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ASYMMETRIC INTELLECTUAL PROPERTY RIGHTS PROTECTION AND NORTH-SOUTH WELFARE

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Abstract

We construct a model of dynamic endogenous product innovation and international trade, using it to calculate the welfare effects of lower intellectual property rights (IPR) protection in the non-innovating South than in the innovating North. We find that it is generally in the North's interest to protect its innovating sector by an import embargo on IPR-offending goods from abroad. We explain the paradoxical outcome where the North gains from weaker IPR enforcement in the South through a decomposition of the dynamic welfare formula. Key features include the ability of lower Southern IPR protection to spur innovation of Northern goods and to make available greater resources for Northern production of current consumption goods. Maintaining Northern IPR standards can be in the South's interests even though the South would favor lower uniform levels of IPR protection.

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Key Words: Intellectual Property Rights, Innovation, Imitation, North, South, Welfare

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1 INTRODUCTION

Intellectual property rights (IPR) enforcement presents a classic incentive problem. Social interest dictates that an innovated product should be available at as low a price as possible. Yet allowing all producers immediate access to innovated technology reduces the market power and profits of the innovator, leaving no incentive for innovation in the future. Price advantages today, therefore must be balanced against innovation tomorrow.

The problem is particularly troublesome when the innovation takes place in one country and consumers of the product reside in another. In this case there are two entities and two jurisdictions where the intellectual property rights can be enforced. If both regions equally enforce intellectual property rights one regime obtains. If they enforce intellectual property rights in an unequal or asymmetric fashion, however, another regime obtains. Typically, the situation of greatest interest is when one region, call this the innovating North, enforces a higher standard of intellectual property rights protection than does the partner trading region, the non-innovating South.

What advantage can there be for the South, which does not innovate and must pay higher prices for imported goods still under patient in the North, to favor the same standards of intellectual property rights protection as in North when its own firms can produce copied (pirated) products at much lower prices than they can import them? In a pathbreaking treatment of intellectual property rights, Helpman (1993) constructs a dynamic model of market-determined product innovation based on Grossman and Helpman (1991a, 1991b). Assuming symmetric IPR enforcement by the North and South, he finds that whether the rate of imitation (piracy) is currently high or currently low in steady state, it is *never* in the South's economic interest to increase the rate of intellectual property rights protection. From careful inspection of his dynamic model Helpman concludes, "My analysis suggests that if anyone benefits [from tighter intellectual property rights protection], it is not the South. The answer is robust with respect to all of the variations that I have examined."

This unambiguous conclusion is both powerful and provocative, especially as the World Trade Organization places more effective standards of intellectual property rights protection high on its list of objectives. The main argument advanced by innovating countries has been that by enforcing a uniform, high standard of intellectual property rights the South aids in the encouragement of innovation in products used by the South. The South thereby reaps the long run benefits of more and newer goods. Helpman's analysis terminates or at least greatly restricts this line of discussion. The Grossman-Helpman approach, building on the seminal paper by Krugman (1979), depends on very few standard assumptions about innovation and market structure, and thus is attractive for further examining these issues. For example, if the South is unable to induce the rest of the world to joint it in lower IPR protection, should it reduce its standard unilaterally? Or phrased differently, if the innovating region of the world enforces one standard of IPR protection does the South gain from enforcing IPR protection to match the same standard? This paper investigates the case for Southern intellectual property rights enforcement in case of designed-to-market goods.

The attention of economists to intellectual property rights and to the specific issue of the geographical extension of IPR protection is growing.[1] Deardorff (1991), in a perceptive and insightful analysis of geographical extension of intellectual property rights suggests that diminishing returns to the effect that extending protection to larger and larger regions of the world has on innovation means that the costs of protection will exceed benefits before protection has been extended fully. Interests of innovating and non-innovating regions are opposed with respect to extending IPR protection to the non-innovating region. Chin and Grossman (1990) examine a Cournot duopoly where innovation takes the form of lower production costs for a common good. Under certain conditions the South can benefit from granting IPR protection when the country "stands to gain much on the consumption side from the fruits of the Northern firm's research efforts," a conclusion that Diwan and Rodrick (1991) reach from a different direction in an interesting static model that emphasizes the effect that different distributions of tastes for goods between regions has on innovated goods mix and its utility to different regions.

A careful review of the intellectual property rights debate shows that many of the positions taken by innovating countries derive from innovating industries, some of which find themselves in a position similar to the American pharmaceutical industry. In pharmaceuticals it is not uncommon to develop drugs that are specific to diseases prevalent in a particular region of the world. Research into a Southern-occurring tropical disease, for example, may be less important for Northern regions than it is for many tropical countries. A Southern market that does not enforce intellectual property rights may find Northern resources redirected to innovation in products that are only marketed in Northern regions. Laxer enforcement of intellectual property rights in the South compared to the North therefore leads to less innovation of goods important to the South, but continuing innovation for goods important to the North. In the short run, the South might gain by its failure to enforce intellectual property rights due to lower prices for products it buys, but lose in the long run due to a smaller range of innovated goods from which to choose.

Growing empirical work on intellectual property rights tends to confirm intuition. Mansfield, Schwartz, and Wagner (1981), for example, empirically estimated the relative cost of imitation versus the cost of

[1] Mansfield (1986) and Farrantino (1993) relate intellectual property rights protection to increased innovation and foreign direct investment while Gould and Gruben (1996), Park (1993) and Park and Ginarte (1997) document a positive association between IPR and growth. Park and Ginarte find that the connection is indirect, however, through the inducement to accumulate factor inputs such as R&D capital. The innovating country,or a country with an innovating sector, therefore tends to benefit in contrast to the country without one. Taylor (1993, 1994) investigates cost-reducing technological innovation and the effect of differential IPR protection on the transfer of technology abroad. Here we consider only innovation of the goods-creating variety.

innovation, finding considerable variation over the industries examined, but, as expected, significantly lower cost to imitation. As a deterrence matter, stronger patent protection does not make entry impossible, but it does increase imitation costs. About half of products examined would not have been introduced without patent production. Feinberg and Rousslag (1990) document the harm done by infringed products, finding that profit looses of suppliers of copied goods are significant and exceed the profits gained by the infringers. Goods which the South imitates in violation of Northern patents are often sold in Northern markets as export goods. Northern innovators find themselves competing with imported copies of their own products, lessening their ability to recoup their innovation outlays. The Northern response to such imports is frequently to ban the importation of goods that violate domestic patents or copyrights. Differentially lax enforcement of intellectual property rights in the South therefore can inhibit Northern innovation, have effects on trade, or both. While the remedy in trade law for the innovating country is to embargo infringing goods, it remains to be shown if this is necessarily welfare-enhancing to the North, even when it protects the viability of the North's innovating sector.

