OPTIMAL COPYRIGHT LENGTH AND EX-POST INVESTMENT:

A MICKEY MOUSE APPROACH

by

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ABSTRACT

This paper formally explores the optimal length of copyright protection when the value of an intellectual work changes over time due to depreciation and value-enhancing ex-post investments. The first main finding is that, in the case of a single project, granting infinitely-lived copyright protection maximizes social welfare when the return on ex-post investments is high relative to the return on the initial investment. We also provide simulation results of our model for the case of multiple heterogeneous projects that show how social welfare varies with the length of copyright protection and the returns on initial and ex-post investments. We then consider what our framework says concerning the social-welfare effects of the 1998 Copyright Term Extension Act. Here we show that, depending on the importance of ex-post investments, the act may have either increased or decreased social welfare. Our final analysis considers the social-welfare implications of replacing fixed-length copyright protection with Landes and Posner's (2003) idea of indefinitely-renewable copyright protection. We find that implementing indefinitely-renewable copyright protection frequently increases social welfare provided the returns on ex-post investments are sufficiently large. We also provide a briefy history of Disney's Mickey Mouse and argue that the history of that character matches quite well with the predictions of our theoretical approach.

I. INTRODUCTION

Conventional economic reasoning regarding copyright length is based on the interaction between two opposing economic forces. On the one hand, an increase in copyright duration promotes innovation by increasing the incentives to create, since monopoly rents can be extracted for longer periods of time. That is, increasing copyright duration decreases what is typically referred to as the underproduction loss. On the other hand, an increase in copyright duration creates social-welfare losses due to underutilization since the deadweight loss from monopoly continues for longer periods. Thus, in the standard argument the policy maker's problem is to select a copyright length that strikes an optimal balance between these two opposing effects.

One critical assumption in the standard approach to optimal copyright policy is that all investments that create value are made up front. Evaluating copyright policy in this context yields that, since the discounted value of monopoly profits far in the future is close to zero, these far in the future profits do not have a significant impact on the incentives to create new works. The natural conclusion, as discussed for example in Akerlof et al. (2002), is that lengthy copyright protection makes no economic sense since extending copyright protection in this way has little impact on reducing the underproduction loss but can substantially increase the underutilization loss.

In what follows we construct a model that takes a distinctly different approach to this issue. As indicated, the standard approach assumes that all creation costs are incurred up front. We argue that this assumption, common to the mainstream literature on copyright, does not hold in many important real-world situations. In many cases, the value of a creative work can be augmented by value-enhancing investments in later periods. As discussed in more detail below, our approach is closely related to Landes and Posner's (2003) arguments that additional investments in creative works and other benefits of ownership are important.

Consider, for example, Disney's Mickey Mouse. While Mickey Mouse was created during the 1920s, his appearance has significantly changed over time. One of the primary reasons Disney feels the need to change Mickey's characteristics over time is changing demographics and social values. Thus, Disney maintains Mickey Mouse's popularity and quality via ex-post investments in the character, using expenditures on focus groups, artists, marketers, etc.[1] If Disney did not have copyright protection, the resulting competitive market would not match Disney's level of ex-post investments in the character. Without copyright protection, all firms in the industry that use the character would potentially benefit from the investments of other firms, so the market would underinvest in equilibrium – a classic free-rider problem.

In other words, in order to avoid ex-post underinvestment in the quality of a copyrighted work, it is helpful if there is copyright protection of the initial creation. Thus, one can potentially justify very long-term copyright protection and retroactive copyright extensions as means to avoid the free-rider problem associated with ex-post investments. It is worth noting that Disney announced a major "make-over" for Mickey Mouse in 1998 shortly after the United States Congress passed the "Copyright Term Extension Act" (CTEA) which extended extant copyright protection for an additional twenty years. It is doubtful that Disney would have invested as much into mainaining the value of Mickey Mouse (and other characters) after 1998 if the Copyright Term Extention Act had not passed.

Our paper formalizes this argument and investigates its implications. Our first analysis shows that for any discount rate, depreciation rate, and initial cost of creation, there are creations for which infinitely-lived copyright protection is socially preferred to any finitely-lived copyright. Traditionally, only the costs to create the original product and the discount rate are elements in determining the optimal length of copyright protection. In contrast, in our analysis investments in maintaining the value of the product over time are also an important factor. More specifically, the magnitude of the returns on ex-post investments in relation to the return on the initial investment is important. Because low initial investment returns imply low initial quality levels, the welfare loss from monopoly underutilization is small for low levels of initial investment return. As a result, holding all else fixed, infinitely-lived copyright protection is optimal when a copyrighted work has a low return on initial investment. In addition, the welfare loss due to underproduction from finitely-lived copyright protection is greater when ex-post investment returns are higher. Thus, holding all else fixed, infinitely-lived copyright protection is optimal when the returns on ex-post investments are high.

[1] See, for example, Wasko (2001) for a discussion.

As is true for our first analysis, traditional analyses of optimal copyright length assume a single product or a set of homogeneous products. However, such an approach misses important real-world complexities that make it inappropriate to serve as a reliable guide to public policy. In our second analysis, we analyze a regulator's decision when creative works are heterogeneous with regard to both initial investment returns and ex-post investment returns. Simulations of this model indicate that when quality enhancing ex-post investments are not possible, the optimal length of copyright protection is finite and, in fact, short relative to real-world copyright length. When ex-post investments are possible, social welfare as a function of copyright duration first increases, reaches a maximum, and then declines with the length of copyright protection. As the length of copyright protection increases even further and firms are encouraged to invest more in ex-post quality improvements, social welfare begins to increase again, finally reaching some asymptotic value. The simulations also indicate that, given the presence of ex-post investments, infinite-length copyright protection can be optimal under quite plausible assumptions concerning the parameters of the model.

In our simulation analysis, we also study the implications of the CTEA. Our analysis suggests that, before the act, the duration of copyright protection was already lengthy, and expected total surplus was close to its asymptotic value. Thus, the model suggests that the adoption of the CTEA induced a small increase in social welfare from new works. Welfare effects of the act on existing works are ambiguous. Retroactive copyright extension decreases social welfare associated with existing works if the existing works have high commercial value primarily because of high initial quality levels. On the other hand, retroactive copyright extension increases social welfare associated with existing works if the existing works maintained high commercial value due to the monopolist's ex-post investments on quality. Overall, combining our findings for new and existing works, our analysis shows that the CTEA could either have increased or decreased social welfare depending on the importance of ex-post investment returns.

Although there are projects that require long-term copyright protection to be undertaken, other works need only a few years of copyright protection to be undertaken. Landes and Posner (2003) argue that, because of this type of heterogeneity, the optimal policy concerning copyright protection might be to have indefinitely-renewable copyright protection. Under indefinitely-renewable copyright protection, a work's creator can renew copyright protection indefinitely by making periodic payments. Our last analysis addresses this issue. Our analysis of this issue suggests that indefinitely-renewable copyright protection can improve social welfare provided projects are sufficiently heterogeneous and the returns on ex-post investments are sufficiently high. However, our analysis also suggests that indefinitely-renewable copyright protection can hurt social welfare if these conditions are not satisfied.

In summary, our analysis shows that incorporating value-enhancing ex-post investments into the framework, which we believe to be a very realistic feature, changes the conclusions concerning optimal copyright policy in important ways. First, in contrast to the standard argument in which very long-term copyright protection cannot be optimal because discounting means monopoly profits in far-off periods have little effect on the incentives to create, the presence of value-enhancing ex-post investments means very long and possibly even infinite-length copyright protection can be optimal. Second, in contast to the standard economic analysis of the issue such as in Akerlof et al. (2002), to the extent that ex-post investments are sufficiently important the passage of the CTEA may have increased rather than decreased social welfare. Third, in the presence of value-enhancing ex-post investments, Landes and Posner's suggestion of indefinitely-renewable copyright protection can be optimal given projects are heterogeneous and the returns on ex post investments are sufficiently high.

As a final introductory point, the goal of the paper is not to show that from a real-world perspective optimal copyright length is necessarily very long or possibly even infinite. Rather, our goal is to show that, because of the possibility of ex-post investments, the issue of optimal copyright length is more complicated than suggested by standard analyses such as found in Akerlof et al. (2002). With this goal in mind and to help make the argument easy to follow, in choosing a model to investigate we intentionally abstract away from some factors that can potentially serve to ameliorate the effects that the presence of ex-post investments can have on the length of optimal copyright protection.

For example, we assume free entry and Bertrand competition after the expiration of copyright protection, so once copyright protection has expired ex-post investments drop to zero. This assumption means that in our model there is a large return to long copyright protection due to increased ex-post investments. In alternative specifications ex-post investments would drop but not drop to zero after copyright expiration, with the result that the return to long copyright protection due to increased ex-post investments would be positive but smaller. As indicated, we assume free entry and Bertrand competition after copyright expiration and we make other related assumptions both because these assumptions simplify the analysis and because they allow us to more easily show that ex-post investments can be important for optimal copyright length. We come back to this issue in the Conclusion.

The outline for the paper is as follows. Section II reviews the relevant literature. Section III presents the model and provides some preliminary results. The main analysis is in Section IV, where specific attention is paid to the conditions in which infinitely-lived copyright protection is optimal and the implications of our analysis for the welfare effects of the CTEA. Section V analyzes the optimality of indefinitely-renewable copyright protection. Section VI discusses the case of Disney's Mickey Mouse and argues that the history of this character matches quite well with the theoretical approach taken in this paper. Section VII presents concluding remarks.

