Appropriation and Intellectual Property[1]

By

Michele Boldrin and David K. Levine[2]

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Abstract: A standard rationale for intellectual property is that by awarding a monopoly to innovators the government increases the amount of social surplus appropriated from invention, thereby improving efficiency. Indeed, if an inventor can appropriate the full surplus from his invention the first best will be obtained. We observe that while full appropriation is sufficient for efficiency, it is not necessary – in fact full appropriation by marginal individuals is sufficient. We then show how in a world in which competitors are strategic agents competition is less fierce over marginal contributions, and as a result government awards of monopoly may be socially undesirable.

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[2] Department of Economics, Washington University in St. Louis.

1. Introduction

One goal of intellectual property is to increase the proportion of social surplus accruing to the innovator. From a formal point of view Ostroy [1980, 1984] and Ostroy and Makowski [1984, 2001] pioneered the idea of the marginal contribution of an individual to society. They were able to capture a common intuition and show that if everyone is able to fully appropriate their individual contribution to social surplus, perfect competition and efficiency are obtained. In fact, they identify the idea of perfect competition with that of full appropriation

> *Our answer is that a perfect competitor is a full appropriator: whatever quantities the perfect competitor supplies, the amounts he extracts from the rest of the economy in exchange are such that others are indifferent between trading with the perfect competitor or not trading with him at all.* [2001, p. 498]

This idea is particularly relevant to the study of innovation, and of intellectual property in particular. Following along the lines of Ostroy and Makowski, insofar as copyrights and patents enable creators and innovators to appropriate a large part of the surplus created by their ingenuity, it should lead to nearly efficient outcomes. In particular, Ostroy and Makowski seem to suggest that a fully efficient level of economic innovation is achieved only when the private benefits innovators appropriate from their participation in the market coincide with the social benefits they contribute to the other side of the market.

Interestingly enough, this idea is implicit in the conventional view of innovation as due to monopoly power based upon intellectual property, argued, among many many other, by Barro and Sala-i-Martin [1999]

> *It would be efficient ex post to make the existing discoveries freely available to all producers, but this practice fails to provide the ex ante incentives for further inventions. A tradeoff arises between restrictions on the use of existing ideas and the rewards to inventive activity.*

Indeed, the idea that there is a trade-off between the appropriation of surplus at the margin and infra-marginal distortion of additional monopoly power has a long history in the literature on industrial organization: Nordhaus [1969] is one early contribution along these lines; recent empirical study of the trade-off can be found in Boldrin and Levine [2009].

Nevertheless, when we consider what Ostroy and Makowski [2001, p. 479-480] call "opportunistic behavior" – game-theoretical considerations, if you like – it becomes clear that the conventional view is problematic. What happens, in other words, when the competitive actors in the model instead of taking price as given choose what to do in an opportunistic and forward-looking fashion? To quote

> *Portraying the individual as a pricetaker was extremely useful for displaying the new equi-marginal principle underlying individual choice. But it had the unfortunate consequence of suppressing the entrepreneurial side of competition.*

Entrepreneurs are innovative individuals, that is individuals capable of "enlarging the production set" by using old commodities in a novel fashion and thereby obtaining a new, previously unknown commodity. Schumpeter's five different forms of innovation all boil down to this, most obvious one. This we call an innovation, and we follow upon the Makowski/Ostroy invitation

> *Our image of the perfect competitor is someone who is active and innovative. Rather than dealing with an impersonal market, perfect competitors interact with one another in an environment involving intense rivalry. A perfect competitor will do whatever he can to increase his gain: bargaining vigorously with others for a better deal, innovating new products if he sees a profit to doing so, ...*

In doing so we blow some strategic life into the flaccid body of the Schumpeterian innovators and imitators of standard "new growth theory" – the theory by which technological fixed costs and increasing returns are the essence of anything good that has ever happened to humans since the inception of civilization.

Let us start with the conventional model of innovation and imitation. Suppose that copies of a new good may be produced by anyone at a common constant marginal cost and without a capacity constraint, as the models of new growth theory assume. Suppose also that the market is extremely competitive – that in fact there is Bertrand competition so that each agent tries to beat the other one by lowering the asking price so as to capture the entire market. This can be justified by opportunistic behavior if issues of private information are set aside and all imitators are assumed to access the same technology once they have paid the setup cost. Then as soon as a single imitator enters the market price is forced to marginal cost and profits to zero – there is no surplus left over to pay the fixed cost of the creator. We reach the standard conclusion, as in Barro and Sala-i-Martin and many others: *ex ante* nobody would be willing to pay the fixed cost of creation.