Asymmetric property rights enforcement fundamentally has to do with market-determined product innovation in a dynamic general equilibrium context. Thus, this paper constructs a dynamic model containing these elements of the Grossman-Helpman-Krugman type to portray the case of interest where goods consumed in the South are differentiated from goods that are consumed in the North. Innovation in Northern and Southern goods occurs in the North. The South may copy goods of either type. When the South copies goods differentiated for its own market, it sells them only in the South (for example, if the South imitates the pharmaceutical developed for its tropical market only, it sells the copied drug domestically), whereas when it copies goods differentiated for the North, it sells them in the North.

If the intellectual property rights are symmetrically enforced, we show that the model is isometric to the Helpman (1993) model and exhibits the same dynamics. When the South drops its enforcement of intellectual property rights, however, this results in a regime change where innovation of Southern goods stops altogether. The South therefore benefits from price reduction for goods formerly under patent and purchased from the North, but it experiences an eventual long run loss due to a slower-growing range of goods in the future (in this case zero-growing) from which to choose. If the South does not innovate (a maintained hypothesis if the Grossman-Helpman-Krugman analysis and the present model), it is permanently relegated to consuming the goods that were available to it at the time of the regime switch. Further, with Section 337-type restrictions in place in the North, the North does not import copies of Northern products that were under patent at the time of the regime change. This adversely affects trade between the two regions with the result that both regions, but especially the South, are harmed by Southern failure to enforce intellectual property rights.

After the regime change the inability of the North to profitably innovate for Southern markets means that the Northern sector devoted to innovating Southern products shrinks. The immediate impact of this on Northern welfare is to free resources for production of consumables and therefore raise welfare. It also acts as a source of resources to devote to innovation of Northern goods. As time passes, however , the loss of the Southern market for sales of innovated products means that a relatively smaller target market is available for Northern innovators. We show that the net effect of the competing forces – increased resources available for Northern innovation, but less motivation for using them – can result either in increased or decreased innovation rate in the North. Paradoxically, in the long run, the North may gain by the failure of the South to provide intellectually property rights protection equal to its own.

Another notable outcome of the present investigation is that it is possible for the South to harm itself by unilateral lax enforcement of intellectually property rights, or, what is the same thing, to help itself by adopting standards of IPR protection enforced in the rest of the world. Mitigating factors include the potentially greater incentive for the start of Southern innovation upon the regime switch, the effects of learning by doing, conditions under which innovation by the North for Southern products will continue little abated with imperfect intellectual property rights enforcement in the South and so on. We return to some of these related issues in our concluding remarks after presenting the main line of analysis. Section 2 presents the elements of the model. Section 3 discusses the model in the regime of symmetric IPR enforcement. Section 4 re-solves the model in the regime of asymmetric IPR enforcement and derives the welfare changes implied by the regime switch for the North and for the South.

2 THE MODEL

In this section we describe dynamics of product innovation, North- South trade, and intertemporal welfare.

2.1 Product Innovation, Market Power, and Trade

Start by assuming that there is a continuum of goods available, identified by number from zero to an upper bound that grows over time with innovation. Goods are designed-to-market for consumption in each of two country locations. For example, we imagine clothing or pharmaceuticals developed for the South being specific to the climate and diseases prevailing in that region. Goods x, ranging from 0 to n_x, are consumed by the North, and goods y, ranging from 0 to n_y, are consumed by the South.

Innovation takes place in both x and y. New products of each type are introduced at the rates g_x and g_y in the innovating North, where they are initially produced under conditions of monopolistic competition. The South imitates Northern-produced products at the rate m_x and m_y. Once a good is imitated we assume that the technology becomes commonly known, and the market structure for those goods becomes perfectly competitive. We will sometimes refer to unimitated goods as "under-patent" and imitated goods produced perfectly competitively as "out-of-patent."

The availability of goods and their prices, $p(i)$ and $q(j)$, can be represented in terms of Figure 1 which linearly arranges goods x and y by pointing them to the right from a common origin. Goods consumed in the North have market prices p; goods consumed in the South have market prices q. Superscript S indicates prices for imitated (out-of-patent) goods;[2] Superscript N indicates prices for unimitated (under-patent) goods.[3] The numbers of goods x and y are given by the length of each line from the origin and ζ_x and ζ_y respectively, are the fractions of x and y type goods that are currently under patent. The numbers of out-of-patent goods imitated by the South are given by $(1-\zeta_x)n_x$and$(1-\zeta_y)n_y$, respectively.

Utility in each region is given by

$$U(t) = \int_t^{\infty} e^{-\rho(\tau - t)} \log u(\tau) d\tau \tag{1}$$

where ρ is the subjective discount rate and log $u(t)$ is the flow of utility at time τ. The flow of utility depends on the flow of consumption

$$\begin{aligned} u^N(\tau) &= \left(\int_0^{n_x} c_x(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \\ u^S(\tau) &= \left(\int_0^{n_y} c_y(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \ \ \varepsilon > 1 \end{aligned} \tag{2}$$

where preferences take the CES form over the continuum of available goods. The resulting demand functions are

$$\begin{aligned} c_x(i) &= \frac{1}{p(i)} \left(\frac{p(i)}{P} \right)^{1-\varepsilon} E^N \\ c_y(j) &= \frac{1}{q(j)} \left(\frac{q(j)}{Q} \right)^{1-\varepsilon} E^S \end{aligned} \tag{3}$$

where E^N and E^S are aggregate spending on consumer goods in the North and South, respectively, and

[2] These are produced in the South in the regime of symmetric IPR protection, though in the regime of asymmetric IPR protection the North will also produce out-of-patent goods.

