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Author

Scotchmer, Suzanne

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THE POLITICAL ECONOMY
OF INTELLECTUAL PROPERTY TREATIES

Suzanne Scotchmer*

National Bureau of Economic Research
Cambridge, MA 02138
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Abstract: Intellectual property treaties have two main types of provisions: national treatment of foreign inventors, and harmonization of protections. I address the positive question of when countries would want to treat foreign inventors the same as domestic inventors, and how their incentive to do so depends on reciprocity. I also investigate an equilibrium in which regional policy makers choose IP policies that serve regional interests, conditional on each other's policies, and investigate the degree to which "harmonization" can redress the resulting inefficiencies.

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1 Introduction

The economic rationale for intellectual property (IP) is that it encourages development of new products, and thus generates consumers' surplus. The net profit that accrues to inventors is also a social benefit, since it is a transfer from consumers. However profit is recognized as a necessary evil, since the flip side of profit is deadweight loss. There is no economic rationale for protecting inventors *per se*.

This reasoning gets subverted in the international arena. To a trade policy negotiator, profit earned abroad is unambiguously a good thing, and the consumers' surplus conferred on foreign consumers does not count at all. There is a domestic interest in capturing profit abroad, and symmetrically, there is a domestic interest in trying to ensure that domestic consumers get access to foreign inventions on competitive terms.

It has been widely argued that the recent expansion of intellectual property rights under TRIPS (the treaty on Trade-Related Aspects of Intellectual Property) has extended intellectual property rights beyond what is optimal. Some commentators (e.g., Hall (2001), Lanjouw and Cockburn (2000)) have suggested that this is because trade negotiators are "captured" by industry. Capture is undoubtedly an important phenomenon, but I argue that intellectual property policies can become overprotective even if trade policy negotiators are equally concerned with all domestic interests, those of both consumers and producers. This is because intellectual property is the only available tool by which cross-border externalities can be recaptured by the innovating country. McCalman (1999) estimates that the TRIPS provisions would have increased the revenues available to holders of U.S. patents issued in 1988 by \$4.5b, in 1988 dollars. Of course the domestic interests of regional innovators must be balanced against the domestic interests of regional consumers; see Maskus (2000a,b) for evidence that national differences give rise to different IP policies, and evidence on how IP policies affect trading relationships and foreign direct investment.

Two important provisions of IP treaties are "national treatment of foreign inventors" and "harmonization." "National treatment" means that within each country, foreign and domestic inventors receive identical treatment, namely, the treatment of nationals.

In Section 2 I give a cursory overview of how national treatment and harmonization have evolved by treaty. Prior to the treaties of the 1880's, national treatment, if provided, had no requirement of reciprocity. I show in Section 4 how this would be a serious impediment to the globalization of intellectual property rights. Without a requirement of reciprocity, there is little incentive for countries to grant national treatment to foreigners. If a country is the recipient of such a benevolent practice abroad, it may nevertheless be better off free-riding on that practice, rather than reciprocating. However, if the benevolence of the foreign jurisdiction will only be extended on condition of reciprocity, there is a profit motive to grant national treatment. Small countries may join a treaty in order to gain the privilege of proprietary pricing in large foreign markets, even though they give up the privilege of free-riding on foreign inventions.

But even assuming that countries participate in a global treaty for national treatment, there remains the confusing issue of what types of innovations will be protected. National treatment does not speak to the question of what will be protected, but only asserts that whatever protections are provided to domestic inventors will also be extended to foreign inventors. "Harmonization" refers to provisions by which signatory states agree to a common set of protections. The first step toward harmonization is usually to state minimum standards, both in the subject matter protected, and the length of protection.

In Sections 5-7, I investigate how domestic intellectual property choices are affected by treaties that provide for national treatment but no harmonization, versus treaties with national treatment that also require harmonization. Among my conclusions are the following, some of which are obvious once the issues are framed, and some of which, such as the penultimate one, are more subtle:

- Independent choices of IP policies can lead to two coordination problems, one involving asymmetric protections and "free-riding," and the other involving too little protection.
- Harmonization on minimum protections can lead to asymmetric protections, just as independent choices can, and these may be more efficient than universal

protections, even if inequitable.

- Harmonization will typically lead to more extensive intellectual property rights than independent choices, and may lead to more extensive intellectual property rights than are optimal, even in the absence of “capture.”
- Holding “innovativeness” constant, small countries will favor more extensive intellectual property rights than large countries.
- Holding “market size” constant, more innovative countries will favor more extensive intellectual property rights than less innovative countries.

If we conclude that intellectual property rights chosen in an international context are more extensive or less extensive than optimal, we must be precise about what is optimal. This is discussed at length in Section 3. Here I want to call attention to the particularly important aspect, “IP as compared to what.” There are two lines of thought about this. The older literature, which follows Nordhaus (1969), sees the alternative to IP as a dearth of innovation. It is argued that, without sufficient intellectual property rights, innovation will be stifled, and consumers will be deprived of innovations. A newer literature, summarized, for example, by Gallini and Scotchmer (2001), sees a viable alternative in public sponsorship. Since public sponsorship can avoid proprietary pricing, there should be a strong presumption that it is a superior way to support research unless offset by some other type of inefficiency. The investigation below is mostly in that spirit.

My focus on public sponsorship as an alternative to private incentives is a departure from the other economics literature in this area, e.g., the papers cited below. I view this departure as appropriate both because it accords with the modern economics view of incentive systems, and because public sponsorship of R&D is, in fact, huge. The OECD reports¹ that in 1999, only 56% of R&D spending in the European Union was by industry. The industrial share is higher in the U.S., about 66%, where public spending on R&D is crowded out by military spending. This is still a considerable departure from 100%. In Latin America, public sponsorship is dominant. In 1996 the government shares of R&D spending in Brazil, Chile, Costa Rica and Mexico were

¹www.oecd.org/pdf/M00026000/M00026476.pdf

substantially over half, while the government shares in Argentina and Venezuela were respectively 46% and 32%.² Of course both public and private investments generate spillovers. An area where R&D investment has been mostly public, at least prior to the era of bio-engineering, is agriculture. In his presidential address to the Australian Agricultural Economics Association, Alson (2002) summarizes evidence that more than half of international agricultural productivity growth has been generated by spillovers.

There are close parallels between treaty-making for intellectual property and extraterritoriality issues in competition policy; see, in particular, Guzman (1998, 2001). Domestic policymakers have less incentive to curb collusion in an export industry than an import industry, since the burden of high prices is imposed on foreign consumers, while the profit accrues domestically. These cross-border externalities are similar to the ones that arise from regional intellectual property decisions.

There are also close parallels between treaty-making for intellectual property and treaty-making on tariff policy. Bagwell and Staiger (1999) have studied how the provisions in the General Agreement on Tariffs and Trade (GATT) can remedy inefficient tariff policies that arise from incentives to protect domestic interests. The premise of their paper is also the premise here: The policy of each country creates uncompensated externalities abroad, which might be remedied by treaty. In their case, the policies are tariffs, which change the terms of trade. The countries' chosen tariffs will not be optimal because countries do not account for the externalities. Negotiation under GATT empowers the countries to remedy that problem for the countries' mutual benefit. In contrast, reciprocity will not remedy the inefficiencies that arise in choosing intellectual property rights, because the countries do not negotiate over all the economic decisions that matter. In particular, they negotiate over intellectual property rights, but not over public R&D spending. In order to isolate the problem of intellectual property, I assume that terms-of-trade issues are divorced from negotiations over intellectual property rights. However my conclusions shed light on why the TRIPS negotiations were linked to tariff concessions, which allowed small countries to be strong-armed into signing IP treaties that would otherwise not be in their interest. For discussions of these negotiations, see, for example, Samuelson (1999),

²www.nsf.gov/sbe/srs/nsf00316/secta.htm

Watal (1998) and Reichman (1997).