So far so good. It is not unreasonable to imagine, though, that competitors copying the innovator's product face at least some small fixed cost of entering the market – reverse engineering the new product, setting up a production line, or website to distribute copies, and so forth. This fixed cost may be considerably smaller than that of the original creator, but no matter. Since each of these potential rivals knows that the moment they enter the market for the new good, competitive (in the sense of Bertrand) price determination forces the price to drop to marginal cost, they too face the prospect of zero profits – and will be unwilling to enter the market. If the original creator cannot pay for her fixed cost, imitators cannot either. Pulling this back, we see that the original creator should innovate if – with the share of social surplus generated by a monopoly – she can cover her fixed costs. For if she can, she can be secure in her knowledge that no rival will wish to create cut-throat competition by entering. In other words, under the very mild assumption that imitators face a positive fixed cost of entry, the discovery can be made freely available to all producers *ex post*, as the *threat of competition* is enough to guarantee the innovator's position of monopoly.[3]

Indeed, even in the limiting case where the fixed cost of entry is zero, there are two equilibria under the assumption that the discovery is made freely available to everyone *ex post.* In one, considered earlier, there is no discovery and if the creator were

[3] Henry and Ponce [2009] follow this line in a different direction examining the incentive of innovators to wait following an initial innovation.

to step off the equilibrium path and innovate, she would be faced by the immediate entry of imitators. In the other, the creator innovates if a monopoly covers the fixed cost – and the rivals, being indifferent, choose not to enter. So the conventional wisdom summarized by Barro and Sala-i-Martin holds only under the assumption of costless entry, and then only for the equilibrium that is the least plausible in the sense that it is not robust to the assumption of tiny fixed costs of entry. With small fixed costs of entry and when the participants in this market are forward looking competitors, appropriation through monopoly is the outcome – and there is no need for intellectual property to appropriate the (share of the) social surplus the innovator needs to find motivation for her creative effort.

This highlights the basic point about intellectual property: to what extent is it useful, or even *necessary*, to appropriate surplus? To move beyond the improbable assumption of instantaneous Bertrand competition with unlimited capacity, we begin by observing that, strictly speaking, the full appropriation condition of Makowski and Ostroy is necessary only for marginal discoveries and marginal inventors. This is because creators and their creations differ in the amount of social surplus they deliver relative to the cost of invention. “High quality” discoveries – tied to “high quality” innovators – for which the social surplus greatly exceeds the fixed cost of creation, require only limited appropriability to guarantee that they are produced. The fixed cost of creating high quality new goods would require appropriating their full social surplus if (and only if) the opportunity cost of their creators were uniformly as high as said social surplus. That is to say: only under the special conditions in which, no matter which occupation the innovator chooses and which activity she carries out, the social value of her product is (uniformly) “high”, her opportunity cost of innovating will match the social surplus she is generating in the specific innovation being considered. In the, admittedly more general not to say more realistic, case in which the innovator generates a high social surplus by doing X, but a smaller one by doing Y, the fixed cost to be recovered to make it incentive-compatible to create X amounts only to the full social surplus generated by Y. When my choice of occupation is between being a rock star and filling tanks at the gas pump, all that is needed is my gas attendant salary plus epsilon to convince me to choose rock-stardom.

This observation suggests that it is “marginal” discoveries – or, “marginal” innovators – for which the social surplus only barely exceeds the fixed cost of creation that require a high degree of appropriability to guarantee they are produced.[4] Moreover, leaving aside the Bertrand case, we might expect the "free" market to produce more competition over goods for which social surplus is great than over those for which social surplus is small. That is, for a given ability to extract a share of social surplus, and a given fixed cost of entry, we would expect more entry – and more competition – over "high quality" discoveries. In other words, while government guarantees of monopoly treat marginal and high quality discoveries alike – or, since the rich have better access to government favors, favor the high quality over the marginal quality – competition by its nature is more generous to the marginal discoverer. And the marginal discoverer is the one whom, when aiming at social efficiency, we most need to encourage. Our goal here is to highlight – in a simple example – the latter point by illustrating how competition is less fierce for "low quality" discoveries than for "high quality" discoveries, and consequently how the artificial legal constraint of intellectual property may simply reduce the usefulness of innovations without actually encouraging creation. [5]

