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Julio R. Robledo

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Julio R. Robledo*

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Abstract

This paper shows that "wasteful" litigation about intellectual property may be welfare enhancing. The aim of an intellectual property protection system is to solve the trade-off between ex-ante innovation incentive and ex-post monopoly welfare loss. The litigation about intellectual property in court decreases the expected rent from intellectual property, therefore reducing the incentive to innovate in the first place leading to a negative effect on social welfare. Yet the legal contest may have the positive welfare effect of breaking the monopoly and allowing an entrant into the market, thus lowering prices and reducing the welfare loss of monopoly. If the welfare effect of increasing competition outweighs the first effect of reduced research, a litigation contest is welfare increasing.

Keywords: Litigation, R&D Spending, Innovation, Contests

JEL Classification: K41, L13, O34

*Department of Economics, University of Vienna, Hohenstaufengasse 9, 1010 Vienna, Austria, e-mail: julio.robledo@univie.ac.at .

1 Introduction

The protection of intellectual property (IP) [1] aims to solve the trade-off between providing innovation incentives ex ante and maximizing social welfare ex post. The innovator needs to have an incentive to research in the first place. But ex post and from an efficiency point of view, once the innovation is found, the public good character of knowledge requires that the dissemination of knowledge is made possible for free. Since the seminal contribution of Nordhaus (1972), many papers have searched for the "optimal" patent, where optimal refers to the optimal mix of "patent length" and "patent breadth" for a given socially optimal rate of innovation. The results depend heavily on the market structure and model assumptions. In the homogenous good model of Gilbert and Shapiro (1990), a patent with narrow breadth and infinite length is optimal, while the location model of Klemperer (1990) may call for short patents with maximal breadth. Although the approach of Denicolo (1996) encompasses and generalizes the previously cited works, there is yet no valid general result regarding the optimal protection of intellectual property.

Therefore it is not surprising that the existing systems of incentives and protection regarding intellectual property are not optimal. In reality, the protection of intellectual property means not only registering for a patent or owning a copyright, but mainly defending and enforcing this intellectual property in court.[2] The present paper shows how litigation, usually assumed to be a waste of resources, may be welfare enhancing by optimizing the trade-off between innovating incentives and monopoly welfare losses. Litigation itself is a fact difficult to explain from an economic perspec-

[1] Intellectual property (IP) embraces patent and copyright protection, trade secrets and other less important protection regimes for innovative and creative processes, see Scotchmer (2004), Chapter 3. Our analysis is more general and does not depend on a specific protection regime, although in the following we will use in most cases the patent regime as the most important system of IP protection. Besides, the first contributions were all concerned with patent protection. From a theoretical point of view, the results apply to copyright, too.

[2] See Scotchmer (2004), Chapter 7.

tive. Why do economic agents go to court, when they can settle the dispute at a lower (expected) cost? Although many cases are settled out of court, there are still many disputes that actually reach the courts.[3]

Asymmetric information and/or asymmetric beliefs about the merits of the legal case play an important role. In the legal praxis, a big part of the litigation costs belongs to the category of fact finding concerning the case. Even after considering possible asymmetries, which should diminish as the parties gather information about the case and update their success beliefs, many important cases are litigated in court. Intellectual property, which is by definition an intangible asset, is a right where information and beliefs may matter more than in other situations, leading to increased litigation, because every party believes in its own right.

Consider as an example the case of the drug Viagra. Its inventor Pfizer found out during clinical trials that the chemical substance Sildenafil, originally aimed to be a therapy for heart disease, had a noticeable side effect as a treatment for erectile dysfunction (Stone and Darlington, 2000). Once Viagra hit the market and due to its blockbuster success (it helped Pfizer to become the world's top pharmaceutical company in terms of market capitalization), competitors rushed to develop similar drugs: Levitra (made by Bayer and GlaxoSmithKline) and Cialis (made by Eli Lilly and ICOS). Pfizer engaged in litigation with both rival products suing for patent infringement. Eventually, first in Europe and then in the US, the rival drugs were allowed into the market leading to lower prices and market sharing among the competing products. [4]

The copyright on software often leads to litigation. In the 1990s, Lotus spreadsheet application 1-2-3 was the market leader. Borland's Quattro application entered the market and in order to make the users' application switch more comfortable, copied

[3]Statistics of the proportion of cases that are settled out of court are notoriously difficult to obtain, because by definition those cases do not reach the courts.

[4]We assume here implicitly that the existence of such drugs is a welfare increase, since consumer behaviour shows there is a high willingness to pay for them.

