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Optimal Intellectual Property Rights Protection and Humanitarian Assistance during an International Health Emergency

by

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Abstract

We analyze policy options during an international health emergency to provide consumers in least developed countries access to patented life-extending pharmaceuticals. We show that a properly specified tariff against reexports achieves optimal price dispersion and is shown to depend on the nature of demand, product development costs and humanitarian concerns by western citizens for patients inside a health emergency zone. A tariff dominates regional exhaustion for achieving optimal price dispersion, improves the efficiency properties of a patent for covering product development cost and is a more efficient tool for internalizing a humanitarian externality than a targeted consumption subsidy.

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I. Introduction¹

Tension between the Trade Related Intellectual Property Rights (TRIPS) Agreement and the ongoing worldwide AIDS epidemic has prompted a discussion of possible amendments or reinterpretations that would provide consumers in developing and least developed countries access to life-extending pharmaceuticals that are currently the subject of patent protection.² During the fourth WTO Ministerial (Doha, November 2001), members of the World Trade Organization (WTO) endorsed the use of Article 31(b) which permits compulsory licensing in the event of a national health emergency. The weakness of the compulsory licensing approach is that pharmaceuticals produced under Article 31 must be intended primarily for domestic use. As a consequence, countries with little or no pharmaceutical production capacity may still have difficulty procuring life-extending drugs once the TRIPS Agreement is completely implemented in 2005. Thus, the TRIPS Council of the WTO was directed to make recommendations concerning access for least developed countries by the end of 2002.

Several strategies were considered. For example, the European Union, with limited support from the United States, argued in favor of amending Article 31(f) to allow production under a compulsory license to be exported to other least developed countries with a public health emergency.³ Alternatively, some developing countries have demonstrated an interest in receiving technical assistance that will help them develop the production capacity necessary to exploit the compulsory licensing provisions in Article 31. Finally, several humanitarian organizations have sought government aid to subsidize the purchase of AIDS drugs.

¹ The authors gratefully acknowledge comments from Alan Deardorff on a previous draft.

² See Maskus (2001) for an extensive discussion of global intellectual property rights.

³ On September 1, 2003, agreement was reached in the TRIPS Council to provide for the export of essential medicines produced under a compulsory license to developing countries with inadequate production capacity. Text of the agreement can be found at http://www.wto.org/english/tratop_e/trips_e/implem_para6_e.htm.

The ultimate objective of all these proposals is to find some mechanism for reducing the price of patented products during a health emergency. This debate necessarily raises the question of how much price variation across countries is globally socially optimal and what policy tools can most efficiently facilitate optimal price dispersion.

Currently, the potential to engage in price discrimination internationally depends critically on the extent to which national markets are segmented. Pharmaceutical firms themselves can exercise some control over the supply chain with the use of batch numbers, bar coding, dating methods and differential packaging. However, more rigorous control is exercised through statutes regulating intellectual property rights exhaustion. Under an international regime in which the principle of *national* exhaustion prevails, the holder of a property right can legally eliminate 'grey market' transactions and can thus set a profit-maximizing price for each market. However, the TRIPS Agreement does not establish universal rules concerning the exhaustion of patent rights, requiring only that each nation's laws be uniform across all products and not violate WTO principles of national treatment and nondiscrimination.⁴

Varian (1986) has established the necessary and sufficient conditions under which third-degree price discrimination is welfare improving. He finds that the welfare impact of an increase in price dispersion depends on the convexity of demand in each market.

Malueg and Schwartz (1994) analyze the issue of socially optimal *international* price dispersion in the context of linear demands. Even though linear demands do not have the

⁴ Richardson (2002) has demonstrated that in a system in which countries are free to set their own rules by which property rights are exhausted, parallel imports are permitted into all relevant foreign markets in a Nash equilibrium. Countries charged a higher-than-average price by virtue of a relatively low demand elasticity will find it welfare-maximizing to promote parallel imports by adopting the principle of *international* exhaustion. As a consequence, even in the case where international price discrimination is globally welfare improving, it is unlikely to emerge in the absence of an agreement establishing national exhaustion as an international norm.

convexity characteristics identified by Varian (1986), the opportunity to price discriminate across national markets may still be welfare improving. This will be the case if the dispersion in market size is so great that some smaller markets would otherwise not be served under a uniform international price.

Danzon (1997) lends further support for welfare-enhancing price discrimination in the case where additional profits finance R&D expenditures. Following Ramsey (1927), Danzon finds that the socially optimal mark-up of price over marginal cost is inversely proportional to the elasticity of demand in each market when firm profits are constrained to cover the cost of product development. She argues further that if the pharmaceutical industry is monopolistically competitive, implying that profits equal development cost, profit-maximizing price discrimination will approximate Ramsey pricing.

Based on their analysis, both Malueg and Schwartz and Danzon favor a principle of national exhaustion provided the pharmaceutical industry is sufficiently competitive. However, in the case of Malueg and Schwartz, while it is welfare improving to allow enough price dispersion to draw unserved consumers into the market, any further price discrimination beyond that critical point, as would be possible under a *national* property-rights exhaustion regime, reduces world welfare. Similarly, while Danzon finds that the Ramsey and profit-maximizing pricing rules bear a nominal resemblance, in fact as we will see below, the two are not approximately equal even if profits are zero.

As a consequence, an intellectual property rights (IPR) regime of national exhaustion, which completely separates two national markets, might facilitate more price discrimination than is socially optimal in the presence of a patent. Exhaustion is a binary policy tool. Therefore, the choice of exhaustion regime can facilitate a uniform international price or complete separation of

markets. Intermediate results in which there is some international price dispersion but not profit-maximizing price discrimination cannot reasonably be supported by an exhaustion regime.⁵

This leads us to consider whether policy tools other than national exhaustion can be used to achieve efficiency-enhancing market separation. In light of the fact that intellectual property-rights protection is at least a second-best tool for promoting innovation (Deardorff, 1992), it is likely that some degree of tariff protection is socially optimal in the presence of global patent protection. The natural issue to investigate, therefore, is whether a tariff that separates national markets by penalizing reexported products can be used to facilitate socially optimal price dispersion. This relates to one approach suggested by Watal (2001), of “establishing the right conditions and leaving (the implementation of differential pricing) to the market”⁶ (p. 13) while simultaneously putting in place mechanisms that prevent diversion of low-priced products to the developed country markets.