II. LITERATURE REVIEW

The economic reasoning regarding optimal copyright length is typically based on the interaction of two opposing economic effects: incentives to create and monopoly underutilization. An increase in copyright duration promotes innovation and increases the supply of works by allowing the authors to extract monopoly rents for longer periods. However, an increase in copyright duration also creates welfare losses because copyrighted works are charged above competitive prices for longer periods. Discussions and analyses that emphasize this trade-off can be found in Arrow (1962) and Hirshleifer and Riley (1979).[2] While it is generally agreed that these two effects are important, there is disagreement among economists concerning the length of copyright protection that strikes an optimal balance between the two effects. This disagreement can be clearly seen in discussions and analyses that followed passage of the 1998 CTEA. Before the act, the length of copyright protection was seventy-five years for

[2] Novos and Waldman (1984) provide a formal analysis of copyright protection along these lines but do not focus on copyright duration. This trade-off also appears in the literature on patent length. See, for example, Nordhaus (1969), Scherer (1972), and Gilbert and Shapiro (1990).

works for hire and fifty years after the author's death for works produced individually. The act extended the duration of copyright protection an additional twenty years for each type of work.

In their *amicus curiae* brief to the Supreme Court of the United States, Akerlof et al. (2002) question the economic rationale behind the CTEA. They argue that the economic incentives from the CTEA's extension of copyright protection are insignificant. In particular, in their analysis extending copyright duration from seventy-five to ninety-five years creates an additional compensation of 0.47% under an assumed discount rate of seven percent. The authors argue that such a small increase in compensation is unlikely to have a significant impact on the supply of new works.[3] Akerlof et al. further argue that the retroactive nature of the extension makes the CTEA even more problematic. Welfare-enhancing benefits of retroactive extensions are not clear since there is no effect on works that have already been created. A retroactive extension might in theory increase the supply of new works if creators believe that the duration of copyright protection would be extended in the future. But the authors argue that the impact of these expectations on compensation is very small as well because there is uncertainty concerning future extensions. Furthermore, retroactive copyright extensions increase the costs to current creators of derivative works. Akerlof et al. conclude that the negative welfare effects of the CTEA clearly outweigh the questionable benefits of the act.

Liebowitz and Margolis (2005) disagree with the above analysis arguing that Akerlof et al. have overlooked important factors. Liebowitz and Margolis emphasize that if the supply of new works was very elastic under the copyright terms in place before the act, then the act could have increased the number of creative works substantially, and thus have had a positive effect on social welfare. The authors elaborate by arguing that many works have relatively short lives and these works are of low commercial value. On the other hand, the works with longer lives have higher commercial value and might be sensitive to changes in copyright duration. In support of their arguments, Liebowitz and Margolis study a sample of books published in the 1920s and show that forty-one percent of all books and fifty-four percent of best sellers remained in print after fifty-eight years. The authors suggest that further empirical analysis is necessary before drawing any firm conclusions concerning the welfare effects of the CTEA.

[3] See Varian (2005) for another discussion along these lines.

Landes and Posner (2003) argue that the CTEA can be rationalized because there are benefits from copyright ownership in addition to the provision of incentives needed for the initial creation of a work (see also Posner (2005)). For example, ownership might preclude the possibility of misuse of a copyrighted work. Also, a creation in the public domain may be overused, whereas ownership of the work deters "overgrazing" by providing incentives for the copyright owner to prevent a premature decline in the commercial value of the work. They also suggest that even retroactive copyright extensions can be beneficial since owners of copyrighted works incur maintenance costs and, most importantly from our perspective, make additional investments that enhance the value of the original work.

Another important part of Landes and Posner's argument is the claim that indefinitely-renewable copyright protection can improve upon the current system of fixed-length copyright protection.[4] To support their proposal, Landes and Posner conduct an empirical analysis of copyrights and renewals for the last one-hundred years. They find that the average life expectancy for copyrights is about fifteen years and that copyright renewals are sensitive to registration fees. They suggest that under renewal fees somewhat higher than present registration fees, only a few works – those for which there are substantial social benefits of ownership – would be renewed for a long period of time. The rest of the works would enter the public domain soon after the works are created.[5]

Our paper formally investigates some of the main ideas in Landes and Posner's important work. We begin by constructing a model that captures the idea of ex-post value-enhancing investments. We show that Landes and Posner are correct concerning the importance of such investments in causing optimal copyright protection to be long. That is, if the returns on such investments are high, then very long and possibly even infinitely-lived copyright protection can be optimal. We also formally consider their proposal of indefinitely-renewable copyright protection. Here we show that Landes and Posner are correct, i.e., indefinitely-renewable

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[4] A related proposal is put forth in Rappaport (2002).

[5] As indicated, Landes and Posner's analysis is based on the registration-fee and renewal-fee system that is currently in place. To give you a sense of how the system works, the current initial registration fee is $30 and currently for works initially produced on or after 1964 but before 1978 registration can be renewed after twenty-eight years for a fee of $60. Registration and renewal are not required for copyright protection but offer some legal benefits.

copyright protection can be optimal, although this is not true in all cases. Further, we identify the conditions needed for indefinitely-renewable copyright protection to be the optimal policy.

III. MODEL AND PRELIMINARY RESULTS

In this section we first present our model and then provide a preliminary analysis. In Section IV we use the model to investigate the optimal length of copyright protection. In Section V we then employ the model to investigate indefinitely-renewable copyright protection.

A) The Model

In this subsection we develop a continuous-time model for optimal copyright length. Let Q(t) denote the product's quality at time t, where the quality of the product depreciates at rate δ, $0<\delta<1$. Denote by h and α the monopolist's investment in the initial quality level and the return on a unit of initial investment. The monopolist's choice of an initial quality level is given by $Q(0)=\alpha h$. The cost of creating the initial product is $z+g(h)$, where $z\geq 0$ is a fixed cost of undertaking the project and g(h) is the variable cost with $g(0)=0$, $g'(0)=0$, $g'(h)>0$ and $g''(h)>0$ for all $h>0$. The monopolist can also invest ex-post in the product's quality at any time t, where i(t) denotes the instantaneous ex-post investment at time t. The instantaneous cost of ex-post quality investment at time t is given by c(i(t)), where $c(0)=0$, $c'(0)=0$, $c'(i(t))>0$ and $c''(i(t))>0$ for all $i(t)>0$. The law of motion for quality is $Q'(t)=-\delta Q(t)+\gamma i(t)$, where $\gamma\geq 0$ represents the return on a unit of ex-post investment.

The instantaneous inverse demand function is given by $P(x(t),Q(t),t)=Q(t)(1-f(x(t))$. Note that x(t) is instantaneous output, 1-f(x(t)) is the inverse demand when the quality of the product equals one, and f(x) is normalized so that $\int_0^{x^{max}}(1-f(x))dx=1$. The discount factor is $r>0$.

Finally, we assume the marginal cost of production is zero and let T denote the length of copyright protection.

The timing of events is as follows. After observing the length of copyright protection, a profit-maximizing monopolist draws α and γ from the cumulative distribution function $F(\alpha,\gamma)$. Next, the monopolist chooses whether or not to undertake the initial project. If the project is undertaken, the monopolist chooses an initial investment level, h, ex-post investments, i(t), and a price for each period, P(t).[6] If the project is not undertaken, then no ex-post investments are possible and the monopolist receives zero profits. Note further that after the expiration of copyright protection, there is a pool of firms any of which can make ex-post investments in quality and any of which can sell the product. We further assume Bertrand competition in this post-copyright-protection time period.

Given the above sequence of events, the monopolist's problem can be described as the following optimal control problem.[7]

$$\max\{0, \max_{h\geq 0} V(Q(0)) - g(h) - z\}$$

$$V(Q(0)) = \max_{P(t),i(t)} \int_0^T (P(t)x(t) - c(i(t)))e^{-rt}\,dt \qquad (1)$$

$$\text{s.t. } Q'(t) = -\delta Q(t) + \gamma i(t), \quad Q(0) = \alpha h, \; i(T) = 0$$

After period T, our assumption of Bertrand competition between the potential sellers means that, independent of the current quality, the price of the product falls to marginal cost which in our model equals zero. Thus, abstracting away from expenditures on ex-post investments in quality, both the original monopolist's profits and profits of each of the potential entrants is zero after the expiration of copyright protection. Further, since abstracting away from expenditures on ex-post investments firms earn zero profits independent of the level of current quality, we also have that all ex-post quality investments stop after the expiration of copyright protection.[8]

Denote the monopolist's optimal initial investment, ex-post investment, price, and quality paths by h*, i*(t), P*(t), and Q*(t), respectively. Fixing the length of copyright protection at T, the total social surplus derived from the monopolist's product, given the project is undertaken, is given by the expression in (2).

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6 There would be no change in results if price and ex-post investment level for each period t were chosen at date t.

7 A Hamiltonian approach yields the same results since the solution is interior.

8 To simplify the analysis, we assume that ex-post investments themselves cannot be copyrighted. In the real world ex-post investments can sometimes be copyrighted if the work is "substantially altered." Allowing for this possibility would not substantially change the qualitative nature of our results since, in the absence of copyright protection for the original work, even with some copyright protection for ex-post investments there would still be ex-post underinvestment due to free riding. A detailed discussion of these issues can be found in Landes and Posner (2003). Also, see the Conclusion for a related discussion.

$$\int_0^T [\int_{P^*}^{Q^*(t)} f^{-1}(1-\frac{P}{Q^*(t)})dP + \int_0^{P^*} f^{-1}(1-\frac{P^*}{Q^*(t)})dP - c(i^*(t))]e^{-rt}dt - g(h^*) - z + \int_T^{\infty} Q^*(t)e^{-rt}dt \tag{2}$$

The regulator's problem is to choose the length of copyright protection, T, in order to maximize total surplus. In the analysis that follows, we solve the model explicitly given linear demand, f(x)=x/2, and cost functions $g(h)=h^k$, k>1, and $c(i)=i^2$.