[3] These are produced exclusively in the North in the regime of symmetric IPR protection, though in the regime of asymmetric IPR protection the South will produce imitation of formerly under-patent Products.

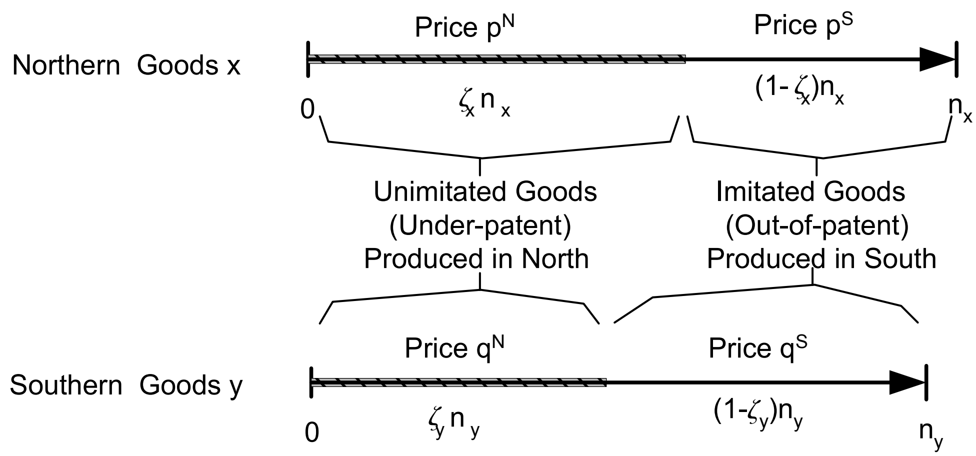

Figure 1: NORTHERN AND SOUTHERN GOODS

the price indexes P and Q are given by

$$\begin{aligned} P &= \left(\int_0^{n_x} p(i)^{1-\varepsilon} di\right)^{\frac{1}{1-\varepsilon}} \\ &= \left(\int_0^{(1-\zeta_x)n_x} (p^S)^{1-\varepsilon} di + \int_{(1-\zeta_x)n_x}^{n_x} (p^N)^{1-\varepsilon} di\right)^{\frac{1}{1-\epsilon}} \\ &= n_x^{\frac{1}{1-\varepsilon}} \left[(1-\zeta_x)\left(p^S\right)^{1-\varepsilon} + \zeta_x \left(p^N\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \end{aligned} \tag{4}$$

$$Q = n_y^{\frac{1}{1-\varepsilon}} \left[(1-\zeta_y)\left(q^S\right)^{1-\varepsilon} + \zeta_y \left(q^N\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

Substituting (3) and (4) into (2) gives the indirect utility functions

$$\begin{aligned} \log u^N &= \log E^N - \log P \\ \log u^S &= \log E^S - \log Q \end{aligned} \tag{5}$$

In deriving (4) we used the model property that prices for goods produced in the North equal p^N and those produced in the South equal p^S, where

$$p^N(i) = p^N = q^N = q^N(j) > p^S(i) = p^S = q^S = q^S(j) \tag{6}$$

Equation (6) follows from the assumption that goods are manufactured with one unit of labor per unit of output. A manufacturer having invented a product in the North can charge a monopoly price as long as the product remains unimitated by other firms. Once a product is imitated (out-of-patent), its technology becomes known to all producers and its price is determined by perfect competition. The demand functions above and the supply conditions just described imply that the equilibrium monopoly and competitive prices, respectively, satisfy[4]

$$p_0^N = \left(\frac{\varepsilon}{\varepsilon - 1}\right) w_0^N > w_0^N > w_0^S = p_0^S \tag{7}$$

where w^N, equal to the manufacturer's marginal cost, is the Northern wage and w^S is the marginal cost of production in the lower-wage South. We will use subscript 0 to refer to equilibrium prices in the initial equilibrium to distinguish them from equilibrium prices in another equilibrium after a regime switch. Since the North charges a markup over marginal cost for under-patent goods, the positive profits from producing under-patent goods in the North exceed the profits that would be earned from producing imitated (out-of-patent) goods. It follows that the South produces only imitated good x and y and the North produces only unimitated goods x and y. Common technology thus implies that $p^N = q^N$ and $p^S = q^S$as in equation (6).

2.2 Endogenous Innovation

An important contribution of Helpman and Grossman (see Helpman and Grossman (1991) or Helpman (1993)) was their description of the market forces endogenizing the innovation rate of new products. We follow their lead to endogenize the rate of innovation. Assume the innovation requires labor input H to produce $HK/a = \dot{n}$ new products per unit time where H represents labor hours employed in innovation, K is the cumulative stock of knowledge (here $K = n_x$ or $K = n_y$) and a is a productivity parameter. This implies that $g_k = H_k/a$, $k = x, y$ so that the resource constraint for the North becomes

[4]We assume that the economy satisfies the feasibility condition

$$g > \frac{1}{2a}\left(L^N - \left(\frac{\varepsilon - 1}{\varepsilon}\right)^{\varepsilon} L^S \frac{\zeta}{1 - \zeta}\right)$$

which implies $w^N > w^S$. See equations (7) and (13).

$$
\begin{aligned}
a_x g_x + \int_0^{\zeta_x n_x} x^N(i)di + a_y g_y + \int_0^{\zeta_y n_y} y^N(j)dj &= L^N, \quad \text{or} \\
a_x g_x + \int_0^{\zeta_x n_x} c_x(i)di + a_y g_y + \int_0^{\zeta_y n_y} c_y(j)dj &= L^N
\end{aligned}
\tag{8}
$$

where $x^N(i)$, $y^N(j)$ are the quantity of goods $x(i)$ and $y(j)$ produced by the North, and L^N is the Northern labor supply.

