Welfare Effects of Global Patent Protection

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This paper uses a simple model of invention and patent protection to examine the welfare effects of extending patent protection from the country where invention takes place to another country that is only a consumer of invented products. It is shown that, while the welfare of the inventing country certainly rises with the extension of patent protection, that of the other country probably falls, and may well fall by more than the increase in welfare of the inventing country. In particular, as patent protection is extended to a larger and larger portion of the world, the effect on the welfare of the world as a whole of extending it to the rest of the world becomes negative.

INTRODUCTION

The Uruguay Round of Multilateral Trade Negotiations has included a major effort by the industrialized countries especially to bring the protection of intellectual property rights under the auspices of the General Agreement on Tariffs and Trade (GATT). The purpose is primarily to extend such protection to countries that currently provide it only weakly or not at all, particularly certain developing countries. This paper will explore one aspect of the economics of this issue, emphasizing in particular the possible adverse welfare effects that would be caused by extending intellectual property protection to all countries of the world. The argument will be formalized in terms of a particularly simple model of patent protection, though the principles apply as well to other forms of intellectual property protection such as copyrights.[1]

As is well known, a primary reason for providing patent protection is to permit inventors to earn a return on their inventions, and therefore to provide an incentive for technology to advance. The cost of providing patent protection, however, is that it permits the patent-holder to exercise monopoly power over the market for the new product, and this prevents the benefits of the new product from being enjoyed optimally by consumers. It is for this reason, some have argued, that patent protection is granted for only a limited time, so as to achieve a desirable balance between incentives to invent and gains to consumers from products after they have been invented.[2] I will argue that the same sort of trade-off may also justify limiting patent protection geographically, as well as over time.

Such a geographical limitation on the coverage of patents is most likely to be desirable when inventive activity is concentrated in one part of the globe, while the benefits from inventions can be enjoyed equally by consumers worldwide. To make the point, I will therefore focus on a particular very simple theoretical model of inventions and patents that has these properties in extreme form.

In the context of this model, I will show first that the trade-off between incentives to invent and the subsequent enjoyment of inventions does justify the use of patent protection, at least as a second-best policy in the country where invention occurs.[3] Thus, the principal motive most often discussed for

extending patent protection around the world is indeed present in my model. However, I will then show that extending this protection to other countries is very likely to be harmful to them, in spite of the fact that they will benefit from increased inventive activity. In those circumstances, if the world as a whole does gain from extending patent protection, it is only in the inventing countries that these gains are experienced, and in fact, they gain even more than the world as a whole because they gain at the rest of the world's expense.[4]

Finally, I show that it is even possible for the world as a whole to lose from extending patent protection, and that such a loss *must* occur, in the context of my model, as the coverage of patent protection is extended to the entire world. Thus, a case can be made, in terms of world welfare, for limiting the coverage of patent protection to less than the entire world.

I recognize that the model in which I demonstrate this result is far from general, and that there are many considerations that are absent from the model that could undermine it. I will discuss several of these in the concluding section. Nor would I argue by any means that the efforts in the Uruguay Round have been misguided. I do not doubt that a good case can be made for extending patent and other intellectual property rights into a number of countries where they currently do not exist, or are only laxly enforced. However, the case for universal patent protection is not a clear one, as my analysis demonstrates, and the concerns of some developing countries that they will be exploited by patent protection are not without foundation.

I. An Economic Analysis of Patent Rights

A single invention in a single country

Consider first the case of a single invention. At a research cost of R, an inventor has designed a new product that can be produced by anyone at a constant marginal production cost of c. Individual consumers have a demand for the new product that is described by their inverse demand function,

$$(1) \qquad p = a - bq.$$

With n identical consumers, the inverse market demand function is

$$(2) \qquad p = a - (b/n)q.$$

which is graphed in Figure 1 as the curve DD.

Competitive production. Suppose first that the inventor is *not* granted a patent. Then anyone at all will be able to produce the new good, and a perfectly competitive market price equal to the marginal cost, c, will be established. The competitive output will be

$$(3) \qquad q^c = n \frac{a-c}{b},$$

and consumers will earn a surplus of

$$(4) \qquad s^o = \int_0^{q^c} [a - (b/n)q - c] \, dq = \frac{n}{2} \frac{(a-c)^2}{b}.$$
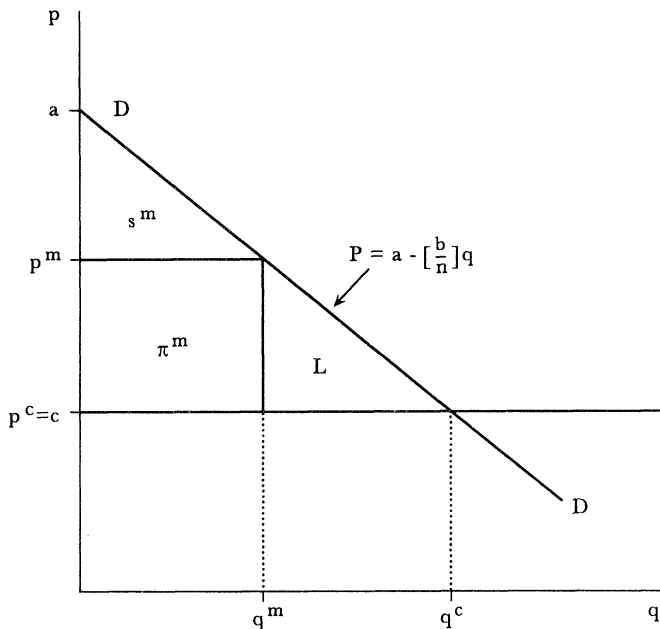
FIGURE 1.   Welfare effects of monopoly pricing of a single invention.