B) Some Preliminary Results

We begin by considering the monopolist's problem given a fixed and finite copyright length. Suppose the project is undertaken with an initial investment level of h. The monopolist's problem is then given by equation (3).

$$V(Q(0)) = \max_{P(t),i(t)} \int_0^T [2(1-\frac{P(t)}{Q(t)})P(t) - (i(t))^2]e^{-rt}dt$$

$$\text{s.t. } Q'(t) = -\delta Q(t) + \gamma i(t) \tag{3}$$

$$Q(0) > 0 \text{ given, } i(T) = 0$$

Since (1-(P(t)/Q(t)))P(t) is maximized when P(t)=Q(t)/2, we have that (3) reduces to (4).

$$\max_{Q(t)} \int_0^T (\frac{1}{2}Q(t) - \frac{1}{\gamma^2}(Q'(t)+\delta Q(t))^2)e^{-rt}dt$$

$$Q(0) > 0 \text{ given, } Q'(T)+\delta Q(T) = 0 \tag{4}$$

The Euler equation for this problem is $Q''(t)-rQ'(t)-\delta(\delta+r)Q(t)=-\gamma^2/4$, where the general solution to this equation takes the form $Q^*(t)=A_1e^{-\delta t}+A_2e^{(\delta+r)t}+A_3$. The values for A_1, A_2, and A_3 are determined by substituting the appropriate boundary conditions which yields $A_1=Q(0)+(\gamma^2/4\delta(\delta+r))((\delta/2\delta+r))(e^{-(\delta+r)T}-1)$, $A_2=-((\gamma^2/4(\delta+r)(2\delta+r))e^{-(\delta+r)T}$, and $A_3=\gamma^2/4\delta(\delta+r)$.

This analysis can be used to show that, if the monopolist decides to undertake the project, then the firm's optimal decisions exhibit several intuitive properties. First, the longer is the length of copyright protection, the higher is the monopolist's benefits from ex-post investments. Thus, increasing the length of copyright protection increases ex-post investment levels, i.e., $\partial i^*(t)/\partial T \geq 0$ for all t<T. Second, ex-post investment levels as a function of copyright length rise at a falling rate, i.e., $\partial^2 i^*(t)/\partial T^2 \leq 0$ for all t<T. There are two reasons for this. One is that the

cost function for ex-post investments is convex. The other is that, because of discounting, monopoly benefits as a function of T rise at a falling rate.

Now consider the dynamics of the optimal ex-post investment levels. As the expiration of copyright protection gets closer, the level of ex-post investment declines, i.e., $\partial i^*(t)/\partial t \leq 0$, because the benefits from investment are derived for a shorter period of time. Moreover, ex-post investment levels decrease at an increasing rate, i.e., $\partial^2 i^*(t)/\partial t^2 \leq 0$. This follows from the same logic as why investment levels as a function of copyright length rise at a falling rate. That is, the driving forces here are again the convexity of the ex-post investment cost function and the fact that discounting means that monopoly benefits from ex-post investment fall more quickly with a decrease in the length of copyright protection when the overall length is shorter. The optimal path of ex-post investment levels as a function of t is presented in Figure 1.

We now turn to the monopolist's initial decisions concerning whether or not to undertake the project and, if it decides to undertake the project, its choice of an initial investment level. We start with the latter decision. If the project is undertaken, then the maximization problem it faces in choosing h is given by equation (5).

$$\max_h V(\alpha h) - h^k - z \tag{5}$$

This yields the first-order condition given in equation (6).

$$h^* = \left(\frac{\alpha V'(\alpha h)}{k}\right)^{\frac{1}{k-1}} = \left(\frac{\alpha(1-e^{-(\delta+r)T})}{2k(\delta+r)}\right)^{\frac{1}{k-1}} = \frac{Q^*(0)}{\alpha} \tag{6}$$

Now consider the monopolist's decision concerning whether or not to undertake the project, i.e., the monopolist should undertake the project if the maximized value of $V(Q(0))-h^k-z$ is positive. Since the maximized value of $V(Q(0))-h^k$ is independent of z, holding all other parameters fixed there exists a critical value for z, call it z^+, such that the project is undertaken if $z<z^+$ and is not undertaken if $z>z^+$. Further, given that we know from earlier that for any fixed h the maximized value of V(Q(0)) is increasing in T, z^+ itself must be increasing in T, i.e., increasing the length of copyright protection makes undertaking projects more attractive and thus the project is undertaken under a wider range of parameterizations.

The last preliminary result concerning finite copyright protection is the derivation of total social surplus, denoted W(T). Given from earlier we know that optimal pricing when copyright protection is in place sets P(t)=Q(t)/2, we have that equation (2) reduces to (7).

$$W(T)=\int_0^T\left(\frac{3}{4}Q^*(t)-\frac{1}{\gamma^2}(Q^{*\prime}(t)+\delta Q^*(t))^2e^{-rt}dt-(h^*)^k-z+\int_T^\infty Q^*(t)e^{-rt}dt\right. \quad (7)$$

Further, substituting into (7) our earlier derived expression for Q*(t) yields (8).

$$\begin{aligned}W(T)=&\frac{3Q^*(0)}{4(\delta+r)}+\frac{Q^*(0)}{4(\delta+r)}e^{-(\delta+r)T}-(h^*)^k-z+\frac{\gamma^2}{8r(\delta+r)^2}\\&-\frac{\gamma^2}{4r(\delta+r)(2\delta+r)}e^{-rT}+\frac{\gamma^2}{8(\delta+r)^2(2\delta+r)}e^{-2(\delta+r)T}\end{aligned} \quad (8)$$

We now consider what happens when copyright protection is infinite. As before, suppose the project is undertaken with an initial investment of h. The monopolist's problem is then given by equation (9).

$$\max_{Q(t)}\int_0^\infty\left(\frac{1}{2}Q(t)-\frac{1}{\gamma^2}(Q'(t)+\delta Q(t))^2\right)e^{-rt}dt$$

$$Q(0)>0 \text{ given} \quad (9)$$

The general solution to this equation again takes the form $Q^*(t)=A_1e^{-\delta t}+A_2e^{(\delta+r)t}+A_3$, where the transversality condition and the initial quality level imply $A_1=Q(0)-(\gamma^2/4\delta(\delta+r))$, $A_2=0$, and $A_3=\gamma^2/4\delta(\delta+r)$.

Now consider the monopolist's ex-post investment levels. This is given by equation (10).

$$i^*(t)=\frac{\gamma^2}{4(\delta+r)} \quad (10)$$

Note that i*(t) is constant when copyright protection is infinite. Figure 1 compares the dynamics of the monopolist's optimal ex-post investment levels when copyright protection is finite and infinite. The optimal ex-post investment path for infinitely-lived copyright protection is always above the optimal ex-post investment path for finite protection because the benefits from ex-post investments are received longer under infinite copyright.

Substituting the expression for i*(t) into the equation for Q*(t) yields that with infinite copyright protection Q*(t) approaches $\gamma^2/4\delta(\delta+r)$ asymptotically. In words, since the ex-post investment level is constant under infinite-copyright protection, in the limit quality approaches the quality level that is just sustainable given the constant ex-post investment level. Holding all other parameters fixed, there exists a critical value for the return on initial investment, call it α', that defines three possible quality paths. First, if $\alpha>\alpha'$, then Q*(t) decreases over time and approaches $\gamma^2/4\delta(\delta+r)$ from above. Second, if $\alpha<\alpha'$, then Q*(t) increases over time and approaches $\gamma^2/4\delta(\delta+r)$ from below. Third, if $\alpha=\alpha'$, then Q*(t) is constant and equal to $\gamma^2/4\delta(\delta+r)$.

Now consider the monopolist's decision to undertake the project. As in the finite case, there exists a critical value for z, call it $z^{+(\infty)}$, such that the project is undertaken when $z<z^{+(\infty)}$ and is not undertaken when $z>z^{+(\infty)}$. Further, z^+ in the finite case approaches $z^{+(\infty)}$ as T gets large.

Finally, since optimal pricing still satisfies P(t)=Q(t)/2, total social surplus in the infinite-copyright-protection case is derived by setting T=∞ in equation (7).

$$W(\infty)=\int_0^\infty(\frac{3}{4}Q^*(t)-\frac{1}{\gamma^2}(Q^{*\prime}(t)+\delta Q^*(t))^2e^{-rt}dt-(h^*)^k-z \tag{11}$$

Substituting our previously derived expression for Q*(t) yields (12).

$$W(\infty)=\frac{3Q^*(0)}{4(\delta+r)}-(h^*)^k-z+\frac{\gamma^2}{8r(\delta+r)^2} \tag{12}$$

IV. THE OPTIMALITY OF INFINITELY-LIVED COPYRIGHT PROTECTION

In this section we investigate the conditions in which infinitely-lived copyright protection is optimal. We start by considering this question for the case of a single product (or multiple identical products), and then consider the issue given multiple heterogeneous products. We then employ our analysis to consider the optimality of the CTEA.

A) Single Product

The standard argument in favor of longer copyright protection concerns the supply of initial works. This argument is simply that longer copyright protection increases the aggregate number of works created. In our model, there are two ways in which infinitely-lived copyright protection might enhance social welfare. First, consistent with the standard argument, infinitely-lived copyright protection increases the number of works created. Second, infinitely-lived copyright protection improves social welfare by encouraging higher levels of initial and ex-post investments for any given work. On the other hand, infinitely-lived copyright protection can decrease social welfare if the welfare loss from increased monopoly underutilization exceeds these benefits.

As indicated, we begin by considering a single product. In considering social surplus as a function of copyright length, it is easy to derive examples in which infinitely-lived copyright length is preferred to any finitely-lived copyright. Proposition 1 given below extends this point and shows that when ex-post investments are possible, for any parameterization of the discount rate, depreciation rate, initial cost, and return on ex-post investments, infinitely-lived copyright protection will be optimal when the return on the initial investment is sufficiently low. Note, all proofs are in the Appendix.

<u>Proposition 1</u>: Holding all other parameters fixed and given $\gamma>0$, there exists a value α^{-}, $\alpha^{-}>0$, such that infinitely-lived copyright protection is optimal when $0<\alpha<\alpha^{-}$.[9]

To understand the intuition behind Proposition 1, fix the initial quality level and consider what happens as copyright protection is increased from any arbitrary finite length to an infinite length. On the one hand, there is a welfare gain because of increased ex-post investments, but, on the other hand, there is a welfare loss from increased underutilization of the product. When the initial quality level is low, the incremental welfare loss from underutilization is low as well and a regulator will prefer infinitely-lived copyright protection. As the initial quality level increases, underutilization losses also increase, making infinitely-lived copyright protection less attractive. This implies a critical value for the initial quality level beyond which finitely-lived copyright protection is optimal. Since the initial quality level is an increasing function of α, there is a critical value for the return on the initial investment as well. Note that an additional factor is how the social-welfare loss from underproduction changes with copyright length. Because the decrease in the underproduction loss in moving from any finite copyright length to an infinite length is decreasing in α, incorporating this factor into the argument does not change the basic logic.

