold to the government. Note also that issues of substituting and complementary patents would need to be addressed under these alternative mechanisms.

VII. Conclusion: Trial Buy-Outs of Patents

This paper examines the use of patent buy-outs to supplement our current system of promoting innovations through patents and government grants. The government could offer to buy out privately developed patents at their private value, as revealed by an auction, times a markup designed to cover the difference between the private and social values of inventions. This mechanism involves somewhat more government discretion than the current patent system, but substantially less discretion than NSF or other direct government funding. Patent buy-outs could potentially increase incentives for original invention closer to their social value; reduce incentives for wasteful “me too” research; and eliminate monopoly pricing distortions.

As the paper has discussed, patent buy-outs could also cause a number of problems.

However, the same is true for existing methods of encouraging innovation. In an 1851 editorial [cited by Dutton, 1984] urging that patents be abolished, *The Economist* wrote that the granting of patents "inflames cupidity, excites fraud, stimulates men to run after schemes. . . begets disputes and quarrels betwixt inventors, provokes endless lawsuits [and] makes men ruin themselves for the sake of getting the privilege of a patent, which merely fosters a delusion of greediness." All this is true, and yet it seems clear that the world is much better off with patents than without them. The same may be true for patent buy-outs.

Based on theory alone, it is impossible to know whether patent buy-outs could provide a useful supplement to the mechanisms currently used to encourage innovation. A limited trial of patent buy-outs could help determine whether inventors will sell their patents, and whether bids are substantially greater than realized profits or revenues, as would be the case if collusion were severe. Based on this information, it would be easier to judge whether patent buy-outs should be abandoned, re-designed, or extended.

Pharmaceuticals are a natural area to try patent buy-outs, since markets would be relatively competitive in the absence of patents; patent protection is effective; monopoly mark-ups are large; drugs are non-durable; "me too" inventions are widespread; and considerable information is generated during the process of FDA approval, so potential bidders could make informed bids. Moreover, because many pharmaceutical patents are valuable, the administrative costs of the system are likely to be a small fraction of the social value that can be gained from patent buy-outs. Once FDA approval has been granted, little new development is typically required.[34]

Distortions in the market for health care may actually strengthen the case for buying out pharmaceutical patents. Although people may consume too much health care due to subsidies, subsidies for pharmaceuticals are generally smaller than for alternative, more expensive, forms of treatment, such as surgery, creating a second-best case for subsidizing pharmaceuticals.

Finally, buying out pharmaceutical patents is likely to have benign distributional consequences, whereas buying out, say, patents for improved yachts will not. Financing pharmaceutical research through patents is equivalent to financing research through a tax on people who suffer from the disease within the patent lifetime. If disease incidence is random, and not fully insurable, people will prefer *ex ante* to insure themselves by funding the research out of general tax revenue.

The system could initially be applied to treatments for a few specific diseases considered to be particularly important, or particularly subject to problems resulting from the patent system. Orphan drug legislation provides a precedent for establishing special rules for drugs designed to treat particular diseases.

It might make sense for a private foundation to conduct an initial trial of patent buy-outs. If the experience of the foundation patent buy-out was positive, the government might consider appropriating, say, $100 million, from general revenue of from the NIH budget, for patent buy-outs over a two-year period. The Rockefeller Foundation recently established a $1,000,000 prize for a diagnostic test for gonorrhea and chlamydia suitable for use in developing countries

[34]However, marketing expenditures are necessary, and the benefits of these expenditures may spill over to other producers.

[Rockefeller Foundation, 1997]. Such a test might be an appropriate place to try a patent buy-out. Gonorrhea and chlamydia are easily treated, and the social value of treating these diseases far exceeds the private value, since the diseases are believed to increase the likelihood of HIV transmission three-to-five fold [Rockefeller Foundation, 1997]. Yet millions of people in developing countries go untreated because tests suitable for use in developing countries are not available.

This case vividly illustrates the shortcomings of existing mechanisms of encouraging research. Patents could provide an incentive for development of appropriate tests. Yet high prices on tests for these diseases would lead many fewer people to get tested, and many more people to be infected with HIV.

To be eligible for the Rockefeller Foundation prize, diagnostic tests must be ninety-nine percent accurate, take less than twenty minutes, require no more power than can be delivered by a nine-volt battery, be storable for six months in tropical conditions, cost less than US$ 0.25 per device to manufacture, and be usable by health workers with primary education after two hours of training [Rockefeller Foundation, 1997]. A shortcoming of this prize mechanism is that it does not allow for trade-offs among these criteria or between the amount of the prize and the performance standards. For example, it might be worth accepting a device that is slightly less accurate if it was much cheaper, faster, and simpler to use. It is also possible that a test that takes twenty-one minutes could be developed very cheaply, but that a nineteen minute test is prohibitively expensive to develop.[35]

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[35]Another possible problem with the prize is that the prize rules require that the inventor license the patent to the Rockefeller Foundation. The Foundation states that it will not use this

Perhaps the Rockefeller Foundation should consider announcing that if the prize has not been claimed by the date the offer expires (March 1, 1999), it would consider using the funds to buy out a patent on a diagnostic test that does not completely fulfill the prize criteria.[36] The foundation might want to buy only part of the patent rights, given the limited funds it is making available. For example, the foundation might buy out the last ten years of the patent, so as to leave the inventor with an incentive to market the test for the first several years. In such an auction, the bidders would bid for the full rights to the patent, and with probability 1-p the foundation would offer to buy out the last ten years of the patent for its estimated full value, and with probability p the foundation would buy out the patent fully, at twice its estimated full value, and then sell the patent rights to the highest bidder at the second highest price.

The issues raised by a limited program of patent buy-outs differ somewhat from those relevant for a general program. Issues of anticipated buy-outs of complementary or substitute patents would not arise for a one-time Rockefeller Foundation patent buy-out, or even for a somewhat larger program of patent buy-outs for pharmaceuticals designed to treat diseases for which there is no effective treatment. On the other hand, if patents were bought out only for drugs to treat specific diseases, second-best considerations suggest that the optimal mark-up

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license if the inventor takes steps to ensure that the device is made available to developing countries at a price no more that ten percent above manufacturing and distribution costs. The Rockefeller prize will therefore provide no additional research incentive if the monopoly value of the patent would be greater than $1,000,000 plus the profits that could be made by selling the invention at ten percent above production cost.

[36]It is unlikely that this announcement would cause researchers to significantly slacken their effort to meet the prize requirements, because this would risk another researcher claiming the prize, thus eliminating the possibility of a patent buy-out.

would be less than the social value of the invention, because scientific talent would be diverted from other areas of innovation. Nonetheless, given that treatment of gonorrhea and chlamydia reduces HIV transmission rates, the social value of improved tests is likely to be many times the private value.

This paper has examined the use of auctions to determine patent buy-out prices, but the general approach to limiting government discretion through public auctions may be more widely applicable. Optimal mechanism design often requires decisions tailored either to individuals, or to small numbers of agents. However, government rules typically restrict the use of some types of information. For example, civil service rules limit discretion over pay and promotion decisions. Similarly, there are extensive rules restricting what types of evidence are admissible in trials, even though other information could shift priors. This paper has considered a system that allows governments to tailor decisions to individuals without allowing unlimited government discretion over small numbers of people. To induce people to reveal the information needed by the government, an auction is held in which bidders need only be awarded the item with a small probability. I am currently exploring whether a similar mechanism can be used to determine a price at which taxpayers would be allowed to purchase exemption from distortionary taxation.

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