Since the innovative process is driven at least in part by the profits that innovation generates, we feel that it is equally important that we investigate the relationship between the optimal tariff regime and optimizing patent duration. Although the results presented below are cast in the setting of a national health emergency, they apply generally to any situation in which demand for a patented good varies across national markets.

The remainder of the paper is structured as follows. In section II, we first consider the optimal tariff without development cost. Then in section III, we introduce the cost of R&D and jointly determine the optimal tariff regime and patent duration. In section IV, we consider the

⁵ Malueg and Schwartz (1994) explore the possibility of varying the degree of price dispersion that emerges by strategically grouping countries. By mixing countries with high and low demand elasticities into groups in which regional exhaustion applies, they can produce a smaller degree of price dispersion, which may be more efficient than grouping like countries together.

⁶ Differential pricing is “the adaptation ... of prices to the purchasing power of consumers in different countries.” (Watal, 2001, p. 11). It is implemented through price discrimination.

optimal tariff in the presence of humanitarian assistance. Some caveats follow in section V and conclusions in section VI.

II. The Optimal Tariff without Innovation

We first consider the welfare-improving role of a tariff against reexports in a static market without innovation. Consider two regions, with region E in a national health emergency that can be ameliorated only with a drug X which is produced at constant marginal cost, c , solely in another location, N . Drug X is covered by a patent that is also owned in N . The inverse demands for X in each region are given by $P_N(X_N)$ and $P_E(X_E)$. The only restriction we place on these inverse demands is the natural one that marginal revenue is non-increasing in output, as given in *Assumption 1*.

Assumption 1: $P_i''(X_i)X_i + 2P_i'(X_i) \leq 0$ ($i = N, E$).

The patent holder is assumed to maximize profits from sales of X in N and E subject to a constraint on the maximum degree of price discrimination that is feasible without inducing reexport from the low-priced to the high-priced market. That is, the firm chooses outputs in the two markets to solve the following program:

$$(1) \quad \max_{\{X_N, X_E\}} \mathbf{p}_0 = P_N(X_N)X_N + P_E(X_E)X_E - c(X_N + X_E) + \mathbf{I}(P_N - P_E - d)$$

where $d \geq 0$ denotes an arbitrary degree of feasible price discrimination and $\mathbf{I} \leq 0$ is a Lagrange multiplier. For our purposes, the presence of an import tariff, \mathbf{t} , imposed by N on reexports of X from E , determines feasible price discrimination. The patent holder acts to solve the program:

$$(2) \quad \max_{\{X_N, X_E\}} \pi_t = P_N(X_N)X_N + P_E(X_E)X_E - c(X_N + X_E) + \mu(P_N - P_E - \tau)$$

where $\mu \leq 0$ is a Lagrange multiplier.

A Welfare-Improving Tariff

A straightforward application of the envelope theorem to program (2) confirms that the patent holder always prefers a higher to a lower tariff. What is much less clear is whether a tariff is welfare improving.

Consider first the case where in the absence of some statutory division of markets the patent holder would choose not to supply E . However, there exists some tariff τ_l above which it becomes profitable to supply both markets. It follows directly from the analysis of Malueg and Schwartz that a tariff just sufficient to induce the patent holder to supply both markets is welfare improving. Denote the unconstrained monopoly output level in both markets by X_i^M ($i = N, E$). Then we can state our first result.

Proposition 1: Suppose that when $\tau = 0$ the solution to (2) is $X_N = X_N^M, X_E = 0$ and that for $\tau \geq \tau_l$

the solution is $X_N(\tau) > 0$ and $X_E(\tau) > 0$. Then any tariff $\tau \geq \tau_l$ weakly Pareto dominates $\tau = 0$.

Proof: 1. A simple revealed preference argument shows that a tariff of at least τ_l increases the patent holder's profits.

2. It is also obvious that such a tariff increases consumer surplus in E since in its absence E would not be supplied.

3. Now consider consumers in N . If $\tau = 0$ output supplied to N satisfies the first-order condition:

$$(a) \quad P'_N(X_N)X_N + P_N(X_N) - c = 0 \Rightarrow X_N = X_N^M$$

while if $\tau \geq \tau_l$ the first-order condition from (2) is:

$$(b) \quad P'_N(X_N)X_N + P_N(X_N) - c = -\mu(\tau)P'_N(X_N) \Rightarrow X_N = X_N(\tau).$$

From *Assumption 1* and $\mu(\tau) \leq 0$ it follows that $X_N(\tau) \geq X_N^M$ and consumers in N do not lose from the tariff.

We turn next to consider whether a tariff above that minimally necessary to induce the patent-holder to serve E is socially desirable. Following Varian (1986), the change in total surplus (dTS) for an increase in price discrimination from some arbitrary level d to τ is bounded above and below by

$$(3a) \quad (P_N(d) - c)[X_N(\tau) - X_N(d)] + (P_E(d) - c)[X_E(\tau) - X_E(d)] > dTS$$

$$(3b) \quad (P_N(\tau) - c)[X_N(\tau) - X_N(d)] + (P_E(\tau) - c)[X_E(\tau) - X_E(d)] < dTS.$$

Manipulating the first-order conditions for maximizing (1) and (2), using the Mean-Value Theorem and substituting into equations (3a) and (3b), we find a necessary condition for welfare-improving price discrimination to be

Condition 1(necessary condition)

$$(3a') \quad 0 < \frac{(\lambda - \mu)}{2} [P_N(X_N(d)) - P_E(X_E(d))] \\ + \frac{[X_N(\tau) - X_N(d)]P_N''(\hat{X}_N)}{2[P_N'(\hat{X}_N)]^2} [P_N(\hat{X}_N) - c][P_N(X_N(d)) - c] \\ + \frac{[X_E(\tau) - X_E(d)]P_E''(\hat{X}_E)}{2[P_E'(\hat{X}_E)]^2} [P_E(\hat{X}_E) - c][P_E(X_E(d)) - c]$$

and a sufficient condition to be

Condition 2 (sufficient condition)

$$\begin{aligned}
 (3b') \quad & 0 < \frac{(\lambda - \mu)}{2} [P_N(X_N(\tau)) - P_E(X_E(\tau))] \\
 & + \frac{[X_N(\tau) - X_N(d)]P_N''(\hat{X}_N)}{2[P_N'(\hat{X}_N)]^2} [P_N(\hat{X}_N) - c][P_N(X_N(\tau)) - c] \\
 & + \frac{[X_E(\tau) - X_E(d)]P_E''(\hat{X}_E)}{2[P_E'(\hat{X}_E)]^2} [P_E(\hat{X}_E) - c][P_E(X_E(\tau)) - c]
 \end{aligned}$$

where $\hat{X}_N \in (X_N(\tau), X_N(d))$ and $\hat{X}_E \in (X_E(d), X_E(\tau))$.