Proposition 1 focuses on the role of the return on the initial quality investment. We now consider the role of ex-post investment returns.

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[9] Infinitely-lived copyright protection will be the unique optimal copyright policy for all α, $0<\alpha<\alpha^{-}$, if z is sufficiently small.

<u>Proposition 2</u>: Holding all other parameters fixed, there exists a value γ^+, $\gamma^+>0$, such that infinitely-lived copyright protection is the unique optimal policy when $\gamma>\gamma^+$.

Proposition 2 states that a regulator will prefer infinitely-lived copyright protection when the return on ex-post investments is high enough. The intuition here is that the welfare loss due to ex-post underproduction is higher when the return on ex-post investments is higher. Thus, infinitely-lived copyright protection is optimal when the return on ex-post investments is sufficiently high because then the return in terms of a lower underproduction loss exceeds the cost of a higher underutilization loss. Propositions 1 and 2 are simply two different ways of looking at the same result. Both propositions follow from the idea that when deciding the duration of copyright protection, the return on ex-post investments relative to the return on initial investments is crucial. That is, it is when the return on ex-post investments is relatively higher, i.e., the return on initial investment is sufficiently low (holding the ex-post investment return fixed) or the return on ex-post investments is sufficiently high (holding the initial investment return fixed), that infinitely-lived copyright protection is optimal.

B) <u>Multiple Heterogeneous Products</u>

Propositions 1 and 2 show that there are always some works that benefit society more if the length of copyright protection is infinite. However, works that fall into this category represent a subset of all works. There are also many works for which the optimal length of copyright protection is finite. In most situations, the regulator does not know ex-ante the specific characteristics of each individual work and thus is not able to tailor copyright protection to the idiosyncratic characteristics of a specific work. With this in mind, what follows is an analysis of a regulator's choice of copyright protection when the regulator assigns a single copyright protection length to a set of heterogeneous works.

To calculate the optimal length of copyright protection in such a setting, we first derive expressions for expected total surplus given any arbitrary copyright protection length imposed on a set of heterogeneous projects. Let $L(\alpha,\gamma,T)$ be an indicator function that takes on a value of one (zero) if a monopolist with realizations for returns on his project given by α and γ and subject to copyright length T undertakes (does not undertake) the project. Also, let $W(\alpha,\gamma,T)$ be the realized societal total surplus as a function of α, γ, and T. Let all firms draw the returns on their projects from the distribution F(α,γ), where α takes on values in the interval $[\alpha_L,\alpha_H]$ and γ takes on values $[\gamma_L,\gamma_H]$. Expected societal total surplus, denoted E[W(T)], is given by equation (13).

$$E[W(T)] = \int_{\gamma_L}^{\gamma_H} \int_{\alpha_L}^{\alpha_H} L(\alpha,\gamma,T) W(\alpha,\gamma,T) f(\alpha,\gamma) d\alpha d\gamma \tag{13}$$

The calculation of optimal copyright length involves taking the derivative of E[W(T)] with respect to T. Since the model is complicated, we first simulate the model for different sets of parameter values. For these simulations, we assume that α and γ are drawn from independent distributions. α is assumed to be distributed according to a uniform distribution on $[\alpha_L,\alpha_H]$, and γ is assumed to take on values 0 and γ* with probabilities 1-φ and φ, respectively. In words, the last assumption simply means that there is a set of works for which ex-post investments are not a factor and a set of works for which quality can be improved via ex-post investments, where all the works in the latter group have the same ex-post investment returns. To be conservative concerning the importance of ex-post investments, we assume that the proportion of works for which ex-post investments are a factor is no greater than one percent. The specific parameterizations we discuss are given in Table 1 and the simulation results for these parameterizations are presented in Figure 2.[10] The horizontal axis in Figure 2 denotes the length of copyright protection while the vertical axis denotes normalized expected surplus. By normalized here we mean that expected surplus in the figure is presented as a percent of expected surplus given copyright length is set at its optimal value.

Our simulations hold everything constant except γ and φ, i.e., the focus is on the proportion of projects with positive ex-post investment returns and the relative return on ex-post investments when they are positive. The simulations show that infinitely-lived copyright protection is optimal for parameterizations C and D – the parameterizations in which a positive proportion of works have positive ex-post investment returns and these returns are relatively high (as in the previous subsection, relatively high here means that the return on ex-post investments is high relative to the return on the initial investment). For parameterizations A and

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[10] We have considered a much larger number of parameterizations and the simulations reported are representative of our findings.

B, in which, respectively, there are no works with positive ex-post investment returns and the works with positive ex-post investment returns have relatively low ex-post returns, finitely-lived copyright protection is optimal.

Consider expected total surplus as the length of copyright protection increases when all ex-post investment returns are zero, as in parameterization A. When the length of copyright protection is close to zero, most projects are rejected and the projects that are undertaken have very low initial quality levels. Therefore, expected total surplus is close to zero. As the length of copyright protection starts to increase, the number and quality of works created both increase rapidly. This, in turn, increases expected total surplus. After a point, however, expected surplus falls as the length of copyright protection increases further. In words, in the absence of positive ex-post investment returns, the welfare loss from monopoly underutilization eventually rises faster than the welfare gain from more and higher quality works being created. Part of the reasoning here is that increases in T increase the probability that a project is undertaken and increase the initial quality of the projects being undertaken, but the rates of increase both fall with T. In the limit, as T approaches ∞, expected total surplus approaches some asymptotic value, since the effect of periods that are far in the future relative to the date of creation have a negligible effect on aggregate initial investment returns. This analysis suggests that expected total surplus in the absence of positive ex-post investment returns typically has a single-peaked shape like that depicted for parameterization A.

Next, consider a parameterization for which ex-post investment returns are a factor. Then, our analysis suggests expected total surplus has two possible shapes. The first is captured by the simulation of parameterization D. For this parameterization, those projects characterized by positive ex-post investment returns have high relative ex-post investment returns on average. The result is that expected total surplus increases monotonically with T. The second possible shape is captured by the simulations for parameterizations B and C. For these simulations, the shape of the expected total surplus curve is somewhere between the shapes of the simulations for parameterizations A and D. For low levels of T, expected total surplus first increases and then decreases similar to what was true for parameterization A. The logic here is that for low levels of T the shape of the curve is mostly driven by projects with zero ex-post investment returns. In contrast, for higher levels of T, expected total surplus increases monotonically similar to what was true for parameterization D. The logic here is that the behavior of expected total surplus for higher levels of T is driven mostly by projects with positive ex-post investment returns.

Employing a strictly analytic approach, we can derive a sufficient condition for the optimality of infinitely-lived copyright protection with heterogeneous products that is similar to the conditions found in Propositions 1 and 2 for a single product. Suppose z=0 and denote the expectations of γ^2 and $\alpha^{k/(k-1)}$ by $E[\gamma^2]$ and $E[\alpha^{k/(k-1)}]$, i.e., $E[\gamma^2]=\int_{\gamma_L}^{\gamma_H}\int_{\alpha_L}^{\alpha_H}\gamma^2 f(\alpha,\gamma)d\alpha d\gamma$ and $E[\alpha^{k/(k-1)}]=\int_{\gamma_L}^{\gamma_H}\int_{\alpha_L}^{\alpha_H}\alpha^{k/(k-1)} f(\alpha,\gamma)d\alpha d\gamma$. Then a sufficient condition for the optimality of infinitely-lived copyright protection is given by equation (14).

$$\frac{E[\gamma^2]}{E[\alpha^{k/(k-1)}]} > \frac{6r(\delta+r)}{(2k(\delta+r))^{1/(k-1)}} \tag{14}$$

The derivation of equation (14) is given in the Appendix. Similar to the intuition given for Propositions 1 and 2, the basic logic here is that the underutilization loss from copyright protection increases with higher initial quality levels. Thus, infinitely-lived copyright protection will be optimal when returns on initial investments in quality are lower, i.e., when the denominator of the left-hand side of (14) is lower. On the other hand, the welfare loss from ex-post underproduction due to any arbitrary finite-copyright-protection length increases as the returns from ex-post investment increase. Thus, if the returns on ex-post investment are high enough, i.e., the numerator of the left-hand side of (14) is high enough, infinitely-lived copyright protection will be optimal. The policy implications of these results are discussed in the next subsection.

C) <u>Copyright Term Extension Act of 1998 and Ex-Post Investments</u>

In 1998, the U.S. Congress passed the Sonny Bono Copyright Term Extension Act. The act has two major provisions: a lengthening of copyright protection for newly created works and the retroactive application of these new copyright terms to works that were produced before the act but for which copyright protection has not already expired. Specifically, CTEA extends copyright protection from fifty years after the author's death to seventy years after death for works produced by individuals. For works for hire, copyright protection was increased from seventy-five years from publication (or one-hundred years from creation, whichever is shorter) to ninety-five years from publication (or one-hundred and twenty years from creation, whichever is shorter). We study the implications of ex-post investments with respect to CTEA separately for works created after the act and for works that were already in place when the act was passed.

First, consider the effects of the CTEA on the total surplus associated with works produced after the act. Critics of the act argue that the impact on social welfare for new works is negative. Our interpretation is that the critics have in mind an analysis very similar to what happens in our model when there are no ex-post investments. Consider Figure 3 which reproduces three of the simulations from Figure 2.[11] Our interpretation is that the critics are implicitly assuming that the true expected total surplus curve looks like the single-peaked curve for parameterization A, and that they further assume copyright length before CTEA was at a value like T_{before} greater than T_{peak} and thus social welfare fell when copyright length was extended due to CTEA to T_{after}. However, given this interpretation, the extension did not reduce the total surplus associated with new works by much since total surplus was close to its asymptotic value before the act. In words, increasing copyright length increased the underutilization loss, but because of discounting and the fact that copyright length was already high there was only a small reduction of total surplus.