Lotus 1-2-3's menu commands, menu structure, etc. This prompted Lotus to sue Borland for copyright infringement in 1990. The Supreme Court ruled five years later in Borland's favor. Ironically, by the mid-1990s, the outcome of the litigation battle no longer mattered. While Lotus and Borland were busy fighting each other at the courts, Microsoft conquered the Windows spreadsheet market with its Excel application.

There are several contributions in the literature on litigation about intellectual property. Lerner (1994) studies biotechnology patents and estimates that on average 6% of patents are litigated. Lanjouw and Schankerman (2001) combine data from the US Patent and Trademark Office with data from US courts and find that patent litigation is heterogenous and varies widely by industry and by firm size. It is concentrated in high-value patents and occurs more often in industries with advanced technology. Individual patent owners are more likely to be sued for patent infringement than corporate patent owners. There are, to my knowledge, no similar studies about copyright litigation.

This paper focuses on the strategic effect of litigation on the innovation process itself: How does the possibility of litigation affect the creative effort and the social welfare? Since the innovation's private value is smaller than its social value, the patent protection system reduce the incentive to innovate, when compared to the socially efficient level of research investment. Additionally, the present IP protection system results in a (temporary) monopoly which generates a deadweight welfare loss.

The aim of our analysis is to allow for the possibility that a patent may be contested in court. Waterson (1990) considers the effect of possible court action on an innovator's patenting decision and on a potential rival's entry decision, without modeling the litigation process explicitly. We concentrate on this litigation process and model the legal dispute as a contest following Farmer and Pecorino (1999). Baye et al. (2005) employ an auction theoretic approach to analyze litigation disputes, and a contest is a special case of an all-pay-auction.[5] We use a contest to model the legal dispute, and not to model the patent race as most of the patent literature does.[6] The innovation process is modeled in a concise way to focus on its uncertain outcome where only the probability of innovation success plays a role, and not the time path of research investment and innovation success.

It turns out that the legal dispute has two effects. In the first place, the litigation contest reduces the potential innovation (monopoly) rent of the researching firm, thus deviating further from the socially efficient research investment level. This reduces social welfare. But the litigation, if the plaintiff prevails, breaks the innovator's monopoly on the new product and allows a new entrant into the market. This lowers prices and increases quantities, thus increasing social welfare. There are situations where the second, competition increasing effect dominates the effect of reduced research expenditures. A litigation contest where resources are "wasted" in principle is then welfare enhancing. This effect is counterintuitive to most of the contest literature, where contest effort is usually associated with waste.[7]

There are some other examples in the literature where contests have a positive effect on social welfare. Kolmar and Wagener (2005) combine a contest with a game of private provision of public goods to achieve under certain conditions an efficient equilibrium with no underprovision of the public good. Shavell and van Ypersele (2001) show that innovation rewards may be superior to intellectual property rights. Maurer and Scotchmer (2003) survey different alternatives to intellectual property including innovation prizes and government grants. They argue that there is no universal single best mechanism for setting innovation incentives. Our aim is to continue in this direction: since there is no optimal system of setting research incentives, the

[5]See Cooter and Rubinfeld (1989) for a survey of the economics of legal disputes.

[6]See Reinganum (1989) for a survey on innovation race models.

[7]Actually, Tullock (1980), in his seminal contribution on contests, was concerned with the rate of "dissipation", that is the rate of which the value of the contest prize is wiped out by the sum of the efforts of all contestants.

present IP protection system may be improved upon, e. g. by allowing a litigation contest among innovating firms.

We proceed as follows. The next section sketches the time structure of our game. Section 3 presents the concise model of the R&D process. The litigation contest is presented in Section 4. Section 5 analyzes the welfare effects of innovation and litigation. A numerical example is presented in Section 6. Section 7 concludes.

2 The structure of the game

Our game has the following structure with four stages:

1. In the first stage, a firm invests in R&D and possibly finds a new product, for which there is a (net) positive willingness to pay. If the research process is not successful, the game ends here.

2. If the firm comes out with a new and valuable innovation, the successful innovator will register for a patent to recover his R&D costs from the resulting monopoly rent.

3. Once the patent is registered, the innovation is common knowledge. A second firm challenges the validity of the patent in court and both firms, innovator and challenger, engage in a litigation contest.

4. Depending on the outcome of the litigation dispute, the new product is produced by the innovative monopolist or by both firms as Cournot duopolists in quantities.

When solving this game, we will concentrate on Stage 1, the "R&D process", and Stage 3, the "litigation contest". Stage 2 simply describes the patent registration and the outcomes of the monopoly and duopoly situations in Stage 4 are well known from the literature.

