# Was global patent protection too weak before TRIPS?

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# 1 Introduction

The global intellectual property (IP) protection system was given a boost by the implementation of the TRIPS agreement (Agreement on Trade-Related Aspects of Intellectual Property Rights), which started a gradual process of IP harmonization in 1995. This agreement effectively requires the strengthening of patent protection of most countries, and forces the world IP protection policies towards harmonization (albeit a partial one). There have been nothing nearly as powerful as TRIPS in its geographic coverage and its ability to enforce rulings, not least because of the large number of countries involved and the credibility of the threat of punishment through trade retaliation. Given the tremendous repercussions of such a coordinated increase in the strengths of IP protection, it is fair to ask whether TRIPS is really a solution to a global coordination problem. It is clear that TRIPS has distributive effect between countries.[1] However, the more important question is whether global IP protection was too weak before TRIPS. If it was, then TRIPS can potentially be welfare-improving from the global point of view, and its inclusion in global trade talks would potentially facilitate negotiations on liberalization of other sectors/areas. For example, if less developed countries (LDCs) lose from TRIPS and developed countries (DCs) gain from TRIPS, but the latter's gains outweigh the former's losses, then it can be mutually beneficial for the LDCs to accept harmonization of IPR standards with the DCs in exchange for the DCs' opening their markets for labor-intensive manufacturing goods or agricultural products from the LDCs. However, if global patent protection was already too strong before TRIPS, then no such synergy exists between talks on trade-related IP negotiations and other issues/areas of global trade talks.

There is no doubt that some countries attempted to coordinate their IP policies somewhat even before TRIPS, but empirical studies have shown that even as late as 1990, market sizes and innovative capabilities significantly affect variation in the strengths of patent protection across the world, as predicted by non-cooperative game theory. So, I start with the working assumption that the world was in a non-cooperative equilibrium before TRIPS, and then ask, Would global patent protection be too weak when left to

[1] McCalman (2001) has shown that the US was by far the largest beneficiary, followed by Germany and France as distant second and third beneficiaries. On the other hand, the greatest loser was Canada, followed by Brazil and UK.

individual governments to decide its own level of protection?

To answer this question, we need to (a) have a theory that explains how global patent protection was determined in a non-cooperative equilibrium; (b) have a theory that explains how the optimal global patent protection is determined; and (c) develop a sufficient condition for global under-protection (or over-protection) of IP. In order to answer (c), we need to explain how a global system of patent protection affects incentives to innovate and how it creates distortions (deadweight losses). Therefore, we need to answer (a) and (b) first. To do so, we modify and extend a model by Grossman and Lai (2004). In Section 2, we shall re-state their theory in a succinct form. Then, we develop an extension that allows us to more realistically evaluate whether non-cooperative equilibrium gives rise to under-protection of IP.

In the basic model of Grossman and Lai (2004), countries play a Nash game in setting the strengths of patent protection. The best response function of a country's government is obtained by setting the strength of patent protection that equates the marginal costs (deadweight loss due to longer duration of monopoly pricing) and marginal benefits (increased incentives of innovation) of extending protection, given the strengths of protection of other countries. Each country conveys positive externalities to foreign countries as it extends patent protection, since it increases profits of foreign firms in the home market, and increases consumer surplus of foreign consumers due to induced innovations. As a result, there is under-protection of patent rights in Nash equilibrium relative to the global optimum. In fact, the degree of under-protection in Nash equilibrium increases with the number of independent decision-makers in the patent-setting game.

However, two factors prevents us from directly applying Grossman and Lai's (2004) basic model to answer the question posed in the title of this paper: "Was global patent protection too weak before TRIPS?". First is that governments may put extra weight on profits as opposed to consumer surplus (e.g. due to firm lobbying or perceived positive spillover effect of protecting patents on the domestic economy). When governments put more weight on profits, the marginal cost of patent protection decreases since deadweight loss is smaller. Therefore, patent protection in Nash equilibrium is stronger. We shall call this firm-biased preferences of governments. Second is the existence of trade barriers. When a firm has only a fraction of the penetration rate in a foreign market as compared to the domestic market (e.g. due to transportation cost and other trade costs), the positive international externalities of patent protection is diminished. Both factors tend to diminish the degree of under-protection in Nash equilibrium relative to the global optimum. If these forces are strong enough, there may even be over-protection of patents in Nash equilibrium. Therefore, whether or not there was under-protection of patents in the non-cooperative equilibrium before TRIPS is an empirical question. In this paper, we incorporate these two features in an extension of the basic Grossman and Lai (2004) model. We then calibrate the model by finding out how small the firm-biasedness parameter and the trade barriers have to be in order for there to be under-protection of patents in Nash equilibrium.

In the basic model, we can find a functional relationship between the global strength of patent protection and global welfare. The same strength of global patent protection creates the same amount of total deadweight losses (what I call distortion) and aggregate flow of new differentiated goods (what I call incentives) in each period. As long as the global strength of patent protection is the same, global welfare is the same, regardless of the combination of individual countries' strengths of patent protection. Therefore, the global optimum is a continuum of combinations of national strengths of patent protection that maxmize global welfare. However, this will not be true in the extended model. In the more general model with trade barriers, there does not exist a scalar measure of the global strength of patent protection such that there is a functional relationship between the global strength of protection and global welfare. Despite this problem, we are able to calculate a sufficient condition under which, starting from Nash equilibrium, global welfare must increase with increases in the strengths of protection in all countries. When this condition is satisfied, we can conclude that there is under-protection in global IP protection.

The key results of the extended model are: 1. There is only one single combination, not a continuum, of national strengths of patent protection that maximizes global welfare. 2. Externalities still exist, but their magnitude decreases with trade barriers. Therefore, the degree of under-protection decreases with trade barriers. 3. The degree of under-protection decreases with the firm-biasedness of governments. 4. Based on the estimates of a parameter from the political economy literature, and our judgement of the plausible value of trade barrier, we conclude that under-protection of global patent protection in the non-cooperative equilibrium is very likely.

# 2 A basic theory of international protection of IP

The theory described in this section basically draws from Grossman and Lai (2004).

## 2.1 Noncooperative Patent Protection

In this section, we study the national incentives for protection of intellectual property in a world economy with imitation and trade. We derive the Nash equilibria of a game in which two countries set their patent policies simultaneously and noncooperatively. The countries are distinguished by their wage rates, their market sizes, and their stocks of human capital. The last of these proxies for their different capacities for R&D. We shall term the countries "North" and "South," in keeping with our desire to understand the tensions that surrounded the tightening of intellectual property rights (IPR) protection in the developing countries in the last decade. Keith E. Maskus (2000a, ch.3) has documented an increase in innovative activity in poor and middle-income countries such as Brazil, Korea, and China, so our model of relations between trading partners with positive but different abilities to conduct R&D may be apt for studying the incentives for IPR protection in a world of trade between such nations and the developed economies.[2] But our model may apply more broadly to relations between any groups of countries that have different wages and different capacities for research. Such differences exist, albeit to a lesser extent than between North and South, in the comparison of countries in Northern and Southern Europe, or the comparison of the United States and Canada. We do not mean the labels North and South to rule out the application of our analysis to these other sorts of relationships.

### 2.1.1 The Global IPR Regime

Consumers in the two countries share identical preferences. In each country, the representative consumer maximizes the intertemporal utility function. The instantaneous utility of a consumer in country $j$ is given by

$$u_j(z) = y_j(z) + \int_0^{n_S(z)+n_N(z)} h[x_j(i,z)]di, \tag{1}$$

[2] He also shows the extent to which patent applications in countries like Mexico, Brazil, Korea, Malaysia, Indonesia and Singapore are dominated by foreign firms, a feature of the data that figures in our analysis.

where $y_j(z)$ is consumption of the homogeneous good by a typical resident of country $j$ at time $z$, $x_j(i,z)$ is consumption of the $i^{th}$ differentiated product by a resident of country $j$ at time $z$, and $n_j(z)$ is the number of differentiated varieties previously invented in country $j$ that remain economically viable at time $z$. There are $M_N$ consumers in the North and $M_S$ consumers in the South. While we do not place any restrictions on the relative sizes of the two markets at this juncture, we shall be most interested in the case where $M_N > M_S$.[3] It does not matter for our analysis whether consumers can borrow and lend internationally or not.

In country $j$, it takes $a_j$ units of labor to produce one unit of the homogeneous good or to produce one unit of any variety of the differentiated product. New goods are invented in each region according to $\phi_j = F(H_j, L_{Rj}/a_j) = A(L_{Rj}/a_j)^b H_j^{1-b}$, where $H_j$ is an input whose quantity determines the innovative capability of country $j$, $L_{Rj}$ is the labor devoted to R&D there. We assume that $a_N < a_S$, which means that labor is uniformly more productive in the North than in the South. We also assume that the numeraire good is produced in positive quantities in both countries, so that $w_j = 1/a_j$ for $j = S, N$, and hence $w_N/w_S = a_S/a_N > 1$. Define $\overline{T} = (1 - e^{-\rho\overline{\tau}})/\rho$, where $\overline{\tau}$ is the product life of a differentiated good.

We now describe the IPR regime. In each country, there is *national treatment* in the granting of patent rights. Under national treatment, the government of country $j$ affords the same protection $\Omega_j = \omega_j T_j$ to all inventors of differentiated products regardless of their national origins, where $\omega_j$ is the probability that a patent is enforced in country $j$ (or the fraction of country $j$'s market where a patent is enforced) at any moment in time, $T_j = (1 - e^{-\rho\tau_j})/\rho$, and $\tau_j$ is the length of the patents granted by country $j$. In other words, we assume that foreign firms and domestic firms have equal standing in applying for patents in any country and that all patents are subject to the same enforcement provisions. National treatment is required by TRIPs and it characterized the laws that were in place in most countries even before this agreement.[4] In our model, a patent

[3] We remind the reader that market size is meant to capture not the population of a country, but rather the scale of its demand for innovative products.