2. The Model

For computational simplicity we assume there is a single good to be created and that demand for that good is linear. If q is the quantity (the number of copies) of the good consumed, we imagine that the margin between price and (the constant) marginal cost of making copies for creator and imitators alike is given by $p = 2v(1-q)$, where $v > 0$ is the social value of the discovery.[6] To make the discovery, the innovator must pay a fixed cost of AF, where $A \geq 1$ is a constant. Imitators or copiers, by way of contrast, must pay only F in order to reverse engineer the discovery and enter the market.[7]

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[4] The crucial role of marginal innovation is also recognized by Pollack [2008a,b] who uses a Stackelberg model of entry and zero fixed cost of imitation to analyze the amount of innovation that will occur without intellectual property and the differential impact of IP across industries. Pollack places particular emphasis on the important point that the marginal innovation is the one that is the least socially costly if it does not take place.

[5] In the model, not only may overall efficiency be reduced by intellectual property due to the fact that all innovations are less useful – but, as we show, in the presence of legal costs, the total amount of innovation is not increased.

[6] That is to say, linear demand with constant marginal cost.

[7] Note that, as is usual in this literature, we consider only the single alternative: innovate or do not innovate. Of course, in practice there can be choice of innovation types or levels and this decision may be affected by the presence or not of intellectual property.

We consider a simple model of Cournot competition.[8] The rationale behind this choice is that of Kreps and Scheinkman [1983] – firms must choose capacity before entering the market and competing over prices. The timing in the market is as follows. First, the creator decides whether or not to innovate. If the creator innovates, she then produces an initial run of q_0 units of output. Before this output can hit the market, but after it is know to them, imitators – of which potentially there are an unlimited number – choose whether or not to enter, with the representative imitator producing $\overline{q}$ units of output. If there are N imitators, the profit of the original creator is

$$2v(1-q_0-N\overline{q})q_0-AF$$

while an imitator who chooses to produce q_i receives a profit of

$$2v(1-q_0-(N-1)\overline{q}-q_i)q_i-F\,.$$

Our notion of equilibrium in this model is that of symmetric subgame perfect equilibrium. Given the number of entrants N, the individual imitators who have entered must optimally choose the identical output level $\overline{q}$. Given the initial production run by the innovator, q_0 and the dependence of $\overline{q}$ on N, the decision of imitators to enter must be optimal. That is, N must be chosen so that imitators' profit is non-negative, and so that any larger number of entrants $N' > N$ yields negative profits. As a computational aid, we will allow N to take on non-integer values, and (since $\overline{q}$ is well defined in this case), calculate the equilibrium number of imitators to be that unique number that leads to zero profit. Finally, given all of this, the creator decides to create only if it is possible to earn a non-negative profit, and must choose q_0 optimally, given that the number of imitators and their output will follow the equilibrium response.

3. Solving the Model

As the equilibrium we are interested in is the subgame perfect one, we should solve the model by backwards induction.

Theorem 1*: Industry output is given by*

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[8] Maurer and Scotchmer [2002] use a similar model albeit to study the commitment consequences of licensing rather than the role of the marginal innovator. Here commitment takes place through the choice of scale by the innovator. Because we are interested in the marginal innovator, we consider a continuum of values v, rather than the simple success/failure setup in Maurer and Scotchmer.

$$q = \max\left\{\frac{1}{2}, 1 - \sqrt{\frac{F}{2v}}\right\} < 1$$

If $v \le 2F$ *then the innovator preempts the market by setting* $q_0 = 1/2$*, earns monopoly profit margin of* v *and a total profit of* $v/2$*. If* $v \le 2F$ *the "marginal innovative firm" is given by* $v^{\pi} = (1+A)^2 F/2$*; creators with higher values enter, and those with lower values stay out.*

Proof: Start with the final stage in which there are N entrants. To find the output of the representative imitator, we compute the usual Cournot first order condition for the output $\overline{q}$ of the representative imitator and solve it to find the condition for zero imitator's profits

$$N\overline{q} = 1 - q_0 - \sqrt{\frac{F}{2v}}.$$

This condition determines total imitator output as a function of innovator output. Note that $1 - q_0 > \sqrt{F/2v}$ is required to guarantee that there is entry with positive output produced.