3 The R&D process

Analysis of patent races often assume a Poisson innovation process, early works are Loury (1979), Lee and Wilde (1980) and Dasgupta and Stiglitz (1980). Since our interest is in the research expenditure level and not in the time path of the research investment, we assume that all research costs are incurred at time zero with no subsequent costs. Research generates a new product with a positive innovation success probability, as in Gilbert and Newbery (1984) and Shavell and van Ypersele (2001).

Suppose there is a risk neutral firm spending an amount k on research to find a new product, say, a new medicine or a new consumer product.[8] The probability of the firm's innovation success is given by $p(k)$, where we plausibly assume that $p'(k) > 0$ and $p''(k) < 0$, e. g., the more the firm invests in research, the higher the probability of finding a new invention, but with diminishing increases. Once an innovation is found, it can be produced with constant returns to scale at a unit cost of production given by c.

Let q be the quantity of the new product. The willingness-to-pay is given by the inverse demand curve $d(q)$ with $d'(q) < 0$. The social surplus $S(q)$ is then given by[9]

$$S(q) = \int_0^q (d(\tilde{q}) - c) d\tilde{q}. \tag{1}$$

Let $S^* = S(q^*)$ be the maximum social surplus for the first best quantity q^*. Social welfare W is the expected value of the innovation minus production costs (as given by the expected social surplus) minus research investment:

$$W = p(k)S^* - k \tag{2}$$

To avoid the trivial case where the innovation is not worthwhile, assume further that the unit cost is low enough (alternatively, that demand is high enough) such that at

[8]The model can be adapted with slight modifications to cover the invention of a new production process.

[9]For the sake of simplicity, we use the Marshallian social surplus as welfare measure, although we are aware of the theoretical shortcomings of this measure.

$q = 0$, producing a unit of q increases social welfare. The first best investment level k^* is the investment level that maximizes the social welfare (2) and is implicitly defined by the first order condition (FOC)

$$p'(k)S^* = 1. \tag{3}$$

The left hand side gives the marginal increase in social welfare from an additional unit of investment, while the right hand side reflects the marginal cost of this additional unit of investment. Equation (3) defines an investment level depending on the social surplus S^*: $k(S^*)$. Implicit differentiation of (3) leads to

$$k'(S) = \frac{-p'(k)}{S \cdot p''(k)} > 0. \tag{4}$$

Thus, research investment k is increasing in social surplus: the greater the surplus S, the higher k. For the first best social surplus S^* and investment level k^*, we obtain the first best social welfare W^*

$$W^* = p(k(S^*))S^* - k(S^*). \tag{5}$$

Suppose now that the firm is able to patent the innovation.[10] The firm enjoys a temporary monopoly on the invention. Let d_m denote the quantity chosen by the profit maximizing monopolist firm and Π_m the resulting monopoly profit. The innovator chooses his research investment level to maximize his expected payoff

$$p(k)\Pi_m - k \tag{6}$$

which leads to the first order condition

$$p'(k_m)\Pi_m = 1, \tag{7}$$

[10]For the sake of simplicity and without loss of generality, we assume that the patent registration is costless. According to Barton (2000), lawyer's costs to obtain a patent approach \$10,000, while the median cost of patent litigation is estimated to be \$1.5 million. Assuming a small registration cost does not change our qualitative results and requires only a slight modification of the model. Patent registration costs are quite small in absolute terms and extremely small in relative terms when compared to the value of the potential monopoly rent associated to the patent.

where k_m is the profit maximizing research expenditures implicitly defined by condition (7). Since $\Pi_m < S^*$, by comparing the first order conditions (3) and (7) we obtain $p'(k_m) > p'(k^*)$. Thus, by the diminishing marginal probability returns of research, under a patent regime the firm invests too little in R&D from a social perspective:

$$k_m < k^*. \tag{8}$$

The monopolist's output q_m is smaller than the socially efficient output q^*, $q_m < q^*$. This leads to the well known monopoly deadweight welfare loss DWL_m:

$$DWL_m = \int_{q_m}^{q^*} (d(\tilde{q}) - c) d\tilde{q} > 0. \tag{9}$$

The social welfare under the patent regime is

$$W_m = p(k(\Pi_m))[S^* - DWL_m] - k(\Pi_m). \tag{10}$$

Since the monopolistic firm both produces and researches too little from an efficiency perspective, social welfare under the patent regime is lower than the first best social welfare:

$$\begin{aligned} W^* - W_m &= p(k^*)S^* - k^* - p(k_m)[S^* - DWL_m] - k_m \\ &= [(p(k^*)S^* - k^*) - (p(k_m)S^* - k_m)] + [p(k_m)DWL_m] > 0. \end{aligned} \tag{11}$$

The welfare loss can be decomposed into two effects. The first bracketed term in (8) is the welfare loss due to suboptimal research activity of the firm, whereas the second bracketed term is the welfare loss commonly associated with a monopoly situation.