But that argument ignores ex-post investments. Two possibilities for what can happen when ex-post investments are possible are also pictured in Figure 3. Contrary to the no ex-post investment case just discussed, for each of the two parameterizations associated with a positive proportion of positive ex-post investments projects total surplus increases when copyright length is increased from T_{before} to T_{after}. However, because of discounting and that copyright length was already long before the act, for each parameterization the increase is small because prior to the act total surplus was close to its asymptotic value. Note, however, although CTEA does increase total surplus somewhat, it is not necessarily optimal. For parameterization B for which returns on ex-post investments are relatively small, the regulator's best policy is to decrease copyright length to T_{peak} rather than increase it to T_{after}. However, for parameterization C for which returns on ex-post investments are relatively large, the regulator's best policy is to implement infinitely-lived copyright protection.

[11] We do not report simulation results for parameterization D since from a qualitative standpoint they are the same as for parameterization C.

Next, consider the implications of the CTEA on existing works, i.e., the implications of retroactive copyright extension on works that were created before the act but for which copyright protection had not yet expired.[12] Figure 4 considers the same three parameterizations considered in Figure 3, but now the exercise is what happens to the surplus associated with existing works when copyright protection is retroactively extended. When ex-post investments are not a factor, there is no welfare gain from retroactive copyright extension since the supply of works is unaffected. However, there is a welfare loss due to monopoly underutilization. Thus, as captured by the total surplus curve for parameterization A in Figure 4, a retroactive copyright extension is welfare reducing for existing works in the absence of ex-post investments.

Now consider retroactive copyright extension when there are positive ex-post investment returns for some existing works. There are two possibilities for what happens to the total surplus associated with existing works, where these two possibilities are captured by the curves for parameterizations B and C in Figure 4. When ex-post investment returns are relatively small as is the case for parameterization B, the increased underutilization loss dominates the decreased underproduction loss with the result that total surplus due to existing works falls with retroactive copyright extension. However, when ex-post investment returns are relatively large as is the case for parameterization C, then the increased underutilization loss is dominated by the decreased underproduction loss with the result that total surplus due to existing works increases with retroactive copyright extension.

In summary, our analysis does not show that CTEA necessarily either increased or decreased aggregate total surplus. Our analysis shows that it is possible that the critics of the act were correct, i.e., the act lowered total surplus. But our analysis also shows that this is not necessarily the case. If ex-post investments, i.e., a factor that the critics completely ignored, were sufficiently important, then CTEA could have increased total surplus both because of

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[12] Note that for these works, the monopolist has already undertaken the initial investment and current quality levels are known. Therefore, we simulate the model by considering the distribution of current quality levels implied by the distribution of initial investment returns assuming the passage of the act itself was unanticipated. We calculate the current quality level of an existing work for each realization of α and γ by keeping track of ex-post investments and quality depreciation. Then, expected total surplus levels associated with various lengths of retroactive copyright extension are calculated by taking into account that the monopolist's future ex-post investments in each work reflect this policy change.

increased surplus associated with new works and increased surplus associated with already existing works.

V. INDEFINITELY-RENEWABLE COPYRIGHT PROTECTION

In the real world intellectual works are heterogeneous and the length of optimal copyright protection will vary with the characteristics of each individual work. Under current copyright policy, however, the duration of actual copyright protection is the same for all works. The government grants the same length of copyright protection for all works because of the prohibitive costs associated with evaluating each project individually and assigning a copyright length based on the work's specific characteristics. These ideas introduce the possibility of a "second best" alternative policy that improves upon the current system's fixed copyright length that does not vary across works. In this section we explore one such possible alternative policy.

Landes and Posner (2003) argue that "indefinitely-renewable copyright" can potentially improve upon the current policy of fixed copyright length. Indefinitely-renewable copyright refers to a policy wherein copyright protection can be renewed indefinitely through periodic payments made by the work's creator. Under such a policy, on the other hand, if the periodic payments are discontinued then the work enters the public domain. In the analysis that follows, we extend our model to study whether indefinitely-renewable copyright can result in welfare higher than that associated with the best fixed-length copyright protection. As we will show, the answer is a qualified yes. That is, depending on the nature of the distribution of initial investment and ex-post investment returns in the economy, moving to an indefinitely-renewable copyright policy may improve welfare but is not guaranteed to do so in all cases.[13]

Denote by ω the instantaneous renewal fee a monopolist pays to extend copyright protection. Under an indefinitely-renewable copyright policy, the monopolist decides the length of copyright protection. More specifically, the monopolist first decides whether or not to undertake the project and, if the project is undertaken, the firm then decides how long to pay the fee, i.e., the length of copyright protection, and initial and ex-post investment levels. To get some intuition for how the model works under indefinitely-renewable copyright protection,

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[13] Yuan (2005) provides an analysis in which the optimal fixed-length copyright policy dominates indefinitely-renewable copyright, but his analysis ignores ex-post investments.

consider the monopolist's optimal behavior given this policy when a project is undertaken. The monopolist's optimization problem in this case is given by (15).

$$\max_{T\in[0,\infty),Q(t),h} \int_0^T \left(\frac{1}{2}Q(t) - \frac{1}{\gamma^2}(Q'(t)+\delta Q(t))^2 - \omega\right)e^{-rt}dt - h^k$$

$$\text{s.t. } Q(0) = \alpha h \tag{15}$$

Equation (15) can be rewritten as (16).

$$\max_T\{\max_{Q(t|T),h}\int_0^T \left(\frac{1}{2}Q(t) - \frac{1}{\gamma^2}(Q'(t)+\delta Q(t))^2 e^{-rt}dt - h^k - \int_0^T \omega e^{-rt}dt\right\} \tag{16}$$

From (16), we see that the level of renewal fees affects the monopolist's initial and ex-post investment levels only indirectly, via the duration of copyright protection. That is, taking as fixed the monopolist's choice of copyright duration, varying the fee does not affect investment levels and prices since the fee is a fixed cost from the monopolist's perspective.[14] Moving one step back, the monopolist undertakes the project if the net revenue from undertaking the project exceeds the initial cost of the project. That is, letting T* denote the monopolist's choice of optimal copyright length given the project is undertaken, the monopolist undertakes the project when (17) is satisfied.

$$\int_0^{T^*} \left(\frac{1}{2}Q^*(t) - (i^*(t))^2 - \omega\right)e^{-rt}dt - h^{*k} \geq z \tag{17}$$

We now compare social welfare under fixed-term copyright protection and indefinitely-renewable copyright protection. We start by considering this comparison when projects are homogeneous. The following proposition shows that in this case indefinitely-renewable copyright never improves upon the optimal fixed-term copyright length and sometimes adopting the policy strictly reduces welfare. Note, below let $W^F(T)$ denote social welfare given a fixed copyright length of T, while $W^R(\omega)$ denotes social welfare given indefinitely-renewable copyright protection where the instantaneous fee is set at ω.[15]

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[14] The argument that a renewal fee should be treated as a fixed cost can also be found in Rappaport (2002). In his analysis, however, the monopolist pays a single upfront fee to extend copyright protection for a discrete amount of time rather than the monopolist facing the instantaneous fee that we consider.

[15] In our calculation of $W^R(\omega)$, fees collected by the government are distributed to consumers on an equal-share basis. As long as we assume a large number of firms, we could equivalently assume that the fees are returned to firms on an equal-share basis.

Proposition 3: Assuming projects are homogeneous and holding all other parameters fixed, there always exists a value T^+ such that $W^F(T^+) \geq W^R(\omega)$ for all ω, ω≥0, where for some parameterizations this inequality is strict.

The intuition behind Proposition 3 is as follows. When there is a single project or multiple homogeneous projects, the renewal fee affects investment levels only by affecting the monopolist's choice of a copyright length. Thus, social welfare under any indefinitely-renewable copyright policy can be matched with a fixed-term policy by setting the fixed length equal to the monopolist's choice of copyright length under the indefinitely-renewable policy. In addition, the absence of a renewal fee in the fixed-length case makes undertaking the initial project more attractive from the monopolist's perspective with the result that social welfare is sometimes higher with the optimal fixed-term copyright length than with indefinitely-renewable copyright and the optimal fee.

To more clearly see why fixed-length copyright protection can be strictly superior in the homogeneous product case, consider the following example. Consider an economy with a single project, where α=1, γ=0, k=3, δ=0.08, r=0.08, and z=0.25. Note that since γ=0 the monopolist does not make positive ex-post investments in this example. Consider first the regulator's optimal choice of a fixed copyright length. Optimal length can be calculated by maximizing social welfare given by equation (8). This calculation yields that the optimal copyright length for this project is 10.1 periods. In turn, substituting this into the relevant expressions yields monopoly profit equals 0.044 and total social surplus equals 3.804. Now consider indefinitely-renewable copyright. The optimal fee for this example is 0.013 which yields a copyright length of 25.2 periods. Monopoly profit now equals 0.008 and total social surplus is 3.735 which is less than total surplus given the best fixed-length copyright policy.

This example illustrates why fixed-length copyright protection can be superior. Under a renewable copyright policy, there is no instantaneous fee that results in the monopolist holding the copyright for exactly 10.1 periods. The first-order condition for monopoly choice of a copyright length yields that achieving this result requires the regulator to charge a renewal fee of 0.039, but this yields monopoly profit of -0.227. Thus, faced with this renewal fee the monopolist would not undertake the project, so total social surplus would be zero. Further, under any renewal fee below ω=0.039 that yields non-negative monopoly profits the monopolist holds the copyright longer than 10.1 periods. So, as indicated, social welfare under indefinitely-renewable copyright and the best renewal fee is below social welfare given the best fixed-length copyright policy.[16]

We now consider what happens when products are heterogenous rather than homogeneous. Here we assume a specification similar to the specification in the simulation analysis of heterogenous projects in Section IV. α and γ are independently distributed in the population. Specifically, α is distributed according to a uniform distribution on $[\alpha_L,\alpha_H]$, while $\gamma=\gamma^*$, $\gamma^*>0$, with probability φ and $\gamma=0$ with probability $(1-\varphi)$, where we now assume $0<\varphi<1$. Also, let ω^* be the optimal instantaneous fee given indefinitely-renewable copyright protection.