Total industry output then adds in the output of the innovator, q_0, giving

$$q = 1 - \sqrt{\frac{F}{2v}}$$

provided that this is greater than the monopoly output of ½. Otherwise, it would be optimal for the creator to produce enough to bring industry output up to ½ and remain a monopolist. This establishes the first result.

When total industry output is at least ½ , we conclude that the unit profit margin in the industry is

$$\sqrt{2vF}\ .$$

If the innovator wishes to enter, it is optimal to preempt imitators by producing the entire market output,[9] giving a profit to the innovator of

[9] Of course, in practice there is some imitation, especially as time elapses, even if the innovator enters the market with the Cournot equilibrium level of output. There are a variety of reasons for this, including the ability of imitators to either make improvements or producing lower quality versions, and uncertainty about imitators true costs. Adding to the model imitators who go for these segments scarcely enhances, and may even weaken, the case for intellectual property.

$$\sqrt{2Fv}\left(1-\sqrt{\frac{F}{2v}}\right)-AF$$

Solving for zero innovator's profit yields the solution for the "marginal innovative firm".

Finally, if $v \leq 2F$ then the target industry output would be below ½. This means that the innovator preempts the market by setting $q_0 = 1/2$, earns monopoly profit margin of v and a total profit of $v/2$. Since this profit is less than or equal to F it is certainly less than AF, so the innovator would not choose to enter in this case. From this we conclude that, under Cournot competition, the active firms are always and only those with $v > 2AF$, as implied by our definition of v^π.

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4. Welfare Analysis

We now examine welfare under both Cournot competition, as described above, and the case in which there is the possibility of obtaining a government monopoly.

Consider the social planner after the fixed cost of innovating has been sunk. Then optimal output is $q^*=1$, corresponding to $p=0$ and, excluding fixed cost, to a social surplus W of v. By way of contrast

Theorem 2: *Equilibrium welfare is given by*

$$W = v - \frac{F}{2}$$

Proof: By Theorem 1

$$q = \max\left\{\frac{1}{2}, 1-\sqrt{\frac{F}{2v}}\right\} < 1$$

hence social surplus is always less than v, but increasing in the latter. More precisely, social surplus at the equilibrium output is the integral under the demand curve (net of marginal cost) between 0 and $1-\sqrt{F/2v}$, as computed above.

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In particular, when $v \to \infty$ the innovation will always take place as $v \geq v^\pi = (1+A)^2 F/2$, and the fraction of social surplus recovered by the simple Cournot-competitive mechanism approaches one. That is to say: for each good that is worth innovating, the social planner would choose an output of $q^*=1$, while the

Cournot-competitive mechanism chooses an output of $1-\sqrt{F/2v}$, which converges to 1 as v grows. Hence, innovations with high social value not only are always implemented in the absence of intellectual property, but most of their potential surplus is appropriated by society through the Cournot-competitive mechanism.

Does this "competitive solution" always yield full social efficiency? No, it does not, as the innovator and her imitators are "collective" monopolists in the equilibrium of the Cournot game we have set them to play, hence they restrict output below the socially efficient value of $q^*=1$. Inefficiency here arises from the well-understood market power of Cournot duopolists, and is not due to the monopoly power that intellectual property bestows upon the original innovator. Indeed, had we assumed the original innovator is assigned such legal right, she would be a sole monopolist and always supply just ½ units of output, thereby engendering an even larger social inefficiency than under the Cournot competition that the lack of intellectual property induces instead.

It is useful also to examine the degree of appropriability by the innovator, that is the ratio of profits (gross, before fixed costs) obtained under the Cournot mechanism versus the total social surplus obtainable.

$$\phi(v) = \frac{\sqrt{2Fv} - F}{v}.$$

We can differentiate to find

$$\phi'(v) = \frac{F - \sqrt{1/2}\sqrt{Fv}}{v^2}$$

This is negative if

$$\sqrt{\frac{F}{v}} < \sqrt{1/2}.$$

Because, $v > 2F$ is necessary if there is to be innovation, the degree of appropriability by the innovator decreases as the social surplus of the innovation increases. In other words, the "full appropriability by innovator" condition becomes less and less necessary for creation to take place as the innovation being considered moves away from the marginal one.

By way of contrast, and to clarify our earlier statement, suppose that the innovator is shielded from competition by a legal monopoly. Then the monopolist's profit is $v/2$.