4 The litigation contest

Once the innovative firm is awarded a patent, it enjoys a monopoly for the new product. But rival firms have several ways to circumvent the patent and thus endanger the monopoly rent. They may produce a similar good which is a good substitute for the innovator's good but is still beyond the scope of the patent, the "patent breadth".[11]

[11] When registering a patent, the innovator has to describe in detail his innovation, therefore restricting himself the application scope of the patent.

A patent may be challenged in court in order to show that the innovation is not really new and that there is so called "prior art", e. g. that the innovation was publicly available knowledge in earlier patents and other published material. Alternatively, a copyright may be challenged in court in order to show that the creation is not really an "original work of authorship".

As an example, consider again Pfizer's bestselling Viagra drug. Shortly after its introduction, rival pharmaceutical firms introduced alternative drugs, Levitra and Cialis. Pfizer sued its rivals for patent infringement. The challengers argued that Pfizer's Viagra patent covered only Viagra's chemical substance in a narrow sense. Thus, their slightly different chemical compounds could be considered prior art in itself and therefore not covered by Viagra's patent.

Beyond famous and outstanding cases, the median litigation per patent claim has been estimated at $1.5 million (Barton, 2000), which may be more than the average value of a patent. According to Scherer and Harhoff (2000), the distribution of patent value is very skewed: very few, high value patents concentrate most of the value. Thus, the cost of enforcing and defending the patent may be even greater than the R&D costs (and the patent value) itself. We model this patent enforcement as an imperfectly discriminating litigation, asymmetric contest (Farmer and Pecorino, 1999). For the sake of simplicity, we assume that there is only one risk neutral challenger C litigating against an innovating monopolist M who owns a patent for the good.[12] Let x_c and x_m denote, respectively, their spending effort to prevail in the litigation dispute. The probability that the contestant $i = c, m$ wins the prize is

$$\frac{x_i}{x_m + x_c}. \tag{12}$$

[12]One could argue that there are many potential challengers. Additionally, if the challenger(s) win(s) the case and the patent is declared void, the knowledge is in the public domain free to use by all firms. We assume that even in this last situation the evolving market structure would still be an oligopoly, e.g. due to high fixed costs. As long as there is a finite number of challengers and the final outcome is not fully competitive, all our results are valid qualitatively.

This contest success function with linear effort technologies was introduced by Tullock (1980) and has been widely used in the literature.[13] The linear technology amounts to assume that contest effort has constant returns to scale. We believe this is a reasonable assumption for the litigation business, which is labor intensive and cannot be rationalized easily.

The litigation contest in Farmer and Pecorino (1999) is asymmetric because they also consider objective merits of the litigation suit favoring the plaintiff or the defendant. It turns out that these objective merits do not play a role in our setting. Thus we assume them to be zero. The asymmetry of our model is caused by the asymmetric valuation of the prize (Hillman and Riley, 1989). If the innovating monopolist successfully defends its position, it earns a monopoly profit Π_m. If the challenging firm prevails, then both firms share the market and are duopolists earning a profit Π_c, with $\Pi_c < \Pi_m$. Thus the prize is different for each contestant. The expected payoffs of challenger and monopolist V_c and V_m are given by:

$$V_c = \frac{x_c}{x_m + x_c}\Pi_c - x_c, \tag{13}$$

$$V_m = \frac{x_m}{x_m + x_c}\Pi_m + \frac{x_c}{x_m + x_c}\Pi_c - x_m = \frac{x_m}{x_m + x_c}(\Pi_m - \Pi_c) + \Pi_c - x_m. \tag{14}$$

The expected payoff of the innovative monopolist firm contains the duopoly profit as a fixed part, because if the plaintiff wins the case and the patent is declared void, the innovator is still able to enter the market as a duopolist. If we disregard the fixed payoff Π_c from the innovator's payoff, the direction of the asymmetry is not a priori clear, as the Cournot profit Π_c may be greater or smaller than the difference between the monopoly and the Cournot profit $\Pi_m - \Pi_c$. Both players maximize their expected payoff (13) and (14) with respect to their own effort for given rival's effort (Nash behavior). The FOCs are:

$$\text{FOC challenger:} \qquad 0 = x_m\Pi_c - (x_m + x_c)^2 \tag{15}$$

$$\text{FOC monopolist:} \qquad 0 = x_c(\Pi_m - \Pi_c) - (x_m + x_c)^2 \tag{16}$$

[13] See Nitzan (1994) for a general survey on contests.