There is also a literature on the “North/South“ problem, which is a stylization of asymmetric innovative capacities. Since it addresses different issues than those discussed here, I do not describe it at length.³

2 A Short History of IP Treaties

The earliest large-scale intellectual property treaties were the Paris Convention of 1883 on patents and other industrial property, and the Berne Convention of 1886 for literary and artistic works. Under various revisions, these treaties have remained in effect since their inception, and now have more than 100 members. Both established the idea of national treatment. The Berne Convention also made the first efforts to harmonize protections across countries, mostly at a procedural level, such as how to apply for copyrights.

For the most part, the principle of national treatment has been maintained since the Paris and Berne Conventions. Reciprocity has been formalized in the treaties. Membership means that a country provides national treatment to inventors in other member countries, and its own inventors receive national treatment in return. There are forms of intellectual property not covered by the treaties, however, and in those cases, reciprocity has been made a *condition* for national treatment. When the U.S. enacted the Semiconductor Chip Protection Act of 1984, the protection of foreign inventors was made conditional on the passage of very similar legislation in the foreign countries. In 1996, the European Union retaliated with their Directive on Databases, which instructs the member states to enact legislation protecting databases beyond the

³A discussion can be found in a previous working paper by this author. See, in particular, Deardorff (1992), Diwan and Rodrik (1991), Lai and Giu (forthcoming), Helpman (1993) and Chin and Grossman (1990). Of particular interest is the (independent) paper of Grossman and Lai (2001), who discuss harmonization on length of protection rather than harmonization on subject matter. Instead I focus on subject matter because that was the main area of controversy in the TRIPS negotiations, and, among the lengths of protection that were under discussion, I view length as having much less impact than the extent of protection as to subject matter. They do not discuss the role of the public sector. Another related paper is Aoki and Prusa (1993), who discuss the profitability and efficiency of asymmetric enforcement activities against potential infringers.

protection already afforded by copyright law. The Directive has a preamble denying national treatment to non-member states (presumably, the U.S.) unless the non-member states also enact such legislation.

A shortcoming of the Paris and Berne Conventions is that they made no provisions for enforcement. Their modern descendants are administered by the World Intellectual Property Organization (WIPO), which has only weak enforcement powers. Better enforcement provisions were introduced in the Agreement on Trade-Related Aspects of Intellectual Property (TRIPS), as administered by the World Trade Organization.

More importantly for this paper is the question of harmonization. The North American Free Trade Association (NAFTA) not only extended national treatment to all intellectual property, at least on the North American continent, but goes some distance in harmonizing protections. However it does not go as far as TRIPS. TRIPS has specific provisions for minimum protection of bioengineered microorganisms, pharmaceuticals, computer software, and databases, and stipulates minimum durations of protection. Disputes are brought before the World Trade Organization, which is authorized to carry out very specific enforcement actions that are widely thought to have teeth.

U.S. history is also informative about the economics and politics of IP treaties. The constitutional convention of 1789 was an early instance where a disjointed and incompatible system of local copyright and patent law was replaced with a federal system. Each of the 13 founding States ceded its authority in this area to the newly established federal government instead of trying to maintain autonomy. The U.S. did not join the Berne Convention for reciprocal copyright policy until 1989 because certain aspects of its substantive and procedural policies were in conflict with U.S. policies. It joined in 1989 because the U.S. had become a major exporter of copyrighted works, and wanted both protection abroad and a voice in the international policy making process. In the meantime, in the 1950's, the U.S. lobbied for the Universal Copyright Convention, which, like the Berne Convention, provided for national treatment, but did not have the same requirements for harmonized protections, procedures, and length of protection. In the more recent attempts at harmonization, the U.S. has been a leader. This is especially true of TRIPS, which is the most powerful harmonization treaty to date for both patentable and copyrightable subject matter, as well as providing a forum

for dispute resolution, the WTO. The U.S. was also very much in favor of NAFTA. The strengthening of protections abroad under NAFTA and TRIPS are aligned with American commercial interests, and largely follow the American model.

3 National Treatment

As a warmup, we will first take the protected intellectual property as given in each country, and consider the incentives to offer national treatment to foreigners. Suppose there are two countries, a, w . We shall focus on country a , and sometimes interpret w as “the rest of the world.” For $i = a, w$, let c^i be the aggregate consumers’ surplus per innovation, assuming perfect competition, and let $c^i m$ be the aggregate consumers’ surplus per innovation, assuming that the product is sold by a monopolist. Let $c^i \pi$ and $c^i d$ be the aggregate profit and deadweight loss per innovation, respectively. The profit and consumers’ surplus are assumed to be the same whether the innovation is supplied by a domestic firm or foreign firm. By definition, $m + \pi + d = 1$. These can be interpreted as present discounted values, and therefore π, d will be larger for longer durations of protection, whereas m will be smaller,

Let (\hat{r}^a, \hat{r}^w) be the numbers of proprietary innovations in the two countries respectively under “autarky”, namely, when intellectual property rights are only available to domestic firms in each country. Let $(\tilde{r}^a, \tilde{r}^w)$ be the numbers of innovations when each country grants rights to foreign firms as well as to domestic firms (“national treatment”). Since national treatment creates additional incentives for inventors, $\tilde{r}^a \geq \hat{r}^a$ and $\tilde{r}^w \geq \hat{r}^w$, and that is all we need to know about incentives for the moment.

We use a function k^i to represent the total cost of innovations by inventors in country i . Under autarky, total social surplus for country a is

$$\hat{r}^a(m + \pi)c^a + \hat{r}^w c^a - k(\hat{r}^a)$$

which includes profit and (monopoly) consumers’ surplus plus the consumers’ surplus generated by a competitive supply of the other country’s inventions. The middle term

should be understood as an uncompensated externality from the rest of the world to country a .

Country a would find it beneficial to grant national treatment to inventors in country w if the following holds.

$$\hat{r}^a c^a (m + \pi) + \hat{r}^w c^a - k(\hat{r}^a) < \hat{r}^a c^a (m + \pi) + \tilde{r}^w m c^a - k(\hat{r}^a) \quad (1)$$

or

$$\tilde{r}^w / \hat{r}^w > 1/m \quad (2)$$

If \tilde{r}^w is sufficiently large, or if \hat{r}^w is sufficiently small, national treatment of foreigners will benefit consumers in country a . Even though IP privileges for foreigners will cause domestic consumers to pay proprietary prices instead of competitive prices for foreign innovations, the increase in such inventions may outweigh the loss in consumers' surplus on each invention, and that is the only motive to grant national treatment.

However it is clear that a small economy will have very little impact on global incentives to invent. If condition (2) holds for any country, it is likely to be a country with a large market. It will not hold for small countries. Nevertheless, the IP treaties described in Section 2 include small, open economies. This seems to contradict the conclusion.