The market value of a product-innovating firm v^N must cover the development costs, or innovation will be unprofitable. It cannot more than cover costs or demand for labor in the innovation sector would become unbounded. Thus $v^N H_k n_k / a - w^N H_k = 0$ or

$$
v^N = \frac{w^N a}{n} \tag{9}
$$

Assuming well functioning capital markets, the return to a firm if it continues operations is

$$
\pi^N dt + (1 - mdt)\, \dot{v}^N dt - mv^N dt
$$

where π^N is the profit earned by the firm over the instant dt, $\dot{v}^N dt$ is the capital gain to the firm (change in market value) if the firm is not imitated during the instant) the probability of being imitated is mdt) less the loss in firm value if the firm is imitated. Against this return, the firm could sell its shares and earn

$$
r^N v^N dt
$$

over the instant dt where r^N is the Northern nominal interest rate. Dividing both terms by dt, and taking the limit as dt approaches zero, equilibrium requires that $r^N v^N = \pi^N + \dot{v}^N - mv^N$ or

$$
r^N = \frac{\pi^N}{v^N} + \frac{\dot{v}^N}{v^N} - m \tag{10}
$$

Expenditures by a Northern consumer with preferences given by (1) satisfy

$$
\frac{\dot{E}^N}{E^N} = r^N - \rho \tag{11}
$$

Using the resource constraint for the Northern labor and demands (3) and (4) with the expression $E^N = p^N(L^N - a_x g_x - a_y g_y)$ allows one to generate an expression for $\dot{E}^N$ and solve the model for the dynamics of

g_x and g_y.

We turn first to the solution of the model for innovation rates, terms of trade, and welfare in the case where North and South equally enforce intellectually property rights. We then re-solve the model to compare this to the asymmetric alternative where the North enforces intellectual property rights but the South does not.

2.3 Symmetric IPR Protection and Growth

In this section we impose simplifying symmetry assumptions. Under these assumptions we show that the model replicates that of Helpman (1993).

Now make the symmetry assumption $\zeta_x = \zeta_y = \zeta$ and $n_x = n_y = n$. We have from (4) that $P = Q$. From the Northern labor constraint (8) and demands (3), we have

$$\begin{aligned} L^N &= 2ag + \frac{1}{p^N}\int_0^{\zeta n} p^N c_x(i)di + \frac{1}{q^N}\int_0^{\zeta n} q^N c_y(j)dj \\ &= 2ag + \frac{1}{p^N}\left(\zeta n\left(\frac{p^N}{P}\right)^{1-\varepsilon}E^N\right) + \frac{1}{q^N}\left(\zeta n\left(\frac{q^N}{Q}\right)^{1-\varepsilon}E^S\right) \\ &= 2ag + \frac{1}{p^N}n\zeta\left(\frac{p^N}{P}\right)^{1-\varepsilon}\left(E^N + E^S\right) \end{aligned}$$

or

$$p^N\left(L^N - 2ag\right) = n\zeta\left(\frac{p^N}{P}\right)^{1-\varepsilon}\left(p^N(L^N - 2ag) + p^S L^S\right) \tag{12}$$

Thus, using (4) and (12) to solve for $\frac{p^N}{p^S}$ gives

$$\frac{p^N}{p^S} = \left(\frac{\zeta}{1-\zeta}\cdot\frac{L^S}{L^N - 2ag}\right)^{1/\varepsilon} \tag{13}$$

as in Helpman (1993).

This equation underscores the fact that northern terms of trade (and hence income) improve as the share of unimitated goods grows larger. Correspondingly, southern welfare improves with greater imitation (more lax IPR enforcement on a symmetric basis between North and South means lower ζ). We examine the effect of more lax IPR enforcement in the South after describing worker welfare for both countries.

On a per worker basis utility is

$$\log\, u^N = \log\, \frac{E^N}{L^N} - \log\, P = \frac{1}{\varepsilon - 1}\left(\log\, n_x + \log\left[\zeta_x + (1-\zeta_x)\left(\frac{p^N}{p^S}\right)^{\varepsilon-1}\right]\right)$$
$$\log\, u^S = \log\, \frac{E^S}{L^S} - \log\, Q = \frac{1}{\varepsilon - 1}\left(\log\, n_y + \log\left[\zeta_y \left(\frac{p^S}{p^N}\right)^{\varepsilon-1} + (1-\zeta_y)\right]\right) \tag{14}$$

where L^N and L^S are the labor supplies in the North and South, respectively. With $\zeta_x = \zeta_y = \zeta$ and $n_x = n_y = n$, (14) reduces to Helpman's (1993) equations (15) and (16).

To solve for the model dynamics, differentiate the identity $E^N = p^N(L^N - 2ag)$ to get

$$\frac{\dot{E}^N}{E^N} = \frac{\dot{p}^N}{p^N} - \frac{2a\dot{g}}{L^N - 2ag} \tag{15}$$

Combining (15) with (11) gives

$$r^N = \rho + \frac{\dot{p}^N}{p^N} - \frac{2a\dot{g}}{L^N - 2ag} \tag{16}$$

From $2ag + 2n\zeta x^N = L^N$, $\pi^N = (1-\alpha)\, p^N x^N$where $\alpha \equiv \frac{\varepsilon-1}{\varepsilon}$ and (9)

$$\frac{\pi^N}{v^N} = \frac{1-\alpha}{\alpha}\left(\frac{L^N}{2a} - g\right)\frac{1}{\zeta} \tag{17}$$

Thus, (10), (16), (17), $\frac{\dot{w}^N}{w^N} = \frac{\dot{p}^N}{p^N}$ and $\frac{\dot{v}^N}{v^N} = \frac{\dot{w}^N}{w^N} - g$ (see (9)) imply

$$\dot{g} = \left(\frac{L^N}{2a} - g\right)\left(\rho + m + g - \frac{1-\alpha}{\alpha}\left(\frac{L^N}{2a} - g\right)\frac{1}{\zeta}\right) \tag{18}$$

Using the definition $m = \frac{\dot{n}^S}{n^N}$ where $n^S = (1-\zeta)\, n$, $n^N = \zeta n$ gives

$$\dot{\zeta} = g - (g + m)\,\zeta \tag{19}$$

The autonomous system (18) and (19) agrees with system (24) and (25) of Helpman (1993).

3 PROPERTY RIGHTS ENFORCEMENT AND GROWTH: THE SYMMETRIC CASE

Section 2 described the dynamics of product innovation, North-South trade, and intertemporal welfare. Under the symmetry assumptions imposed where North and South equally enforce intellectual property rights we showed that the model reduces to the model of Helpman (1993). The analysis of Helpman therefore applies in the present case.

The two significant conclusions arising from the autonomous system (18) and (19) are contained in the following theorem.