The sign of the right hand sides of (3a') and (3b') largely turn on the curvature of the demand functions when sales are positive in both markets. If we make the assumption that region E is the beneficiary of price-discrimination, *Conditions 1* and *2* given by the inequalities in (3a') and (3b') will more likely be satisfied if $P_E'' > 0$ and $P_N'' < 0$. Simply put, price discrimination is more likely to be welfare enhancing if demand in the "strong" market⁷ is concave and in the "weak" market is convex.

Clearly, if these convexity conditions are satisfied then profit-maximizing price discrimination is also the most efficient degree of price discrimination. In fact, if *Condition 2* holds for all values of d , then the more price discrimination the better. In this case, the optimal tariff facilitates profit-maximizing price discrimination and is given by

$$(4) \quad \tau^{max} = \frac{c}{1 - \frac{1}{\epsilon_N}} - \frac{c}{1 - \frac{1}{\epsilon_E}}$$

where ϵ_i , $i = N, E$, are the demand elasticities in each region.

⁷ Schmalensee (1981).

This implies that if *Condition 2* is satisfied then, in the presence of patent rights, optimizing market separation can be achieved if a principle of national exhaustion is adopted by N which completely separates the two markets. However, if *Condition 1* is not satisfied, optimal price dispersion requires a smaller degree of market separation, as can be accomplished with a tariff. This brings us to our second result:

Proposition 2. If *Condition 1* for welfare-improving price discrimination is not satisfied for values of d that produce positive sales in both markets and region E is not supplied in the absence of a tariff then

- (a) the efficient tariff, τ_l , is just large enough to induce the patent holder to supply E and
- (b) a tariff set at τ_l is more efficient than a principle of regional exhaustion for N .

Proof. The proof is largely self-evident. (a) From *Proposition 1*, a tariff rate of τ_l weakly Pareto dominates $\tau = 0$. However, since *Condition 1* is not satisfied, any increase in the tariff rate above τ_l is welfare reducing. (b) Regional exhaustion permits the patent holder to set a profit-maximizing price independently for each market which, by (a), is more price dispersion than is socially optimal.

Simply put, the tariff of τ_l benefits the firm, consumers in E and does not harm consumers in N .

However, if the demand structures in E and N do not satisfy the convexity conditions of *Condition 1*, any greater tariff reduces welfare.

Linear Demands

The value of a tariff against reexports of X , relative to a principle of exhaustion, can be most readily appreciated when demands are linear. With this type of demand, *Condition 1* is not satisfied, with the result that, if both markets are served in the absence of a tariff, any tariff is

welfare reducing. An important exception, as implied by *Proposition 1*, (see also Malueg and Schwartz, 1994) is the case in which the demands in the two regions are so widely dispersed that it is not profit-maximizing for the patent holder to serve both markets.

Assume that the inverse demand curves in N and E are respectively

$$(5a) \quad P_N = a_N - bX_N$$

$$(5b) \quad P_E = Aa_N - bX_E$$

where $A \in (0,1)$ is a measure of the relative choke prices in the two regions. With this demand specification we can normalize marginal costs to $c = 0$ without loss of generality.

Assume first that there is no tariff so that if both markets are served the patent holder charges the same price in the two markets. The profit-maximizing decision of the patent holder is depicted in *Figure 1*. Owing to the kink in the demand curve at $P = Aa_n$, aggregate marginal revenue curve is discontinuous at $X = a_N(1 - A)/b$. As a result, there is a critical value of A above which the patent holder will choose to supply only N charging the monopoly price

$P_N = a_N / 2$, selling quantity $X_N = a_N / 2b$ and earning profits $\pi_N = a_N^2 / 4b$. We state this as:

Result 1: If demands are linear, given by equations (5a) and (5b), $\tau = 0$ and $A < \sqrt{2} - 1$ the patent holder will supply only N .

Proof: Profit if both markets are served is $\pi_B = (1 + A)^2 a_N^2 / 8b$ and if only N is served is

$$\pi_N = a_N^2 / 4b. \quad \pi_B < \pi_N \Rightarrow A < \sqrt{2} - 1.$$

Result 1 is illustrated in *Figure 1*. Serving both markets rather than only N reduces profit from N by area B and generates additional profit from E of area C .

(Figure 1 near here)

However, there exists some tariff levied by N against reexports of X from E that will induce the patent holder to supply E . The patent holder, of course, would like to push the tariff high enough to set a profit-maximizing price in each market. That is, the firm would like to see the tariff set at or above

$$(6) \quad \tau^{\max} = (1 - A)a_N / 2$$

thereby earning profits of $\pi_B(\tau^{\max}) = (1 + A^2)a_N^2 / 4b$. However, such a large tariff is not necessary to induce the firm to supply both markets.

Suppose that the tariff is set at $\tau_l \leq \tau \leq \tau^{\max}$. Then prices and sales are given by

$$(7a) \quad P_E = \frac{a_N(1 + A)}{4} - \frac{\tau}{2}$$

$$(7b) \quad P_N = \frac{a_N(1 + A)}{4} + \frac{\tau}{2}$$

$$(8a) \quad X_E = \frac{(3A - 1)a_N}{4b} + \frac{\tau}{2b}$$

$$(8b) \quad X_N = \frac{(3 - A)a_N}{4b} - \frac{\tau}{2b}.$$

Profits are given by

$$(9) \quad \mathbf{p}_B(\mathbf{t}) = \frac{\bar{A}^2}{2b} + \frac{\mathbf{t}}{2b}[(1 - A)a_N - \mathbf{t}],$$

where $\bar{A} = (1 + A)a_N / 2$ is the average of the two choke prices, and consumer surplus is given by

$$(10a) \quad CS_E = \left[\frac{(3A - 1)a_N}{2} + \tau \right]^2 \frac{1}{8b}$$

$$(10b) \quad CS_N = \left[\frac{(3 - A)a_N}{2} - \tau \right]^2 \frac{1}{8b}.$$

It is necessary only that the tariff be set large enough such that $\pi_B(\tau) > \pi_N$. Simple evaluation gives this tariff as $\tau_l = (1 - A(\sqrt{2} + 1))a_N/2$. *Proposition 2* indicates that a tariff rate greater than τ_l is not warranted. This can be confirmed directly since the impact of a small increase in the tariff on total surplus, $TS = CS_E + CS_N + \pi$, once both markets are served is given by $dTS/d\tau = -\tau/2b < 0$.