[4] National treatment is required by the Paris Convention for the Protection of Industrial Property, to which 127 countries subscribed by the end of 1994 and 164 countries subscribe today (see http://www.wipo.org/treaties/ip/paris/index.html). There were, however, allegations from firms in the United States and elsewhere that prior to the signing of TRIPS in 1994, nondiscriminatory laws did not always mean nondiscriminatory practice. See Suzanne Scotchmer (2004) for an analysis of the

is an exclusive right to make, sell, use, or import a product for a fixed period of time (see Maskus, 2000a, p.36). This means that, when good $i$ is under patent protection in country $j$, no firm other than the patent holder or one designated by it may legally produce the good in country $j$ for domestic sale or for export, nor may the good be legally imported into country $j$ from an unauthorized producer outside the country. We also rule out parallel imports — unauthorized imports of good $i$ that were produced by the patent holder or its designee, but that were sold to a third party outside country $j$.[5] When parallel imports are prevented, patent holders can practice price discrimination across national markets.

We solve the Nash game in which the governments set their patent policies once-and-for-all at time 0. These patents apply only to goods invented after time 0; goods invented beforehand continue to receive the protections afforded at their times of invention. So long as the governments cannot remove protections that were previously granted, the economy has no state variables that bear on its choice of optimal patent policies at a given moment in time. This means that the Nash equilibrium in once-and-for-all patents is also a sub-game perfect equilibrium in the infinitely repeated game in which the governments can change their patent policies periodically, or even continuously. Of course, the repeated game may have other equilibria in which the governments base their current policies on the history of prior actions. We do not investigate such equilibria with tacit cooperation here, but rather postpone our discussion of cooperation until a later section.

Let us describe, for given patent strengths $\Omega_N$ and $\Omega_S$, the life cycle of a typical differentiated product. During an initial phase after the product is introduced, the inventor holds an active patent in both countries which is only partially enforced. The patent holder earns an expected flow of profits of $\omega_N M_N \pi$ from sales in the Northern market and an expected flow of profits of $\omega_S M_S \pi$ from sales in the Southern market,

incentives that countries have to apply national treatment in the absence of an enforcible agreement.

[5] The treatment of parallel imports under TRIPs remains a matter of legal controversy. Countries continue to differ in their rules for territorial exhaustion of IPRs. Some countries, like Australia and Japan, practice international exhaustion, whereby the restrictive rights granted by a patent end with the first sale of the good anywhere in the world. Other countries or regions, like the United States and the European Union, practice national or regional exhaustion, whereby patent rights end only with the first sale within the country or region. Under such rules, patent holders can prevent parallel trade. See Maskus (2000b) for further discussion.

where $\pi$ is earnings per consumer for a monopoly selling a typical brand. Notice that monopoly profits per consumer are the same for sales in both markets, because consumers share identical preferences. Also, they do not depend on where a good was invented or where it is produced, because the productivity gap between the countries exactly offsets the wage differential. Each Northern consumer realizes a flow of expected surplus of $\omega_N C_m + (1 - \omega_N) C_c$ from his purchases of the good, where $C_m$ is the surplus that a consumer derives from purchases of a good produced at a cost of $w_j a_j = 1$ and sold at the monopoly price $p_m$ and $C_c$ is the surplus he derives from a product sold for the competitive price of $p_c = 1$. Similarly, a Southern consumer realizes an expected flow of consumer surplus of $\omega_S C_m + (1 - \omega_S) C_c$ from his purchases of the good.

After a while, the patent will expire in one country. For concreteness, let's say that this happens first in the South. Then the good will be legally imitated by competitive firms producing there, for sales in the local (Southern) market. The imitators will not, however, be able to sell the good legally in the North, because the live patent there, if enforced, affords protection from such infringing imports. When the patent expires in the South, the price of the good falls permanently to $w_S a_S = 1$, and the original inventor ceases to realize profits in that market. The flow of consumer surplus in the South rises to $M_S C_c$.

Eventually, the inventor's patent expires in the North. Then the Northern market can be served completely by competitive firms producing in either location. At this time, the price of the good in the North falls to $p_c = 1$ and households there begin to enjoy the higher flow of consumer surplus $M_N C_c$. The original inventor loses his remaining source of monopoly income. Finally, after a period of length $\bar{\tau}$ has elapsed from the moment of invention, the good becomes obsolete and all flows of consumer surplus cease.

### 2.1.2 The Best Response Functions

Consider the choice of patent policies $\Omega_N$ and $\Omega_S$ that will take effect at time 0 and apply to goods invented thereafter. The expressions for the aggregate welfare in country

$i$, discounted to time 0, is given by

$$W_i(0) = \Lambda_{i0} + \frac{w_i L_i}{\rho} + \frac{r_i H_i}{\rho} + \frac{M_i(\phi_S + \phi_N)}{\rho}\left[\Omega_i C_m + (\bar{T} - \Omega_i) C_c\right]$$

$$= \Lambda_{i0} + \frac{w_i(L_i - L_{Ri})}{\rho} + \frac{M_i(\phi_S + \phi_N)}{\rho}\left[\Omega_i C_m + (\bar{T} - \Omega_i) C_c\right]$$

$$+ \frac{\phi_i}{\rho}\pi\left(M_S \Omega_S + M_N \Omega_N\right), \text{ for } i = S, N, \qquad (2)$$

where $\Lambda_{i0}$ is the fixed amount of discounted surplus that consumers in country $i$ derive from goods that were invented before time 0. The second equality arises from the fact that there is zero profit for each firm, so that $r_i H_i + w_i L_{Ri} = \phi_i v = \phi_i \pi\left(M_S \Omega_S + M_N \Omega_N\right)$, where $v = (M_S \Omega_S + M_N \Omega_N)\pi$ is the value of a new patent.

We are now ready to derive the best response functions for the two governments. The best response expresses the strength of patent protection that maximizes a country's aggregate welfare as a function of the given patent policy of its trading partner. Consider the choice of $\Omega_S$ by the government of the South. This country bears two costs from strengthening its patent protection slightly. First, it expands the fraction of goods previously invented in the South on which the country suffers a static deadweight loss of $M_S(C_c - C_m - \pi)$. Second, it augments the fraction of goods previously invented in the North on which its consumers realize surplus of $M_S C_m$ instead of $M_S C_c$. Notice that the profits earned by Northern producers in the South are not an offset to this latter marginal cost, because they accrue to patent holders in the North. The marginal benefit that comes to the South from strengthening its patent protection reflects the increased incentive that Northern and Southern firms have to engage in R&D. If the welfare-maximizing $\Omega_S$ is positive and less than $\bar{T}$, then the marginal benefit *per consumer* of increasing $\Omega_S$ must match the marginal cost, which implies

$$\phi_S(C_c - C_m - \pi) + \phi_N(C_c - C_m) = \frac{\gamma_S \phi_S + \gamma_N \phi_N}{v} M_S \pi \left[C_m \Omega_S + C_c(\bar{T} - \Omega_S)\right], \qquad (3)$$

where $\gamma_j$ is the responsiveness of innovation in region $j$ to changes in the value of a patent (in elasticity form), i.e. $\frac{\partial \phi_j}{\partial v} = \gamma_j \frac{\phi_j}{v}$.

Similarly, in the North, the marginal benefit of strengthening patent protection must match the marginal cost at any interior point on the best response curve. The marginal cost in the North is different from that in the South, because the North's national income includes the profits earned by Northern patent holders but not those earned by

Southern patent holders. The marginal benefit differs too, because the effectiveness of patent policy as a tool for promoting innovation varies according to the importance of a country's market in the aggregate profits of potential innovators and because the surplus from a typical product over its lifetime depends upon a country's patent regime. The condition for the best response of the North, analogous to (3) above, is

$$\phi_S(C_c - C_m) + \phi_N(C_c - C_m - \pi) = \frac{\gamma_S\phi_S + \gamma_N\phi_N}{v} M_N\pi \left[C_m\Omega_N + C_c(\bar{T} - \Omega_N)\right]. \quad (4)$$

Noting that $\gamma_S = \gamma_N = \gamma$, [6] the two best response functions can be written similarly as

$$C_c - C_m - \mu_i\pi = \gamma \frac{M_i\Omega_i}{M_S\Omega_S + M_N\Omega_N}\left[C_m + C_c(\frac{\bar{T} - \Omega_i}{\Omega_i})\right] \quad \text{for } i = S, N, \quad (5)$$

where $\mu_i = \phi_i/(\phi_S + \phi_N)$ is the share of world innovation that takes place in country $i$. Moreover, $\mu_i = H_i/(H_S + H_N)$ for this research technology. Thus, both $\mu_i$ and $\gamma$ are independent of the patent policies in the Cobb-Douglas case. It follows from (5) that the best response functions are linear and downward sloping in this case, and that the best response function for the South is steeper than that for the North, when the two are drawn in $(\Omega_S, \Omega_N)$ space.

Thus, the patent policies of the two countries are strategic substitutes. To understand the strategic interdependence between the governments in choosing their policies, consider the choice of patent protection by the South. Suppose the North were to strengthen its patent protection; i.e., to increase $\Omega_N$. This would shrink the fraction of total discounted profits that an innovator earns in the South and so, ceteris paribus, reduce the responsiveness of global innovation to patent policy in the South. Moreover, the increase in $\Omega_N$ would draw labor into R&D in the North and South. If $\beta < 0$, the elasticity of innovation with respect to patent value would fall. The South would find that its market is relatively less important to potential innovators and that these innovators are less responsive to its patent policy. For both reasons, the marginal benefit to the South of strengthening its patent protection would fall and so the government

[6] The fact that the two supply elasticities $\gamma_S$ and $\gamma_N$ are equal despite the differences in human capital endowments, in employment, and in labor productivity is a property of the Cobb-Douglas research technology. It follows from the observation that

$$\gamma_i = \frac{b}{(1-b)} \quad \text{for all } i$$

would respond to the increase in $\Omega_N$ with a reduction in patent length or an easing of enforcement.

It is easy to show using (5) that the best response curve for the South must have a slope that is everywhere greater in absolute value than $M_S/M_N$, while the best response curve for the North must have a slope that is everywhere smaller in absolute value than $M_S/M_N$.[7] It follows that the curve for the South must be steeper than that for the North at any point of intersection. This guarantees uniqueness of the Nash equilibrium and ensures stability of the policy setting game.