The key is that regions do not usually grant national treatment as a unilateral gift, but rather in return for reciprocity. With reciprocity, the outflow of profit to foreign inventors is not provided as a unilateral gift, but rather in return for access to proprietary pricing in a large global market. If region a 's choice is between *reciprocal* national treatment and autarky, the decision criterion is to choose reciprocal national treatment if

$$\hat{r}^a c^a m + \hat{r}^w c^a + \hat{r}^a c^a \pi - k(\hat{r}^a) < \tilde{r}^a c^a m + \tilde{r}^w c^a m + \tilde{r}^a \pi (c^a + c^w) - k(\tilde{r}^a) \quad (3)$$

A sufficient condition for this inequality is again (2), assuming that the profit available to domestic firms goes up when profit opportunities abroad are added ($\hat{r}^a c^a \pi - k(\hat{r}^a) < \tilde{r}^a \pi(c^a + c^w) - k(\tilde{r}^a)$). If the additional profit is substantial, the inequality (3) may hold even if (2) does not hold. Even this incentive may fail, and then the country must be induced to participate by granting additional concessions such as trade concessions and membership in the WTO (see Lai and Giu (forthcoming)).

It is straightforward that if the countries agree to reciprocal national treatment, then the agreement enhances social welfare. If the agreement would decrease social welfare, at least one of the countries would oppose it. Further, reciprocal national treatment can only enhance welfare if it increases innovation enough to outweigh the additional deadweight loss due to the expansion of intellectual property rights.

We thus have

Remark 1 (National Treatment)

(i) Without a requirement of reciprocity, small countries are unlikely to grant national treatment to foreign inventors. (ii) If a country's national treatment privileges abroad depend on granting national treatment to foreigners at home, then even small countries may grant national treatment. (iii) IP treaties will not form unless they increase all members' welfare, and that will not occur unless innovation is stimulated enough to outweigh the additional deadweight loss.

4 Global Efficiency

My objective in the remainder of this paper is to understand, within the framework of reciprocal national treatment, whether the harmonization efforts undertaken in the TRIPS negotiation were efficiency-enhancing. To that end, we must first have a concept of efficiency.

If there were no social advantage in delegating R&D to private firms, and if there were no uncompensated externalities across borders, public support would be the best way

to fund R&D, since public support can avoid deadweight loss. The political obstacle to public funding is that it does not provide a mechanism to repatriate any of the external benefits conferred on foreigners. In contrast, intellectual property allows some of those benefits to come back as profit. However, even aside from the fact that IP allows the country to repatriate benefits, private spending has other advantages. One important advantage is that public sponsors are less good at responding to users' needs than private inventors. Another is that private sponsors are more efficient at conducting R&D. In this model I shall assume the latter.

Maintaining the market structure above for each innovation, index "subject matter" by R&D cost, say $x \in [0, \infty]$. Let x and kx be the costs if undertaken by the private and public sectors respectively, where $k > 1$. Thus, the innovations are ordered so that the cost advantage of the private sector, $(k - 1)x$, is increasing in x .

Two questions addressed by the TRIPS negotiators were the appropriate length of global (harmonized) protections and the subject matters that would be protected. This paper focusses on subject matter, which was more controversial and resulted in more fundamental changes, than the changes to length. I show in the appendix how the controversy over length mirrors the controversy over subject matter, but with an important exception. Harmonization on length can always remedy inefficiencies, provided length can be tailored to cost. But when length cannot be tailored to cost (as assumed in the body of this paper), harmonization on subject matter will not always remedy the inefficiencies that would otherwise arise in equilibrium.

The efficiency analysis has three considerations: which investments should be undertaken at all, whether they should be funded under private incentives or public sponsorship, and if private, where the subject matter should be protected. I will say that the system of intellectual property protection and public sponsorship is *globally efficient* if it maximizes worldwide consumers' surplus without regard to distribution. This is a definition that intentionally ignores the conflicts that arise due to uncompensated externalities. Those conflicts lead to a discrepancy between the outcome of a treaty negotiation and the system of intellectual property rights that would be efficient if nations could make side payments to internalize externalities. I have chosen a definition of efficiency that allows me to illuminate that discrepancy.

Before characterizing the efficient intellectual property regime, I point out a serious limitation of global rights. Suppose that for some subject matter, protection in any one of the large markets, the U.S., Europe or Japan, is enough to compensate an inventor, regardless of where the inventor is domiciled. Then, for such a subject matter, a natural and un wasteful system would be domestic, but not foreign, protection. That is, each inventor would be protected in his own jurisdiction, but not elsewhere. Such a system would create reciprocal externalities in the sense that American consumers would get competitive supply of European inventions and vice versa, but would pay proprietary prices for their own domestic inventions. Globalizing the protection of each invention would be inefficient in the sense that it would impose deadweight loss without (by hypothesis) calling forth new inventions.

Such a system of domestic rights is impossible under a treaty that provides for national treatment. If the U.S. protects bioengineered organisms for U.S. bioengineers, then it gives the same protection to Japanese bioengineers. With national treatment, the only way to limit protection to a single market is for one jurisdiction, say the U.S., to protect *all* bioengineering, regardless of where the bioengineer is domiciled, and for other jurisdictions to grant *no* protection. However that system is very asymmetric. All the deadweight loss is borne by consumers in the protective jurisdiction (e.g., the U.S.), and none in the unprotective jurisdictions (e.g., Japan), regardless of where the inventions originate (the U.S. or Japan). Uncompensated externalities will lead to conflict. The U.S. is likely to favor a system of global protection rather than unilateral protection, because it allows repatriation of some of the external benefits.

The efficient intellectual property regime is described in Tables 1 and 2 below. It is important to realize that the considerations in Tables 1 and 2 will not be reflected in any administrator's objective function. For example, from a global perspective, public sponsorship is more efficient than intellectual property whenever $(k-1)x < d(c^a + c^w)$. But this will not be a decision criterion of either region.

Table 1 describes the efficient regime when the two regions are symmetric, in the sense that they have the same size markets ($c = c^a = c^w$) and, implicitly, innovative capacities.

Table I

Global Efficiency with Symmetric Regions

SUBJECT MATTER (COST)	INTELLECTUAL PROPERTY?
$x \in [0, \frac{dc}{(k-1)})$	public sponsorship in both regions
$x \in [\frac{dc}{(k-1)}, \pi c)$	IP in only one region
$x \in [\pi c, \frac{2dc}{(k-1)})$	public sponsorship in both regions
$x \in [\frac{2dc}{(k-1)}, 2\pi c)$	IP in both regions
$x \in [2\pi c, \frac{2c}{k})$	public sponsorship in both regions

For the asymmetric case, we will assume without loss of generality (since the indices can be reversed) that $c^a < c^w$ (the world market is larger than region a 's market), so that $\frac{dc^a}{(k-1)} < \frac{dc^w}{(k-1)}$ and $\pi c^a < \pi c^w < \pi(c^a + c^w)$. In addition, we assume for purposes of the table that $\frac{dc^a}{(k-1)}, \frac{dc^w}{(k-1)} < \pi c^a, \pi c^w$ and $\frac{d(c^a+c^w)}{(k-1)} < \pi(c^a + c^w)$. It is clear how to modify the table if these relationships do not hold.

Table 2

Global Efficiency with Asymmetric Regions

SUBJECT MATTER (COST)	INTELLECTUAL PROPERTY?
$x \in [0, \frac{dc^a}{(k-1)})$	public sponsorship in a and w
$x \in [\frac{dc^a}{(k-1)}, \pi c^a)$	IP in a , public sponsorship in w
$x \in [\pi c^a, \pi c^w)$	IP in w , public sponsorship in a
$x \in [\pi c^w, \frac{d(c^a+c^w)}{(k-1)})$	public sponsorship in a and w
$x \in [\frac{d(c^a+c^w)}{(k-1)}, \pi(c^a + c^w))$	IP in a and w
$x \in [\pi(c^a + c^w), \frac{(c^a+c^w)}{k})$	public sponsorship in a and w

As in the symmetric case, an efficient regime may provide for intellectual property in only a single region, in particular, for the less costly innovations. If so, IP should be granted in the smallest market that generates enough revenue to cover the cost of the invention. Costly innovations may require profits in both markets.