Theorem 1 (Helpman):[5] For economies that begin in steady state, the South gains from weaker intellectual property rights enforcement (higher m). The North also gains from weaker intellectual property rights if the rate of imitation is sufficiently small.

The implications of Theorem 1 are significant for international negotiations about the level of intellectual property rights protection because they imply that it is in the interest of a non-innovating country always to press for weaker IPR protection. Innovating countries, in contrast, must seek to optimize the value of protection. Their worries derive from the possibility of choosing such overly-high protection that the losses from monopoly power granted outweigh the gains from greater induced innovation.

The South favors lower worldwide IPR standards. What are its interests if the rest of the world does not join it in lower IPR protection? In view of their different regional interests, the next section considers the asymmetric case where the South drops its intellectual property rights protection and the North does not.

4 PROPERTY RIGHTS ENFORCEMENT AND GROWTH: THE SYMMETRIC CASE

We now drop the symmetry assumptions $\zeta_x = \zeta_y = \zeta$ and $n_x = n_y = n$ and re-solve the model to find the effects on both regions of asymmetric intellectual property rights enforcement. In the asymmetric regime the North enforces IPR but the South does not. We consider two possibilities. In the first case, we assume that the North imposes a ban on the importation of newly copied x goods, while remaining open to the importation of x goods that were already imitated (out of patent) at the time of the regime switch. An import embargo is the conventional remedy in law against foreign products found to violate domestic firms' intellectual property rights. In the United States this is the standard remedy applied by Section 337 of the trade regulations, for example.

We also consider a second case where the North does not impose an embargo, but remains open to imports of all goods from South. We examine the effect on the Northern welfare in both open to imports of all goods from the South. We examine the effect on Northern welfare in both alternatives. We find that the loss of intellectual property rights protection generally harms the North either way, but that Northern

[5] See Theorems 1 and 2 of Helpman (1993)

welfare is higher if it imposes an embargo than if it does not. An embargo on imports of newly copied products, therefore, is a sensible strategy for the North.

4.1 The Effect of Asymmetric IPR Enforcement on Trade

We consider the embargo and no-embargo cases in turn.

4.1.1 *Asymmetric IPR Enforcement: Embargo Case*

In the absence of Southern protection for Northern intellectual property

$$m_y = 1 > m_x \geq 0$$

Southern producers imitate y-type products as soon as they are invented in the North and the number of y-type products produced in the South equals the full range of these products available. Northern producers of y goods therefore lose monopoly power at the point of the regime switch. With Northern refusal to import x goods that are newly copied by the South, however, Northern producers of non-imitated goods x still charge a monopoly price p^N. Continuation of trade in the new regime therefore implies wage equalization $w^S = w^N$.[6] Thus

$$q_1^N = q_1^S = p_1^S = w_1^S = w_1^N < \left(\frac{\varepsilon}{\varepsilon - 1}\right) w_1^N = p_1^N \tag{20}$$

where subscript 1 denotes equilibrium prices in the regime of asymmetric intellectual property rights enforcement to distinguish them from equilibrium prices with subscript 0 in the initial regime. South producers export out-of-patent x goods to the North in return for imports of an equal value of y goods from the North.

This new equilibrium has two special features that deserve mention.

First, Northern producers continue to innovate x goods and to produce them at the monopoly price p^N. The range of Northern goods, therefore, continues to grow. However, the range of Southern goods are frozen at the regime-switch level due to the cessation of Northern innovation in y goods (such innovated products would be immediately copied in the South).

Second, although trade continues after the regime switch, it has no welfare consequences. That is, Northern imports of x goods from the South are paid for by Northern exports of y goods. But, were the North to produce domestically its imported x goods, it could do so at the same prices using the labor it employs to produce its y-good exports. A similar statement applies for the South. The world is welfare-equivalent to

[6] If $w^S < w^N$, Southern producers would produce y goods and out-of-patent x goods at prices below Northern producer prices. The North could not export y goods to pay for its imports. If $w^S > w^N$ Northern producers would produce y goods and out-of-patent x goods at prices below Southern producer prices. The South could not export x goods to pay for its imports.

two autarkic economies, therefore, with the static South producing y goods for local consumption and the innovating North producing x goods for local consumption.

4.1.2 *Asymmetric IPR Enforcement : No Embargo Case*

The preceding description applies when the South drops IPR protection and the North responds by refusing to import goods that were under Northern patent at the time of the regime switch. As noted, this agrees with the usual remedy applied by innovating countries when a foreign nation denies intellectual property rights protection for their products. Were the North to allow unrestricted imports of any good, all Northern innovation would cease because any innovated good would be immediately copied by the South to undersell the Northern innovator.

Trade between North and South would still be possible, consisting of x goods sold to the North in return for y goods sold to the South, but all goods in both regions would be produced perfectly competitively. If not, Southern firms would imitate and undersell the product. Wages would be equalized between North and South because productive technology is the same between regions. Identical technology between North and South would also mean that the welfare of each country would be the same as if there were no trade between areas and both regions produced all of their own goods.

Comparing the consequences of no embargo to the embargo case, therefore, we find that the primary difference is that without embargo the North looses the viability of its innovation sector. We will use this fact when we compute Northern welfare. In the next section we return to the embargo case to examine the effect of the regime switch on Northern innovation dynamics.

4.2 The Effects of Asymmetric IPR Enforcement on Innovation: Embargo Case

In the presence of a Northern embargo Northern producers continue to innovate x goods, but cease to innovate y-type products after the regime switch. Resources used to innovate y goods are redirected. This redirection alters the innovation and growth rates applying to x-type goods. To derive the dynamic equation system for the regime of asymmetric IPR enforcement we follow a similar process to that described in Section 2.3. In the asymmetric case Northern consumption based on preferences (2) satisfies

$$c_x^{UP}(i) = c_x^{UP} = \frac{1}{p^N}\left(\frac{p^N}{P}\right)^{1-\varepsilon} E^N \tag{21}$$

$$c_x^{OP}(i) = c_x^{OP} = \frac{1}{p^S}\left(\frac{p^S}{P}\right)^{1-\varepsilon} E^N \tag{22}$$

$$p^N = \left(\frac{\varepsilon}{\varepsilon-1}\right) w^N = \frac{1}{\alpha} w^N = \frac{1}{\alpha} p^S \tag{23}$$

and $c_x^{UP}(i)$ denotes goods under-patent and $c_x^{OP}(i)$ denotes goods out-of-patent. Price p^N applies to Northern goods under-patent and p^S applies to Northern goods out-of-patent.