We summarize the most important findings in this section as follows.

**Proposition 1** *Let the research technology be $\phi_j = A\left(L_{Rj}/a_j\right)^b H_j^{1-b}$ in country $i$, for $i = S, N$. Since the two patent policies are strategic substitutes in both countries, there exists a unique and stable Nash equilibrium of the policy setting game.*

## 2.2 International Patent Agreements

In this section, we study international patent agreements.[8] We begin by characterizing the combinations of patent policies that are jointly efficient for the two countries.[9] Then we compare the Nash equilibrium outcomes with the efficient policies, to identify changes in the patent regime that ought to be effected by an international treaty. Finally, we address the issue of policy harmonization. By that point, we will have seen that

[7] We have not discussed the shape of the best response functions where they hit the axes or where the constraint that $\Omega_i \leq \bar{T}$ begins to bind. The best-response curve of the South becomes vertical if it hits the vertical axis at a point below $\Omega_N = \bar{T}$. It also becomes vertical if the South's best response is $\bar{T}$ for some positive value of $\Omega_N$. Similarly, the best-response curve for the North becomes horizontal if either it hits the horizontal axis before $\Omega_S = \bar{T}$ or if the North's best response is $\bar{T}$ for some positive value of $\Omega_S$. Thus, the best response curve for the South must be steeper than that for the North at any point of intersection, even if these additional segments of the best response functions are taken into account.

[8] See also McCalman (2002), who discusses globally efficient patent policies in his two-country extension of the Nordhaus (1969) model. Lai and Qiu (2003) consider whether the joint welfare of the two countries would be increased if the South were to extend its patents so as to be equal in length to those chosen by the North in a Nash equilibrium.

[9] Ours is a constrained efficiency, because we assume that innovation must be done privately and that patents are the only policies available to encourage R&D. We do not, for example, allow the governments to introduce R&D subsidies, which if feasible, might allow them to achieve a given rate of innovation with weaker patents and less deadweight loss.

harmonization is neither necessary nor sufficient for global efficiency. We proceed to investigate the distributional properties of an agreement calling for harmonized patent policies and ask whether both countries would benefit from such an agreement in the absence of some form of direct compensation.

### 2.2.1 Efficient Patent Regimes

We shall begin by showing that the sum of the welfare levels of the two countries depends only on a measure $Q$ of the *overall* protection afforded by the international patent system. This means that the same aggregate world welfare level can be achieved with different combinations of $\Omega_S$ and $\Omega_N$ that imply the same overall level of protection. One particular level of $Q$—call it $Q^*$—maximizes the sum of the countries' welfare levels. For a wide range of distributions of world welfare, efficiency is achieved by setting the individual patent policies so that the overall index of patent protection is $Q^*$.

In particular, let $Q = M_S\Omega_S + M_N\Omega_N$. This measure of global patent protection weighs the degree of patent protection in each country by the size of the country's market. A firm that earns a flow of expected profits of $\omega_S M_S \pi$ for a period of length $\tau_S$ in the South and a flow of expected profits of $\omega_N M_N \pi$ for a period of $\tau_N$ in the North earns a total discounted sum of expected profits equal to $Q\pi$. Thus, $Q$ governs the allocation of resources to R&D in each country, regardless of the particular combination of patent policies in the separate countries.

Consider the choice of patent policies $\Omega_N$ and $\Omega_S$ that will take effect at time 0 and apply to goods invented thereafter. Summing the welfare expressions in (2) for $i = S$ and $i = N$, we find that

$$\rho\,[W_S(0) + W_N(0)] = \rho\,(\Lambda_{S0} + \Lambda_{N0}) + w_S(L_S - L_{RS}) + w_N(L_N - L_{RN}) \\ + (M_S + M_N)\,\bar{T}(\phi_S + \phi_N)C_c - Q\,(\phi_S + \phi_N)\,(C_c - C_m - \pi) \qquad (6)$$

Since $v_S = v_N = \pi Q$, $L_{RS}$ and $L_{RN}$ are functions of $Q$.[10] The same is true of $\phi_S$ and $\phi_N$. It follows that different combinations of $\Omega_S$ and $\Omega_N$ that yield the same value of $Q$

[10] In country $i$, the allocation of labor to research is determined by

$$\pi Q F_L(L_{Ri}/a_i, H_i) = 1/a_i.$$

also yield the same level of aggregate world welfare.[11]

If international transfer payments are feasible, then a globally efficient patent regime must have $M_S\Omega_S + M_N\Omega_N = Q^*$, where $Q^*$ is the value of $Q$ that maximizes the right-hand side of (6).[12] Notice that a range of efficient outcomes can be achieved without the need for any international transfers. By appropriate choice of $\Omega_N$ and $\Omega_S$, the countries can be given any welfare levels on the efficiency frontier between that which they would achieve if $\Omega_S = 0$ and $\Omega_N = Q^*/M_N$ and that which they would achieve if $\Omega_S = Q^*/M_S$ and $\Omega_N = 0$.[13]

Although aggregate world welfare does not vary with the national policies $\omega_i$ and $\tau_i$ as long as $M_S\Omega_S + M_N\Omega_N = Q^*$, the countries fare differently under the alternative combinations of policies that can be used to achieve global efficiency unless compensating transfers take place. In particular, the welfare of the North increases and that of the South decreases as $\Omega_S$ is increased and $\Omega_N$ is decreased in such a way as to keep the weighted sum constant. It follows that, absent any international transfer payments, the countries have a strong conflict of interest over the terms of an international patent agreement.

### 2.2.2 Pareto-Improving Patent Agreements

How do the efficient combinations of patent policies compare to the policies that emerge in a noncooperative equilibrium? The answer to this question — which informs us about the likely features of a negotiated patent agreement — is illustrated in Figure 1. The figure depicts the best response functions and the efficient policy combinations on the same diagram.

[11] This result is anticipated by a similar one in McCalman (2002), who studied efficient patent agreements in a partial equilibrium model of cost-reducing innovation by a single, global monopolist.

[12] The first-order condition for maximizing $\rho[W_S(0) + W_N(0)]$ implies

$$C_c - C_m - \pi = \gamma \left\{ C_m + C_c \left[ \frac{(M_S + M_N)\bar{T} - Q^*}{Q^*} \right] \right\}.$$

The second-order condition is satisfied at $Q = Q^*$ when $\beta \leq 1/2$.

[13] This statement ignores the ceiling on patent lengths imposed by the finite economic life of differentiated products. A more precise statement is that a range of distributions of maximal world welfare can be achieved by varying $\Omega_S$ between $\Omega_S = \max\{0, (Q^* - M_N\bar{T})/M_S\}$ and $\min\{Q^*/M_S, \bar{T}\}$ while varying $\Omega_N$ between $\Omega_N = \min\{Q^*/M_N, \bar{T}\}$ and $\max\{0, \left(Q^* - M_S\bar{T}\right)/M_N\}$ in such a way that $M_S\Omega_S + M_N\Omega_N = Q^*$.

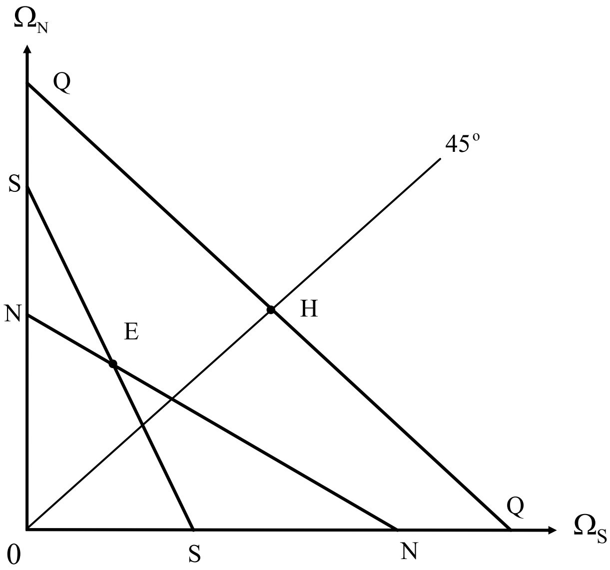


Figure 1: Comparison of Nash Equilibrium and an Efficient Patent Regime

In the figure, the efficient policy combinations are depicted by the line $QQ$.[14] We show this line being situated to the right of the $SS$ curve and above the $NN$ curve, which is a general feature of our model. The reasons are clear. Starting from a point on the South's best response function, a marginal strengthening of IPR protection in the South increases world welfare. Such a change in Southern policies has only a second-order effect on welfare in the South, but it conveys two positive externalities to the North. First, it provides extra monopoly profits to Northern innovators, which contributes to aggregate income there. Second, it enhances the incentives for R&D, inducing an increase in both $\phi_S$ and $\phi_N$. The extra product diversity that results from this R&D creates additional surplus for Northern consumers.

By the same token, a marginal increase in the strength of Northern patent protection from a point along $NN$ increases world welfare. Such a change in policy enhances profit income for Southern firms and encourages additional innovation in both countries. It follows, of course, that the $QQ$ line must lie outside the Nash equilibrium. We record

[14] If international transfer payments are infeasible, the set of Pareto efficient policy combinations includes the segment of the vertical axis above its intersection with $QQ$ and extending as far as the point $(0, \bar{T})$ and the segment of the horizontal axis to the right of its intersection with $QQ$ and extending to $(\bar{T}, 0)$.

our finding in

**Proposition 2** *Let* $(\Omega_S, \Omega_N)$ *be an interior equilibrium in the noncooperative policy game and let* $(\Omega_S^*, \Omega_N^*)$ *be any efficient combination of patent policies. Then* $M_S\Omega_S^* + M_N\Omega_N^* > M_S\Omega_S + M_N\Omega_N$.

The proposition implies that, starting from any interior Nash equilibrium, an efficient patent treaty must strengthen patent protection in at least one country. It also implies that the treaty will strengthen global incentives for R&D and induce more rapid innovation in both countries.