There will be no monopoly profits earned on the invention, and the inventor will have lost entirely the cost of research, R. None the less, given that the product has already been invented, this competitive outcome is also optimal in the sense of maximizing joint consumer and producer welfare, and the consumer surplus in equation (4) is therefore superscripted with an o for optimal.

Monopolized production.   Now suppose instead that a patent is granted to the inventor. The inventor will now be able to charge a monopoly price that maximizes the monopoly profit on production,

(5) $\pi = (p - c)q,$

where p is given by the market demand function, (2). It is seen that, because demand is linear and marginal cost is constant, the monopoly output will be exactly half of the competitive output,

(6) $q^m = \tfrac{1}{2}n \dfrac{a-c}{b}$

with a monopoly price halfway between cost c and the demand parameter a,

(7) $p^m = \tfrac{1}{2}(a+c),$

and monopoly profit

(8) $\pi^m = \tfrac{1}{4}n \dfrac{(a-c)^2}{b} = \tfrac{1}{2}s^o.$

As noted here and as illustrated in Figure 1, monopoly pricing in this linear case extracts exactly half of the optimal consumer surplus in the form of monopoly profit.

Consumers in this monopoly situation derive an even smaller surplus:

$$(9) \qquad s^m = \int_0^{q^m} [a - (b/n)q - p^m]\,dq = \tfrac{1}{8}n\frac{(a-c)^2}{b} = \tfrac{1}{4}s^o,$$

that is, only one-quarter of what they would have obtained with perfect competition. The benefit to society as a whole of having the invention produced by a monopoly includes both the monopoly profit and the consumer surplus, and is therefore three-quarters of the benefit that would have acrued under competition:

$$(10) \qquad b^m = \pi^m + s^m = \tfrac{3}{4}s^o.$$

Therefore, there is a deadweight loss of one-quarter of the optimal consumer surplus that is attributable to monopoly pricing.

This is illustrated in Figure 1, where the demand curve DD and the constant marginal cost c give rise to a competitive (and optimal) output of q^c at a price $p^c = c$. A patent that grants monopoly power to the patent-holder cuts output in half, raises price, and creates a deadweight loss that is labelled L. However, the advantage of the patent is also indicated in that the patent holder now earns the monopoly profit π which then provides some return on the cost of the invention.

Unfortunately, even this return may not be enough to compensate the inventor for a worthwhile invention. If we now consider the *ex ante* problem of whether the invention was worthwhile, it is clear that the invention would have been worth the cost to society as long as the optimal consumer surplus, s^o, were to exceed the cost of research, R. Since only half of s^o, i.e. π, accrues to the patent-holder, one would expect that some worthwhile inventions will not be created, even when there is patent protection. Patents are therefore an imperfect method of fostering invention, both because they lead to monopoly distortions of consumer choice, and because they fail to foster all worthwhile inventions. This latter point will be made more clearly if we now consider multiple inventions and bring the choice of the level of invention explicitly into the analysis.

Multiple inventions in a single country

The case of multiple inventions will be most tractable if we consider a continuum of them and hence abstract from the indivisibility of individual inventions and the discontinuities that this would imply. As long as the actual number of inventions is large, this simplification will not matter appreciably for the results.

Suppose then that inventions are indexed by non-negative real numbers, z. Let $a(z)$, $b(z)$, $c(z)$ and $R(z)$ be the demand and cost parameters for invention z, as in the analysis above. Then let $s^o(z)$ be the optimal consumer surplus corresponding to invention z, as in (4), but normalized to be expressed per unit of research cost. That is,

$$(11) \qquad s^o(z) = \frac{n}{2}\frac{[a(z) - c(z)]^2}{b(z)} \Big/ R(z).$$

Without loss of generality, let inventions be ordered so that

(12) $z_1 > z_2 \implies s^o(z_1) \leq s^o(z_2).$

Because of the assumed linearity of demand and cost, this ordering of inventions by optimal consumer surplus will also be the ordering by monopoly profit, and therefore the inventions that will be undertaken will always be those with the lowest indices, z, up to some cutoff point.

I will measure the level of invention by its research cost. Hence if all inventions from $z = 0$ to some $z = \hat{z}$ are invented, then the total cost of invention, I, will be

(13) $I(\hat{z}) = \int_0^{\hat{z}} R(z) \, dz.$

Since $dI(\hat{z})/d\hat{z} = R(\hat{z}) > 0$, the function $I(\cdot)$ is monotonic and can be inverted. I therefore re-express the optimal consumer surplus of the marginal invention in terms of I, the total cost of invention:

(14) $s^o(I) = s^o[I^{-1}(I)].$

From (12) and (13), $s^o(I)$ is also weakly monotonically decreasing in I. What it represents is the optimal consumer surplus per dollar of research obtainable from the marginal dollar of research, given that I dollars have already been spent on all inventions yielding a greater surplus per dollar.