Both tables show that three types of subject matter should be publicly sponsored: (1) innovations whose cost is relatively low, so that the cost efficiency of the private

sector does not outweigh the deadweight loss even in the smallest market, (2) high-cost subject matter for which cost cannot be covered by revenue even in both markets, and (3) innovations whose cost cannot be covered in a single market, but for which the deadweight loss in both markets would be more burdensome than the inefficiency of public sponsorship.

The distributional issues ignored in Tables 1 and 2 become key in the equilibrium analysis below. Neither region wants to be the sole provider of intellectual property rights, because their consumers bear all the deadweight loss, while their innovators and public sponsors confer uncompensated externalities on the other region. A region would always want to have its own intellectual property reciprocated abroad, so that it can recoup part of the externality it confers, as profit.

5 Equilibrium Choices of IP: the Symmetric Case

We now investigate whether an intellectual property policy such as the one in Table 1 would be implemented.

Region a 's willingness to provide intellectual property rights for a given subject matter with cost x will depend on whether region w also provides such rights. If it does, then rights in w may be sufficient to cover the costs of innovation in region a as well as w , and region a has no incentive to increase the incentive still further. This is the best possible situation for a . When the region w offers intellectual property rights for a given subject matter, region a would only offer such rights if

1. protection in both markets is necessary to cover the costs of innovation, and
2. region a is better off with IP than public sponsorship, when it takes account of the cost efficiency as well as profit flows and local deadweight loss.

But this observation suggests a coordination problem. If the revenue in either market would be sufficient to cover cost, then there are two equilibria. In one equilibrium,

region a (but not region w) protects the subject matter, and in the other equilibrium, it is the other way around. In the asymmetric case discussed below, there is no guarantee that the efficient outcome will be implemented. It may be the larger market where the subject matter receives protection, even though the smaller market would suffice.

Of course both regions would like to be in the favored position of not protecting the subject matter. Which region achieves that status depends on history, but however it arises, the equilibrium can become self-reinforcing and unalterable.

To understand equilibrium behavior, we also have to understand the equilibrium response of region a when a subject matter is *not* protected in region w . Region a will symmetrically choose not to protect it if either

1. Unilateral protection would be ineffective because the cost is greater than the profit available in a single market; or
2. Region a prefers public sponsorship to being the only region granting intellectual property.

In what follows, we show that an equilibrium with independent choices may be inefficient. For subject matters such that a unilateral grant of IP would be efficient, each region may nevertheless prefer public sponsorship in order to avoid the outflow of profit that would follow from a unilateral grant of IP. For subject matters such that bilateral protection is required, the regions may nevertheless arrive at an impasse in which neither provides protection. The latter of these is a coordination problem. Another coordination problem is that, when a single region is willing unilaterally to provide IP protection, there is no guarantee that it will be the market that minimizes deadweight loss.

We will now investigate more systematically what happens in equilibrium. Each region's strategy is a decision for each subject matter whether to include it in intellectual property protection. An equilibrium is a strategy for each region which is optimal given the strategy of the other region. For example, a region might not protect a sub-

ject matter if it is protected in the other region, and unilateral protection is sufficient, but might protect it if the other region does not.

We shall first assume that the regions are identical in both the sizes of their markets and their innovative capacities. The payoff to region a if it grants IP protection is summarized in Tables 3 and 4. In all of the tables, we have written the payoff to region a , as it depends on region a 's strategy and the strategy of region w . (The payoffs to region w can be ascertained by reversing a and w in the tables.) In each table, we have also indicated which of a 's strategies is a best response to w 's policy, and what the best response depends on. The payoff to region a for each subject matter x depends on whether region w is also protecting the subject matter, and also depends on whether IP protection in a single region would cover cost (as in Table 3) or not (as in Table 4).

Table 3*: Payoffs to Region a

	IP in w	no IP in w
IP in a	$2c(1 - d) - x$	$c(2m + \pi) - x$
no IP in a	$c(2 + \pi) - x$ (best response)	$2c - kx$ (best response iff $(k - 1)x \leq c(2d + \pi)$)

*Table 3 assumes symmetry and also assumes that monopoly profit in a single region will cover costs. In addition, absent IP, public sponsors will invest.

Table 4*: Payoffs to Region a

	IP in w	no IP in w
IP in a	$2c(1 - d) - x$ (best response iff $2dc < (k - 1)x$)	$2c - kx$
no IP in a	$2c - kx$	$2c - kx$ (best response)

*Table 4 assumes symmetry and that both markets are required to cover costs. Absent IP, public sponsors will invest.

Even without considering the problems introduced by asymmetry, a comparison of Table 1 with Tables 3 and 4 shows two inefficiencies that can arise in equilibrium:

Remark 2 [The Symmetric Case: Inefficiencies] *Suppose the two regions a and w have identical markets and are equally innovative. Then there are subject matters for which*

- (a) *unilateral IP protection would be effective and efficient, but neither region provides it;*
- (b) *bilateral IP protection is required to cover R&D costs, and would be efficient, but neither region provides it.*

The first problem is indicated by Table 3. Suppose the subject matter satisfies $2cd < (k - 1)x < c(2d + \pi)$. Then, referring to Table 1, IP in a single region is the efficient way to fund R&D, but neither region will volunteer. Unilateral protection may be efficient from a global perspective, but to grant it, a region would end up donating profit πc to the other region. This is more expensive to the region than the cost inefficiency of public sponsorship.

The second problem is a coordination problem. For those subject matters that require IP protection in both regions, there may be an equilibrium impasse in which each region's failure to grant IP protection is an equilibrium response to the other region's

failure to grant it. Granting IP protection in a single region is ineffective. For these subject matters, there is always a second equilibrium in which both regions provide protection, but, with independent choices of IP, there is no way to ensure that the efficient equilibrium arises instead of the inefficient one with no protection.

Harmonization can cure the coordination problem, but cannot cure the reluctance of each region to be the sole provider of IP incentives.

Our interpretation of harmonization is that the regions can agree to bilateral protection of certain subject matters, but this does not restrict regions from adding additional protections, provided the principle of national treatment is maintained. Such was the premise of the TRIPS negotiation.

There will be some harmonizations on which the regions agree, such as to overcome an inefficient impasse where no protection is provided. There will be other harmonizations on which they disagree, such as to protect a subject matter that would alternatively be protected by a single region. That region will prefer bilateral protection, but the other region prefers to freeride.

We will refer to *least protective* harmonization as the one that arises when disagreements are resolved in favor of no protection. We will refer to the *most protective* harmonization as the one that will arise when disagreements are resolved in favor of protection. In cases of agreement, there is no difference.

Remark 3 [The Symmetric Case: Harmonization] *Suppose the two regions a and w have identical markets and are equally innovative.*

(a) In the least protective harmonization, intellectual property will extend to all subject matters for which bilateral protection is efficient and preferred by both regions to public sponsorship;

(b) In the least protective harmonization, there may be too little intellectual property, in the sense that some inventions are publicly sponsored even though protection in a single region would be more efficient.

(c) The most protective harmonization will be efficient.