III. Innovation

Proponents of the TRIPS Agreement commonly refer to the beneficial impact of intellectual property rights protection on product innovation. Provisions, such as compulsory licensing, that undermine the ability of inventors to protect intellectual property may have the undesired effect of reducing the number of future discoveries. For this reason, we now turn to consider optimal price dispersion taking explicit account of its impact on research and development.

Consider a continuum of products all with the same demand and marginal cost of production.⁸ However, suppose that the discovery cost, DC , increases along the continuum according to

$$(11) \quad DC(I) = kI^a$$

where $a > 0$. The product at location I will be uncovered as long as its aggregate profits p are sufficient to offset the discovery cost, implying that the marginal discovery is determined by

$$(12) \quad I = \left[\frac{p}{k} \right]^{1/a}.$$

Total surplus over all discoveries is then:

$$(13) \quad TS = \int_0^{\left(\frac{\pi}{k}\right)^{\frac{1}{a}}} [CS_N + CS_E + \pi - DC(I)] dI = (CS_N + CS_E + \frac{\alpha}{\alpha+1} \pi) \left[\frac{\pi}{k} \right]^{1/\alpha}.$$

Profits and consumer surplus in equation (13) depend on the duration of the patent, P .

Assume that both markets are served and that the firm can earn \mathbf{p}^p in each period that the patent is in effect and zero thereafter. Then we can define the present discounted value of operating profits to be

$$(14) \quad \mathbf{p} = \mathbf{p}^p \int_0^P e^{-rt} dt = \frac{1}{r} (1 - e^{-rP}) \mathbf{p}^p,$$

where r is the discount rate. Similarly, aggregate consumer surplus is

$$(15) \quad CS = CS^p \int_0^P e^{-rt} dt + CS^* \int_P^\infty e^{-rt} dt = \frac{1}{r} (1 - e^{-rP}) CS^p + \frac{1}{r} e^{-rP} CS^*$$

where $CS^p = CS_N^p + CS_E^p$ and $CS^* = CS_N^* + CS_E^*$. The superscript p denotes the instantaneous (per period) profit and consumer surplus stream when the patent is in effect and an asterisk denotes consumer surplus under marginal-cost pricing.

To find the optimal policy configuration, we simply differentiate equation (13) with respect to τ and P , to give the first order conditions

$$(16a) \quad \frac{dT S}{d\tau} = \pi \left[\frac{d\pi}{d\tau} + \frac{dCS_N}{d\tau} + \frac{dCS_E}{d\tau} \right] + \frac{[CS_N + CS_E]}{\alpha} \frac{d\pi}{d\tau} \geq 0$$

$$(16b) \quad \frac{dT S}{dP} = \pi \left[\frac{d\pi}{dP} + \frac{dCS_N}{dP} + \frac{dCS_E}{dP} \right] + \frac{[CS_N + CS_E]}{\alpha} \frac{d\pi}{dP} \geq 0.$$

Consider first the determination of the optimal tariff as controlled by equation (16a). The second term is positive for $\tau < \tau^{\max}$ while the sign of the first term is determined by the convexity of the demand equations. If demands satisfy *Condition 2*, then profit-maximizing price discrimination is welfare-enhancing and the optimal tariff is given by equation (4).

However, if *Condition 1* is not satisfied then we must consider the weight of the second term in equation (16a). This term captures the value to consumers of the discovery of new goods

⁸ For a similar approach to innovation see Deardorff (1992).

financed by the incremental profits that emerge with intensified price discrimination. Even if greater price discrimination in any single market is welfare reducing, it may nevertheless be socially desirable if the value of newly discovered products outweighs the welfare cost of the increased distortion in existing products.

We can be more precise about the determination of optimal patent life and tariff by substituting (14) and (15) into (16). After simplifying we have:

$$(16a') \quad \frac{dTS}{d\tau} = \left(\frac{1}{r} (1 - e^{-rP}) \right)^2 \left[\pi^P \left[\frac{d\pi^P}{d\tau} + \frac{dCS^P}{d\tau} \right] + \frac{1}{\alpha} \frac{d\pi^P}{d\tau} \left[CS^P + \frac{1}{(e^{rP} - 1)} CS^* \right] \right] \geq 0$$

$$(16b') \quad \frac{dTS}{dP} = \frac{1}{r} (1 - e^{-rP}) e^{-rP} \mathbf{p}^P \left[\mathbf{p}^P + CS^P - CS^* \right] + \frac{1}{\mathbf{a}} \left[CS^P + \frac{1}{(e^{rP} - 1)} CS^* \right] \geq 0.$$

Optimal Patent Duration

In analyzing the first order condition determining optimal patent duration we must allow for the possibility that there may not be an interior solution.⁹ Assume first that the optimal patent life is finite. Then equation (16b') holds with strict equality and the optimal patent life is implicitly determined by

$$(16b'') \quad \frac{1}{e^{rP} - 1} = \frac{\alpha [CS_N^* + CS_E^* - \pi^P - CS_N^P - CS_E^P] - (CS_N^P + CS_E^P)}{CS_N^* + CS_E^*}.$$

The left hand side of (16b'') is positive, monotonically decreasing in the patent length, P , and tends to zero as P tends to infinity. It follows, then, that the optimal patent life is finite if and only if the right hand side of (16b'') is also positive. That is

$$(17) \quad \alpha > \frac{CS_N^P + CS_E^P}{CS_N^* + CS_E^* - \pi^P - (CS_N^P + CS_E^P)}.$$

⁹ There is an additional requirement that the optimal tariff that emerges from this analysis be large enough to ensure that both markets are served. We deal with this requirement explicitly when we analyze the linear case below.

Additionally, note from equation (16b'') that the optimal patent life is decreasing in a .

Equations (16b'') and (17) capture a tradeoff between the costs and benefits of extending the patent life. Extending the patent life encourages R&D and so creates a benefit from additional discoveries. But this additional benefit comes at a direct and indirect cost: the direct resource cost of undertaking the research (captured by a) and the indirect welfare cost of postponing the full consumer gains from the research (captured by $CS_N^* + CS_E^* - p^p - CS_N^p - CS_E^p$). The greater are these costs the shorter is the optimal patent life. By contrast, if the resource cost of additional discoveries is sufficiently small, so that inequality (17) is not satisfied, then the optimal patent life is infinite.