From the earlier analysis of a single invention, it follows that various properties of a monopoly equilibrium can also be calculated from $s^o(I)$. In particular,

(15) $\pi^m(I) = \frac{1}{2}s^o(I)$

is the monopoly profit, per dollar of research, from the marginal invention, and

(16) $s^m(I) = \frac{1}{4}s^o(I)$

is the consumer surplus, per dollar of research, from the marginal invention, given that production is monopolized.

From their derivation, it is clear that these functions ought actually to be step functions, declining discontinuously at each level of investment that completes the full research cost, $R(z)$, of the marginal invention. For simplicity, however, I will assume that the number of inventions is large, so that these functions can be approximated as continuous. Further, and much more restrictively, I will assume that these functions are linear, represented by

(17) $s^o(I) = n(f - gI),$

where $f, g > 0$ are parameters of this linear function and n, as before, is the number of consumers in the country.

Population is included here explicitly in order to facilitate analysis of the two-country case below. It appears multiplicatively because of its role in (4). Note, therefore, that $f - gI$ is the optimal consumer surplus per dollar of research for a representative consumer and that, from (4), $f = [a(z) - c(z)]^2/2b(z)$ for $z = 0$, highest-priority invention. The slope parameter g indicates the rapidity with which diminishing returns to invention set in. A particular level of invention, $\bar{I} = f/g$, represents the total research cost of all

available inventions whose products would be demanded if competitively priced and thus provides an upper bound on the level of invention that will actually take place.

Competitive invention.   I can now examine the equilibrium levels of invention and welfare under various scenarios. The competitive case is simplest, because nothing happens. Without patent protection, the level of invention will be zero in this model, since there will be no way for any inventor to recover the cost of research. Levels of total consumer surplus, S^c, and monopoly profit, Π^c, will also be zero:

$$(18) \qquad I^c = S^c = \Pi^c = 0.$$

Optimal invention.   The optimal level of invention, I^o, will include all inventions that yield an optimal consumer surplus greater than their cost of research, and hence whose optimal consumer surplus per dollar is greater than 1. Thus, from (17),

$$(19) \qquad I^o = s^{o^{-1}}(1) = \frac{nf-1}{ng}.$$

Since the optimal consumer surplus is obtainable only if products are competitively priced, the monopoly profits corresponding to this optimal level of invention must be zero:

$$(20) \qquad \Pi^o = 0.$$

The total consumer surplus obtained in this optimal situation will then be found by adding across all inventions the optimal consumer surplus per dollar, multiplied by the research cost of each invention. With the assumed continuity of the surplus function, s^o, this addition is accomplished by integration:

$$(21) \qquad S^o = \int_0^{I^o} s^o(I)\, dI = \int_0^{(nf-1)/ng} n(f-gI)\, dI = \frac{(nf)^2 - 1}{2ng}.$$

Finally, the net gain to society from this optimal level of invention is the sum of the consumer and producer gains (the latter being zero in this case) minus the research cost, I^o, of the inventions:

$$(22) \qquad N^o = S^o + \Pi^o - I^o = \frac{(nf)^2 - 1}{2ng} - \frac{nf-1}{ng} = \frac{(nf-1)^2}{2ng}.$$

Monopolized invention.   If inventors are protected with patents, then production will take place under conditions of monopoly, as discussed above. The level of invention will be that which equates the monopoly profit from the marginal invention to its research cost, or in other words which equates the monopoly profit per dollar to unity. Thus,

$$(23) \qquad I^m = s^{m^{-1}}(1) = s^{o^{-1}}(2) = \frac{nf-2}{ng}.$$

The level of monopoly profit is obtained by integrating the profit function from (15) and (17), i.e.

$$(24) \qquad \Pi^m = \int_0^{I^m} \tfrac{1}{2} s^o(I)\, dI = \int_0^{(nf-2)/ng} \tfrac{1}{2} n(f-gI)\, dI = \frac{(nf)^2 - 4}{4ng},$$

while the level of consumer surplus is obtained by integrating (16):

$$(25) \qquad S^m = \int_0^{I^m} \tfrac{1}{4} s^o(I) \, dI = \int_0^{(nf-2)/ng} \tfrac{1}{4} n(f-gI) \, dI = \frac{(nf)^2-4}{8ng} \,.$$

Summing (24) and (25) and subtracting (23), the net gain to society from invention in the patent-protected monopoly situation is

$$(26) \qquad N^m = S^m + \Pi^m - I^m$$

$$= \frac{(nf)^2-4}{8ng} + \frac{(nf)^2-4}{4ng} - \frac{nf-2}{ng} = \frac{(nf-2)(3nf-2)}{8ng} \,.$$

These results are illustrated in Figure 2. The uppermost curve represents the optimal consumer surplus per dollar cost of research, and is drawn as the straight line $n(f-gI)$. Its intersection with the horizontal line at 1 indicates the socially optimal level of invention, so long as goods once invented are also produced optimally. The total consumer surplus generated by this level of invention is the area under the $s^o(I)$ curve between $I=0$ and $I=I^o$. The net gain to society, however, is smaller by the cost of research, and is therefore given by the area of the triangle under $s^o(I)$ and above 1.