Proposition 4: Holding all other parameters fixed, there exists a value γ', $\gamma'>0$, such that $W^R(\omega^*)\geq W^F(T)$ for all T, $T\geq 0$, if $\gamma^*>\gamma'$ (where $W^R(\omega^*)>W^F(T)$ for all T, $T\geq 0$, if $\gamma^*>\gamma'$ and in addition $k>2$ and α_L is not too small).

Proposition 4 states that indefinitely-renewable copyright protection will be optimal as long as ex-post investment returns are sufficiently high. The logic here is as follows. With indefinitely-renewable copyright protection, as opposed to fixed-length copyright protection, the length of copyright protection is the endogenous choice of each work's creator (or whoever the creator assigns the right to). So an important issue concerning whether indefinitely-renewable copyright improves welfare is whether it results in efficient matches between endogenously chosen copyright lengths and optimal copyright lengths. We know from earlier that optimal copyright length tends to be long, possibly infinite, when relative ex-post returns are high. So indefinitely-renewable copyright protection is likely to be efficient when it results in periodic renewals for works with high relative ex-post returns and quick termination of payments for works with low relative ex-post returns.

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[16] In our analysis the renewal fee is a constant rather than a function of how long the copyright has been held. If we allowed the renewal fee to vary with current copyright duration, then in the homogeneous-product case indefinitely-renewable copyright and the best renewal-fee function would always yield the same social surplus as the best fixed-length copyright policy.

Given this, consider what happens in our model when γ^* gets large. Then basically there are two types of projects – those with low or in our specification zero relative ex-post returns and those with high relative ex-post returns. By setting a moderate fee the government is frequently able to achieve an endogenous choice of copyright lengths that dominates any arbitrary fixed-length copyright policy. The reason is that firms whose projects are characterized by $\gamma=\gamma^*$ continually pay the fee which is optimal given the high relative ex-post returns, while those characterized by $\gamma=0$ stop paying the fee after a relatively short time period which is optimal given the low relative ex-post returns. Hence, when γ^* is large implementing indefinitely-renewable copyright protection frequently improves welfare in our model.[17]

We can now summarize the conditions in which our analysis indicates that the adoption of an indefinitely-renewable copyright policy is likely to be welfare improving. The first condition is that intellectual works are sufficiently heterogeneous that a fixed single copyright length results in an outcome far from the first best. The second is that for the projects with positive ex-post returns these returns are sufficiently high. When this is the case indefinitely-renewable copyright is optimal because the works that are continuously renewed are exactly the set of works for which very long copyright protection is optimal. Or, in other words, as indicated above, Landes and Posner's claim that the adoption of indefinitely-renewable copyright can improve welfare is correct but it is not guaranteed to do so in all cases.

VI. A BRIEF HISTORY OF MICKEY MOUSE

In this section we briefly discuss the history of Disney's Mickey Mouse. The CTEA was passed just before copyright protection for Mickey Mouse was scheduled to expire and the passage of the act significantly extended copyright protection for the character. We believe the history of the character both before and after passage of the act supports our argument that very

[17] The role of the conditions $k>2$ and α_L not too small is that they ensure that as γ^* gets large the optimal instantaneous fee is strictly positive. That is, without these conditions it is possible that as γ^* gets large the optimal fixed copyright length is ∞ and the optimal instantaneous fee equals zero. Clearly when this is the case the optimal fixed copyright length and the optimal instantaneous fee yield the same value for social welfare.

long copyright protection, or more precisely in this case retroactive copyright protection, can significantly increase ex-post investments in a copyrighted product.[18]

Mickey Mouse was created in 1928 by Walt Disney and Ub Iwerks who was the chief animator at Disney Studios. Mickey first appeared in a series of cartoons including Steamboat Willie which was one of the early cartoons to feature a sound track. These cartoons were typically shown in movie theaters prior to the main feature. After the release of Steamboat Willie the Mickey Mouse character quickly achieved broad popularity and over the next few years numerous cartoons were produced and the character also appeared in comic strips and eventually comic books. The quick success of the character, in fact, led to an Oscar presented to Walt Disney in 1932 for the original creation of the character.

Over the next few decades the character continued to be popular in various ways. He appeared in various cartoons and movies including The Sorcerer's Apprentice segment in Disney's classic Fantasia. With the growth of television in the 1950s Mickey jumped into the new medium. The original Mickey Mouse Club was introduced in 1955 and became the most popular children's show on television, and this was followed by later versions of the show introduced in 1977 and 1989. Mickey has also had an important role in the various theme parks and resorts that Disney has opened around the world, including various "lands" focused on the character.

But by the mid 1990s Mickey had become a much less important part of Disney's entertainment offerings. Although he still had an important role in a number of the company's theme parks and as a corporate symbol for the company, his use and popularity in terms of children's entertainment had clearly waned. His film appearances were few and he had little presence in the numerous children's television programs produced by Disney that appeared on the Disney channel and elsewhere. In terms of television programs and other children's entertainment Disney relied almost exclusively on various other characters most of which were created and therefore copyrighted long after Mickey's introduction in 1928.

But this situation has changed in the last few years as Disney has announced a number of efforts to revive the character. The results of Disney's efforts include various cartoon shows

[18] Histories of Mickey Mouse can be found in Hollis and Sibley (1986) and Heide et al. (2001). Also, for a more recent discussion see Stanley (2006).

including Mickey Mouse Works which appeared in 1999-2000, Disney's House of Mouse which played from 2001 to 2003, and Mickey Mouse Clubhouse which was introduced in 2006. Also, in 2004 two Mickey Mouse made-for-video features were released – The Three Musketeers and Mickey's Twice Upon a Christmas. More generally it is clear that Disney has decided to expend resources in various ways to increase the character's popularity including making the television shows and movies mentioned above and promoting Mickey in various other ways such as having Mickey be the Grand Marshal of the Tournament of Roses Parade on New Year's Day of 2005.

The other interesting aspect from our perspective of Mickey Mouse's history is how much the nature of the character and how the character has been used have changed over time. Mickey started out as a somewhat mischievous and roguish character. Over time, however, as he became an important corporate symbol for Disney, Mickey's personality became less colorful and many of the more comedic aspects of the films and comics were given to Mickey's best friends Goofy and Donald Duck. It is also the case that although the animation films were mostly focused on comedy, the comic strip combined comedy with adventure. Finally, in Mickey's most recent incarnation in the 2006 children's television program, Mickey Mouse Clubhouse, the program has a more educational format like Sesame Street and Mickey's character can best be described as similar to the classic children's entertainer Mr. Rogers.

From our standpoint, what is most interesting about this history is how well it matches the predictions of our theory. Clearly the Mickey Mouse character is one for which ex-post investments have been very important. Rather than the character staying static as one might expect given the standard theoretical framework for looking at copyright protection, the character has changed over time as circumstances and society itself have changed. And just as is true for the creation of the original character, these changes were not free but required investments in the creative process that allowed Mickey to evolve in a fashion that has kept him popular for a very long period of time.

Further, how the commercial success of the character has varied over time is also consistent with our theoretical framework. Our analysis predicts that, as the time of initial copyright expiration approached, Disney should have invested less in maintaining the character with a subsequent reduction in revenues and profits generated through the use of the character. In turn, after the copyright was extended in 1998, Disney should have increased investments used to improve the popularity of the character with a corresponding increase in revenues and profits derived from the character. And these predictions are consistent with exactly what happened. Prior to 1998 the nature of the character became quite stagnant and profits derived from television shows and videos focused on the character became very small. However, soon after the passage of the CTEA in 1998, Disney announced a "make-over" of the character with the result being significant changes in the nature of the character and dramatic increases in the commercial use of the character both in terms of television programs and videos.

Overall, we believe the history of Disney's Mickey Mouse clearly supports the idea that ex-post investments can be important and that, when this is the case, very long copyright protection and even retroactive copyright protection can be useful for stimulating investments used to sustain the popularity of the character. We believe it is hard to reconcile Mickey's history with the traditional theory of copyright in which all investments are made up front and a work's current commercial viability depends on how well those original investments are a match with current tastes. Such a framework has trouble explaining Mickey's loss in popularity and commercial use by the mid 1990s and quick resurgence after passage of the CTEA in 1998. But these events are not at all difficult to explain with our theory that gives an important role to ex-post investments.[19]

VII. CONCLUSION

The standard approach for analyzing optimal copyright protection is to assume that all investments are incurred by the time the product is introduced. But in reality there are many important cases, such as the example of Mickey Mouse and Disney, where significant quality-enhancing investments are made long after the product is introduced. This is important because the introduction of such ex-post investments qualitatively changes the potential benefits of very long-term or even infinitely-lived copyright protection. In the absence of such investments, very long-term or infinitely-lived copyright protection makes little sense because discounting means

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[19] One difference between the Mickey Mouse example and our model is that, even in the absence of copyright protection, Disney retains some property rights concerning the character because of trademark protection. However, it seems quite plausible that those property rights are stronger when copyright protection is also in place, and thus that Disney's incentive to make ex-post investments in Mickey Mouse should have risen with the passage of the CTEA.

that profits far off in the future have little effect on the incentives for the original creation of a product. But if such investments are present, then there can be important benefits associated with very long-term copyright protection because of the incentives created for ex-post investments.