In this imperfectly discriminating contest there exists an interior Nash equilibrium in pure strategies (see Hillman and Riley, 1989) and the participation constraint for both contestants is satisfied, e. g., both innovator and challenger prefer to litigate rather than choose a corner solution with zero litigation effort (Farmer and Pecorino, 1999). The payoff maximizing choices of the contestants are found by finding the effort couple (x_c, x_m) that simultaneously solve conditions (15) and (16):

$$
\begin{aligned}
x_c &= \frac{\Pi_c}{\Pi_m^2}(\Pi_m - \Pi_c) \cdot \Pi_c && (17)\\
x_m &= \frac{\Pi_c}{\Pi_m^2}(\Pi_m - \Pi_c) \cdot (\Pi_m - \Pi_c) && (18)
\end{aligned}
$$

Notice that the effort asymmetry depends on the relative size of $\Pi_m - \Pi_c$ and Π_c. Depending on this relationship, it is the innovator or the challenger who has a higher incentive to invest a higher effort in litigation. Further, both contestants invest less than their valuation of the contest prize, because the coefficient in front the prize in expressions (17) and (18) is equal for both contestants and it is smaller than 1:

$$
\begin{aligned}
\frac{\Pi_c}{\Pi_m^2}(\Pi_m - \Pi_c) &< 1\\
\Longleftrightarrow \quad \Pi_c\Pi_m - \Pi_c^2 &< \Pi_m^2\\
\Longleftrightarrow \quad \Pi_c\Pi_m &< \Pi_m^2 + \Pi_c^2
\end{aligned}
$$

The rent dissipation lost in the litigation contest is given by

$$
x_c + x_m = \frac{\Pi_c}{\Pi_m}(\Pi_m - \Pi_c). \qquad (19)
$$

Since this expression is smaller than either $\Pi_m - \Pi_c$ (the innovative monopolist's valuation of the litigation prize) and Π_c (the challenger's valuation of the litigation prize), the prize is not fully dissipated.[14]

The probabilities of winning the litigation contest are Π_c/Π_m for the challenger and, accordingly, $1 - \Pi_c/\Pi_m$ for the monopolist. The maximal expected payoffs of

[14] Strictly speaking, the concept of rent dissipation may be ambiguous in the case of asymmetric valuations of the contest prize. In our situation, the sum of contest efforts is smaller than either prize valuation.

challenger and monopolist are

$$V_c = \frac{\frac{\Pi_c}{\Pi_m^2}(\Pi_m - \Pi_c)\Pi_c}{\frac{\Pi_c}{\Pi_m}(\Pi_m - \Pi_c)}\Pi_c - \frac{\Pi_c}{\Pi_m^2}(\Pi_m - \Pi_c)\Pi_c = \frac{\Pi_c^3}{\Pi_m^2}, \tag{20}$$

$$V_m = \frac{\frac{\Pi_c}{\Pi_m^2}(\Pi_m - \Pi_c)^2}{\frac{\Pi_c}{\Pi_m}(\Pi_m - \Pi_c)}(\Pi_m - \Pi_c) - \frac{\Pi_c}{\Pi_m^2}(\Pi_m - \Pi_c)^2 + \Pi_c = \frac{(\Pi_m - \Pi_c)^3}{\Pi_m^2} + \Pi_c \tag{21}$$

The difference in expected payoff between defendant and plaintiff is positive:

$$V_m - V_c = \frac{(\Pi_m - \Pi_c)^3 - \Pi_c^3}{\Pi_m^2} + \Pi_c \tag{22}$$

$$= \frac{(\Pi_m - \Pi_c)(\Pi_m^2 - \Pi_m\Pi_c + 2\Pi_c^2)}{\Pi_m^2} > 0, \tag{23}$$

but this depends crucially on the certain rent Π_c accruing to the original innovator. If we disregard this duopoly rent and consider only the expected payoff of the litigation contest in a narrow sense, (22) shows that this payoff difference again depends on the relative size of $\Pi_m - \Pi_c$ and Π_c.

We summarize the main characteristics of the legal dispute in the following proposition:

Proposition 1 (Litigation contest)

Assume a litigation contest with linear contribution technologies and asymmetric prizes $\Pi_m - \Pi_c$ and Π_c. Both the plaintiff and the defendant choose a litigation effort level greater than zero and less than their valuation. The rent is not fully dissipated. The relative size of both the optimal effort choices and the maximal expected payoff depend on the relative size of the prizes.