The Northern expenditure and labor constraints satisfy[7]

$$p^N \zeta_x n_x c_x^{UP}(i) + p^S(1-\zeta_x(t)) n_x c_x^{OP}(i) = E^N \tag{24}$$

$$a g_x + \zeta_x n_x c_x^{UP}(i) + (1-\zeta_x(t)) n_x c_x^{OP}(i) = L^N \tag{25}$$

Thus

$$\begin{aligned}
E^N &= p^N \left(L^N - a g_x - (1-\zeta_x) n_x c_x^{OP}\right) + p^S (1-\zeta_x) n_x c_x^{OP} \\
&= p^N (L^N - a g_x) - p^N (1-\zeta_x) n_x c_x^{OP} \left(\frac{1}{\varepsilon}\right) \\
&= p^N (L^N - a g_x) - \left(\frac{p^N}{p^S}\right) p^S (1-\zeta_x) n_x c_x^{OP} \left(\frac{1}{\varepsilon}\right) \\
&= p^N (L^N - a g_x) - (\frac{1}{\varepsilon-1}) \gamma_x E^N
\end{aligned}$$

or

$$E^N = \left(\frac{\varepsilon-1}{\varepsilon-1+\gamma_x}\right) p^N (L^N - a g_x) \tag{26}$$

where γ_x is defined as the value of Northern labor devoted to producing out-of-patent goods as a share of

[7] Which x goods are produced in the South depends on the amount of trade. If $1-\zeta_x(t)$ denotes the out-of-patent range of x-goods imported by the North from the South can be distinguished from those the North produces at home: $\left[\left(1-\bar{\zeta}(t)\right) n_x(0)\right] c_x^{OP} + \left[(1-\zeta(t)) n_x(t) - \left(1-\bar{\zeta}(t)\right) n_x(0)\right] c_x^{OP} = (1-\zeta_x(t)) n_x(t) c_x^{OP}$ where the range of goods produced by the South is not greater than the out-of-patent range of goods, $\left(1-\bar{\zeta}(t)\right) \leq (1-\zeta_x(t))$, and $\left[\left(1-\bar{\zeta}(t)\right) n_x(0)\right] c_x^{OP}$ represents goods produced in the South. The second term represents goods produced in the North.

Northern expenditure,[8]

$$
\begin{aligned}
\gamma_x &= \frac{(1-\zeta_x)n_x p^S c_x^{OP}}{E^N} \\
&= \frac{(1-\zeta_x)n_x (p^S)^{1-\varepsilon}}{(1-\zeta_x)n_x (p^S)^{1-\varepsilon} + \zeta_x n_x (p^N)^{1-\varepsilon}} \\
&= \frac{1-\zeta_x}{1-\zeta_x+\zeta_x\left(\frac{p^N}{p^S}\right)^{1-\varepsilon}} \qquad (27)
\end{aligned}
$$

Differentiating (26) gives

$$
\frac{\dot{E}^N}{E^N} = -\frac{\dot{\gamma_x}}{\varepsilon-1+\gamma} + \frac{\dot{p}^N}{p^N} - \frac{a\dot{g_x}}{L^N - a g_x}. \qquad (28)
$$

Using (11),

$$
r^N = \rho - \frac{\dot{\gamma_x}}{\varepsilon-1+\gamma_x} + \frac{\dot{p}^N}{p^N} - \frac{a\dot{g_x}}{L^N - a g_x}. \qquad (29)
$$

Applying (10), $\frac{\dot{v}^N}{v^N} = \frac{\dot{w}^N}{w^N} - g$ and $\frac{\dot{w}^N}{w^N} = \frac{\dot{p}^N}{p^N}$ as in section 2.3 gives

$$
r^N = \frac{\pi^N}{v^N} + \left(\frac{\dot{p}^N}{p^N} - g_x\right) - m_x \qquad (30)
$$

From $\pi^N = (1-\alpha)\, p^N c_x^{UP}$, (9) and (26) we next get

$$
\frac{\pi^N}{v^N} = \frac{1-\alpha}{\alpha}\left(\frac{(\varepsilon-1)(1-\gamma_x)}{\varepsilon-(1-\gamma_x)}\right)\left(\frac{L^N}{a} - g_x\right)\frac{1}{\zeta_x} \qquad (31)
$$

Combining (29)-(31) gives

$$
\dot{g}_x = \left(\frac{L^N}{a} - g_x\right)\left[\rho + g_x + m_x - \frac{(\varepsilon-1)(1-\gamma_x)}{\varepsilon-(1-\gamma_x)}\left(\frac{1-\alpha}{\alpha}\right)\left(\frac{L^N}{a} - g_x\right)\frac{1}{\zeta_x} - \frac{\dot{\gamma}_x}{\varepsilon-(1-\gamma_x)}\right]. \qquad (32)
$$

The law of motion for ζ_x is the same as obtained under the symmetric regime,

$$
\dot{\zeta}_x = g_x - (g_x + m_x)\zeta_x \qquad (33)
$$

[8]The North exports out-of-patent y goods in exchange for a range of x goods from the South that are out-of-patent. As noted however, any imported x goods could have produced in the North using labor devoted to producing the y goods that paid for those imports. Since labor is the only production cost and wages between North and South are equalized, $(1-\zeta_x(t))\, n_x(t)\, p^S c_x^{OP}$ equals the value of labor devoted to producing out-of-patent goods in the North.

$$0 \leq g_x < \frac{L^N}{a}, \;\; 0 \leq \zeta_x \leq 1$$

and using (27) the motion of γ_x is given by

$$\frac{\dot{\gamma_x}}{1-\gamma_x} = -\frac{\dot{\zeta}_x}{\zeta_x}\left[\gamma_x + \alpha^{1-\varepsilon}\left(1-\gamma_x\right)\right] \tag{34}$$

Equations (32)-(34) constitute the autonomous dynamic system applying to the asymmetric regime. Notice that in the former regime of symmetric IPR enforcement, the North did not produce any out-of-patent goods; i.e., $\gamma_x = 0$ for all t. Setting $\gamma_x = 0$ and replacing $L^N$by $L^N/2$ the autonomous system (32) and (33) reverts to (18) and (19).