The marginal innovating firm, indifferent to entry and innovating or staying out, is $v^m = 2AF$. The social surplus generated by monopoly is $(3/4)v$. In particular, monopoly always yields ¾ of the social surplus, regardless of how valuable the innovation is. That is, as $v \to \infty$ the regime without intellectual property does approximately 33% better than the one with intellectual property, and the absolute size of the social loss grows without bound. Under which regime is there more innovation? Everything else equal, under legal monopoly all innovations better than $2AF$ are implemented, while under (Cournot) competition only those better than $(1+A)^2 F/2$ are. Because $(1+A)^2 > 4A$ for $A > 1$ there are always more innovations under legal monopoly, as would be expected. But this need not translate into more social surplus as what is gained by having more innovations may be compensated, or more than compensated when v increases, by the under supply of copies of the new good. Finally, while under competition, appropriability drops as the value of the innovation increases, under monopoly it remains fixed at $1/2$.

Next consider the case that is likely to arise in practice, where legal monopoly can only be obtained at a cost. Suppose in particular that an additional fixed cost of bF is required to obtain a monopoly from government. This might, for example, represent the cost of hiring lawyers to enforce a copyright or patent claim. Under legal monopoly, profits exceed those under Cournot competition by $v/2 - \sqrt{2vF} + F$, so it is worth the additional fixed cost if

$$v/2 - \sqrt{2vF} + F - bF \geq 0 .$$

What then is the marginal firm willing to invest in a legal monopoly? It is given by

$$v^M = 2F\left(1 + \sqrt{b}\right)^2 .$$

How is v^M related to v^π, the marginal firm that will produce under competition? We see that $v^M > v^\pi$ if $4b > (A-1)^2$. When this is the case, the marginal firm in the market will actually not choose to use intellectual property to maximize its profits, and a grant of monopoly such as copyright will not help her: it serves merely to enrich the inframarginal ones.

5. Uncertain Success

So far we have examined the case in which the demand for a new product is common knowledge among both creator and imitators. In practice, it is often argued that there is uncertainty about the market value of a given innovation and that innovators must pay the initial fixed cost under conditions of uncertainty. Imitators, on the other hand, can wait to see if an innovation is a success or failure before deciding whether or not to imitate. Here we begin addressing this issue by positing that at the time the initial creation decision is made – at the time AF must be committed – the social value v is uncertain and is drawn from a commonly known distribution. After the innovation takes place, but before the decision to imitate and pay F is undertaken, both the innovator and the imitators learn the true value of v. Our goal is to study the extent to which shifts in the distribution of v affect appropriation.

Specifically, we suppose that v is drawn from a common knowledge cumulative distribution function G. The specific value of v is unknown prior to invention, and is learned by both the inventor and imitators after the innovation takes place but before the imitation decision is taken. Notice that whatever the value of v that is drawn (provided it is non-negative) the inventor will always choose to enter, whereas the imitator may decide to stay out once uncertainty is resolved. That is, in our example of symmetric Cournot imitation and linear demand where v is known with certainty, the inventor only produces if $v \geq v^{\pi} = (1+A)^2 F/2$. *Ex post* after the fixed cost AF has been paid, however, it is a sunk cost, and the inventor should produce as long as $v \geq 0$.

We can summarize the situation by means of a private appropriation function

$$g(v) = \begin{cases} v/2 & v \leq 2F \\ \sqrt{2Fv} - F & v \geq 2F \end{cases}.$$

representing the private value obtained by innovators for a given realization of the social value. We are interested in the degree of expected appropriability, as measured by

$$\Phi_G = \frac{\int g(v)dG(v)}{\int v dG(v)}.$$

If

$$\int g(v)dG(v) - AF \geq 0$$

then the (risk neutral) inventor will choose to innovate. Our goal is to examine whether more marginal innovations – as measured by a G that places greater weight on smaller values of v – in fact have the desirable property of having greater appropriability. That is, our interest is in whether Φ is decreasing as G shifts to the right.