In this paper we formally analyzed this issue and found three main results. First, consistent with the above discussion, the introduction of ex-post investments means that long-term, possibly even, infinitely-lived copyright protection can be optimal. In particular, this will be the case when the return on ex-post investments is sufficiently high relative to the return on initial investments. Second, in contrast to the argument of Akerlof et al. (2002), the passage of the CTEA may have increased rather than decreased social welfare. This will be the case when the projects with positive ex-post investment returns have sufficiently high returns because then extending the length of copyright protection helps social welfare associated with both existing works and newly-created works. Third, we consider Landes and Posner's (2003) idea of indefinitely-renewable copyright protection and show that it is likely to improve upon the best fixed-term copyright policy when again the returns on ex-post investments are sufficiently high.

There are a number of directions in which the paper's analysis can be extended. One set of directions concerns the issue of modeling strategy briefly mentioned in the Introduction. That is, in this paper, partially in order to make our argument easy to follow, we intentionally abstracted away from a number of factors that can serve to limit the effects that the presence of ex-post investments can have on optimal copyright length. Although we believe that incorporating these factors would not change the qualitative nature of the results, we believe it would be worthwhile investigating this issue formally. There are three specific factors that we feel are worth investigating. First, related to a brief discussion in the Introduction, we believe it is worth considering how results change when the free-rider problem after copyright expiration is less severe so that some ex-post investments are made even when there is no longer copyright protection. Second, related to the discussion in footnote 8, in future work we plan to allow some copyright protection for ex-post investments themselves – specifically, when the investments significantly alter the nature of the product. Third, we think it would be interesting to incorporate heterogeneous depreciation. In particular, we think incorporating this feature could be important for better understanding the circumstances in which indefinitely-renewable copyright protection is optimal.

The other direction for future research that we think is important is the empirical investigation of how significant ex-post investments are in real-world settings. Clearly, such as in the case of Mickey Mouse, there are important real-world examples in which ex-post investment returns are present and large. However, given the extent to which large ex-post investment returns are required for our main findings, the fact that they sometimes exist is suggestive but clearly what is important is how common they are and how large they are. This is an empirical question and one that needs to be investigated to get an accurate sense of what optimal copyright policy looks like in real-world settings.

APPENDIX

Proof of Proposition 1: Take any δ, r, γ, k and z. If the project is undertaken under a finite-length copyright policy, the project will be undertaken under an infinite-length copyright policy as well. Social welfare from finite-length and infinite-length copyright policies are given below.

$$W(T) = \frac{\alpha h_T^*}{4(\delta+r)} + \frac{3\alpha h_T^*}{4(\delta+r)} e^{-(\delta+r)T} + (\frac{\alpha h_T^*}{2(\delta+r)}(1-e^{-(\delta+r)T}) - (h_T^*)^k) - z + + \frac{\gamma^2}{8r(\delta+r)^2} - \frac{\gamma^2}{4r(\delta+r)(2\delta+r)} e^{-rT} + \frac{\gamma^2}{8(\delta+r)^2(2\delta+r)} e^{-2(\delta+r)T} \quad \text{(A1)}$$

$$W(\infty) = \frac{\alpha h_\infty^*}{4(\delta+r)} + (\frac{\alpha h_\infty^*}{2(\delta+r)} - (h_\infty^*)^k) - z + \frac{\gamma^2}{8r(\delta+r)^2} \quad \text{(A2)}$$

Social surplus under an infinite-length copyright policy is greater than social surplus under any finite-length copyright policy if W(∞)≥W(T) for any T≥0. Noting that $h_\infty^* > h_T^*$ and that $(\frac{\alpha h_T^*}{2(\delta+r)}(1-e^{-(\delta+r)T}) - (h_T^*)^k) \leq (\frac{\alpha h_\infty^*}{2(\delta+r)} - (h_\infty^*)^k)$, W(∞)>W(T) holds if (A3) is satisfied.

$$\frac{\gamma^2}{4r(\delta+r)(2\delta+r)} e^{-rT} - \frac{\gamma^2}{8(\delta+r)^2(2\delta+r)} e^{-2(\delta+r)T} > \frac{3\alpha h_T^*}{4(\delta+r)} e^{-(\delta+r)T} \quad \text{(A3)}$$

After substituting h_T*, the optimality condition for an infinite-length copyright policy can be rewritten as (A4).

$$\gamma^2 \frac{((2\delta+r)e^{\delta T}+r(e^{\delta T}-e^{-(\delta+r)T}))}{6r(\delta+r)(2\delta+r)}\left(\frac{2k(\delta+r)}{1-e^{-(\delta+r)T}}\right)^{\frac{1}{k-1}} > \alpha^{\frac{k}{k-1}} \quad \text{(A4)}$$

Noting that $e^{\delta T}-e^{-(\delta+r)T}\geq 0$, $e^{\delta T}\geq 1$ and $(1/(1-e^{-(\delta+r)T}))^{1/(k-1)}\geq 1$, one can derive the following condition for the optimality of an infinite-length copyright policy.

$$\gamma^2 \frac{(2k(\delta+r))^{1/(k-1)}}{6r(\delta+r)} > \alpha^{k/(k-1)} \quad \text{(A5)}$$

Choose $\alpha^- = (\gamma^2(2k(\delta+r))^{1/(k-1)}/(6r(\delta+r))^{(k-1)/k}$. Since the left-hand-side of (A5) is strictly positive, social welfare under an infinite-length copyright policy is higher than social welfare under any finite-length copyright policy whenever α is in region $(0,\alpha^-]$.

Proof of Proposition 2: Take any δ, r, α, k and z. Consider ex-post investment return values such that $\gamma\geq 4(\delta+r)\sqrt{(rz)}$. This condition guarantees that the project is undertaken when the length of copyright protection is infinite. Following the proof of Proposition 1, a sufficient condition for the optimality of an infinite-length copyright policy can be rewritten as (A6).

$$\gamma^2 > \frac{6\alpha^{k/(k-1)}r(\delta+r)}{(2k(\delta+r))^{1/(k-1)}} \quad \text{(A6)}$$

Let $\gamma^+=\max\{4(\delta+r)\sqrt{(rz)}, [6\alpha^{k/(k-1)}r(\delta+r)(2k(\delta+r)^{1/(k-1)}]^{1/2}\}$. Since the right-hand side of inequality (A6) is positive, an infinite-length copyright policy is preferred to any finite-length copyright policy whenever γ is in the region $[\gamma^+,\infty)$.

Proof of Proposition 3: Take any α, z, δ, r, γ, k and ω≥0, and let T^F be the copyright length under the fixed-length policy and T^R the endogenously chosen length under the indefinitely-renewable policy. If the monopolist optimally decides not to undertake the project given the indefinitely-renewable policy, then social welfare under the indefinitely-renewable copyright policy is zero. Therefore, under any choice of T^F, the total surplus under fixed-length copyright is at least the level of total surplus under renewable copyright. Suppose the monopolist undertakes the project and renews the copyright for T^R periods under the renewable copyright policy. Choose $T^F=T^R$. Under a fixed-length copyright policy of T^F periods, the monopolist's ex-post investment and quality paths are the same under the two policies. The monopolist's revenue from undertaking the project under the fixed-length copyright policy is at least the level of revenue from the renewable copyright policy since the monopolist does not have to pay the renewal fee. Thus, the monopolist undertakes the project under the fixed-length copyright policy and social welfare is the same under the two policies. Further, the example in the text proves that the inequality is sometimes strict.

Proof of Proposition 4: Fix all parameters except γ^*. First, we will show that $W^R(\omega^*) \geq W^F(T)$ for all T, $T \geq 0$, whenever $\gamma^* > \gamma^+$. Let $\gamma^+ = ((6r(\delta+r)\alpha_H^{k/(k-1)})/(\varphi(2k(\delta+r))^{1/(k-1)}))^{1/2}$. Under this condition, the monopolist chooses infinite copyright protection whenever $\gamma^* > \gamma^+$ because for each realization of α infinite copyright is preferred to finite length copyright. Then, we can choose $\omega^*=0$ and the monopolist holds projects indefinitely both under fixed length and renewable copyright policies. Thus, social welfare levels are the same if $\omega^*=0$ whenever $\gamma^* > \gamma^+$.

Next, let $k>2$ and $\alpha_L > k(k+2)(\delta+r)[z/(k-1)]^{(k-1)/k}/2$. Let a renewal fee equal $\omega^* = \min\{\omega_1, \omega_2\}$, where $\omega_1 = [4(\alpha_L/2)^k/(k(\delta+r)(k+2))^k]^{1/(k-1)}(k-2)/2$ and $\omega_2 = r(k-1)\,[2\alpha_L/(k(\delta+r)(k+2))]^{k/(k-1)})/2 - rz/2$. Take any γ_1 such that the monopolist with $\alpha=\alpha_L$ decides to hold the renewable copyright forever when the monopolist's ex-post investment return is γ_1 and the renewal fee is ω^*. We will show that indefinitely-renewable copyright is strictly preferred to fixed-term copyright when $\gamma^* > \gamma^+$, where
$\gamma^+ = \max\{\gamma_1, ((6r(\delta+r)\alpha_H^{k/(k-1)})/(\varphi(2k(\delta+r))^{1/(k-1)}))^{1/2}\}$.