## 2.3 Patent Policy with Many Countries

In this section, we extend our analysis to a trading world with many countries. Our main finding is that adding countries exacerbates the free-rider problem that plagues the noncooperative policy equilibrium. Small countries are inclined to allow others to provide the incentives for innovation so as to avoid the deadweight losses in their home markets. In the limit, as the number of countries grows large and each one is small in relation to the world economy, the unique Nash equilibrium has universal patents of strength zero. Then, a patent treaty is critical for creating incentives for private innovation.

We assume that there are $J$ countries, and that country $i$ has market size $M_i$, human capital endowment $H_i$, and labor productivity $1/a_i$. The research technology in country $i$ is $\phi_i = F\left(H_i, L_{Ri}/a_i\right) = A\left(L_{Ri}/a_j\right)^b H_i^{1-b}$. All consumers share the preferences given in (1).

Suppose that there is no cooperation between nations in setting their patent policies. In country $i$, either $\Omega_i = 0$ and the marginal cost of providing the first bit of patent protection exceeds the marginal benefit, $\Omega_i = \bar{T}$ and the marginal benefit of providing the last bit of patent protection exceeds the marginal cost, or $0 < \Omega_i < \bar{T}$ and the marginal benefit of strengthening patent protection equals the marginal cost. Equality between marginal benefit and marginal cost implies

$$C_c - C_m - \mu_i\pi = \frac{M_i}{Q}\gamma[\Omega_i C_m + C_c(\bar{T} - \Omega_i)] \ , \tag{7}$$

where $Q = \sum_j M_j \Omega_j$ measures the strength of global patent protection in the Nash equilibrium.

Observe first that as $\mu_i \to 0$, the left-hand side of (7) approaches $C_c - C_m$; a small country captures virtually none of the monopoly profits from innovative products, so the marginal cost of a patent per consumer and product is the difference between the competitive and monopoly levels of consumer surplus. But as $M_i \to 0$, the right-hand side of (7) approaches zero, because a small country provides innovators with virtually none of their global profits and so worldwide innovation is hardly responsive to a change in such a country's patent policy. It follows that a small country will set its index of patent protection equal to zero in a Nash equilibrium.

If all countries choose positive patent strengths that are less than $\bar{T}$, equation (7) holds for every $i$. Then we can sum (7) across the $J$ countries, which gives

$$J\left(C_c - C_m\right) - \pi = \gamma \left[C_m - C_c + \frac{C_c\left(\sum_j M_j\right)\bar{T}}{Q}\right]. \qquad (8)$$

Then, for a given size of the world market, $Q$ depends only on the *number* of countries $J$ and not on the distribution of consumers and human capital across countries. Moreover, the greater is the number of countries, the weaker are the global incentives for innovation in a noncooperative equilibrium. As the number of countries grows large (holding constant the size of the world market), the aggregate incentives for innovation approach zero.[15] Evidently, the free-rider problem becomes increasingly severe as the number of independent decision makers in the world economy expands.

Finally, note that the requirements for global efficiency do not depend on the number of countries. Again, the sum of all national welfare levels is a function of the aggregate world incentive for innovation. This sum is maximized when

$$C_c - C_m - \pi = \gamma \left[C_m - C_c + \frac{C_c\left(\sum_j M_j\right)\bar{T}}{Q^*}\right]. \qquad (9)$$

Thus, if international compensation is possible, an efficient global patent treaty will have $\sum_j M_j \Omega_j = Q^*$, where $Q^*$ is solved from (9). Notice that $Q^*$ must exceed $Q$, the

[15]Suppose $Q$ were to approach a finite number as $J \to \infty$. Then $\gamma$ would approach a finite number as well, and the right-hand side of (8) would be finite. But the left-hand side of (8) approaches infinity as $J \to \infty$.

aggregate patent protection in the Nash equilibrium. Even if international compensation is not feasible, an efficient agreement will have $\sum_j M_j \Omega_j = Q^*$ for a range of distributions of world welfare.

# 3 Extension of the basic model

In the basic model, countries play a Nash game in setting the strengths of patent protection. The best response function of a country's government is obtained by setting the strength of patent protection that equates the marginal costs (deadweight loss due to longer duration of monopoly pricing) and marginal benefits (increased incentives of innovation) of extending protection, given the strengths of protection of other countries. Each country conveys positive externalities to foreign countries as it extends patent protection, since it increases profits of foreign firms in the home market, and increases consumer surplus of foreign consumers due to induced innovations. As a result, there is under-protection of patent rights in Nash equilibrium relative to the global optimum. In fact, the degree of under-protection in Nash equilibrium increases with the number of independent decision-makers in the patent-setting game.

However, two factors prevents us from directly applying Grossman and Lai's (2004) basic model to answer the question posed in the title of this paper: "Was global patent protection too weak before TRIPS?". First is that governments may put extra weight on profits as opposed to consumer surplus (e.g. due to firm lobbying or perceived positive spillover effect of protecting patents on the domestic economy). When governments put more weight on profits, the marginal cost of patent protection decreases since deadweight loss is smaller. Therefore, patent protection in Nash equilibrium is stronger. We shall call this firm-biased preferences of governments. Second is the existence of trade barriers. When a firm has only a fraction of the penetration rate in a foreign market as compared to the domestic market (e.g. due to transportation cost and other trade costs), the positive international externalities of patent protection is diminished. Both factors tend to diminish the degree of under-protection in Nash equilibrium relative to the global optimum. If these forces are strong enough, there may even be over-protection of patents in Nash equilibrium. Therefore, whether or not there was under-protection of patents in the non-cooperative equilibrium before TRIPS is an empirical question.

In this paper, we incorporate these two features in an extension of the basic Grossman and Lai (2004) model. We then calibrate the model by finding out how small the firm-biasedness parameter and the trade barriers have to be in order for there to be under-protection of patents in Nash equilibrium.

In the basic model, we can find a functional relationship between the global strength of patent protection and global welfare. The same strength of global patent protection creates the same amount of total deadweight losses (what I call distortion) and aggregate flow of new differentiated goods (what I call incentives) in each period. As long as the global strength of patent protection is the same, global welfare is the same, regardless of the combination of individual countries' strengths of patent protection. Therefore, the global optimum is a continuum of combinations of national strengths of patent protection that maxmize global welfare. However, this will not be true in the extended model. In the more general model with trade barriers, there does not exist a scalar measure of the global strength of patent protection such that there is a functional relationship between the global strength of protection and global welfare. Despite this problem, we are able to calculate a sufficient condition under which, starting from Nash equilibrium, global welfare must increase with increases in the strengths of protection in all countries. When this condition is satisfied, we can conclude that there is under-protection in global IP protection.

The key results of the extended model are: 1. There is only one single combination, not a continuum, of national strengths of patent protection that maximizes global welfare. 2. Externalities still exist, but their magnitude decreases with trade barriers. Therefore, the degree of under-protection decreases with trade barriers. 3. The degree of under-protection decreases with the firm-biasedness of governments. 4. Based on the estimates of a parameter from the political economy literature, and our judgement of the plausible value of trade barrier, we conclude that under-protection of global patent protection in the non-cooperative equilibrium is very likely.

## 3.1 The extended model

Let $y$ be the probability that an invention with commercial value in the domestic market is sold in a foreign market (we shall call it import penetration rate); $v_i$ be the expected value of a patent for an invention by a firm in country i; $1+a$ be the weight a government puts on profits when a weight of one is put on consumer surplus (if $a$ is solely coming from firm lobbying as per Grossman and Helpman, it stands for the weight a government puts on contribution when it puts a weight of one on welfare — see the appendix).

Therefore,

$$v_i = \pi \left[ \sum_{k \neq i} (y M_k \Omega_k) + M_i \Omega_i \right]$$

Note that the flow of patents from country i

$$\phi_i = f(H_i, L_{Ri}) = A (L_{Rj}/a_j)^b H_j^{1-b}$$

Define $\frac{1}{M_i} \frac{\partial W_i(a)}{\partial \Omega_i} = MB_i - MC_i(a)$, where $W_i(a)$ is country i's government's objective function, $MC_i(a)$ is the per consumer marginal cost and $MB_i$ is the per consumer marginal benefit from the point of view of government $i$. Country i's best response function ($BRF_i$) is obtained from $\frac{1}{M_i} \frac{\partial W_i(a)}{\partial \Omega_i} = 0$, which is equivalent to $MC_i(a) = MB_i$. Note that $W_i(a)$ and $MC_i(a)$ are functions of $a$ since the additional weight government i puts on firm profits affects the deadweight loss as patent strength is increased, and so it appears in both expressions. But $MB_i$ is not a function of $a$ since the effect of induced innovation is not affected by government i's firm-biased preferences. Hereinafter, we shall put an argument $a$ in the name of a function if we want to emphasize that firm-biasedness influences the value of that function.

It can be shown that $MC_i(a)$ is

$$y\phi_i (C_c - C_m) + (1-y) \phi_i (C_c - C_m) - \phi_i (1+a) \pi + y \left( \sum_{j \neq i} \phi_j \right) (C_c - C_m)$$

$$= y \left( \sum_j \phi_j \right) (C_c - C_m) + \phi_i [(1-y)(C_c - C_m) - (1+a)\pi]$$

On the other hand, $MB_i$ is

$$\left( \sum_j \gamma \frac{\phi_j}{v_j} \right) y^2 \pi M_i f_i + \gamma \frac{\phi_i}{v_i} (1 - y^2) \pi M_i f_i$$

where $f_i \equiv C_c \overline{T} - (C_c - C_m) \Omega_i$ is the present discounted value of consumer surplus a consumer derives from a differentiated good over its product life.

Define $\frac{1}{M_i} \frac{\partial W^w}{\partial \Omega_i} = MB_i^w - MC_i^w$, where $W^w = \sum_i W_i$ is world welfare (without firm-biasedness), $MC_i^w$ and $MB_i^w$are the corresponding per consumer marginal cost and marginal benefit respectively. The first order condition ($FOC_i$) in maximization of global welfare with respect to $\Omega_i$ is obtained from $\frac{1}{M_i}\frac{\partial W^w}{\partial \Omega_i} = 0$, which is equivalent to $MC_i^w = MB_i^w$. Hereinafter, we shall put a superscript $w$ on a variable name to denote that it is associated with (maximization of) global welfare.