At this point we will drop the special assumption of Cournot competition and linear demand, and examine more general appropriation functions that are compatible with other market arrangements and, in particular, with the presence of positive external effects from innovation. We assume that $g(v)$ is strictly increasing, so that if there is more social value, there is greater private value; that $g(v) \leq v$ so that it is not possible to appropriate more than the total social value (this excludes sizeable negative externalities), that $g(v) \geq 0$ so that the innovator never loses money by choosing to enter and, finally, that $g(v)$ is concave. Note that all the properties are satisfied in the linear-Cournot example. Moreover, we can show that the concavity of $g(v)$ implies non-increasing appropriability when there is no uncertainty. Specifically, in the case of certainty, appropriability is defined as

$$\phi(v) = \frac{g(v)}{v}.$$

Noting that a concave function is continuously differentiable except on a discrete set, we can differentiate with respect to v we get

$$D\phi = \frac{g'(v)v - g(v)}{v^2} = \frac{g'(v)v - g'(v')v}{v^2}$$

where by the mean value theorem $0 < v' < v$. Since $g(v)$ is concave $g'(v') \geq g'(v)$, so indeed $D\phi \leq 0$.

We are interested in the extent to which this result generalizes for non-degenerate distributions of social value G. A natural conjecture is that if H first order stochastically dominates G then $\Phi_H \leq \Phi_G$. It turns out that this is not always the case. We can build intuition by first considering the case where G places weight on only two points: the innovation is either a success yielding v_1 with probability π, or a failure yielding v_0 with probability $1-\pi$. Appropriability is then given by

$$\Phi_G = \frac{(1-\pi)g(v_0) + \pi g(v_1)}{(1-\pi)v_0 + \pi v_1}.$$

Start with the special case in which $v_0 = 0$, so a failure results in no profit at all. Since we have assumed $0 \le g(v) \le v$, this implies as well that $g(v_0) = 0$, so

$$\Phi_G = \frac{g(v_1)}{v_1}.$$

In this case if the distribution G shifts to the right by increasing the probability of success π, then appropriability does not change. If the distribution of G shifts to the right by increasing the benefit of success v_1, then appropriability falls.

Consider next the case in which $v_0 > 0$, with $v_0 > g(v_0) \ge 0$, and profitability improves because the probability of the good outcome increases, that is, π increases. Then we compute

$$D_\pi \Phi_G = \frac{[g(v_1) - g(v_0)][(1-\pi)v_0 + \pi v_1] - (v_1 - v_0)[\pi g(v_1) + (1-\pi)g(v_0)]}{[(1-\pi)v_0 + \pi v_1]^2} = \\ = \frac{v_0 g(v_1) - g(v_0)v_1}{[(1-\pi)v_0 + \pi v_1]^2} \le 0, \text{ because } \frac{g(v_1)}{v_1} \le \frac{g(v_0)}{v_0}.$$

In other words, when failure is worth something, increasing the probability of success reduces appropriability. This fits the initial intuition.

On the other hand, we can use the simple two point case to show that stochastic dominance alone is not enough to keep appropriability from rising. Specifically, suppose that v_0 increases – we refer to this as “improving the dogs,” that is improving the profitability of a poor result. Then

$$D_{v_0}\Phi = \frac{1-\pi}{((1-\pi)v_0 + \pi v_1)^2}[g'(v_0)((1-\pi)v_0 + \pi v_1) - (1-\pi)g(v_0) - \pi g(v_1)].$$

The sign of $D_{v_0}\Phi$ is then the sign of

$$g'(v_0)((1-\pi)v_0 + \pi v_1) - (1-\pi)g(v_0) - \pi g(v_1),$$

that is the sign of

$$\pi\{g'(v_0)(v_1 - v_0) - [g(v_1) - g(v_0)]\} + [g'(v_0)v_0 - g(v_0)].$$

This can go either way. Concavity implies the term in curly brackets is positive but it also implies the second is negative because $g(0) = 0$. Hence, for small values of π the overall expression is negative. On the other hand, if, as is true for the linear Cournot model, $g(v)/v \to 0$ as $v \to \infty$, then for sufficiently large v_1 and values of π near one, $D_{v_0}\Phi$

will be positive. Improving the dogs, in other words, may increase rather than decrease appropriability, although it does generate stochastic dominance.

From the two-point case, we have the intuition that it is increasing the social value at the upper bound or its probability that decreases appropriability, whereas appropriability may increase when the value of the worst innovations improves. Before proving a result in this direction, we observe that increasing risk (increasing the dispersion in the social value of innovations) lowers appropriability.

Theorem 3: *If* H *is a mean preserving spread of* G *then* $\Phi_H \leq \Phi_G$.