5 Welfare Effects

The litigation dispute influences a rational profit maximizing firm doing R&D activities in the first place. The firm will choose its research investment level takes to maximize

$$p(k)V_m - k, \tag{24}$$

resulting in the first order condition

$$p'(k_l)V_m = 1, \tag{25}$$

where k_l denotes the profit maximizing research expenditures with subsequent litigation implicitly defined by condition (25). From Section 4 we know that $V_m < \Pi_m < S^*$. Thus, analogously to Section 3, we obtain by the diminishing marginal probability returns of research:

$$p'(k_l) > p'(k_m) > p'(k^*) \quad \Longleftrightarrow \quad k_l < k_m < k^*. \tag{26}$$

The litigation contest increases the deviation from the first best research level, reducing social welfare when compared to the situation of a monopoly without litigation.

But the legal dispute has also a positive effect on social welfare. With a positive probability, the IP right is successfully challenged in court and the monopoly changes into a duopoly. Prices drop and quantities increase, resulting in a smaller deadweight welfare loss DWL_l under litigation:

$$DWL_l = \int_{q_l}^{q^*} (d(\tilde{q}) - c)d\tilde{q} < DWL_m, \tag{27}$$

where q_l is the duopoly output, $q_l > q_m$.

The probabilities that the plaintiff (challenger) and the defendant (monopolist) prevail in the litigation contest are given by $p_c = \Pi_c/\Pi_m$ and $p_m = (\Pi_m - \Pi_c)/\Pi_m$. The social welfare under the patent regime with subsequent litigation is then given by

$$\begin{aligned} W_l &= p(k(V_m))[S^* - p_c \cdot DWL_l - p_m \cdot DWL_m - x_m - x_c] - k(V_m) \\ &= p(k_l)[S^* - \frac{\Pi_c}{\Pi_m} DWL_l - \frac{\Pi_m - \Pi_c}{\Pi_m} DWL_m - \frac{\Pi_c}{\Pi_m}(\Pi_m - \Pi_c)] - k_l. \end{aligned} \tag{28}$$

Consider now the welfare difference between the situations with and without litigation:

$$
\begin{aligned}
W_l - W_m &= \underbrace{[(p(k_l)S^* - k_l) - (p(k_m)S^* - k_m)]}_{<0} \\
&\quad + p(k_l)\underbrace{[-\frac{\Pi_c}{\Pi_m}DWL_l - \frac{\Pi_m - \Pi_c}{\Pi_m}DWL_m - \frac{\Pi_c}{\Pi_m}(\Pi_m - \Pi_c)]}_{<0} \qquad (29) \\
&\quad + p(k_m)\underbrace{DWL_m}_{>0}
\end{aligned}
$$

The first term in (29) is negative because litigation acts as a disincentive for research. The second term reflects the (expected) welfare loss in the litigation situation and the litigation effort expenses. Last, the third term is the welfare loss under monopoly with no legal challenge. The sign of expression (29) depends on the specification of demand and on the specific probability function of the firm's innovation success. For certain specifications, we may obtain the following result

Proposition 2 (Welfare increase due to litigation)
If the effect of increased competition outweighs the effect of reduced research investment plus litigation effort, then the legal dispute may lead to a welfare increase.

6 A numerical example

In the following we present an example to show that the situation described in Proposition 2 can arise assuming commonly used utility and distribution functions. Suppose the inverse market demand is given by $p_q(q) = a - bq$ and the marginal cost is constant at c, where a, b and c are positive with $a > c$. Table 1 briefly presents the outcome of the different market situations: monopoly, duopoly and perfect competition.

The monopoly profit Π_m, the profit of one duopolist firm Π_c, the monopoly deadweight loss DWL_m, and the duopoly deadweight loss after (successful) litigation DWL_l can all be expressed in terms of the efficient social surplus $S^* = \dfrac{(a-c)^2}{2b}$.

Table 1: Market outcomes

	Monopoly	Duopoly	Perf. Comp.
Quantity	$\frac{a-c}{2b}$	$\frac{2(a-c)}{3b}$	$\frac{a-c}{b}$
Price	$\frac{a+c}{2}$	$\frac{a+2c}{3}$	c
PS	$\frac{(a-c)^2}{4b}$	$\frac{2(a-c)^2}{9b}$	0
CS	$\frac{(a-c)^2}{8b}$	$\frac{2(a-c)^2}{9b}$	$\frac{(a-c)^2}{2b}$
S	$\frac{3(a-c)^2}{8b}$	$\frac{4(a-c)^2}{9b}$	$\frac{(a-c)^2}{2b}$
DWL	$\frac{(a-c)^2}{8b}$	$\frac{(a-c)^2}{18b}$	0

Notes: PS = producers's surplus, which in absence of fixed costs equals the profit of the firm(s), CS = consumers' surplus, S = social surplus, $DWL = S^* - (PS + CS)$ = deadweight loss.