These conclusions can be seen from Tables 2 and 4. Both regions can improve their welfare by harmonizing on any subject matter for which $2dc < (k - 1)x$, as is efficient. As stated in Remark 2, for such subject matters there are two equilibria, one in which protection does not materialize. Harmonization can overcome this problem.

Since harmonization leads to bilateral protection, it cannot address the inefficiencies that arise when only unilateral protection is required. These become important in the asymmetric cases.

6 Asymmetric Market Sizes

Tables 5 and 6 show region a 's best response to region w 's policy, assuming that the regional markets differ in size ($c^a < c^w$), but that their innovative capacities are the same for each subject matter. Each region has one unit of innovative capacity. (This accounts for the "2" in the payoffs. There is one innovation in each region.)

Table 5*: Payoffs to Region a

	IP in w	no IP in w
IP in a	$2c^a(1 - d) + \pi(c^w - c^a) - x$	$2c^am + c^a\pi - x$ (best response iff $(k - 1)x > c^a(2d + \pi)$)
no IP in a	$2c^a + c^w\pi - x$ (best response)	$2c^a - kx$

*Table 5 assumes that monopoly profit in a single region will cover costs, and that, absent IP, public sponsors will invest.

Table 6*: Payoffs to Region a

	IP in w	no IP in w
IP in a	$2c^a(1 - d) + \pi(c^w - c^a) - x$ (best response iff $2dc^a - \pi(c^w - c^a) < (k - 1)x$)	$2c^a - kx$
no IP in a	$2c^a - kx$	$2c^a - kx$ (best response)

*Table 6 assumes that it takes IPR in both regions to cover costs, and that, absent effective IP, public sponsors will invest.

With respect to the subject matters for which unilateral protection would suffice, described in Table 5, two kinds of inefficiency may arise, stated in Remark 4(iv)(v) below. Suppose the subject matter satisfies $(c^a + c^w)d < (k - 1)x < c^a(2d + \pi)$ and $x < c^a\pi$. Then, referring to the efficiency criteria in Table 2, unilateral protection by region a (the smaller market) is efficient. Protection in region a is sufficient to cover cost, and the deadweight loss is less than the cost inefficiency of public sponsorship. However, as seen in Table 5, region a will not provide unilateral protection, due to the resulting outflow of profit to w .

Remark 4(v) notices that, even if a region was willing to protect the subject matter unilaterally, there could be an inefficient equilibrium in which the subject matter is protected in the larger market, with greater deadweight loss, rather than in the smaller market, which would be sufficient.

Turning to those subject matters that require bilateral protection, it follows from Table 6, as in the symmetric case, that there may be two equilibria. In one equilibrium, both regions protect the subject matter, and in the other equilibrium, neither protects it. If one region prefers public sponsorship to bilateral protection, it can ensure that outcome by not providing IP. Either region can block protection, and force public sponsorship.

To see this, assume $c^a < c^w$. Then it holds that

$$2dc^a - \pi(c^w - c^a) < d(c^a + c^w) < 2dc^w - \pi(c^a - c^w)$$

The minimum cost saving $(k - 1)x$ such that region a prefers bilateral protection to public sponsorship is the expression on the left, and the minimum for region w is the expression on the right. From Table 2, the minimum for *efficient* bilateral protection is the expression in the middle. Suppose then that, for a particular subject matter,

$$2dc^a - \pi(c^w - c^a) < (k - 1)x < 2dc^w - \pi(c^a - c^w)$$

Bilateral protection for such a subject matter may or may not be efficient (depending on whether $(k - 1)x$ is smaller or larger than $d(c^a + c^w)$), but in any case, will be blocked by region w , the larger market. Hence

Remark 4 [Asymmetric Markets: Inefficiencies] *When the sizes of the regional markets are different, but the regions have the same innovative capacities, then there are subject matters for which, in equilibrium,*

- (i) bilateral protection is efficient, and will be favored by the smaller region, but not by the larger region, which will block it;*
- (ii) bilateral protection is inefficient, will nevertheless be favored by the smaller region, but not favored by the larger region, which will block it;*
- (iii) bilateral protection is efficient, and both regions prefer it to public sponsorship, but it does not occur in equilibrium.*
- (iv) unilateral protection would be efficient, but it does not arise in equilibrium;*
- (v) unilateral protection would be efficient, but the “wrong” market is protected.*

Again we can consider the least protective harmonization, where the regions only harmonize on a subject matter if both prefer such harmonization, and the most protective harmonization, where the regions harmonize if either regions wants to.

Remark 5 [Asymmetric Markets: Harmonization] *When the sizes of the regional markets are different, but the regions have the same innovative capacities, the region with the smaller market prefers to harmonize on more subject matters than the region with the larger market. Further,*

(i) In the least protective harmonization, intellectual property will extend to all subject matters for which bilateral protection is efficient and preferred by both regions to public sponsorship;

(ii) In the least protective harmonization, there may be too little intellectual property, in the sense that some inventions are publicly sponsored even though bilateral intellectual property would be more efficient.

(iii) In the most protective harmonization, there may be too much intellectual property, in the sense that some inventions receive protection even though public sponsorship would be more efficient, and some inventions are protected in both regions, even though protection in a single region would suffice.

It may seem odd that the smaller region is more keen on IP than the larger region. However the smaller region incurs less deadweight loss than the larger region. At the same time, having the same innovative capacity as the larger market, it earns more profit from abroad. The positive net flow of profit is from the larger region to the smaller region.

However, this conclusion seems inconsistent with what we observed in the TRIPS negotiation, where an expansion of harmonized protections was mostly advocated by the large developed countries such as the U.S. What it illustrates is that the incentive to harmonize protections is largely drive by innovative capacities, which change the importance of profit flows, rather than market size *per se*. We now turn to asymmetries in innovative capacity.

7 Asymmetric Innovative Capacity

Let $\gamma^a, \gamma^w \in R_{++}$ measure the two regions' innovativeness. γ^i represents the number of innovations of each subject matter x that region i can make. For the conclusions

below, it is only the ratio γ^a/γ^w that is relevant. In the previous section, $\gamma^a = \gamma^w = 1$.

Table 7*: Payoffs to Region a

	IP in w	no IP in w
IP in a	$c(\gamma^a + \gamma^w)(1 - d) + \pi c(\gamma^a - \gamma^w) - \gamma^a x$	$(\gamma^a + \gamma^w)cm + \gamma^a c\pi - \gamma^a x$ (best response iff $\gamma^a(k - 1)x > c\gamma^w(d + \pi) + c\gamma^a d$)
no IP in a	$(\gamma^a + \gamma^w)c + \gamma^a c\pi - \gamma^a x$ (best response)	$(\gamma^a + \gamma^w)c - \gamma^a kx$

*Table 7 is for subject matter such that monopoly profit in a single region will cover costs, and that, absent IP, public sponsors will invest.

Table 8*: Payoffs to Region a

	IP in w	no IP in w
IP in a	$(\gamma^a + \gamma^w)c(1 - d) + \pi c(\gamma^a - \gamma^w) - \gamma^a x$ (best response iff $(1 + \frac{\gamma^w}{\gamma^a})dc - \pi c(1 - \frac{\gamma^w}{\gamma^a}) < (k - 1)x$)	$(\gamma^a + \gamma^w)c - \gamma^a kx$
no IP in a	$(\gamma^a + \gamma^w)c - \gamma^a kx$	$(\gamma^a + \gamma^w)c - \gamma^a kx$ (best response)

*Table 8 is for subject matter such that IPR in both regions is needed to cover costs, and that, absent effective IP, public sponsors will invest.