Proof: Follows directly from the definition

$$\Phi = \frac{\int g(v)dG(v)}{\int vdG(v)}$$

When we switch to H since the spread is mean-preserving, the denominator does not change, while the numerator decreases because g is concave.

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We can then prove the following rather crude result concerning decreasing appropriability as social value increases. Define $\max_G v$ to be the essential maximum – that is the largest value in the support of G.

Theorem 4: *Suppose that* $E_H v > \max_G v$ *and that* $g(v)$ *is not linear on* $[\max_G v, E_H v]$. *Then* $\Phi_H < \Phi_G$.

Proof: We already showed that $g(v)/v$ is non-increasing. Let $\overline{v} = \max_G v$. Hence for $v < \overline{v}$ we have $g(v)/v \geq g(\overline{v})/\overline{v}$. It follows that

$$\int \frac{g(v)}{v}\overline{v}vdG(v) \geq \int \frac{g(\overline{v})}{\overline{v}} v\overline{v}dG(v).$$

Rearranging gives

$$\Phi_G = \frac{\int g(v)dG(v)}{\int vdG(v)} \geq \frac{g(\overline{v})}{\overline{v}}.$$

Finally, we observe that under our hypothesis $g(E_H v)/E_H v < g(\overline{v})/\overline{v}$. Since H is a mean preserving spread of the point mass at E_H we may apply Theorem 1 to get the desired result.

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6. Which Case is Empirically Relevant?

So, in practice, does a shift towards higher *ex ante* social value tend to increase or decrease appropriability, in a general competitive setting?

Two industries which are notorious for having a great deal of *ex ante* uncertainty are the film industry and the pharmaceutical industry. Here we examine data from the film industry, as there is a reasonable and reasonably available measure of both *ex ante* expected social value and *ex post* social value. First observe that because of copyright, the film industry effectively operates under monopoly, not competition. Consequently, according to our model, the industry should capture a constant fraction of social value independent of how great that social value is. So we can use observed profits as a proxy for social value. We then pose the question: if the industry were instead to operate under competition, would appropriability be increasing or decreasing with social value?

Our measure of *ex ante* expected social value is the budget (BUDGET) of the film. The budget is front money provided by investors and, because of the way the industry works, it does not represent the social cost of production but rather represents the belief of the investors as to the expected return on the film. In fact, as we discuss below, much of the budget goes to rents above opportunity costs for such factors of production as big movie stars and directors. Our measure of *ex post* social value is the U.S. box office gross of the film (REVENUE).

Does the budget measure *ex ante* expected social value? First, we investigate whether the budget is in fact a measure of expected box office gross. We attack this problem in several different ways. We use an OLS regression to see if the expected value of REVENUE is indeed equal to BUDGET. Then we use data on sequels to successful films to argue that a substantial portion of BUDGET includes monopolistic rents.

Examining an OLS regression of revenues on budget (in millions) for 2,204 films we see that

REVENUE = 12.59 + 1.082 * BUDGET ($R^2 = 0.3183$)
(1.488) (.00371)

where standard errors are in parenthesis. Note that the high intercept term indicates that small budget films have higher rates of return than large budget films. The most likely explanation of this is sample selection bias: high budget films are far more likely to have data on revenue and budget available. Low budget films are likely to be reported only if they are successful, otherwise they tend to disappear from the radar. Note that the high intercept is not due to large budget films earning more overseas than small budget films: if we examine the observations for which both U.S. and World Grosses are available, we find that the ratio of World to U.S. declines slightly with the size of the budget. It may be, however, that other forms of revenue, DVD sales and merchandising, are relatively more important for large budget films. In any case, this regression suggests that budgets are a pretty good measure of ex-ante expected revenues.

To further examine the extent to which the “budget” of a film might reflect the social cost of making the film consider that in general intellectual property allows scarce factors such as the big stars and great directors to command a portion of the monopolistic rents. These rents appear to be substantial, leading to a total cost that is greatly higher than the opportunity cost, so that this component of the budget does not reflect social cost. Of course larger budget films generally do involve higher costs such as more elaborate sets and more expensive locations, which do reflect social cost.