It can be shown that $MC_i^w$ is

$$\begin{aligned} & y\phi_i \left[C_c - C_m - \pi\right] + (1-y)\,\phi_i \left[C_c - C_m - \pi\right] + y\left(\sum_{j\neq i}\phi_j\right)(C_c - C_m - \pi) \\ = \; & y\left(\sum_j \phi_j\right)(C_c - C_m - \pi) + (1-y)\,\phi_i \left[C_c - C_m - \pi\right] \end{aligned}$$

On the other hand, $MB_i^w$ is

$$\begin{aligned} & \left[\left(\sum_j \gamma\frac{\phi_j}{v_j}\right) y^2\pi + \gamma\frac{\phi_i}{v_i}\left(1-y^2\right)\pi\right] M_i f_i \\ & + \left(\sum_j \gamma\frac{\phi_j}{v_j}\right) y^2\pi \sum_{k\neq i} M_k f_k + \left[\sum_{k\neq i}\gamma\frac{\phi_k}{v_k} y\,(1-y)\,\pi M_k f_k\right] \end{aligned}$$

For the purpose of illustrating the intuition involved, it proves useful to present the case with symmetry, i.e. $M_i = M$, and $H_i = H$ for all i. For the purpose of calibrating the model, however, we go back to the case with asymmetry.

## 3.2 Symmetry

With symmetry, assume that $J$ is the number of countries, $\Omega^E$ is the common Nash equilibrium strength of patent protection for all countries, $\phi$ is common flow of inventions in each period from each country. It is easy to show that the Nash equilibrium is obtained by setting $\Omega_i = \Omega^E$, $\forall i$ in $BRF_i$:

$$\begin{aligned} & y\,(C_c - C_m) + \frac{1}{J}\left[(1-y)\,(C_c - C_m) - (1+a)\,\pi\right] \\ = \; & \frac{\gamma y^2\left[C_c\overline{T} - (C_c - C_m)\,\Omega^E\right]}{J\left[(J-1)y+1\right]\Omega^E} + \frac{\gamma\,(1-y^2)\left[C_c\overline{T} - (C_c - C_m)\,\Omega^E\right]}{J\left[(J-1)y+1\right]\Omega^E} \\ = \; & \frac{\gamma\left[C_c\overline{T} - (C_c - C_m)\,\Omega^E\right]}{J\left[(J-1)y+1\right]\Omega^E} \end{aligned}$$

which is equivalent to

$$1+(J-1)\,y-(1+a)\,\theta_2=\frac{\gamma}{[(J-1)y+1]}\left(\frac{\theta_1}{\Omega^E}-1\right) \tag{10}$$

where $\theta_1 \equiv \frac{C_c}{C_c-C_m}$ and $\theta_2 \equiv \frac{\pi}{C_c-C_m}$. Therefore, the marginal cost decreases while marginal benefit increase as trade barrier increases (i.e. as $y$ decreases). This shifts the best response functions out for all countries. An increase in $a$ reduces the marginal cost of protection and shifts the best response functions out further. An increase in the number of independent decision-making governments shifts best reponse functions in, which offsets the effects of $a$ and $y$. Refer to Figure 2, which illustrates the two-country case. If $a$ is sufficiently large and $y$ is sufficiently small, then for any given $J$, it is possible that point $E$ ends up to the northeast of point $G$, which means that there is over-protection in Nash equilibrium.

In the more general case with asymmetry, a sufficient condition for under-protection is

$$0 \;<\; \left(\sum_i \frac{1}{M_i}\frac{\partial W^w}{\partial \Omega_i}\right)-\left(\sum_i \frac{1}{M_i}\frac{\partial W_i\,(a)}{\partial \Omega_i}\right)$$
$$\text{in Nash equilibrium } \left\{\Omega_i^E\right\}_{i\in\mathcal{N}}$$

This is true because in Nash equilibrium $\frac{\partial W_i(a)}{\partial \Omega_i}=0, \forall i$. On the other hand, $\left(\sum_i \frac{1}{M_i}\frac{\partial W^w}{\partial \Omega_i}\right)>0$ implies that if we increase each $\Omega_i$ such that $M_i d\Omega_i = d\overline{\Omega} \quad \forall i$, then $dW^w = \left(\sum_i \frac{\partial W^w}{\partial \Omega_i}d\Omega_i\right) = \left(\sum_i \frac{1}{M_i}\frac{\partial W^w}{\partial \Omega_i}\right)d\overline{\Omega} > 0$. That is, global welfare increases as each $\Omega_i$ increases slightly.

The above equation is equivalent to

$$\left(\sum_i \frac{1}{M_i}\frac{\partial W_i\,(a)}{\partial \Omega_i}-\frac{1}{M_i}\frac{\partial W_i}{\partial \Omega_i}\right)<\left(\sum_i \frac{1}{M_i}\frac{\partial W_{-i}}{\partial \Omega_i}\right)\text{in Nash equilibrium } \left\{\Omega_i^E\right\}_{i\in\mathcal{N}}$$

where $W^w = W_i + W_{-i}$. The LHS is the excess marginal cost of maximizing global welfare as opposed to maximizing domestic welfare (it can be positive as a result of firm-biased government preferences), while the RHS is the corresponding excess marginal benefit of doing so (as a result of externalities). If LHS $<$ RHS at the equilibrium $\left\{\Omega_i^E\right\}_{i\in\mathcal{N}}$, we can conclude that there is under-protection.

With symmetry, the above equation becomes

$$\left[\frac{(1+a)-(1-y)}{J}-y\right]\pi$$

$$< \frac{\gamma y^2 (J-1)\left[C_c\overline{T}-(C_c-C_m)\,\Omega^E\right]}{J\left[(J-1)y+1\right]\Omega^E}+\frac{\gamma y\,(1-y)\,(J-1)\left[C_c\overline{T}-(C_c-C_m)\,\Omega^E\right]}{J\left[(J-1)y+1\right]\Omega^E}$$

which is equivalent to

$$\left[\frac{a-(J-1)\,y}{J}\right]\theta_2<\frac{\gamma y\,(J-1)}{J\left[(J-1)y+1\right]}\left(\frac{\theta_1}{\Omega^E}-1\right)$$

or

$$\left[a-(J-1)\,y\right]\theta_2<\frac{\gamma y\,(J-1)}{\left[(J-1)y+1\right]}\left(\frac{\theta_1}{\Omega^E}-1\right) \tag{11}$$

Recall from $BRF_i$ (10) that

$$\frac{\gamma}{\left[(J-1)y+1\right]}\left(\frac{\theta_1}{\Omega^E}-1\right)=1+(J-1)\,y-(1+a)\,\theta_2$$

Substituting this expression in the RHS of (11), we get the sufficient condition for there to be under-protection when $\Omega_i=\Omega^E$, $\forall i$:

$$\left[a-(J-1)\,y\right]\theta_2<\left[1+(J-1)\,y-(1+a)\,\theta_2\right](J-1)\,y$$

A sufficient condition of this is

$$a-(J-1)\,y<\left[1+(J-1)\,y-(1+a)\right](J-1)\,y \text{ since } \theta_2<1$$

which is equivalent to

$$a-(J-1)\,y<\left[(J-1)\,y-a\right](J-1)\,y$$

which is equivalent to

$$\left[(J-1)\,y\right]^2+(1-a)\,(J-1)\,y-a>0$$

Solving for $(J-1)\,y$, we get

$$(J-1)\,y>a$$

What is a reasonable value for $a$? In the political economy literature (e.g. Grossman and Helpman 1994, Maggi and Goldberg 1999), researchers have tried to estimate the weight the US government puts on campaign contribution when it puts a weight of one on welfare. They rarely come up with a number more than 0.5. Since this is a preference parameter, it should be the same in the context of patent protection. Suppose there is a patent-lobby, and suppose there is no consumer lobby or lobbying from other sectors of the economy to compete with the patent-lobby. Then, we can show that the value the government puts on contribution is exactly the same as $a$ in our model. (See the appendix.)

What is a reasonable value for $J$? This is the number of independent government decision-makers in the patent-setting game. So, it is the number of countries in the world that consume and trade patent-sensitive goods, and that adopt a non-corner solution to patent protection (neither zero or full protection). This would be a very large number. To be conservative, we choose $J = 20$, and see what happen.

When $a < 0.5$, $J > 20$, a sufficient condition for the Nash equilibrium to be under-protecting patents is $y > \frac{1}{40}$. This is obviously a very plausible range of import penetration rate. However, the world is not symmetric; so we need to find a sufficient condition for under-protection (or over-protection) taking into account the degree of asymmetry of the real world. Thus, whether there is under- or over-protection in the non-cooperative equilibrium is an empirical question.

## 3.3 Asymmetry

In the basic model, we can find a functional relationship between the global strength of patent protection and global welfare. The same strength of global patent protection creates the same amount of total deadweight losses (what I call distortion) and aggregate flow of new differentiated goods (what I call incentives) in each period. As long as the global strength of patent protection is the same, global welfare is the same, regardless of the combination of individual countries' strengths of patent protection. Therefore, the global optimum is a continuum of combinations of national strengths of patent protection that maxmize global welfare. However, this will not be true in the extended model. In the more general model with trade barriers, there does not exist a scalar measure of the global strength of patent protection such that there is a functional relationship between the global strength of protection and global welfare. Despite this problem, we are able to calculate a sufficient condition under which, starting from Nash equilibrium, global welfare must increase with increases in the strengths of protection in all countries. When this condition is satisfied, we can conclude that there is under-protection in global IP protection.

First refer to Figure 3 for an idea of the relationship between Nash equilibrium and global optimum. In that diagram, point E is the Nash equilibrium while point G is the global optimum. Note that the slopes of the iso-global-welfare lines $W^w = \overline{W}$ are always equal to $\frac{M_S}{M_N}$ at their intersection with the line $\frac{1}{M_S}\frac{\partial W^w}{\partial \Omega_S} + \frac{1}{M_N}\frac{\partial W^w}{\partial \Omega_N} = 0$. This is because, along $W^w = \overline{W}$, $\frac{d\Omega_N}{d\Omega_S} = -\left(\frac{\partial W^w}{\partial \Omega_S} / \frac{\partial W^w}{\partial \Omega_N}\right)$. But on the line $\frac{1}{M_S}\frac{\partial W^w}{\partial \Omega_S} + \frac{1}{M_N}\frac{\partial W^w}{\partial \Omega_N} = 0$, we have $-\left(\frac{\partial W^w}{\partial \Omega_S} / \frac{\partial W^w}{\partial \Omega_N}\right) = \frac{M_S}{M_N}$. Consequently, it is not hard to see that the slope of the iso-global-welfare line at any point to the left of GG must be less than $\frac{M_S}{M_N}$.