The inefficiencies that can arise in Table 7, where a single market can cover costs, are the same as those we described with asymmetric market sizes, and we will not explain part (iv) of the following Remark. We will focus on the subject matters for which bilateral protection is needed in order for IP to be effective.

The firms' asymmetric preferences about which subject matters to protect bi-

laterally will arise from their different innovative capacities rather than the sizes of their markets. I now show that the following features of equilibrium hold:

Remark 6 [Asymmetric Innovative Capacities: Inefficiencies] *When the regional markets are the same size, but the regions have different innovative capacities, then there are subject matters for which*

(i) bilateral protection is efficient, and will be favored by the more innovative region, but not by the less innovative region, which will block it;

(ii) bilateral protection is inefficient, will nevertheless be favored by the more innovative region, but not by the less innovative region, which will block it;

(iii) bilateral protection is efficient, and both regions prefer protection to public sponsorship, but there is an equilibrium in which neither region provides it;

(iv) unilateral protection would be efficient, but it does not arise in equilibrium.

To show this, use Tables 2, 7 and 8. It is efficient to grant bilateral protection on all subject matters x that satisfy

$$(\gamma^a + \gamma^w)2cd \leq (\gamma^a + \gamma^w)(k - 1)x \quad (4)$$

From Table 8, region a prefers bilateral protection to public sponsorship if and only if

$$(\gamma^a + \gamma^w)dc - \pi c(\gamma^a - \gamma^w) < \gamma^a(k - 1)x \quad (5)$$

The symmetric condition for w is

$$(\gamma^a + \gamma^w)dc - \pi c(\gamma^w - \gamma^a) < \gamma^w(k - 1)x \quad (6)$$

The sum of (5) and (6) yields (4), which proves that whenever the two regions agree on bilateral protection, such agreement is efficient. However, it is not true that whenever agreement for bilateral protection would be efficient they will agree.

If $\gamma^w < \gamma^a$, the following holds

$$(1 + \frac{\gamma^w}{\gamma^a})dc - \pi c(1 - \frac{\gamma^w}{\gamma^a}) < 2cd < (1 + \frac{\gamma^a}{\gamma^w})dc - \pi c(1 - \frac{\gamma^a}{\gamma^w}) \quad (7)$$

Ignoring the middle term, this shows there are subject matters for which (5) holds, but (6) does not, which proves Remark 6(i). Region a will prefer bilateral protection on subject matters x for which

$$(1 + \frac{\gamma^w}{\gamma^a})dc - \pi c(1 - \frac{\gamma^w}{\gamma^a}) < (k - 1)x < 2cd$$

for which protection would be inefficient. However region w will oppose it. Region w will oppose bilateral protection on subject matters x , as follows, for which protection would be efficient.

$$2cd < (k - 1)x < (1 + \frac{\gamma^a}{\gamma^w})dc - \pi c(1 - \frac{\gamma^a}{\gamma^w}) \quad (8)$$

Together, these two inequalities prove Remark 6(ii).

With independent choices, either region can block bilateral protection. Bilateral protections will be constrained by the region least willing to grant them. This proves Remark 6(iii).

Turning to harmonization, the regions need to resolve their differences on subject matters that satisfy

$$\frac{(\gamma^a + \gamma^w)}{\gamma^a}dc - \pi c \frac{(\gamma^a - \gamma^w)}{\gamma^a} < (k - 1)x < \frac{(\gamma^a + \gamma^w)}{\gamma^w}dc - \pi c \frac{(\gamma^w - \gamma^a)}{\gamma^w}$$

In the most protective harmonization, all such subject matters will be protected, and in the least protective harmonization, none will be protected. Neither of these outcomes

is efficient, as the least protective harmonization excludes some subject matters for which protection is efficient, and the most protective includes subject matters for which protection is not efficient.

Remark 7 [Asymmetric Innovative Capacities: Harmonization] *When the regional markets are the same, but the regions have different innovative capacities, then*

(i) In the least protective harmonization, intellectual property will extend to all subject matters for which bilateral protection is efficient and preferred by both regions to public sponsorship;

(ii) In the least-protective harmonization, there may be too little intellectual property, in the sense that some inventions are publicly sponsored even though bilateral intellectual property would be more efficient.

(iii) In the most protective harmonization, there may be too much intellectual property, in the sense that some inventions receive protection even though public sponsorship would be more efficient, and some inventions are protected in both regions, even though protection in a single region would suffice.

(iv) The more innovative region prefers to harmonize on more subject matters than the less innovative region.

8 Summary

The arguments above lead to the following conclusions.

- Regional incentives to provide intellectual property diverge from social efficiency because of profit flows and uncompensated externalities.
- When IP incentives are only required in one region to be effective, then it can nevertheless occur in equilibrium that neither region provides them, or that the “wrong” region provides them.
- When IP incentives are only effective if provided by both regions, it can nevertheless occur in equilibrium that neither region provides IP incentives, even when

that would be efficient, and even when it would serve their joint interests. This is a coordination problem in which there are two equilibria - with and without protection. This is the problem that harmonization can reliably cure.

- When the regions disagree on which subject matters should receive bilateral protection, among those that need it, the region that is least enthusiastic about IP has control. If that region does not protect the subject matter, then the other region will also not protect it. As a consequence, the global system of intellectual property can be “dictated” by the region that is least keen.
- When regions are asymmetric, it will typically be the case that one region wants to protect more subject matters than optimal, and the other will want fewer. Depending on how this disagreement is resolved, harmonization can either lead to underprotection or overprotection.
- When regions have different size markets but the same innovative capacities, it is the region with the smaller market that is most keen for an expansion of intellectual property.
- When regions have different innovative capacities but the same size markets, it is the more innovative region that is most keen for an expansion of intellectual property.

In the TRIPS negotiations, it was widely believed that the large developed economies, such as the U.S., were behind the expansion of intellectual property rights. The last two points indicate that this was probably not due to size of market, but rather to their disproportionate capacities for innovation.

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9 Appendix: Global Protection and Patent Life

In the discussion above, I have taken the length of protection as given, in order to focus on subject matter. However the TRIPS negotiation also concerned length. I mainly focus on subject matter because it caused the most controversy and because regional protections prior to TRIPS did not differ very much in length. The negotiation did not stray beyond that narrow range. The focus on subject matter also recognizes the “one size fits all” nature of patents and copyrights, which provide for the same duration of protection regardless of the invention’s per-period profit or R&D cost.

Nevertheless, it is worth pointing out the ways in which the controversy over length was similar and different than the controversy over subject matter. The analysis here differs from that of, for example, Grossman and Lai (2001), in that regions are thought to see public sponsorship as a viable alternative, as above.

In order to isolate the conflicts over length of protection, I will assume for this appendix that inventions in all subject matters have the same cost x of R&D (or, alternatively, that length can be tailored to subject matter).

If a regime of global protection gives the same incentives (same profit) as a regime of regional protection, protection can be shorter, but the efficiency losses due to proprietary pricing are the same in both regimes. To see this, let T^a, T^w represent the lengths of protection in a and w respectively. To simplify notation, assume that time has already been discounted, that is,

$$T^a = \int_0^{\tau_a} e^{-rt} dt$$

for some appropriate τ_a , and similarly for T_w . In discounted time, $T^a, T^w \in [0, \frac{1}{r}]$.