The Optimal Tariff in the Presence of Innovation Costs

Now consider the determination of the optimal tariff rate. Given an interior solution we can rewrite the first-order condition on τ as:

$$(16a'') \quad \pi^p \left[\frac{d\pi^p}{d\tau} + \frac{dCS^p}{d\tau} \right] + \frac{1}{\alpha} \frac{d\pi^p}{d\tau} \left[CS^p + \frac{1}{(e^{r^p} - 1)} CS^* \right] = 0.$$

It is clear from equation (16a'') that the optimal tariff depends on the patent length.

Consider first the implications of *sub-optimal* patent duration for the optimal tariff.¹⁰ Rewriting (16a'') allows us to identify the implications for tariff setting of sub-optimality in the patent length:

$$(16a''') \quad \frac{-\pi^p \left[\frac{d\pi^p}{d\tau} + \frac{dCS^p}{d\tau} \right]}{\frac{d\pi^p}{d\tau}} = \frac{1}{\alpha} \left[CS^p + \frac{1}{e^{r^p} - 1} CS^* \right]$$

¹⁰ According to the TRIPS Agreement Article 33, a patent must be granted for at least 20 years and under Article 27.1, the patent regime must not discriminate by product category and, thus, does not vary with the cost of

Clearly, the right-hand side of (16a''') is decreasing in τ and P . We also know that $\frac{d\pi^p}{d\tau} \rightarrow 0$ as τ approaches τ^{max} so the left-hand side of (16a''') is increasing in τ and tends to infinity as τ tends to τ^{max} . We can, therefore, illustrate (16a''') as in *Figure 2* where L denotes the left-hand and R denotes the right-hand side of (16a''').

(Figure 2 near here)

It follows immediately that the optimal tariff is a decreasing function of the patent length.¹¹ Both the tariff and the patent length encourage innovation. As a result, when the patent length is sub-optimally short ($P < P^*$ in *Figure 2*) we can compensate with a greater than optimal tariff while if the patent length is sub-optimally long ($P > P^*$) the tariff rate can be set lower than would otherwise be optimal.

The interdependence of the optimal tariff and patent duration has an important implication for policy during a health emergency. Our analysis suggests that allowing fine-tuning of the patent length during a national health emergency may help alleviate the health crisis in E , without compromising the benefits that flow from future discovery of new AIDS drugs. The reason is simple to explain. Shortening the patent duration for AIDS drugs increases the optimal tariff and so increases price discrimination. Consumers in E then benefit from the reduction in price that is facilitated by this greater price discrimination.

The Optimal Tariff-Patent Duration Configuration

We now turn to consider the optimal tariff when the patent length has been set optimally. Assume that there is an interior solution $\{\tau^*, P^*\}$ to (16'). Then substituting from (16b') into (16a') implies that the optimal tariff is implicitly determined by:

innovation. As a consequence, the statutory patent length may not coincide with the optimum for any particular class of inventions.

$$(18) \quad \frac{-\left[\frac{d\pi^p}{d\tau} + \frac{dCS^p}{d\tau}\right]}{\frac{d\pi^p}{d\tau}} = \frac{CS^* - \pi^p - CS^p}{\pi^p}.$$

The left-hand side of (18) is a measure of the welfare loss per dollar of profits of a marginal increase in the tariff rate while the right-hand side is the welfare loss per dollar of profits of a marginal increase in the patent length. When both patent length and tariff rate are set optimally these welfare losses are balanced.

Upon further inspection of (18), it is clear that when the patent length is set optimally the optimal tariff rate is independent of a and P^* . The implication is that there is an optimal assignment of policy tools to policy objectives. The horizon over which monopoly control is extended, P^* , does indeed depend on the resource cost of product innovation. However, the form in which monopoly control is exercised, i.e., price-discrimination vs. marginally longer patent life, depends only on the nature of demand.

The above analysis brings us to our central conclusion concerning the optimal tariff in the presence of a patent. It follows from *Figure 2* and (18) that if the optimal patent duration is finite then the optimal tariff must be positive even if both markets would be served in the absence of a tariff. However, the optimal tariff is smaller than τ^{max} . Further, if the optimal patent life is infinite then the optimal tariff still lies between zero and τ^{max} . In this case the right-hand side of (16a''') is CS^p / a . As a consequence the optimal tariff is now decreasing in a but approaches τ^{max} only as a approaches zero. That is, profit-maximizing price discrimination is socially optimal only when the discovery cost is constant over all varieties.

¹¹ This also follows directly from equation (16a').

We conclude then, that an optimal property rights configuration (in the absence of an optimal R&D subsidy) includes a mix of patent protection and market separation even when both markets are served in the absence of the opportunity to price discriminate:

Proposition 3. If *Condition 1* is not satisfied and both markets are served with a uniform international price then

- (a) optimal patent protection requires positive but less than profit-maximizing price discrimination and
- (b) a tariff combined with optimal patent duration is a more efficient stimulant of innovation than a principle of regional exhaustion with optimal patent duration.

Proof. The proof follows directly from the discussion above. (a) The welfare loss per dollar of profits of a marginal increase in the tariff rate tends to infinity as τ approaches τ^{max} while the welfare loss of a marginal increase in the patent length is finite. Hence the optimal tariff rate is $\tau^* < \tau^{max}$. (b) Under regional exhaustion, $P_N - P_E = \tau^{max}$. But from (a) this is more price discrimination than is socially optimal.

Innovation and Linear Demand

Assume once again that inverse demands in the two markets are linear, given by (5). It is clear that *Result 1* applies to the with-innovation case with the consequence that the minimum tariff rate that ensures both markets will be served is $\tau_l = (1 - A(\sqrt{2} + 1))a_N/2$. Further assume that there is an interior solution to (16). Then we can show¹² that the optimal tariff rate is

$$\tau^* = \frac{(1 + A)a_N \left(\sqrt{2(1 + a^2)} - (1 + a) \right)}{2(1 - A)}. \text{ Recall, however, that an implicit assumption in deriving } \tau^*$$

is that both markets are served, which requires a minimum tariff rate of τ_l . We have that $\tau^* < \tau_l$ if $A < A_l = 0.2745$, giving:

Result 2: If demands are linear, given by (5), the tariff rate and patent length are set optimally, and the patent length is finite, then the optimal tariff rate is

$$(19) \quad \tau^{**} = \begin{cases} (1 - A(\sqrt{2} + 1))a_N / 2 & \text{if } A < 0.2745 \\ \frac{(1 + A)a_N(\sqrt{2(1 + A^2)} - (1 + A))}{2(1 - A)} & \text{if } A > 0.2745 \end{cases}$$

It is straightforward to confirm that $0 < \tau^{**} < \tau^{max}$ and that $\tau^{**} \rightarrow 0$ as $A \rightarrow 1$. In other words, as indicated by *Proposition 3*, with innovation the optimal tariff rate is positive (but less than τ^{max}) even if both markets would be served in the absence of a tariff.