As was found from the analysis of a single invention, the monopoly profits, π^m, and the consumer surplus in the presence of monopoly, s^m, are one-half and one-quarter, respectively, of s^o. These are therefore also drawn in Figure 2 as straight lines, starting from correspondingly lower intercepts and ending at the same level of invention $\bar{I}$. Since monopolists earn only π^m per dollar of research, patent rights will foster invention only up to the point where these
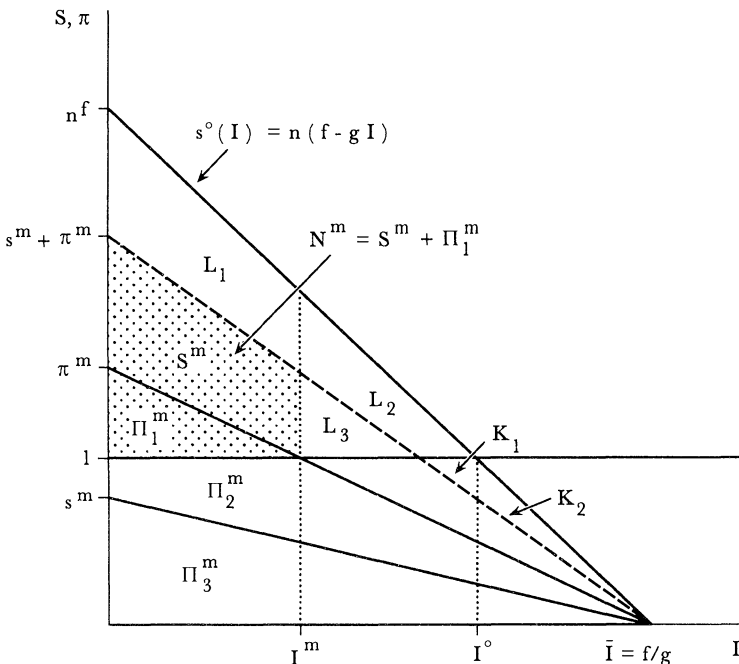

FIGURE 2.   Welfare effects of many inventions per dollar of research.

monopoly profits equal one dollar. Thus, the level of invention with patent protection is shown as I^m.

With this construction, the total profits from all inventions up to I^m are given by the area under π^m, shown in Figure 2 as the sum of areas Π_1^m, Π_2^m and Π_3^m. Consumer surplus is the area under s^m between 0 and I^m, which is equal to Π_3^m, but is shown separately by first adding together π^m and s^m in the line $s^m + \pi^m = (3/4)s^o$. Consumer surplus is then the area S^m, below this line and above π^m. The total net benefit to society due to inventions up to I^m is the sum of consumer surplus and profit, minus the cost of research. Since the latter is the area of the rectangle under the horizontal line at 1, this net benefit is simply the shaded area, $S^m + \Pi_1^m$.

Comparing this with the larger triangle of optimal social benefit from invention, there is a deadweight loss of areas $L_1 + L_2 + L_3$. Area L_1 represents the loss of consumer surplus arising from the monopoly pricing of products that are invented. Area $L_2 + L_3$, on the other hand, represents the consumer surplus that is forgone because less than the optimal amount of invention takes place, even when inventors are granted monopoly patent rights. The total deadweight loss is calculated from (22) and (26) as[5]

$$(27) \qquad N^o - N^m = \frac{(nf-1)^2}{2ng} - \frac{(nf-2)(3nf-2)}{8ng} = \frac{nf^2}{8g}.$$

Multiple inventions in two countries

Suppose now that there are two countries, A and B. All invention takes place in country A, but once a good has been invented the technology is known and it can be produced in either country, subject of course to any limitations imposed legally by patent rights. Consumers in the two countries have identical individual demand functions for all goods. Populations (numbers of consumers) in the two countries are n^A and n^B respectively. It will be convenient to define

$$(28) \qquad n = n^A + n^B$$

and to express results in terms of n and the fraction of the world's population that is in country A:

$$(29) \qquad \gamma = \frac{n^a}{n}.$$

As before, let (1) represent the common individual inverse demand functions for a particular good, so that the market inverse demand functions in the two countries are

$$(30) \qquad p^J = a - (b/n^J)q^J, \qquad J = A, B.$$

With marginal cost, c, of producing the good common to both countries, the optimal consumer surplus for the good in country J is

$$(31) \qquad s^{oJ} = \frac{n^J}{2}\frac{(a-c)^2}{b} = n^J\tilde{s},$$

where $\tilde{s}$ is the optimal *per capita* consumer surplus for the good.

As before, let inventions be ordered by decreasing values of $\tilde{s}/R$, and assume that these values can be expressed as a linear function of I. That is,

$$(32) \quad \tilde{s}(I) = f - gI$$

is the optimal *per capita* consumer surplus per dollar of research for the marginal invention, given that I dollars have been spent inventing all goods of equal or greater $\tilde{s}/R$. The relevant values of consumer surplus and monopoly profits for the two countries can then also be expressed in terms of this linear function. First, multiplying the *per capita* consumer surplus in (32) by population,

$$(33) \quad s^{oJ}(I) = n^J(f - gI), \qquad J = A, B,$$

is the total optimal consumer surplus per research dollar in country $J = A, B$ owing to the marginal invention at level of invention I (and would be received by consumers in country J if the good were competitively priced there). From this, again exploiting the linearity of demand, properties of the monopoly equilibria can be found as well:

$$(34) \quad \pi^J(I) = \tfrac{1}{2}s^{oJ}(I) = \tfrac{1}{2}n^J(f - gI), \qquad J = A, B,$$

is the monopoly profit per dollar of research to be obtained by selling the product of the marginal invention in country J at the monopoly price. Similarly,

$$(35) \quad s^{mJ}(I) = \tfrac{1}{4}s^{oJ}(I) = \tfrac{1}{4}n^J(f - gI), \qquad J = A, B,$$

is the consumer surplus per dollar received by consumers in country J from the marginal invention if they pay the monopoly price.