If we interpret πc^a as the per-period profit of an innovation in a (instead of interpreting it as total profit, as above), the total profit that accrues to an inventor by marketing his proprietary product in both a and w is $\pi(c^a T^a + c^w T^w)$. The ac-

companying deadweight loss is $d(c^a T^a + c^w T^w)$. Thus, all combinations (T^a, T^w) that provide the same total profit, say x , also provide the same total deadweight loss, dx/π . Among the policies that hold overall incentives for R&D fixed, harmonization has no efficiency consequence. In particular, an asymmetric equilibrium in which region a protects the subject matter is as efficient as an equilibrium in which w protects it, provided that in both cases the duration is minimally sufficient to cover cost. This is true even if the regions are asymmetric. In contrast, as argued above, an asymmetric equilibrium with respect to subject matter itself can be inefficient or efficient, depending on which region protects it. This is because of the “one size fits all” nature of protection, which means that duration cannot be tailored to subject matter.

Suppose again that the innovativeness of the two regions are γ^a, γ^w . Let $\tilde{W}^a(x), \tilde{W}^w(x)$ represent the social welfare generated in the two regions if inventions in the subject matter with cost x are public sponsored:

$$\begin{aligned}\tilde{W}^a(x) &= (\gamma^a + \gamma^w)c^a \frac{1}{r} - \gamma^a kx \\ \tilde{W}^w(x) &= (\gamma^a + \gamma^w)c^w \frac{1}{r} - \gamma^w kx\end{aligned}$$

If the subject matter is protected by the minimum effective intellectual property, the length should satisfy $\pi(c^a T^a + c^w T^w) = x$, generating deadweight loss of $d(c^a T^a + c^w T^w) = dx/\pi$. The additional cost that would be imposed by the public sector is $(k - 1)x$. Thus, IP is more efficient than public sponsorship if and only if

$$\frac{d}{\pi} < (k - 1) \tag{9}$$

However, that is not the consideration that will motivate a trade policy negotiator. The trade policy negotiator wants to save costs for taxpayers, including deadweight loss, but will balance domestic costs against the net flow of profit.

Let

$$\mathcal{T}(x) = \{T^a \in [0, \frac{1}{r}], T^w \in [0, \frac{1}{r}] \mid \pi(c^a T^a + c^w T^w) \geq x\}$$

Patent lives $(T^a, T^w) \in \mathcal{T}(x)$ are sufficient to cover the cost x .

For given x , let $W^a : \mathcal{T}(x) \rightarrow \mathbf{R}$ (symmetrically, W^w) represent region a 's welfare, defined as

$$\begin{aligned}
 W^a(T^a, T^w, x) = & \\
 & \gamma^a \pi(c^a T^a + c^w T^w) + m c^a (\gamma^a + \gamma^w) T^a & \text{if } (T^a, T^w) \in \mathcal{T}(x) \\
 & + (\frac{1}{r} - T^a) c^a (\gamma^a + \gamma^w) - \gamma^a x & \\
 \tilde{W}^a(x) & & \text{if } (T^a, T^w) \notin \mathcal{T}(x)
 \end{aligned}$$

and symmetrically for w . The second line recognizes the assumption that if $(T^a, T^w) \notin \mathcal{T}(x)$, then the patent lives are irrelevant because public sponsors will step in and put their inventions in the public domain.

Let the function \hat{T}^a be the minimum T^a such that IP will cover cost x when the other region has patent life T^w . $\hat{T}^a(x, T^w) = 0$ if $\pi c^w T^w \geq x$ and otherwise is the T^a that satisfies

$$\pi(c^a T^a + c^w T^w) = x \tag{10}$$

An *equilibrium with independent choices* is a pair (T^a, T^w) such that $W^a(T^a, T^w, x) \geq W^a(\tilde{T}^a, T^w, x)$ and $W^w(T^a, T^w, x) \geq W^w(T^a, \tilde{T}^w, x)$ for each x and all $\tilde{T}^a, \tilde{T}^w \in [0, \frac{1}{r}]$

It is easy to see that a 's (symmetrically, w 's) best response is to choose between two options: the minimum length that is required for the two jurisdictions to support innovation, $\hat{T}^a(x, T^w)$, or no protection at all, $T^a < \hat{T}^a(x, T^w)$, e.g., $T^a = 0$. Further, if $(0, T^w) \in \mathcal{T}(x)$, the best response of region a to T^w is $T^a = 0$. That is, if region w 's protection is sufficient to support private investment in R&D, region a can free-ride. It may be in w 's interest to provide all the incentives $((0, T^w) \in \mathcal{T}(x))$ if the cost inefficiency of public sponsorship $(k - 1)$ is very large, although w would obviously prefer not to be caught in that situation.

Remark 8 Let (T^a, T^w) be an equilibrium with independent choices such that intellectual property is effective, i.e., $(T^a, T^w) \in \mathcal{T}(x)$. Then (10) holds (the total duration is minimally sufficient), and (9) holds (intellectual property is efficient).

To show why this Remark is true, we first show that, assuming (10) holds, (9) holds if and only if (11) holds:

$$[W^a(T^a, T^w, x) + W^w(T^a, T^w, x)] \geq \tilde{W}^a(x) + \tilde{W}^w(x) \quad (11)$$

Using the definitions,

$$\begin{aligned} & [W^a(T^a, T^w, x) + W^w(T^a, T^w, x)] \\ &= (\gamma^a + \gamma^w) \left[\pi(c^a T^a + c^w T^w) + m(c^a T^a + c^w T^w) + \frac{1}{r}(c^a + c^w) - (c^a T^a + c^w T^w) - x \right] \\ &= (\gamma^a + \gamma^w) \left[-d(c^a T^a + c^w T^w) + \frac{1}{r}(c^a + c^w) - x \right] \\ &= (\gamma^a + \gamma^w) [(k-1)x - d(c^a T^a + c^w T^w)] + [\tilde{W}^a(x) + \tilde{W}^w(x)] \end{aligned}$$

Since (10) holds for (T^a, T^w) , it follows that $[(k-1)x - d(c^a T^a + c^w T^w)] = x[(k-1) - d/\pi]$. Hence (11) holds if only if (9) holds.

We show the Remark in two parts. Suppose first that $T^a = 0$ and $(0, T^w) \in \mathcal{T}(x)$. Then $T^w \geq x/\pi c^w$. In fact, since $W^w(0, T^w, x) < W^w(0, (x/\pi c^w), x)$ if $T^w > x/\pi c^w$, equilibrium requires that $T^w = x/\pi c^w$. Further, $W^w(0, (x/\pi c^w), x) > W^w(0, 0, x) = \tilde{W}^w(x)$, which implies $(d/\pi) \leq (k\gamma^w/(\gamma^a + \gamma^w)) - 1 \leq k - 1$, so (9) holds.

Suppose then that $T^a, T^w > 0$. Suppose that (10) does not hold for the equilibrium (T^a, T^w) . Then for some $\varepsilon > 0$, $(T^a - \varepsilon, T^w) \in \mathcal{T}(x)$, and since $W^a(T^a - \varepsilon, T^w, x) > W^a(T^a, T^w, x)$, this would contradict that (T^a, T^w) is an equilibrium. Since $W^a(T^a, T^w, x) \geq W^a(0, T^w, x) = \tilde{W}^a(x)$ and $W^w(T^a, T^w, x) \geq W^w(T^a, 0, x) = \tilde{W}^w(x)$, (11) holds, hence (9) holds.