Implicit in *Result 2* is the assumption that the patent length is set optimally and is finite. The same calculations as above show that:

Result 3: If demands are linear, given by (5) and the tariff rate is given by (19) then patent length is finite if and only if

$$(20) \quad \alpha > \begin{cases} \frac{3 - 2A + 3A^2}{(1 + a)^2} & \text{when } A < 0.2745 \\ \frac{1 + \sqrt{2}A + (2 - \sqrt{2})A^2}{1 - \sqrt{2}A + (2 + \sqrt{2})A^2} & \text{when } A > 0.2745 \end{cases}$$

It follows from *Result 3* that a necessary condition for patent life to be finite is that $a > 1.648$ and a sufficient condition for patent life to be infinite is $a < 1$.

¹² The explicit equations are too complex to report here. Calculations were performed using *Mathematica*®: the notebook is available from the authors on request.

Figure 3 illustrates e^{Pr} for a range of values of A and a .¹³ The change in the comparative statics at $A = A_l$ derives from (19). When the choke price in E is “very low” the tariff rate is $\tau_l > \tau^*$. That is, the tariff rate is set higher than that which would be optimal from (16). This is offset by a reduction in the optimal patent length.

We can also recall our comments on the benefits of fine-tuning patent length in the presence of a national health emergency. *Figure 3* indicates that when the choke price in E is “low” an optimal property rights configuration requires a short patent length combined with the tariff rate that is just sufficient to ensure that E is supplied.

(Figure 3 near here)

IV. Humanitarian Assistance

Socially optimal price discrimination characterized in the previous section does not account for any humanitarian concern that consumers in N might have for patients inside the emergency zone. Consider, then, a positive external effect, e , generated onto consumers in N per unit of drug X consumed in E . It is obvious that the presence of an external effect will both reduce the social cost of price discrimination facilitated by t and also raise the cost of each additional period of patent duration.

Returning to equation (18), the presence of an external effect reduces the LHS and raises the RHS. As a consequence, the optimal tariff-patent configuration requires a shorter patent duration and a higher tariff once an external effect is introduced into the analysis. Thus, the presence of a humanitarian externality lends further support to the proposition that the patent duration should be shortened and the degree of price discrimination increased during an international health emergency.

¹³ When the tariff rate is set according to (19) optimal patent life is independent of a_N .

Internalizing the External Humanitarian Effect

There are several possible policy configurations that can be used to internalize the humanitarian concern of citizens in N . A tariff may be enlisted for this purpose or, alternatively, citizens in N may attempt to subsidize treatment with drug X in the emergency zone. Consider then a per-unit subsidy, s , to purchases of drug X in the emergency zone, under the assumption that *Condition 1* is not satisfied. Total surplus in the presence of an external effect is given by

$$(21) \quad TS = CS_E + CS_N + \mathbf{p} + (e - s)X_E.$$

Optimizing (21) with respect to τ and s , (abstracting from the use of price discrimination to support innovation), it is straightforward to show that in the case of linear demands

$$(22) \quad \tau^* = e.$$

That is, globally optimizing price discrimination opens up a gap between the price inside and outside of the emergency zone equal to the external humanitarian effect. Furthermore, the optimal tariff is independent of the size of the subsidy.

The impact of a subsidy depends on its size relative to the tariff.

Case 1: $s > \tau$. The price the patent holder can charge in N is bounded above by $P_N \leq P_E - s + \tau$ once the subsidy has been introduced. In the event that $s > \tau$ then $P_N < P_E$. Thus, the patent holder will maximize profits by selling only to E at price P_E , with the knowledge that most of its sales will be purchased by arbitrageurs and resold to N . By channeling sales through E to N , the patent holder is able to secure the subsidy for all of its sales, not just those that will actually be used in E . In the linear case, the firm will choose P_E to maximize

$$(2') \quad \pi = (P_E - c) \left[\frac{Aa_N - (P_E - s)}{b} + \frac{a_N - (P_E - s + \tau)}{b} \right]$$

yielding consumer prices

$$(6a') \quad P_E' = \frac{a_N(1+A)}{4} + \frac{c-s}{2} - \frac{\tau}{4}$$

$$(6b') \quad P_N' = \frac{a_N(1+A)}{4} + \frac{c-s}{2} + \frac{3\tau}{4}.$$

Although this is a rather peculiar arrangement, it is welfare improving from a world point of view. Notice that the effect of the subsidy is to lower price in both markets, thereby reducing the monopoly distortion brought about by the patent.

Case 2: $\tau > s$. In order to prevent reexports once the subsidy has been put in place it is necessary to constrain $s < \tau$, implying that $P_E < P_N$. As a consequence, the patent holder once again maximizes profits by selling into each market directly. Profits to be maximized become

$$(2'') \quad \pi = (P_E - c) \left[\frac{Aa_N - (P_E - s)}{b} \right] + (P_E - s + \tau - c) \left[\frac{a_N - (P_E - s + \tau)}{b} \right]$$

yielding consumer prices of

$$(6a'') \quad P_E' = \frac{a_N(1+A)}{4} + \frac{c-\tau}{2} - \frac{s}{4}$$

$$(6b'') \quad P_N' = \frac{a_N(1+A)}{4} + \frac{c+\tau}{2} - \frac{s}{4}.$$

Equations (6a') - (6b'') lead us to our central conclusions concerning the role of a subsidy motivated by humanitarian concerns. First, by virtue of the no-arbitrage condition, a subsidy, even though paid only to consumers in the emergency zones, has an equal impact on prices in both markets. In light of the fact that the subsidy cannot produce a differential price effect across markets, it is not an efficient tool for internalizing an external humanitarian effect when used in isolation. Rather, in this case, the benefit of a consumption subsidy stems primarily from the impact it has on reducing the monopoly distortion.