It is now possible to calculate the totals of consumer surplus and monopoly profit for different patent protection regimes by first using (34) to identify the level of invention that will take place, and then integrating these various functions. The two regimes that I will consider are 'restricted patent protection', in which patent protection is provided only in country A, and 'extended patent protection', in which protection is extended to country B as well.

Restricted patent protection. With patent protection only in country A, monopoly profits will be earned only there, and invention will take place up to the point where

$$(36) \quad \pi^A(I^r) = 1.$$

Using (34) and (29), it follows that

$$(37) \quad I^r = \frac{\gamma nf - 2}{\gamma ng}.$$

Integrating (35) up to this level of invention and using (29), the level of total consumer surplus in country A may be found as

$$(38) \quad S^{rA} = \int_0^{I^r} \frac{1}{4}n^A(f - gI)\, dI = \frac{\gamma^2 n^2 f^2 - 4}{8\gamma ng}.$$

Monopoly profits are made only in country A, and thus may be found by integrating (34) for country A alone. Since (34) is just twice (35), profits are found immediately as twice (38):

$$(39) \quad \Pi^r = \Pi^{rA} = \frac{\gamma^2 n^2 f^2 - 4}{4\gamma ng}.$$

Finally, because patent protection is limited to country A, consumers in country B have access to a competitive supply of all invented goods. Their total consumer surplus is therefore obtained by integrating (33) for country B:

$$(40) \qquad S^{rB} = \int_0^{I^r} n^B (f - gI)\, \mathrm{d}I = \frac{(1-\gamma)(\gamma^2 n^2 f^2 - 4)}{2\gamma^2 ng}.$$

The net gain to all residents of country A, including their monopoly inventors, is their consumer surplus plus their monopoly profit, minus the cost of invention. Using (37), (38) and (39),

$$(41) \qquad N^{rA} = S^{rA} + \Pi^r - I^r = \frac{(\gamma nf - 2)(3\gamma nf - 2)}{8\gamma ng}.$$

The net gain to all residents of country B includes only their consumer surplus, $N^{rB} = S^{rB}$, in (40). Together, these give the net gain for the world as a whole as

$$(42) \qquad N^{rW} = N^{rA} + N^{rB} = \frac{(\gamma nf - 2)[\gamma(3\gamma nf - 2) + 4(1-\gamma)(\gamma nf + 2)]}{8\gamma^2 ng}.$$

All of this is illustrated in Figure 3, which replicates Figure 2 for country A in the top panel and for country B, upside down, in the bottom panel. With monopoly profits earned only in country A, invention takes place up to I^r, where the marginal per-dollar profit in country A, π^A, intersects the horizontal line at 1. Gross profits are then the area under π^A, or $u_1 + u_2 + u_3$. Consumer surplus in country A is area u_1. Since the cost of invention, I^r, is the area $u_1 + u_2$, the net gain for country A is $u_1 + u_3$.

Meanwhile, consumers in country B get a free ride, receiving the optimal, or competitive, consumer surplus equal to area $v_1 + v_2 + v_3$.

Extended patent protection. If patent protection is now extended to country B as well as country A, then an invention once patented in country A will also entitle the inventor to monopoly profits in country B.[6] With potential investors knowing this, invention in country A will take place up to the point where the total profits from the two sources from the marginal invention just covers the cost of research. Thus,

$$(43) \qquad \pi^A(I^e) + \pi^B(I^e) = 1.$$

Using (34), this can be solved to yield

$$(44) \qquad I^e = \frac{nf - 2}{ng}.$$

As before, the totals of consumer surplus and monopoly profits in the two countries can be found by integrating (34) and (35) up to I^e. In country A this gives

$$(45) \qquad S^{eA} = \int_0^{I^e} \frac{1}{4} n^A (f - gI)\, \mathrm{d}I = \frac{\gamma(n^2 f^2 - 4)}{8ng}$$

and

$$(46) \qquad \Pi^{eA} = \int_0^{I^e} \frac{1}{2} n^A (f - gI)\, \mathrm{d}I = \frac{\gamma(n^2 f^2 - 4)}{4ng},$$