Recall the sufficient condition for under-protection:

$$0 < \left(\sum_i \frac{1}{M_i}\frac{\partial W^w}{\partial \Omega_i}\right) - \left(\sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i}\right)$$
$$\text{in Nash equilibrium } \left\{\Omega_i^E\right\}_{i \in \mathcal{N}}$$

a sufficient condition of which is

$$0 < \left(\sum_i \frac{1}{M_i}\frac{\partial W^w}{\partial \Omega_i}\right) - \left(\sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i}\right)$$
$$\text{for all } \{\Omega_i\}_{i \in \mathcal{N}} \text{ that satisfy } \sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i} = 0$$

These combinations of course includes the $\left\{\Omega_i^E\right\}_{i \in \mathcal{N}}$, the Nash equilibrium combination. In the context of Figure 4, this is equivalent to saying that the curve EE is to the left of curve GG. At any point that lies on EE (including the Nash equilibrium point E), any small change in $\Omega_S$ and $\Omega_N$ such that $M_S d\Omega_S = M_N d\Omega_N$ would increase global welfare, since $\frac{1}{M_S}\frac{\partial W^w}{\partial \Omega_S} + \frac{1}{M_N}\frac{\partial W^w}{\partial \Omega_N} > 0$.

We can explain this a bit differently, but the intuition is the same: Refer to Figure 3, and note that since the slope of the iso-global-welfare line is always less than $\frac{M_S}{M_N}$ to the left of GG, starting from any point to the left of GG, any small increase in $\Omega_S$ and $\Omega_N$ such that $M_S d\Omega_S = M_N d\Omega_N$ (or $\frac{d\Omega_N}{d\Omega_S} = \frac{M_S}{M_N}$) would result in an increase in $W^w$. Therefore, if the line EE is to the left of GG, then starting from any point on EE, any small increase in $\Omega_S$ and $\Omega_N$ such that $\frac{d\Omega_N}{d\Omega_S} = \frac{M_S}{M_N}$ would result in an increase in $W^w$. Since the Nash equilibrium point E lies on EE, any such small increase in $\Omega_S$ and $\Omega_N$ from point E must be globally welfare-improving. Thus, there is under-protection of patents at Nash equilibrium $\left(\Omega_S^E, \Omega_N^E\right)$. Therefore, the fact that EE is to the left of GG is a sufficient condition for patent protection to be too weak in Nash equilibrium.

Under asymmetry, recall that $\frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i}$ is equal to

$$\left(\sum_{j\neq i}\gamma\frac{\phi_j}{v_j}\right)y^2\pi M_i f_i + \gamma\frac{\phi_i}{v_i}\pi M_i f_i$$
$$-\left\{\left[y\sum_j \phi_j + (1-y)\,\phi_i\right](C_c - C_m) - \phi_i\,(1+a)\,\pi\right\}$$

In other words, along the line $\frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i} = 0$,

$$\begin{aligned}
&\left[y\sum_j \phi_j + (1-y)\,\phi_i\right](C_c - C_m) - \phi_i\,(1+a)\,\pi \\
=\;& \gamma\left[y\left(\sum_{j\neq i}\phi_j\frac{y}{v_j}\right)\pi M_i f_i + \phi_i\frac{1}{v_i}\pi M_i f_i\right] \\
<\;& \frac{\gamma}{\pi y Q}\left[y\left(\sum_{j\neq i}\phi_j y\right)\pi M_i f_i + \phi_i \pi M_i f_i\right] \text{ since } \pi y Q < v_j \;\; \forall j, \text{ where } Q \equiv \sum_k M_k\Omega_k \\
=\;& \frac{\gamma}{\pi y Q}\left[y^2\left(\sum_j \phi_j\right)\pi M_i f_i + \phi_i\left(1-y^2\right)\pi M_i f_i\right]
\end{aligned}$$

Summing over i, we know the following must be true along the line $\sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i} = 0$:

$$\begin{aligned}
&\left\{yJ\left(\sum_j \phi_j\right) + \left(\sum_j \phi_j\right)(1-y)\right\}(C_c - C_m) - \left(\sum_j \phi_j\right)(1+a)\,\pi \\
<\;& \frac{\gamma}{\pi y Q}\left[y^2\left(\sum_j \phi_j\right)\pi\left(\sum_i M_i f_i\right) + \left(1-y^2\right)\pi\left(\sum_i \phi_i M_i f_i\right)\right] \qquad (12)
\end{aligned}$$

On the other hand, recall from subsection 3.1 that

$$\begin{aligned}
&\frac{1}{M_i}\frac{\partial W^w}{\partial \Omega_i} - \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i} \\
=\;& \left(MB_i^w - MB_i\right) - \left[MC_i^w - MC_i(a)\right] \\
=\;& \left(\sum_j \gamma\frac{\phi_j}{v_j}\right)y^2\pi\sum_{k\neq i} M_k f_k + \left[\sum_{k\neq i}\gamma\frac{\phi_k}{v_k}y\,(1-y)\,\pi M_k f_k\right] \\
&-\left\{\pi\left[(1+a) - (1-y)\right]\phi_i - y\pi\left(\sum_j \phi_j\right)\right\}
\end{aligned}$$

Therefore, a sufficient condition for under-protection is

$0 < \left(\sum_i \frac{1}{M_i}\frac{\partial W^w}{\partial \Omega_i}\right) - \left(\sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i}\right)$, which is equivalent to

$$\begin{aligned} & \sum_i \left\{ \pi \left[ (1+a) - (1-y) \right] \phi_i - y\pi \left( \sum_j \phi_j \right) \right\} \\ < \; & \sum_i \left( \sum_j \gamma \frac{\phi_j}{v_j} \right) y^2 \pi \sum_{k \neq i} M_k f_k + \left[ \sum_{k \neq i} \gamma \frac{\phi_k}{v_k} y (1-y) \pi M_k f_k \right] \end{aligned} \tag{13}$$

for all combinations of $\{\Omega_i\}_{i \in \mathcal{N}}$ that satisfy $\sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i} = 0$.

The above inequality is equivalent to

$$\begin{aligned} & \pi \left[ (1+a) - (1-y) \right] \left( \sum_i \phi_i \right) - y\pi J \left( \sum_j \phi_j \right) \\ < \; & y^2 \pi \left( \sum_j \gamma \frac{\phi_j}{v_j} \right) (J-1) \left( \sum_k M_k f_k \right) + y (1-y) \pi (J-1) \left( \sum_k \gamma \frac{\phi_k}{v_k} M_k f_k \right) \end{aligned}$$

for all combinations of $\{\Omega_i\}_{i \in \mathcal{N}}$ that satisfy $\sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i} = 0$.

Since $\pi Q > v_j \;\; \forall j$, a sufficient condition for the above is

$$\begin{aligned} & \theta_2 \left\{ \left[ (1+a) - (1-y) \right] \left( \sum_i \phi_i \right) - yJ \left( \sum_j \phi_j \right) \right\} \\ < \; & \frac{\gamma}{\pi Q (C_c - C_m)} \left[ \left( \sum_j \phi_j \right) y^2 \pi (J-1) \left( \sum_k M_k f_k \right) \right. \\ & \qquad \left. + y (1-y) \pi (J-1) \left( \sum_k \phi_k M_k f_k \right) \right] \\ = \; & \frac{\gamma (J-1)}{Q (C_c - C_m)} y^2 \left( \sum_j \phi_j \right) \left( \sum_k M_k f_k \right) + y (1-y) \left( \sum_k \phi_k M_k f_k \right) \end{aligned} \tag{14}$$

for all combinations of $\{\Omega_i\}_{i \in \mathcal{N}}$ that satisfy $\sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i} = 0$.

Recall equation (12), and define

$$\Psi \equiv \frac{y^2 \left( \sum_j \phi_j \right) \left( \sum_i M_i f_i \right) + (1-y^2) \left( \sum_i \phi_i M_i f_i \right)}{y^2 \left( \sum_j \phi_j \right) \left( \sum_k M_k f_k \right) + y (1-y) \left( \sum_k \phi_k M_k f_k \right)}.$$

We know $1 < \Psi < \frac{1}{y}$ since $\left( \sum_j \phi_j \right) \left( \sum_k M_k f_k \right) > \sum_k \phi_k M_k f_k$, and so $\frac{1}{\Psi} > y$.

Therefore, along $\sum_i \frac{1}{M_i}\frac{\partial W_i(a)}{\partial \Omega_i} = 0$,

$$\begin{aligned}
& \frac{\gamma}{Q\left(C_c - C_m\right)}\left[y^2\left(\sum_j \phi_j\right)\left(\sum_k M_k f_k\right) + y\left(1-y\right)\left(\sum_k \phi_k M_k f_k\right)\right] \\
= & \frac{\gamma}{\Psi Q}\left[y^2\left(\sum_j \phi_j\right)\left(\sum_i M_i f_i\right) + \left(1-y^2\right)\left(\sum_i \phi_i M_i f_i\right)\right]\frac{1}{C_c - C_m} \\
> & y\frac{\gamma}{Q}\left[y^2\left(\sum_j \phi_j\right)\left(\sum_i M_i f_i\right) + \left(1-y^2\right)\left(\sum_i \phi_i M_i f_i\right)\right]\frac{1}{C_c - C_m} \\
> & y^2\left\{yJ\left(\sum_j \phi_j\right) + \left(\sum_j \phi_j\right)\left(1-y\right) - \left(\sum_j \phi_j\right)\left(1+a\right)\theta_2\right\}
\end{aligned}$$

where the last inequality is due to (12).