One way to examine our claim would be by comparing current salaries for stars to those of stars in the early years of film, when movie stars were probably scarcer but monopoly rents were certainly smaller because IP protection was weaker and the market size was an order of magnitude smaller than it currently is. It is hard to argue that such great actors as Charles Chaplin or Humphrey Bogart were in some way inferior to current stars. Such data not being available, though, one must get by with the impressionistic fact that monopolistic rents accruing to stars have increased ten-fold while their social (opportunity) cost decreased somewhat. However, a more direct method to quantify the relevance of monopolistic rents in the appropriation rate of movies is to examine the budgets of sequels to successful films.

Date	Film	Producer	Budget	US Gross	World Gross
6/23/89	Batman	Warner Bros.	$35M	$251M	$413M
6/19/92	Batman Returns	Warner Bros.	$80M	$162M	$282M
5/25/77	Star Wars	20th Century Fox	$11M	$460M	$797M
5/21/80	Empire Strikes Back	20th Century Fox	$23M	$290M	$534M
7/14/99	Blair Witch Project	Artisan	$.035M	$140M	$248M
10/27/00	Book of Shadows: Blair Witch 2	Artisan	$15M	$26M	$47M
9/26/86	Crocodile Dundee	Paramount	$5M	$174M	$328M
4/20/01	Crocodile Dundee in Los Angeles	Paramount	$25M	$25M	$39M
6/20/75	Jaws	Universal	$12M	$260M	$470M
6/16/78	Jaws 2	Universal	$20M	$102M	$208M
3/21/80	Mad Max	Filmways	$.2M	$8M	$99M
5/21/82	Mad Max 2	Warner Bros.	$2M	$24M	Unknown

The key fact is that the budget for a sequel is much higher – generally double or more – the budget of the original – although the revenues are generally less. There is no reason a sequel should require a greater social cost, so we take this as evidence that the budget reflects primarily rents to the scarce factors: the stars, directors and owners of the rights to the original.

Appropriability and ex ante uncertainty: Can we apply Theorem 4 to the film industry and conclude that higher budget films yield both higher social surplus and, in the absence of IP, would command less appropriability? The striking fact about the film data is that despite the importance of several low budget high revenue outliers – the *Blair Witch Project* is the extreme example having a budget of only $35,000 and a U.S. Box Office of $140,539,099 – we can nevertheless apply Theorem 4. In particular, no film with a budget of less than $1.488 million[10] (213 movies in the sample) ever earned revenues equal to the average revenue of films with budgets of $142-160 million – these films on average earned $149,916,667. In other words, large budget films do not simply increase the revenues relative to small budget films, but they increase the probability and value of success as well. This means that, were movies not covered by the legal monopoly of copyright as they are, decreasing appropriability would emerge under Cournot-competition. This is reinforced by an examination of the revenues earned by the top 10% within each budget category. In the $1.8-2.1 million budget category the top 10% earned on average $26.5 million; in the $10 million budget category, the top 10% earned on average $74.6 million; while in the $90-110 million budget category, the top 10% earned $327 million.

Recall why decreasing appropriability is relevant in our context: it signals that approximate, or asymptotic, efficiency can be obtained under conditions of competition and that the full-appropriation requirement, while sufficient, is certainly not necessary. The data suggests that our assumptions are likely to be satisfied in the movie industry.

7. Conclusions

Appropriability of social surplus being at the core of the private incentives to innovate, one is naturally interested in the relation between degree of appropriability and efficiency under different market arrangements. Motivated by the work of Ostroy and Makowski, we study the relation between degree of appropriability and social value of innovation in a model with free entry and imitation in which the innovator and her competitors compete a-la Cournot. We derive the conditions under which the Cournot allocation is socially more efficient than the one that obtains when the innovator holds a legal monopoly.

We also examine uncertainty about the social value of innovation. When there is no uncertainty the degree of appropriability decreases with the value of the innovation. When the social value is uncertain for the innovator, but revealed to imitators before they decide to enter or not, appropriability may not necessarily decrease with the value of innovation, at least for general distributions of the uncertain value of the innovation. In particular, when the expected value of the innovation increases because either the

[10] The budget of *Snow White*.

probability or the size of the “good” outcomes increases, appropriability decreases. The opposite occurs when the expected value increases because the bad outcomes improve.

In general a mean-preserving increase in risk lowers appropriability. We use this fact to derive conditions under which a general competitive appropriability function is decreasing in the (expected) social value of the innovation. We then examine data from Hollywood movies: despite the notorious *ex ante* uncertainty about the success of films, we show that even in this industry the conditions for decreasing appropriability with increased social value is satisfied.

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