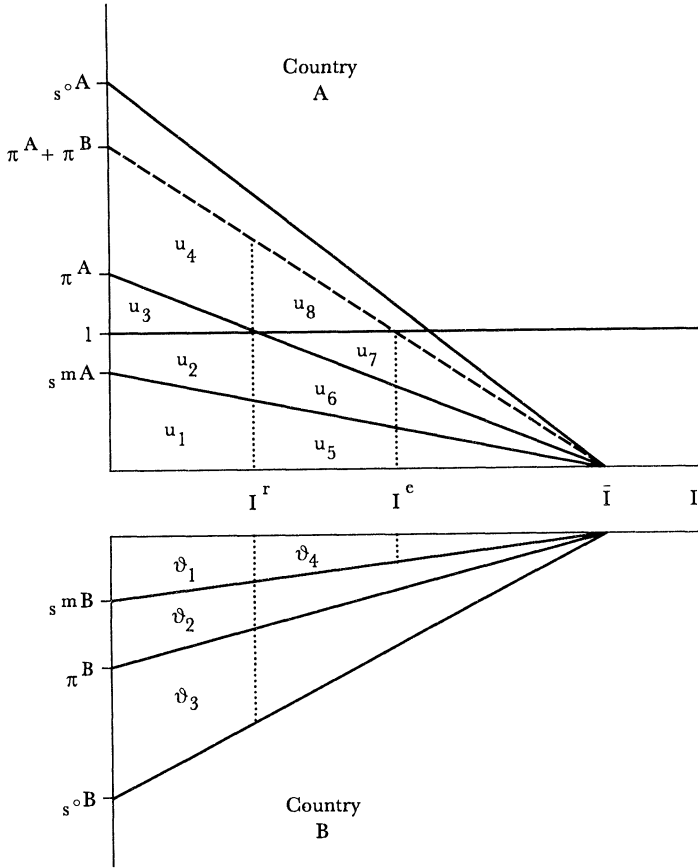where Π^{eA} is now only a portion of the total profits.

FIGURE 3.   Welfare effects in two countries of inventions in one, with restricted and extended patent protection.

In country B the inventors from country A also earn monopoly profits equal to

$$(47) \qquad \Pi^{eB} = \int_0^{I^e} \frac{1}{2} n^B (f - gI) \, dI = \frac{(1-\gamma)(n^2 f^2 - 4)}{4ng} .$$

Consumers in country B now get only the reduced consumer surplus of the monopoly case:

$$(48) \qquad S^{eB} = \int_0^{I^e} \frac{1}{4} n^B (f - gI) \, dI = \frac{(1-\gamma)(n^2 f^2 - 4)}{8ng} .$$

Total profit is

$$(49) \qquad \Pi^e = \Pi^{eA} + \Pi^{eB} = \frac{n^2 f^2 - 4}{4ng} ,$$

which is the same expression found in the single-country case in (24), since the monopolist inventors are now treating the world as essentially a single

market. The net gain to country A is found from (44), (45) and (49):

$$(50) \qquad N^{eA} = S^{eA} + \Pi^e - I^e = \frac{nf - 2}{8ng} [(2 + \gamma)(nf + 2) - 8].$$

Finally, the net gain to country B is again just its gain in consumer surplus,

$$(51) \qquad N^{eB} = S^{eB}.$$

The net benefit to the world is therefore

$$(52) \qquad N^{eW} = N^{eA} + N^{eB} = \frac{(3nf - 2)(nf - 2)}{8ng}.$$

To illustrate these results in Figure 3, the marginal profit earned in country B, π^B, is first added to π^A in the top panel. The level of invention with extended patent protection, I^e, is then found where this new line crosses the horizontal line at 1. In country A, consumer surplus expands to include u_5, while profits now include $u_5 + u_6$ earned on sales in country A as well as $u_4 + u_7 + u_8$ on sales to country B. Deducting the research cost, I^e, the net benefit to country A is $u_1 + u_3 + u_4 + u_5 + u_8$.

Consumers in country B now earn only the monopoly consumer surplus under s^{mB} for all goods up to I^e. Thus their total benefit is now $v_1 + v_4$.

Comparison of restricted and extended regimes. It is clear from Figure 3 that residents of country A gain unambiguously from extending patent protection to country B. Consumers in A get consumer surplus from the additional goods that are invented, as shown by the area u_5. The monopolist inventors in country A also gain the even larger area u_4, which is the monopoly profit on sales to country B of goods they would have invented anyway, plus u_8, the excess monopoly profits in both markets on the additional inventions. Formally, the gain to country A from extending patent protection is found from (41) and (50) to be

$$(53) \qquad N^{eA} - N^{rA} = \frac{2(1 - \gamma)}{8\gamma ng} [\gamma n^2 f^2 - 2(1 - \gamma)].$$

As long as

$$(54) \qquad \gamma nf = n^A f > 2,$$

so that I^r in (37) is positive, (53) is also positive, verifying the gain to country A.

Residents of country B, on the other hand, are likely to lose. The monopoly pricing of the goods they were previously getting competitively causes them to lose three-quarters of the optimal consumer surplus on those goods. In Figure 3 this loss is area $v_2 + v_3$. In return for this they do get consumer surplus on the new goods whose invention is stimulated by the extended protection, but even on these they only get the monopoly consumer surplus, shown as v_4 in Figure 3. If $v_2 + v_3$ is greater than v_4, as drawn in the figure, they lose.

Formally, the change in welfare for country B is found from (40) and (48) to be

$$(55) \qquad N^{eB} - N^{rB} = -\frac{1 - \gamma}{8\gamma^2 ng} [3\gamma^2 n^2 f^2 + 4(\gamma^2 - 4)].$$

If γnf is only slightly greater than required in (54), this will be negative

regardless of the value of γ alone. That is,

$$(56) \quad \gamma n f = n^A f > \sqrt{\frac{16}{3}} = 2.31$$

is sufficient for (55) to be negative. Alternatively, as long as the fraction of the world's population that is located in the innovating country, γ, is sufficiently large, then country B will lose. If

$$(57) \quad \gamma^2 > \sqrt{\frac{16}{4+3n^2 f^2}},$$

then (55) will also be negative.