Using the above inequality to substitute for $\frac{\gamma}{Q(C_c - C_m)}\left[y^2\left(\sum_j \phi_j\right)\left(\sum_i M_i f_i\right) + y\left(1-y\right)\left(\sum_i \phi_i M_i f_i\right)\right]$ in (14), we get a sufficient condition for there to be under-protection in Nash equilibrium

$$\begin{aligned}
& \theta_2\left\{\left[\left(1+a\right) - \left(1-y\right)\right]\left(\sum_i \phi_i\right) - yJ\left(\sum_j \phi_j\right)\right\} \\
< & y^2\left(J-1\right)\left\{yJ\left(\sum_j \phi_j\right) + \left(\sum_j \phi_j\right)\left(1-y\right) - \left(\sum_j \phi_j\right)\left(1+a\right)\theta_2\right\}
\end{aligned}$$

which is equivalent to

$$\theta_2\left[\left(a+y\right) - Jy\right] < y^2\left(J-1\right)\left[Jy + \left(1-y\right) - \left(1+a\right)\theta_2\right]$$

a sufficient condition of which is

$$\left(a+y\right) - Jy < y^2\left(J-1\right)\left[Jy - \left(a+y\right)\right] \text{ since } \theta_2 < 1$$

which is equivalent to

$$Jy > \left(a+y\right) \tag{15}$$

This is exactly the same condition as the symmetric case. Again, when $a < 0.5$, $J > 20$, a sufficient condition for the Nash equilibrium to be under-protecting patents is $y > \frac{1}{40}$. Since this is a very plausible range of import penetration rate, we conclude that there was very likely under-protection of patents before TRIPS.

# 4 Conclusion

We undertake an extension of the Grossman and Lai (2004) model to answer the question, "Was global patent protection too weak before TRIPS?" by introducing firm-biased government preferences and trade barriers in the model. We make use of the estimates of a parameter from the political economy literature to proxy for the degree of governments' firm-biasedness. Then we calculate the range of trade barriers that is sufficient to give rise to under-protection of patents in the global system before TRIPS. We make the judgement that the true trade barrier between countries very likely falls within this range of under-protection. Therefore, we conclude that there was probably under-protection of patents before TRIPS. It means that the free-rider problem with a large number of independent players overrides the effects of firm-biasedness and trade barriers.

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# Appendix

In this appendix, we try to justify using the parameter estimated from the political economy literature (in particular lobbying as per Grossman and Helpman 1994) as a proxy for the firm-biasedness parameter $a$ in our model. We analyze lobbying when there are two or more countries, which trade freely with each other and set their national patent policies non-cooperatively. We introduce the "rest of the world" to a generic country $j$. For ease of exposition, we only focus on the case with free trade, i.e. $y = 1$. The case with $y < 1$ has the same expressions for the marginal cost, which is the focus of what we want to show here. Therefore, there is no loss generality by assuming $y = 1$ here.

The setup in this appendix is based on what we presented in Section 2. Here, we extend the model by considering the possibility that interest groups lobby the government to set policy in their favor. In particular, the IP industry has a strong self-interest in obtaining extensive IP protection. We follow the recent "protection for sale" literature[16] in modelling the interaction between the IP-lobby and the government. That is, we set up a lobbying game that is based on the menu auction approach of Bernheim and Whinston (1986): In such a game, the IP lobby submits a contribution schedule $C_{IP}(\tau)$ to the policy-maker who then chooses the optimal patent length $\tau$.

Let us start with a closed economy. The IP-lobby represents the interests of the owners of human capital $H$ that, in the Grossman-Lai model, is employed exclusively in the production of new designs of differentiated goods. Defining $r$ as the returns to human capital, the income of these capital owners is $rH$, which is the residual of the revenue from IP-sensitive products minus the labor costs necessary to produce them:

$$rH = M\phi\pi\Omega - wL_R, \tag{16}$$

where $M$ is the number of consumers, $\phi$ is the flow of new inventions, $\pi$ is the instantaneous profit per product, $\Omega \equiv (1 - e^{-\rho\tau}/\rho)$ is the present discounted value of a flow of one dollar during the patent life $\tau$ of the product, $w$ is wage, and $L_R$ the labor employed in the R&D sector. In this appendix, we assume that patents are perfectly enforced so that patent length completely captures the degree of patent protection. The IP lobby thus faces the following gross pay-off function:

$$W_{IP} = \frac{rH}{\rho} = \frac{M\phi\pi\Omega - wL_R}{\rho},$$

[16] See the seminal contribution by Grossman and Helpman (1994) that represents the starting point of this literature.

which is the discounted present value of its flow of profits. Note that we consider neither a labor union nor a consumer lobby. Workers in this framework are paid their marginal product and thus have no surplus to lobby and we could not find any empirical evidence for the role of consumers' interests.

Taking into account the contribution schedule of the IP-lobby, it is the government that will set policy. Its objective function takes the following form:

$$W\left(a\right) = W(0) + aC_{IP}(\tau)\,. \tag{17}$$

As usual in the "protection for sale" literature, the government's objective is a weighted sum of social welfare and contributions. The first term represents social welfare and can be written more explicitly as follows:

$$W(0) = \frac{M\phi\pi\Omega - wL_R}{\rho} + \frac{M\phi[C_m\Omega + C_c(\overline{T} - \Omega)]}{\rho}.$$

where $\overline{T} \equiv (1 - e^{-\rho\bar{\tau}}/\rho)$ is the present discounted value of a flow of one dollar during the economic lifetime $\bar{\tau}$ of the product. The second term in equation (17) represents the influence of the lobbying contribution and $a$ indicates the importance of this channel.

Now let us consider an open economy with free trade. In an open economy, the patent-lobby in each country $j$ now seeks to maximize the following objective function:

$$W_{IP}^{j} = \frac{\phi_j(\Omega_j M_j + \Omega_{-j} M_{-j})\pi}{\rho} - \frac{w_j L_{R,j}}{\rho}$$

The set $\{-j\}$ represents the rest of the world, which consists of more than one country. In that case, all variables with a subscript "$-j$" are vectors that represent the values of the variable of the rest of the world, with the number of rows equal to the number of countries in the rest of the world. Note the additional middle term in the above equation represents the profits from the foreign market. Next, let us redefine $W_j(0)$, which now contains several foreign terms:

$$\begin{aligned} W_j(0) \quad &= \quad \frac{w_j(L_j - L_{Rj})}{\rho} + \frac{\phi_j(\Omega_j M_j + \Omega_{-j} M_{-j})\pi}{\rho} + \\ &\quad\quad \frac{(\phi_j + \phi_{-j})\Omega_j M_j C_m}{\rho} + \frac{(\phi_j + \phi_{-j}) M_j (\overline{T} - \Omega_j) C_c}{\rho} \end{aligned}$$

As in the closed economy case, the government in country $j$ maximizes a weighted sum of (appropriately modified) social welfare $W_j(0)$ plus the contributions it is offered:

$$W^{j}\left(a\right) = W_j(0) + aC_{IP}^{j}(\tau_j)$$

We use the menu auction approach of Bernheim and Whinston (1986), in particular, conditions 2 and 3 of (their) Lemma 2:

ii) $\tau^0 \in \arg\max_{\tau_j} W_j(0) + aC^j_{IP}(\tau_j)$

iii) $\tau^0 \in \arg\max_{\tau_j} W_j(0) + a\, C^j_{IP}(\tau_j) + W^j_{IP} - C^j_{IP}(\tau_j)$

Using in addition the standard assumption that the contribution schedule $C^j_{IP}(\tau_j)$ is differentiable, we can combine *ii)* and *iii)* as follows:

$$\frac{\partial W_j(0)}{\partial \tau_j} + a\frac{\partial W^j_{IP}}{\partial \tau_j} = 0$$

The resulting best-response function of country $j$'s government can be written as:

$$\phi_j(C_c - C_m) - (1+a)\phi_j\pi + \phi_{-j}(C_c - C_m) = \frac{\gamma_j\phi_j + \gamma_{-j}\phi_{-j}}{v} M_j\pi \left[C_m\Omega_j + C_c(\bar{T} - \Omega_j)\right]$$

where $v$ is the value of a global patent. Note the similarity with equations (3) and (4), with additional weight given to the IP-sensitive sector's profits. In our model, this extra weight arises as the result of lobbying.

Taking into account the property that $\gamma_j = \gamma_{-j} = \gamma$ under a Cobb-Douglas innovation function, the following best response function implicitly defines the Nash equilibrium:

$$C_c - C_m - (1+a)\mu_j\pi = \gamma\frac{M_j\Omega_j}{M_j\Omega_j + M_{-j}\Omega_{-j}}\left(C_m + C_c\frac{\bar{T}_j - \Omega_j}{\Omega_j}\right), \qquad (18)$$

where $\mu_j \equiv \phi_j/(\phi_j + \phi_{-j})$ is the share of world innovation originating in country $j$. Note the similarity with equation (5).