4.3 Southern Welfare

Having completed the preliminary work, we can now assess the effects of the regime switch on the South's intertemporal welfare. This assessment assumes that both the North and South were initially in steady state in the regime where IPR enforcement was symmetric $m_x = m_y = m$ and the economy-determined equilibrium steady state innovation growth rate before the regime switch was g_0. In the initial regime, the rate of innovation $g_x(t) = g_y(t) = g(t)$ and the fraction of unimitated (under-patent) products $\zeta_x(t) = \zeta_y(t) = \zeta(t)$ were fixed at g_0 and $\zeta_0 = g_0/(g_0+m)$, respectively. Given the initial condition $n_x\left(0\right) = n_y\left(0\right)$, the numbers of x-type and y-type products, $n_x(t) = n_y(t)$, grew according to $n_x(0)e^{g_0 t} = n_y(0)e^{g_0 t}$ at time t.

When the South drops its IPR enforcement at $t = 0$, the resulting effects on the South's welfare are the same in the embargo case as in the no embargo case.[9] The regime shifts to a new steady state where $g_y(t) = 0$ and $\zeta_y(t) = 0$ for $t \geq 0$. Prices are determined by domestic production. Using equation (14), present value of the South's per-capita utility (discounted from $t = 0$ to infinity) in the initial regime of symmetric IPR enforcement is

$$\begin{aligned} U_0^S &= \int_0^\infty e^{-\rho t} \log u_0^S\left(t\right) dt \\ &= \frac{1}{\varepsilon-1}\int_0^\infty e^{-\rho t}\log\left[n_y(0)e^{g_0 t}\right]dt + \frac{1}{\varepsilon-1}\int_0^\infty e^{-\rho t}\log\left[\zeta_0\left(\frac{p_0^S}{p_0^N}\right)^{\varepsilon-1} + (1-\zeta_0)\right]dt \end{aligned} \tag{35}$$

and that in the new regime of asymmetric IPR enforcement is given by

[9]This is because the innovation of y-goods ceases in either case and trade is welfare-neutral for the South as explained earlier.

$$U_1^S = \int_0^\infty e^{-\rho t} \log\, u_1^S(t)dt = \frac{1}{\varepsilon - 1}\int_0^\infty e^{-\rho t} \log\, n_y(0)dt \tag{36}$$

Subtracting (35) from (36):

$$\triangle U^S = U_1^S - U_0^S = \triangle^S_{Product-availability} + \triangle^S_{Terms-of-trade} \tag{37}$$

with

$$\triangle^S_{Product-availability} = -\frac{g_0}{(\varepsilon-1)\,\rho^2} < 0$$

$$\triangle^S_{Terms-of-Trade} = -\frac{1}{(\varepsilon-1)\,\rho} \log\left[\zeta_0\left(\frac{p_0^S}{p_0^N}\right)^{\varepsilon-1} + (1-\zeta_0)\right] > 0$$

In welfare terms, the adverse product availability effect harms the South, because Southern consumers lose the opportunity to consume an otherwise growing range of products. The terms-of-trade effect benefits the South because Southern consumers can consume existing products at a lower price when y production is relocated from the higher-cost North to lower-cost South.[10] With respect to the flow of utility, it is clear that the South gains in the short run from lesser IPR enforcement because the terms-of-trade gains outweigh product-availability losses. However, as time passes, terms-of-trade gains will sooner or later be outweighed by product-availability losses. In present value terms, therefore the South could gain or lose from halting IPR protecting for Northern-produced goods.

Table 1 provides simulation results for $\triangle U^S$ and its components $\triangle^S_{Product-availibility}$ and $\triangle^S_{Terms-of-Trade}$.[11] The results indicate that product-availability losses dominate. The South loses from its failure to provide intellectual property rights protection. This outcome stands in stark contrast to Theorem 1 (*For economies that begin in steady state, the South gains from looser intellectual property rights.*). The possibility of losses to the South from weaker IPR protection constitutes a major finding of the present analysis. In the model of Theorem 1 the goods consumed in the North and South were perfect substitutes. When Northern goods and Southern goods are not perfect substitutes (we have examined here the polar case of zero substitutability) and the South enforces a lower level of intellectual property rights than the North, Southern welfare losses

[10] $\triangle^S_{Terms-of-Trade}$ can be written $\frac{1}{(\varepsilon-1)\rho} \log \left[\frac{\zeta_0\left(\frac{q_1^S}{q_1^N}\right)^{\varepsilon-1} + (1-\zeta_0)}{\zeta_0\left(\frac{p_0^S}{p_0^N}\right)^{\varepsilon-1} + (1-\zeta_0)}\right]$ which shows it as the differences of two logs where $1 = \frac{q_1^S}{q_1^N} > \frac{p_0^S}{p_0^N}$ represents the Southern terms-of-trade improvement.

[11] To simulate the model we linearize the dynamic system (32)-(34) around its steady state (g_1, ζ_1) corresponding to imitation rate m close to m^{**}, the imitation rate that leaves $g_0 = g_1$ and $\zeta_0 = \zeta_1$. See Figure 2. Evaluating the linearized system produces Table 1.

Table 1: SOUTHERN WELFARE:
IPR Enforcement to No IPR Enforcement in South

Rate of Imitation, m	Product Availability Gain	Terms of Trade Gain	Total Welfare Change
		($\rho = .0025$)	
$.90m^{**}$ (= .0215)	-4348.94	215.53	-4133.41
$.95m^{**}$(= .0227)	-4350.41	208.48	-4141.92
m^{**} (=.0239)			
1.05 m^{**} (=.0251)	-4353.22	195.75	-4157.47
1.10 m^{**} (=.0263)	-4354.56	189.96	-4164.60
		($\rho = .015$)	
$.90m^{**}$ (=.0182)	-107.32	36.77	-70.54
$.95m^{**}$ (=.0192)	-107.55	35.63	-71.92
m^{**} (=.0202)			
$1.05m^{**}$(=.0212)	-108.00	33.56	-74.43
1.10 m^{**} (=.0222)	-108.21	32.62	-75.59
		($\rho = .03$)	
$.90m^{**}$ (=.0145)	-22.67	18.88	-3.79
$.95m^{**}$ (=.0154)	-22.78	18.33	-4.45
m^{**} (=.0162)			
1.05 m^{**} (=.0170)	-22.99	17.33	-5.65
1.10 m^{**} (=.0178)	-23.09	16.88	-6.20

Notes: m^{**} is the critical imitation rate at which the regime switch does not alter the initial steady-state equilibrium. Other than m and ρ, the simulations use these parameter values: $L^N = 1$, $L^S = 12$, $a = 3$, $\varepsilon = 3$.

emerge.