Clearly, much depends on the size of the two populations, together with the parameter f. The latter represents the intercept of the optimal consumer surplus function, and hence the per capita consumer surplus optimally obtainable from the highest priority invention, per dollar cost of research needed for that invention. Condition (54) merely requires that this highest-priority invention yield a total benefit to the population of country A that is twice its cost. Likewise, condition (55) implies that, if the per dollar benefit from the highest-priority invention for the world, nf, is, say, ten times its cost ($nf = 10$), then country B will be hurt by extending patent protection if the share of world population in country A is greater than only $16/304 = 5 \cdot 3$ per cent. Thus, it seems quite likely that (55) will indeed be negative under plausible circumstances.

Turning finally to effects on the world as a whole, these can be observed in Figure 3 by first noting that areas u_4 and v_3 are equal, so that part of the gain to country A cancels directly with part of the loss to country B. This leaves the net effect on the two countries together as $u_5 + u_8 + v_4 - v_2$. As drawn in Figure 3, it appears that the three areas of gain are together larger than the single area of loss, v_2, and that the world gains here from extending patent protection.

This is not inevitable, however, as Figure 4 shows. There, the relevant portions of Figure 3 are reproduced, but the proportions are changed. As a result, the three areas of gain from extended patent protection, shown as the shaded areas u_5, u_8 and v_4, are much smaller than in Figure 3, while the area of loss, the cross-hatched area v_3, is larger. As drawn, the latter area is larger than the former, and the case drawn is therefore one in which extended patent protection lowers welfare of the world as a whole.

How do Figures 3 and 4 differ? In drawing Figure 4, I attempted to capture what would happen if population were shifted from country B to country A, thus expanding all of the amounts of surplus and profit in country A and contracting them in country B. By doing this, the level of invention in the restricted protection equilibrium is made larger, since inventors in A have a larger protected market, and at the same time the scope for expanding invention still further by extending protection is reduced.

To check that this is a correct interpretation, consider the more formal expression for the gain to the world from extending protection. From (42) and (52),

$$(58) \quad N^{eW} - N^{rW} = \frac{1-\gamma}{8\gamma^2 ng} (16 - 4\gamma - n^2 f^2 \gamma^2).$$
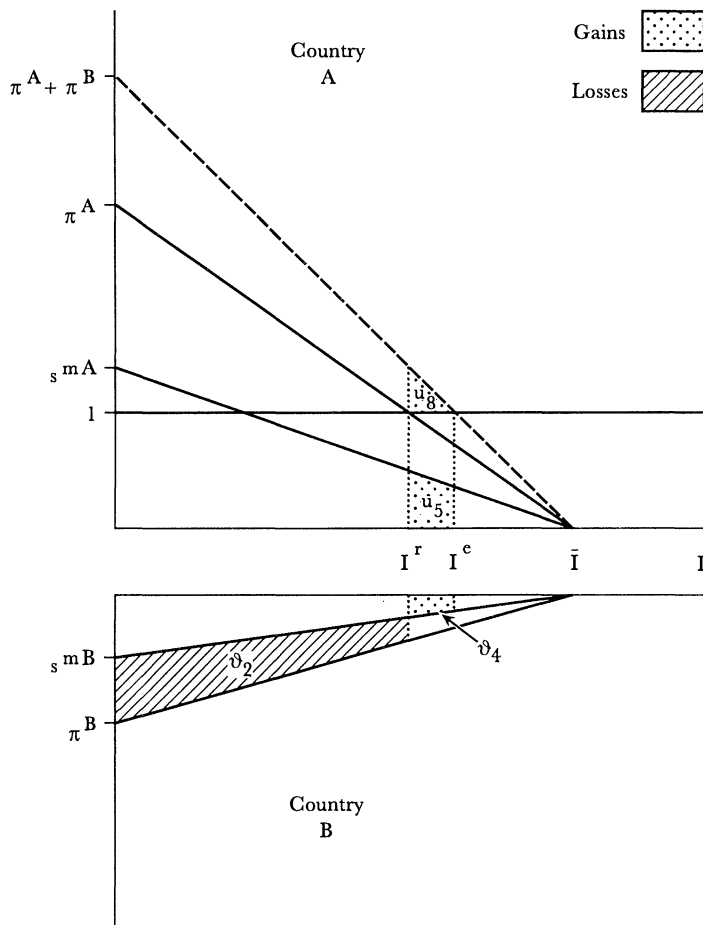
FIGURE 4.   World welfare effects of extending patent protection to a relatively small country.

The sign of this depends on the expression in parentheses. Setting that expression equal to zero for $\gamma = 1$, it follows that if

$$(59) \quad nf > \sqrt{12} = 3 \cdot 46,$$

then (58) will be negative for γ sufficiently close to 1. I will assume from here on that (59) is indeed satisfied, that is, that the most desirable invention would yield a surplus for world consumers at least three-and-a-half times its cost.

    Under that assumption, then, the world as a whole loses from extended patent protection once the portion of the world already covered by patent protection is sufficiently large. In particular, it cannot be optimal from a world welfare standpoint for patent protection to be extended to the entire world.