Thus, we obtain

$$\begin{aligned}
\Pi_m &= \frac{(a-c)^2}{4b} = \frac{1}{2}S^* \\
\Pi_c &= \frac{(a-c)^2}{9b} = \frac{2}{9}S^* \\
DWL_m &= \frac{(a-c)^2}{8b} = \frac{1}{4}S^* \\
DWL_l &= \frac{(a-c)^2}{18b} = \frac{1}{9}S^*
\end{aligned}$$

The welfare difference given by expression (29) simplifies to

$$
\begin{aligned}
W_l - W_m &= [(p(k_l)S^* - k_l) - (p(k_m)S^* - k_m)] \\
&\quad + p(k_l)[-\frac{\frac{2}{9}S^*}{\frac{1}{2}S^*}\frac{1}{9}S^* - \frac{\frac{1}{2}S^* - \frac{2}{9}S^*}{\frac{1}{2}S^*}\frac{1}{4}S^* - \frac{\frac{2}{9}S^*}{\frac{1}{2}S^*}(\frac{1}{2}S^* - \frac{2}{9}S^*)] \qquad (30) \\
&\quad + p(k_m)\frac{1}{4}S^* \\
&= [(p(k_l)S^* - k_l) - (p(k_m)S^* - k_m)] - p(k_l)[\frac{101}{324}S^*] + p(k_m)\frac{1}{4}S^* \qquad (31) \\
&= [k_m - k_l] + [p(k_l)(1 - \frac{101}{324}) - p(k_m)(1 - \frac{1}{4})]S^* \qquad (32) \\
&= [k_m - k_l] + [p(k_l)(\frac{223}{324}) - p(k_m)(\frac{3}{4})]S^* \qquad (33)
\end{aligned}
$$

The stochastic relationship between the rate of research and the innovation success is often assumed to follow a Poisson process, see the patent race models by Loury (1979), Lee and Wilde (1980) and Dasgupta and Stiglitz (1980). Let k be the rate of research. The probability of a successful innovation is then given by

$$p(k) = 1 - e^{-\lambda k}, \qquad (34)$$

where the λ is the hazard rate and the expected innovation success is given by $1/\lambda$. This exponential distribution is "memoryless" in the sense that the random success of the innovator does not depend on the past research investment rate.

Remember that k_m and k_l are the profit maximizing choices of an unrestricted monopolist and of a monopolist facing litigation, respectively, and are implicitly defined by the FOCs (7) and (25):

$$
\begin{aligned}
p'(k_m)\Pi_m &= 1 \quad \Longrightarrow \quad e^{-\lambda k_m}(\frac{1}{2}S^*) = 1 \quad \Longleftrightarrow \quad k_m = \frac{1}{\lambda}\ln\frac{S^*}{2} \qquad (35) \\
p'(k_l)V_m &= 1 \quad \Longrightarrow \quad e^{-\lambda k_l}(\frac{2}{9}S^*) = 1 \quad \Longleftrightarrow \quad k_l = \frac{1}{\lambda}\ln\frac{2S^*}{9} \qquad (36)
\end{aligned}
$$

Computing the corresponding probabilities $p(k_m) = p(\frac{1}{\lambda}\ln\frac{S^*}{2}) = 1 - \frac{2}{S^*}$ and $p(k_l) = p(\frac{1}{\lambda}\ln\frac{2S^*}{9}) = 1 - \frac{9}{2S^*}$ and replacing k_m, k_l, $p(k_m)$ and $p(k_l)$ with their values, we obtain the following expression for the welfare difference $W_l - W_m$:[15]

$$W_l - W_m = (\frac{1}{\lambda}\ln\frac{S^*}{2} - \frac{1}{\lambda}\ln\frac{2S^*}{9}) + (\frac{2S^*-9}{2S^*}\cdot\frac{223}{324} - \frac{S^*-2}{S^*}\cdot\frac{3}{4}) \qquad (37)$$

If expression (37) is positive, then welfare under litigation is greater than welfare under the patent monopoly. Figure 6 shows the plot of (37) for given (λ, S^*). For any given S^* there exists a λ leading to this welfare improvement. If λ is small enough, litigation is welfare improving, although the litigation contest effort is "wasted". A small λ is equivalent to a high mean of the distribution, e. g. innovation processes where successful innovations are relatively seldom. Intuitively, a small λ means a relatively flat density function, with much of the probability mass on high values of k (thus the high mean of the distribution for small values of λ). For a given optimal social surplus S^*, a small λ enlarges the left bracketed term in expression (37).