Take any $\gamma^* > \gamma^+$. Under a fixed-term copyright, the regulator sets an infinite copyright term because expected return on ex-post investments is high enough. Consider the projects with positive ex-post investment returns. Under indefinitely renewable copyright, the monopolist with positive ex-post returns holds the project forever as well because $\gamma^* > \gamma_1$. Thus, the levels of social welfare for works with positive ex-post investment returns are the same under both copyright systems. Now take any project with the initial investment return of α and with zero ex-post investment returns. From equation (8), socially optimal copyright term for this project is $T^* = [\ln((k+2)/(k-2))]/(\delta+r)$ periods. Furthermore, equation (8) implies that social welfare for this project is strictly decreasing from T^* on, i.e., $W(T^*)>W(T_1)>W(T_2)>W(\infty)$ for $T^*<T_1<T_2$. Under indefinitely renewable copyright, the monopolist would hold the copyright for $T(\alpha)$ periods, where $T(\alpha)$ is derived from equation (16) by equating the marginal revenue from

holding the project an extra period to the marginal cost of holding the project for an extra period. In other words, T(α) satisfies MR(T) = MC(T) such that $MR(T^+)<MC(T^+)$ for $T^+>T(\alpha)$, where $MR(T) = (\frac{(\alpha/2)^k}{k(\delta+r)})^{1/(k-1)} e^{-(\delta+r)T}(1-e^{-(\delta+r)T})^{1/(k-1)}$ and $MC(T) = \omega e^{-rT}$. The monopolist's optimal copyright duration T(α) is unique under the renewal fee ω*. Note that T* < T(α) < ∞ since

$$\begin{aligned} &MR(T^*) - MC(T(\alpha)) = [4(\alpha/2)^k/(k(\delta+r)(k+2)^k)]^{1/(k-1)}(k-2) - \omega^* e^{-rT(\alpha)} > \\ &> [4(\alpha_L/2)^k/(k(\delta+r)(k+2)^k)]^{1/(k-1)}(k-2) - \omega_1 = \\ &= [4(\alpha_L/2)^k/(k(\delta+r)(k+2)^k)]^{1/(k-1)}(k-2)/2 > 0. \end{aligned} \tag{A7}$$

Also that monopoly profits are strictly positive when the monopolist holds the project for T(α) periods:

$$\begin{aligned} &\pi(T(\alpha)\mid\omega^*) > \pi(T^*\mid\omega^*) \ge \pi(T^*\mid\omega_2) = \\ &[2\alpha/(k(\delta+r)(k+2))]^{k/(k-1)}(k-1)/2 - z - \omega_2(1-e^{-rT^*})/2 > \\ &> [2\alpha_L/(k(\delta+r)(k+2))]^{k/(k-1)}(k-1)/2 - z - \omega_2/r = \\ &= [2\alpha_L/(k(\delta+r)(k+2))]^{k/(k-1)}(k-1)/4 - z/2 > 0. \end{aligned} \tag{A8}$$

Therefore, social welfare is strictly greater under indefinitely-renewable copyright.

The optimality condition for an infinite-length copyright policy given heterogeneous products.

Suppose z=0 and fix T. Following the proof of proposition 1, W(∞)>W(T) if (A9) is satisfied.

$$\begin{aligned} &\int_{\gamma_L}^{\gamma_H}\int_{\alpha_L}^{\alpha_H} \gamma^2 \frac{((2\delta+r)e^{\delta T} + r(e^{\delta T} - e^{-(\delta+r)T}))}{6r(\delta+r)(2\delta+r)} (\frac{2k(\delta+r)}{1-e^{-(\delta+r)T}})^{1/(k-1)} f(\alpha,\gamma)\,d\alpha\, d\gamma > \\ &> \int_{\gamma_L}^{\gamma_H}\int_{\alpha_L}^{\alpha_H} \alpha^{k/(k-1)} f(\alpha,\gamma)\,d\alpha\, d\gamma \end{aligned} \tag{A9}$$

Noting that $e^{\delta T}-e^{-(\delta+r)T}\geq 0$, $e^{\delta T}\geq 1$ and $(1/(1-e^{-(\delta+r)T}))^{1/(k-1)}\geq 1$, equation (A9) simplifies to (A10).

$$\frac{E[\gamma^2]}{E[\alpha^{k/(k-1)}]} > \frac{6r(\delta+r)}{(2k(\delta+r))^{1/(k-1)}} \tag{A10}$$

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Table 1: Simulation Parameters

	A	B	C	D
α_H	11	11	11	11
α_L	1	1	1	1
γ	-	1.6	2.1	3
φ	0	0.01	0.01	0.01
z	0.2	0.2	0.2	0.2
k	3	3	3	3
δ	0.08	0.08	0.08	0.08
R	0.08	0.08	0.08	0.08

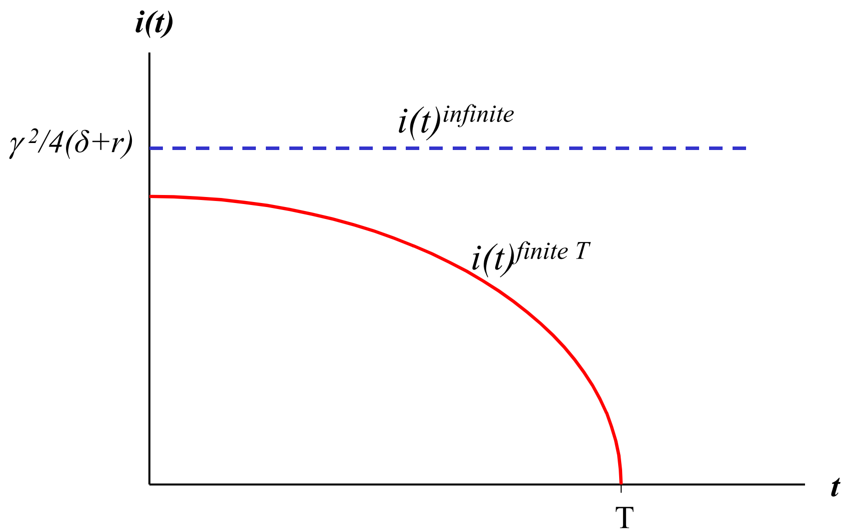

Figure 1: The Dynamics of Monopolist's Ex-Post Investment

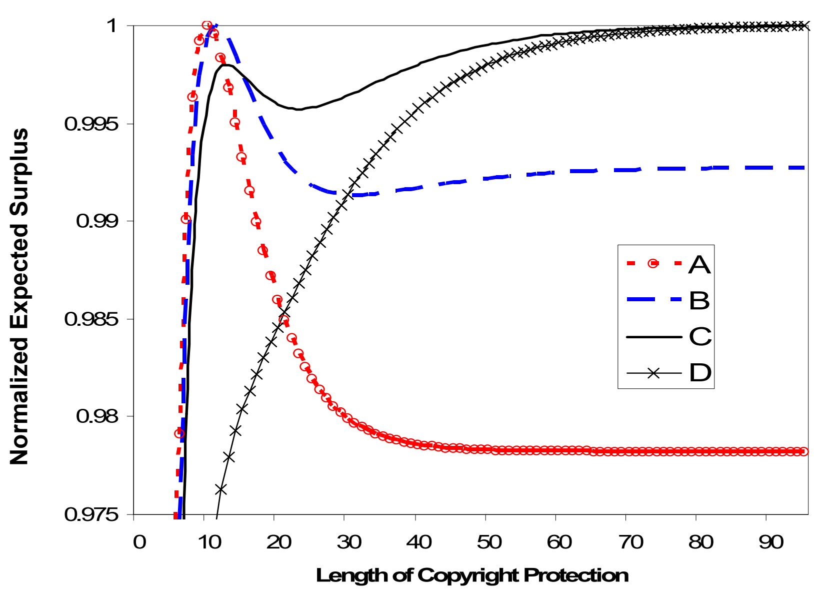

Figure2: Normalized Expected Total Surplus Simulations

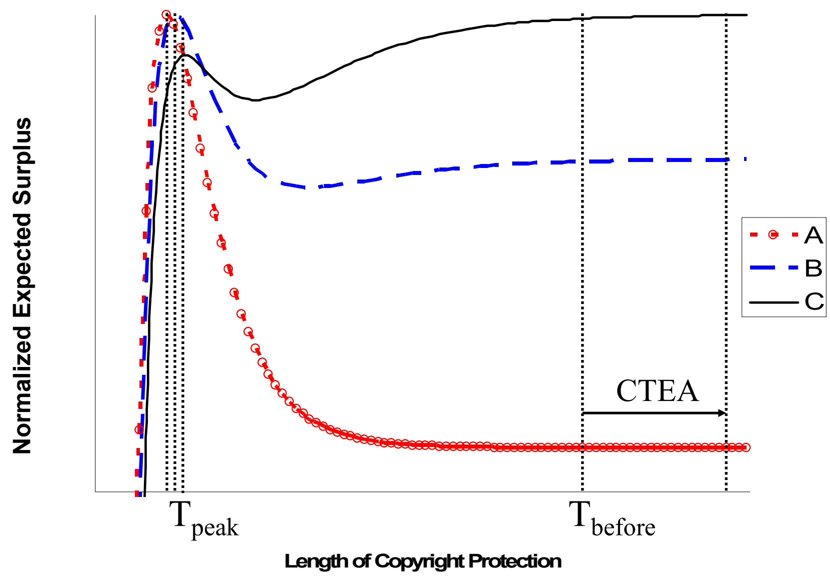

Figure 3: The Implications of CTEA for New Creative Works

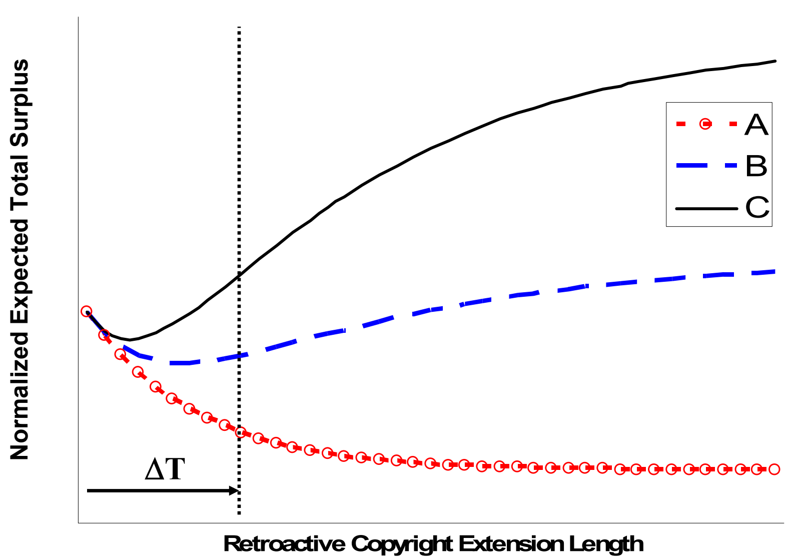

Figure 4: The Implications of CTEA for Existing Works