Remark 9 *An equilibrium (T^a, T^w) with independent choices might not support incentives to invest, $(T^a, T^w) \notin \mathcal{T}(x)$, even if private incentives are efficient ((9) holds).*

To show the remark, we must show that there can be an equilibrium with public sponsorship even if (9) holds. Take the symmetric case $c^a = c^w = c$, $\gamma^a = \gamma^w = 1$. If $(k - 1) > d/\pi > (k/2) - 1$, $(T^a, T^w) = (0, 0)$ is an equilibrium even though (9) holds. By hypothesis

$$\frac{1}{2}k - 1 \leq \frac{d}{\pi}$$

hence, rearranging, and adding $2c/r$ to each side,

$$2\frac{c}{r} - kx \geq 2\frac{c}{r} - 2\frac{x}{\pi}(d + \pi)$$

which implies $\tilde{W}^a(x) \geq W^a((x/\pi c), 0, x)$, (symmetrically, $\tilde{W}^w(x) \geq W^w(0, (x/\pi c), x)$).

The symmetric case shows that there may be multiple equilibria, one involving public sponsorship and one involving private investment. In the above paragraph, it is assumed that (9) holds so that intellectual property is efficient, but nevertheless, $(0, 0)$ (public sponsorship) is an equilibrium. However, $(T^a, T^w) = (\frac{x}{2\pi c}, \frac{x}{2\pi c})$ is also an equilibrium, which is efficient. Indeed, there may also be other efficient equilibria (T^a, T^w) which are asymmetric. This immediately shows one of the benefits of harmonization. If the regions think that, absent a harmonization agreement, they will play the inefficient equilibrium $(0, 0)$, then they are both better off agreeing to a minimum duration $T = \frac{x}{2c\pi}$, which both will then play.

By “harmonization” we mean that the two jurisdictions must agree on a minimum level of protection T , although each may choose a longer duration if it wishes.

A *T-harmonized equilibrium* is a pair $(T^a, T^w) \geq (T, T)$ such that $W^a(T^a, T^w, x) \geq$

$W^a(\tilde{T}^a, T^w, x)$ for all $\tilde{T}^a \in [0, \frac{1}{r}]$ and $W^w(T^a, T^w, x) \geq W^w(T^a, \tilde{T}^w, x)$ for all $\tilde{T}^w \in [0, \frac{1}{r}]$.

Whether a region would be better off harmonizing on some minimum T depends on the equilibrium that would otherwise be played. This expectation might be formed, for example, by an equilibrium currently in effect.

In the following Remark, I characterize the harmonized T 's that would unequivocally make each region better off, in any T -harmonized equilibrium that they might subsequently play.

Let \bar{T}^a (symmetrically, \bar{T}^w) be the (unique) length such that for some $T^w \in [0, \frac{1}{r}]$, (10) holds and $W^a(T^a, T^w, x) = \tilde{W}^a(x)$. That is, \bar{T}^a is the maximum length such that, if region w makes up the additional duration required to cover cost, region a is exactly as well off as with public sponsorship.

Let

$$\begin{aligned}\beta^a &= (\gamma^a + \gamma^w)(d + \pi)c^a - \gamma^a\pi(c^a + c^w) \\ \beta^w &= (\gamma^a + \gamma^w)(d + \pi)c^w - \gamma^w\pi(c^a + c^w)\end{aligned}$$

Notice that $\beta^a + \beta^w = d(\gamma^a + \gamma^w)(c^a + c^w) > 0$. If $(T, T) \in \mathcal{T}(x)$,

$$\begin{aligned}W^a(T, T, x) &= -\beta^a T + \frac{1}{r}c^a(\gamma^a + \gamma^w) - \gamma^a x \\ W^w(T, T, x) &= -\beta^w T + \frac{1}{r}c^w(\gamma^a + \gamma^w) - \gamma^w x\end{aligned}\tag{12}$$

Remark 10 [Preferences as to Harmonization] *Suppose that an equilibrium (T^a, T^w) is anticipated.*

(a) *If $\beta^a < 0$ (symmetrically for w) then region a prefers to harmonize on the maximum, $T = \frac{1}{r}$.*

(b) *If $(T^a, T^w) \in \mathcal{T}(x)$ and $T^a > T^w$, then region a is better off in any T -harmonized*

equilibrium with $T > T^w$.

(c) If $(T^a, T^w) \in \mathcal{T}(x)$ and $T^a < T^w$, then region a is worse off harmonizing on any $T > T^a$.

(d) If $(T^a, T^w) \notin \mathcal{T}(x)$, if (9) holds, and if $\beta^a, \beta^w > 0$, then regions a and w are both better off harmonizing on $T \in \min\{\bar{T}^a, \bar{T}^w\}$.

Proof: (a) If $\beta^a < 0$ and $(T, T) \in \mathcal{T}(x)$, $W^a(T, T, x) > [\frac{1}{r}c^w(\gamma^a + \gamma^w) - \gamma^w kx] + \gamma^a(k - 1)x$, hence region a prefers any such T to public sponsorship. And since $W^a(T, T, x)$ is increasing in T , the preferred T is the maximum $\frac{1}{r}$. (b) We showed above 8 that, if the equilibrium satisfies $(T^a, T^w) \in \mathcal{T}(x)$, (10) holds. Thus, if region a can force region w to increase its length, region a will decrease its own length in equilibrium, both of which increase the value of $W^a(\cdot)$. (c) Such a harmonization will cause region a to increase its protection, and region w to decrease its protection, which decreases the value of $W^a(\cdot)$.

Part (d) addresses the impasse in which there is an inefficient reliance on public sponsorship. Suppose the minimum is \bar{T}^a . That is the maximum length that would make region a as well off as with public sponsorship, assuming that region w will complement the length so that private incentives are minimally supported, as stated in Remark 8. Further, since (9) holds, (11) holds. Since region a is equally well off with public sponsorship and with the minimally sufficient protection that would follow the harmonization, region w is also at least as well off. Thus both regions will be at least as well off in the T -harmonized equilibrium as in the equilibrium involving public sponsorship. \square

If, absent a harmonization, an asymmetric equilibrium $(T^a, T^w) \in \mathcal{T}(x)$ would be played, the regions will disagree on how to harmonize. The less protective region (shorter duration) will oppose a harmonization, or, at best, only want to harmonize on a T that will have no effect. The more protective region, namely the one that is providing more incentive with its longer duration of protection, will want to harmonize above the other region's equilibrium duration, in order to share the burden more equally. The outcome of bargaining might be to equalize durations, but as shown above, this will have no overall efficiency effect. One region's gain is the other region's loss.

The most severe conflict arises in the case $\beta^a < 0$, which occurs when region a is extremely innovative relative to w , or has a very small market, so that it suffers very little deadweight loss from intellectual property protection. In that case, region a will want to harmonize on a long T so that it collects a lot of profit from the other region, without suffering very much deadweight loss. If region a prevails in this negotiation, then T could end up longer than required to cover R&D costs, and harmonization will impose inefficiencies that could not arise in an equilibrium with independent choices.

On the other hand (in good news), harmonization can get the two regions out of an impasse in which neither provides enough intellectual property protection to cover costs, similarly to the coordination problem discussed above for protection of subject matters. Regardless of the conflicts, in cases of inefficiency, there is always a harmonized T that will improve (or not decrease) the welfare of both regions. As a consequence,

Remark 11 [Harmonization: Efficiency] *Any inefficiency that may arise in an equilibrium on length can be remedied by a harmonization which would make both regions better off.*

This result is in stark contrast to our conclusions above for harmonization on subject matter, where efficiency will typically not be achieved.