Indeed, it is straightforward to demonstrate that the optimal policy configuration in the presence of a patent and linear demands consists of a subsidy $s^* = a_N(1 + A) + 2e$ and a tariff rate $\tau^* = e$. This results in consumer prices of $P_N = c$ and $P_E = c - e$. Once again, we have an optimal assignment of policy tools to targets. A tariff is used most efficiently to internalize the humanitarian externality while the subsidy serves to reduce the monopoly distortion created by the patent.

Second, and perhaps more importantly, a consumption subsidy motivated by humanitarian concerns will have a greater humanitarian impact if a tariff against reexports of subsidized drugs is simultaneously imposed. Returning to equation (16a'), the introduction of a consumption subsidy, s , that is unaccompanied by a tariff against reexports, will lower the price paid by

consumers in E by $s/4$. That is, $\frac{dP_E'}{ds} = \frac{s}{4}$. However, if a tariff is simultaneously introduced

such that, $d\tau = ds$, then $\frac{dP_E'}{ds} = \frac{3s}{4}$. The impact of the subsidy on consumers in E is clearly

diluted by the presence of the unsubsidized market to which E is linked through the no-arbitrage condition. The tariff serves to break the link, thereby increasing the humanitarian value of the subsidy.

In the event that *Condition 2* is satisfied, profit-maximizing price discrimination dominates any lesser degree of price discrimination. The optimal tariff then supports perfect price discrimination between the two markets. Thus, if before external humanitarian concerns are incorporated into the analysis, the tariff has been set high enough to permit profit-maximizing price discrimination between the two markets then an increase in the tariff will have no effect on the firm's pricing decision. Prices have already been set to maximize profits in each market. As

a consequence, the patent holder will cut the price in E further only if consumption is directly subsidized.

V. Caveats

Before concluding, a couple of caveats are worth noting.

Defection

In order to implement any of the tariff strategies discussed above, it is necessary for all national governments in N to impose the prescribed tariff. However, while it may be in the global interest to introduce such tariffs, it is not in the interest of any individual country outside of E to cooperate. In such a situation, the patent holder will treat the market created by the countries in E plus the defectors as a single market.

The impact of defection depends on the nature of the demand curve of the defector. For example, if it is small and more convex than the average for the countries in E , defection may increase the optimal degree of price discrimination. By contrast, if the demand of the defector is large and inelastic, defection may substantially increase the subsidy cost of engineering the desired price reduction for countries legitimately in the emergency zone.¹⁴

The problem with defection can be mitigated somewhat by substituting an export tax scheme whereby a country in the emergency zone is required to impose the prescribed export tax in order to receive the subsidy. In this case, a government in the emergency zone that has an interest in securing life-extending drugs for its citizens at lowest cost has an incentive to impose and enforce the export tax. However, corrupt officials would still benefit from purchasing the drug and reselling it on the black market in countries outside of the zone.

¹⁴ Defection may not arise as a practical matter. Japan, Europe and North America constitute over 75 percent of the world pharmaceutical market by value. All three regions are likely to be sufficiently motivated by humanitarian concerns and the interest of their firms to promote socially optimal price dispersion.

Compulsory Licensing

In the preceding analysis, we have considered the role of tariffs and IPR exhaustion as two strategies for separating national markets. However, licensing for local production can also afford the patent holder additional protection against reexport.

In the case of a license *voluntarily* granted by the patent holder, the licensee can produce both for domestic sale and for export. Trade diversion can be mitigated to some degree since the variety produced by the licensee would be easily differentiated from that marketed by the patent holder. In addition, the licensed variety would have to obtain separate regulatory approval for importation into industrialized countries.

Even greater separation can be accomplished through *compulsory* licensing. Under the terms of the current TRIPS Agreement, pharmaceuticals produced under a compulsory license cannot be exported legally. Thus, if the optimal degree of price dispersion is equal to or greater than profit-maximizing price discrimination and the developing country has sufficient production capacity, optimal price dispersion can be accomplished through compulsory licensing *without* a tariff. This is the case provided that the local government ensures that the product is marketed at the socially optimal price.¹⁵ Further, under amendments to the TRIPS Agreement recently agreed to, pharmaceuticals produced with a compulsory license can also be exported to least developed countries that do not have adequate production capacity themselves.

Compulsory licensing can improve the humanitarian impact of a consumption subsidy in the absence of a tariff against reexport. For, when a subsidy is routed through an international agency that can purchase pharmaceuticals produced under a compulsory license rather than from

¹⁵ Under the current TRIPS Agreement, a compulsory license cannot be granted to a single firm, thus increasing the possibility that the pharmaceutical is offered at or close to marginal cost.

the patent holder, the full value of the subsidy accrues to consumers in the emergency zone. The opportunity for the patent holder to capture the subsidy is eliminated.

The weakness of relying on compulsory licensing concerns the long-term impact on innovation. Excessive resort to the TRIPS safeguard provisions, particularly by middle income countries, will reduce the incentive to develop products particularly targeted to developing country markets.

VI. Conclusions

This paper presents a simple model that is used to analyze the policy options available during an international health emergency. We find that under some circumstances a regime of nationally exhausted IPR and compulsory licensing with the option to export to other least developing countries can produce socially optimal international price dispersion. Such a regime will be optimal if demand curves satisfy the convexity conditions characterized by Varian (1986).

However, we also show that the optimal degree of price discrimination can always be achieved with a properly specified tariff against reexports no matter the convexity/concavity of demand. When patent length can be manipulated as an explicit policy tool we also identify a clear policy assignment. The tariff rate should be set to achieve social welfare objectives while the patent length can be used to control the resource cost of innovation.

When explicit account is taken of the role of innovation we find a trade-off between patent length and the relevant optimal tariff rate. If the patent length is too short (too long) there must be an offsetting higher (lower) tariff rate than would otherwise be socially optimal. This implies that there is a possible welfare benefit from using the patent length as an explicit policy tool during a national health emergency. In the linear case, for example, we find that when the

country facing a national health emergency is “small” the optimal policy configuration is a short patent length combined with a tariff rate just sufficient to ensure that the small country is supplied.

We also consider the role of a tariff when a positive externality is generated onto western consumers from consumption of life-extending drugs by poor consumers. Although current proposals emphasize the use of a consumer subsidy to internalize the external humanitarian effect, we find that a tariff against reexports is a more efficient tool for this purpose. A consumption subsidy, even if paid only to consumers in the health emergency zone, also lowers price outside the emergency zone through the no-arbitrage condition and, therefore, cannot produce a differential price effect. By contrast, a tariff against reexports from the emergency zone can be used to produce a price differential between the two markets equal to the external humanitarian effect. A subsidy in this case serves primarily to reduce the monopoly distortion.