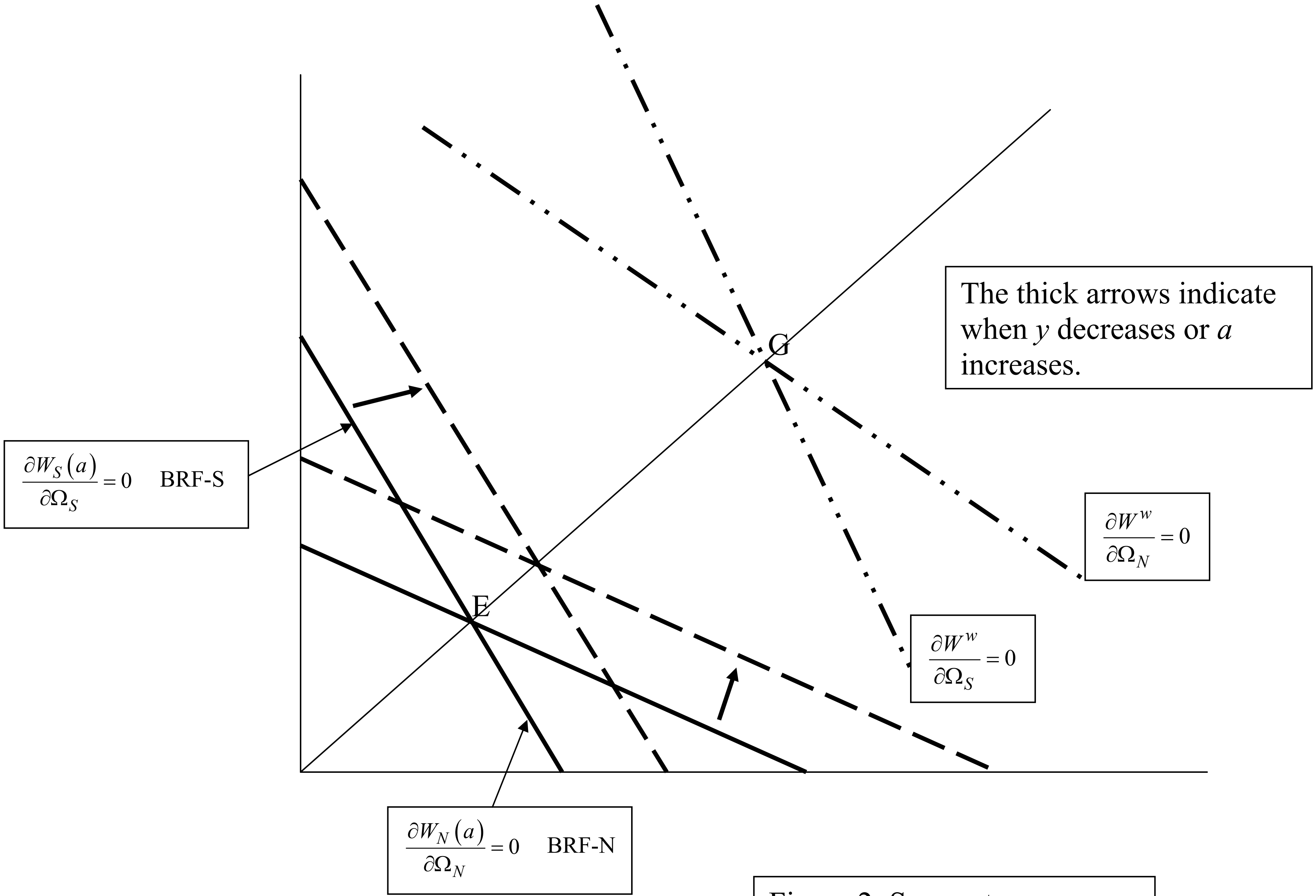


Figure 2: Symmetry

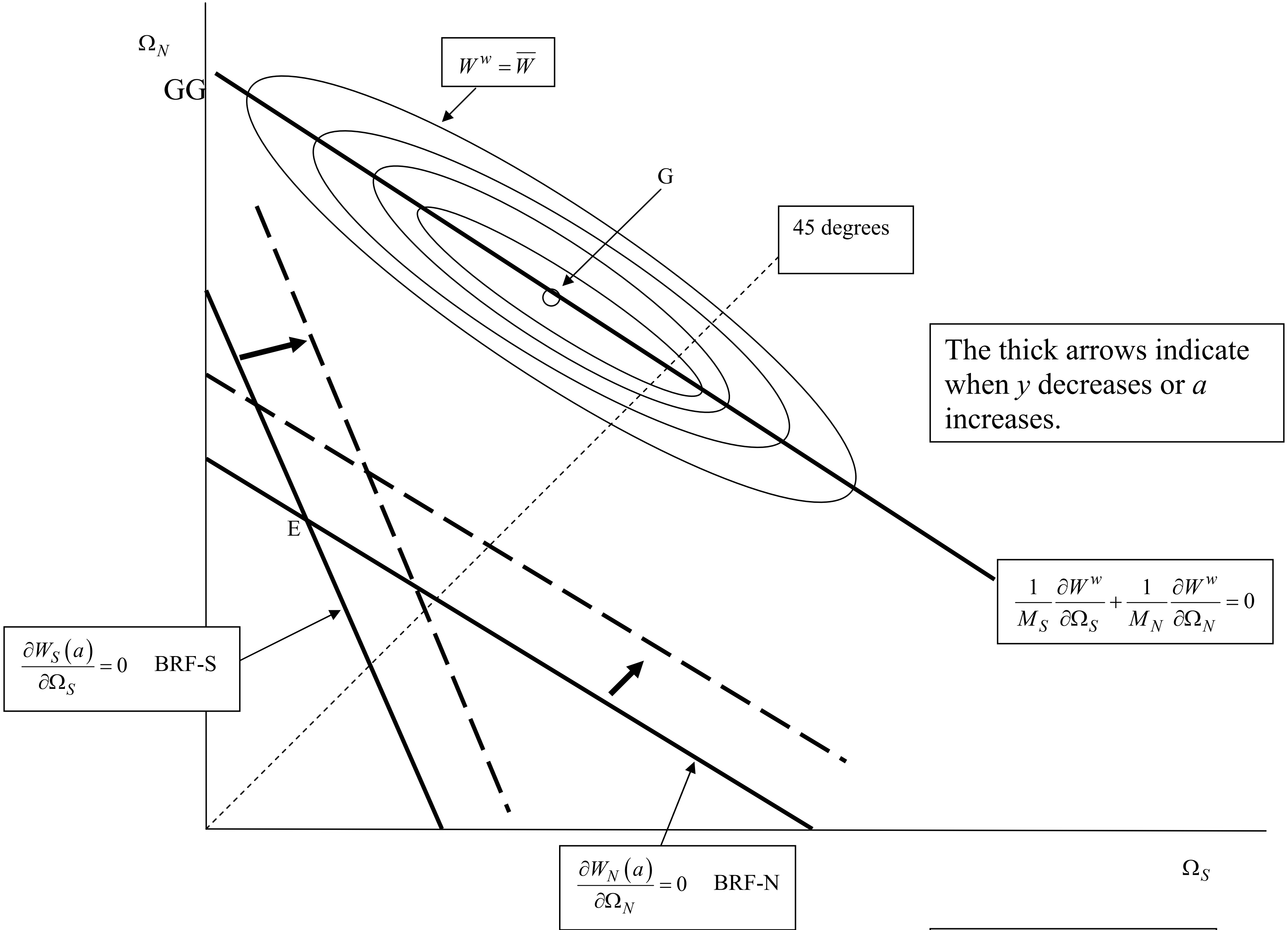


Figure 3: Asymmetry

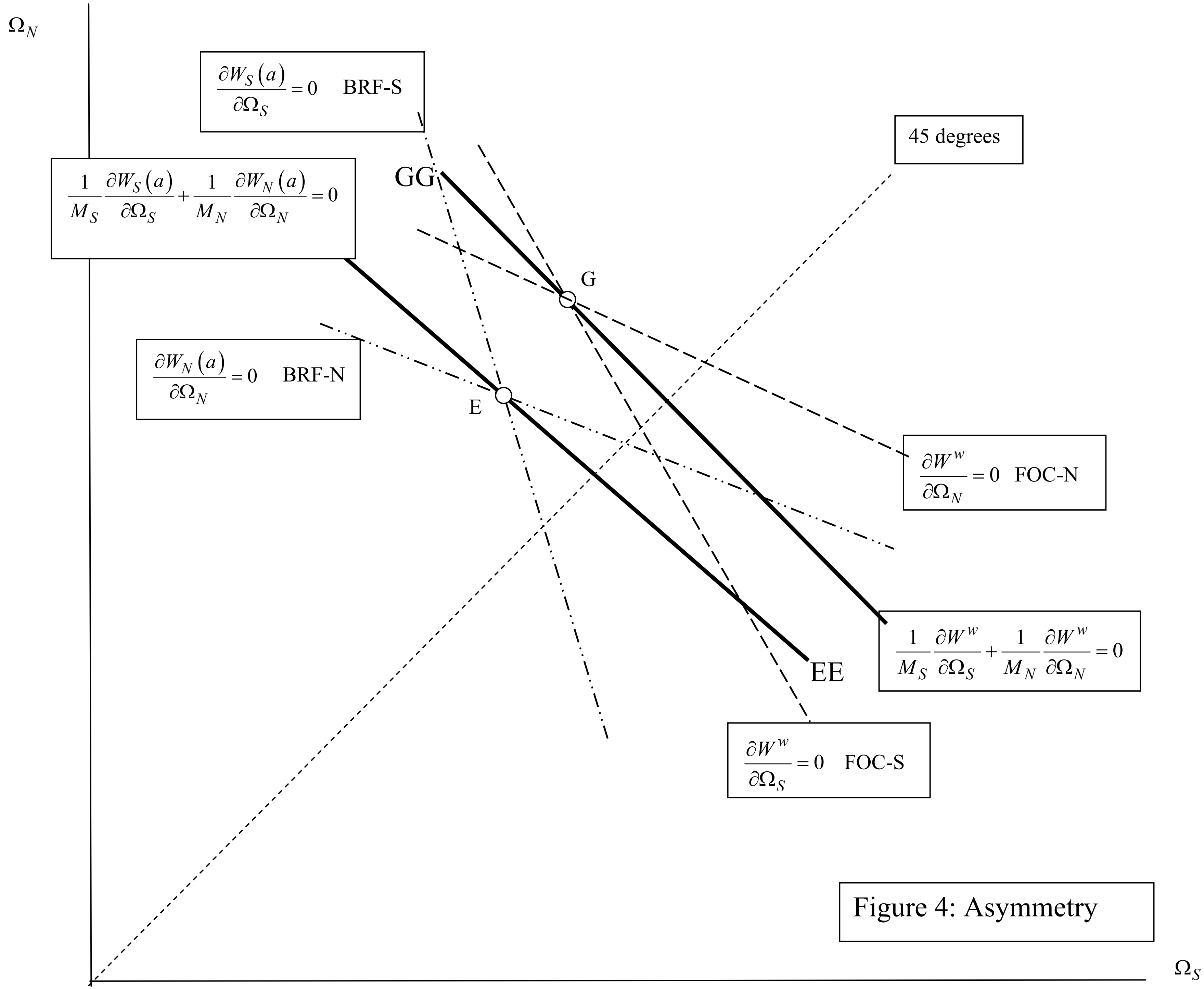


Figure 4: Asymmetry