Of course this result depends heavily on the demand and probability distribution function chosen in the example. By assuming commonly used parametrizations, we stress that the result described in Proposition 2 can plausibly arise in a practical sense.

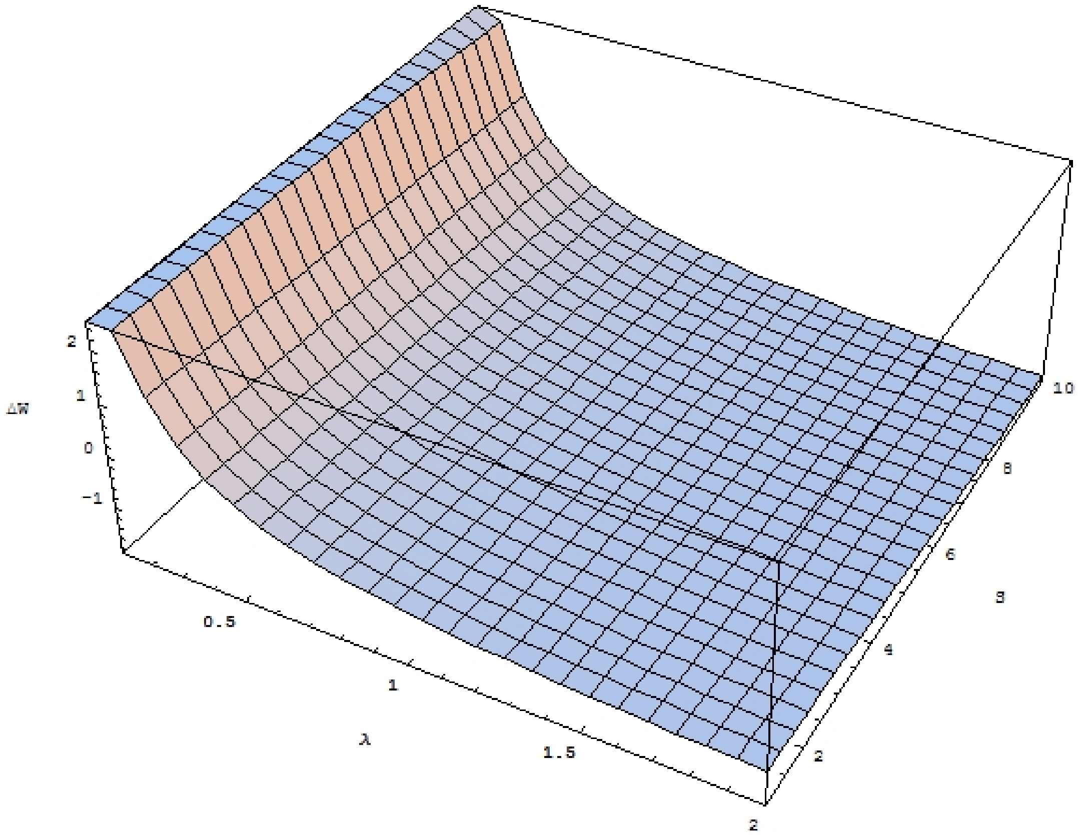
7 Conclusions

Contests are usually assumed to waste resources and to dissipate the contest prize. Our paper presents a situation where a litigation contest may turn out to be welfare improving. In our model, legal disputes have the positive welfare effect to break the monopoly of the innovator and so to reduce the associated deadweight welfare loss.

Still, this result is only valid within the framework of the existing patent protection system. We take the laws protecting intellectual property as given. There are innovation inducing mechanisms other than patent monopolies that do not result in a monopoly, e.g. an innovation award. If such a reward is contested in court, the litigation efforts of the contestants are really wasted and do not enhance social welfare.

[15]We assume implicitly and without loss of generality that S^* is large "enough" to generate positive probabilities smaller or equal than 1.

Figure 1: The welfare difference as a function of the exponential parameter λ and the social surplus S^*



This improvement in social welfare is only feasible, from a theoretical perspective, if the situation at the beginning was not efficient. Thus, our results confirm once again that the present IP protection system does not lead to an efficient outcome. Litigation may help to improve on that outcome by fine-tuning the trade-off inherent to the protection of IP: incentive to innovate on the one side, and social welfare maximization on the other.

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