Perhaps more importantly, a consumption subsidy motivated by humanitarian concerns will have a greater humanitarian impact if a tariff against reexports of subsidized drugs is simultaneously imposed. We found that in the case of linear demands, the price reduction to consumers in the emergency zone brought about by a subsidy accompanied by an equal tariff is three times as large as the price reduction with the subsidy alone.

Finally, we would like to note at this point that the optimal tariff in the linear case provides for less price dispersion than will emerge if firms are allowed to engage in profit-maximizing price discrimination between N and E . As a consequence, even if firms enter with new varieties until profits just barely cover the cost of product development, profit-maximizing price discrimination does not approximate Ramsey pricing, as claimed by Danzon.

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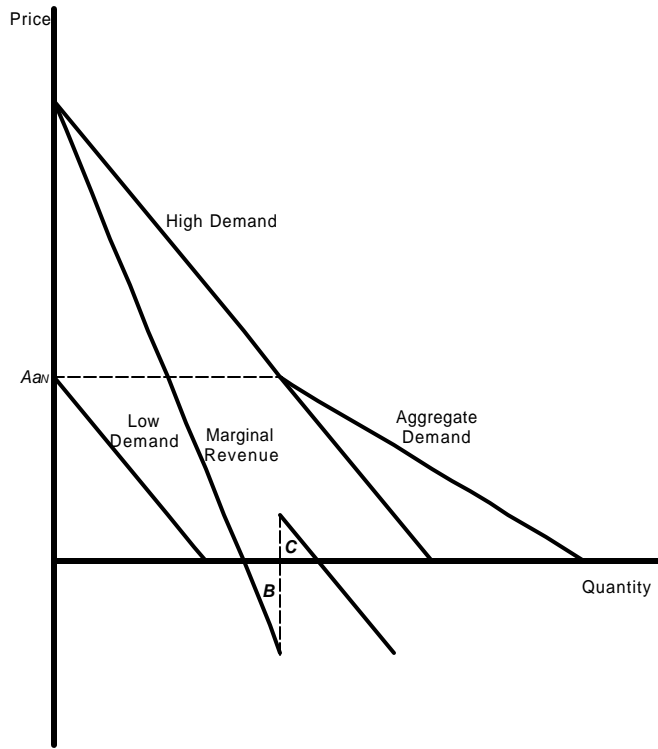


Figure 1: Linear Demand and Market Serving

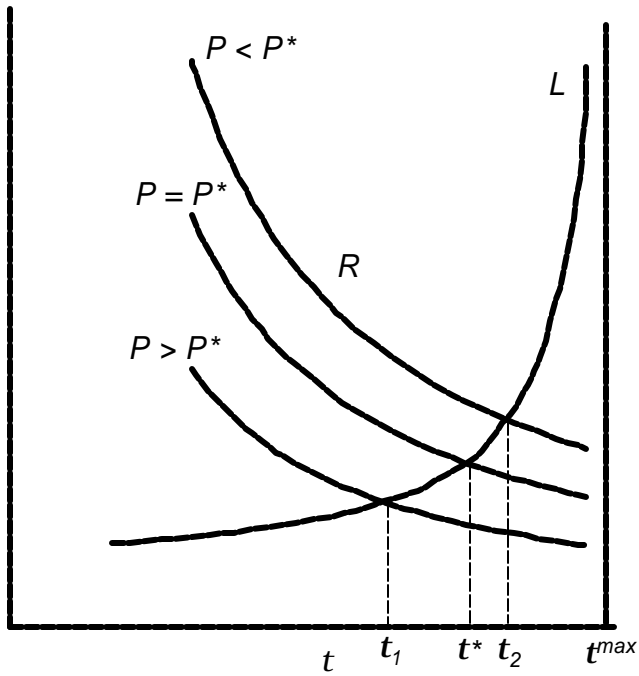
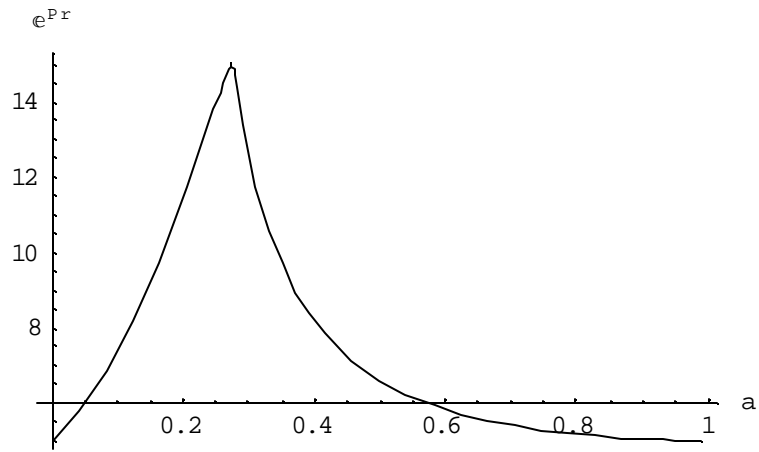


Figure 2: The Optimal Tariff

$$\alpha = 2$$



$$\alpha = 3$$

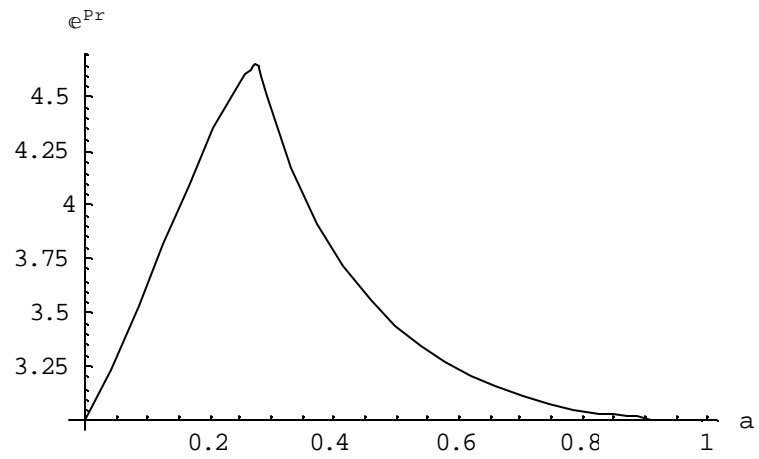


Figure 3: Optimal Patent Life

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