II. CONCLUSIONS AND QUALIFICATIONS

I have now shown what I set out to show: that under specified circumstances it is not optimal to extend patent protection to all countries of the world. The

reason for this result is implicit in the analysis. Patent protection has the offsetting effects of, on the one hand, permitting inventors to earn monopoly profits on their inventions and thus stimulating inventive activity and, on the other hand, distorting consumer choice by monopoly pricing. If all innovation originates in one part of the world, then extending patent protection to a broader and broader area does have these two effects, but there are diminishing returns to the first of them. That is, as more and more of the world is already covered by patent protection, the extra market that can be covered, and hence the extra invention that can be stimulated by extending patent protection still further, becomes smaller. Thus, at some point the costs due to extending monopoly pricing to existing inventions come to outweigh the benefits of generating new ones.

   Many assumptions are explicit, and others implicit, in this analysis, and the results depend to varying degrees upon all of them. Let me conclude by suggesting my own judgements as to the importance of some of these assumptions for the main result.

Location of invention

First, it is not crucial to world welfare, though it may be to the individual countries, that no invention take place in country B. If inventors in both countries had a chance of creating the inventions of the model and of patenting them wherever patent protection is available, then some of the monopoly profits that I have modelled as accruing to country A would accrue instead to inventors in country B. With free trade, however, the same levels of invention would take place in equilibrium, and levels of world welfare would be the same.

Identical demands

On the other hand, it is crucial that *per capita* demands for invented goods be the same, or at least similar, in both countries. If they are not—if some inventions would be demanded more in country B than in country A—then an important benefit to extending patent protection to B is missing from the model. Patent protection in country B will stimulate precisely those inventions that are of particular importance to B's population, and thus will yield a greater benefit to B than to A. This possibility would therefore increase the net gain, both to country B and to the world as a whole, of extended patent protection.

Linearity

The analysis here has been greatly facilitated by assuming that demands for goods were linear and that the function relating optimal surplus to the level of invention was linear as well. Linearity of demands seems of comparatively minor importance: what really matters is that there be some welfare loss arising from monopoly pricing, and this would be the case for a wide variety of demand functions.

   Linearity of the surplus function is a bit more critical, as is seen in Figure 3, for example. If the curves were not linear, there would be the possibility that they would, say, turn sharply downward just to the right of I^r. In that case, there would be very little additional invention stimulated by extending patent protection, and the case against it would be strengthened. In contrast,

if the curves were to flatten out just to the right of I^r, then I^e might be pushed to a much higher level, and the benefits to extending patent protection would be increased. Thus, the cases for and against extending protection can be materially altered by the curvature and position of these curves. On the other hand, in the absence of any information about what these curves do in fact look like, the linear case seems to be about as neutral as one could hope for.

Transmission of information

I have assumed here that, once an invention is discovered, the information about how to produce it is freely available worldwide. This is important, since otherwise production could not take place at all in country B in the absence of patent protection, and the main source of loss arising from extending protection, both for country B and for the world as a whole, would be removed. It is of course true that information about many new inventions is not costlessly transmitted abroad, and that extending patent protection may therefore be beneficial to the extent that it stimulates the transfer of technology. On the other hand, the demands for protection on the part of innovating firms in the United States and other advanced countries make it clear that, in at least some industries, information about new products is diffusing without patent protection much more readily than the innovating firms would like.

I am sure that many other objections to this model can and will be raised as discussion proceeds. It may well be that extending patent protection to a larger part of the world is in fact in the interest of the world as a whole, and perhaps even in the interests of some of the developing countries who may resist such a change. All I have tried to establish is the intellectual legitimacy of the position that worldwide patent protection may not be desirable. I am inclined to believe, on the basis of this model and other considerations discussed in Deardorff (1990), that at least the very poorest of countries should be exempted from any new agreement that is made to extend patent protection under the GATT.

NOTES

1. Trademarks, on the other hand, seem to play a distinctly different role from patents and copyrights, and I would not extend the argument to them.
2. See Nordhaus (1969) and Scherer (1980).
3. A first-best policy would eliminate the monopoly distortion and somehow subsidize invention more directly. However, given the difficulty of measuring the value of inventive activity for this purpose, this may not be feasible.
4. Chin and Grossman (1990) have also made this point elegantly in the context of a somewhat different model of process innovation. They too found the possibility of a welfare loss for the world as a whole as a result of extending patent protection, though they did not relate it to the portion of the world that is covered.

5. It is intriguing—though not at all important, as far as I can see—that this expression turns out to be so simple. Noting that nf and f/g are the vertical and horizontal intercepts of the s^o line in Figure 2, this expression for net loss is exactly one-quarter of the area of the triangle formed by s^o and the two axes. Since $s^m + \pi^m = (3/4)s^o$, this means that the awkwardly shaped area $L_1 + L_2 + L_3$ is actually equal to the triangle between $s^m + \pi^m$ and s^o. This implies that the area L_3 is equal to the area $K_1 + K_2$, a result that can also be shown using the traditional tools of plane geometry. The proof, which I leave to interested readers or their highschool-age children, uses the fact that the vertical line above I^m is broken into four equal segments by the lines that cross it.

6. It is not necessary, of course, that the inventor also be the producer in country B. The inventor can license someone else to produce there and can extract the monopoly profit by setting the licence fee at an appropriate level.

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