The case where terms of trade gains dominate and the South gains from non-enforcement of IPR rights can be seen by considering the limiting case where m approaches 0^+ . In this case $\zeta_0 \to 1$, $g_0 \to (1-\alpha)\left(\frac{L^N}{2a}\right) - \alpha\rho$ and $\frac{p_0^N}{p_0^S}$ becomes infinitely large according to (13). With initial large adverse terms of trade, relocating production to the South by failing to protect Northern intellectual property can yield tremendous terms-of-trade gains that dominate in present value the future product availability losses.

We summarize our results in the following proposition.

Proposition 1 (*Southern Welfare*): For economies that begin in steady state with symmetric IPR enforcement, dropping IPR enforcement in the South may lead to higher or lower Southern welfare. If the initial rate of imitation is sufficiently small (resp. large), Southern welfare is helped (resp. harmed).

4.4 Northern Welfare

The effect of the regime switch on Northern welfare would appear at first glance to be less interesting than Southern welfare because the North obviously suffers both a terms-of-trade loss and loses the Southern market within which to sell its innovated y products. Both effects work against Northern welfare, the latter

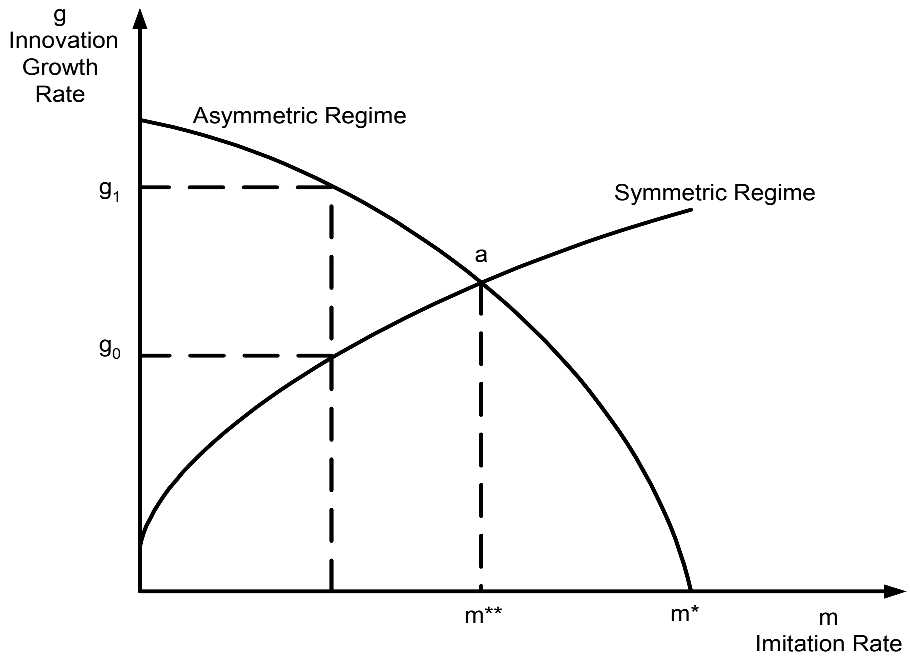

Figure 2: RELATIONSHIP BETWEEN STEADY-STATE INNOVATION RATE AND IMITATION RATE

because a small market means less profit opportunity and incentive for innovation. If the North does not impose an embargo on imports of newly copied x-goods, it also suffers the loss of its x-good innovation sector.

On the other hand, taking resources out of y innovation means more available resources for potential x type innovation when the viability of x innovation is protected by an embargo. Competing against the x innovation sector for resources with the passage of time are Northern firms that competitively produce products for zero economic profit instead of producing under-patent products as in the symmetric regime. These take resources away from innovation activities and production of higher-profit under-patent goods. Coupled with the North's lost gains from trade, these cause the North to finance innovation from a potentially lower standard of living. Whether the freeing of resources previously devoted to y innovation can lead to a sufficient increase in x-innovation and future consumption that it generates welfare gains for the North is an open question. We show in what follows that both alternatives are possible. The rate of imitation plays an important role in determining which of the competing forces dominate and lead to a reduction or increase in the pace of innovation and change in the present value of Northern welfare.

Table 2: NORTHERN INNOVATION RATES:
Steady-State Innovation Growth Rates and Share of Products Under Patent Asymmetric Regime

Rate of Imitation, m	Symmetric Regime Innovation Growth Rate g_0, %	Asymmetric Regime Innovation Growth Rate g_1, %	Symmetric Regime Products under Patent ζ_0	% of Products under Patent ζ_1
		($\rho = .0025$)		
$.90m^{**}$ (=.0215)	5.4361	5.9944	71.6260	73.5702
$.95m^{**}$ (=.0227)	5.4380	5.7173	70.5215	71.5519
m^{**} (=.0239)				
1.05 m^{**}(=.0251)	5.4415	5.1619	68.4130	67.2623
1.10 m^{**}(=.0263)	5.4432	4.8837	67.4060	64.9797
		($\rho = .015$)		
$.90m^{**}$ (=.0182)	4.8297	5.4072	72.5832	74.7727
$.95m^{**}$ (=.0192)	4.8401	5.1301	71.5383	72.7080
m^{**} (=.0202)				
1.05 m^{**}(=.0212)	4.8601	4.5673	69.5445	68.2127
1.10 m^{**}(=.0222)	4.8696	4.2808	68.5925	65.7521
		($\rho = .03$)		
$.90m^{**}$ (=.0145)	4.0823	4.7016	73.6619	76.3093
$.95m^{**}$ (=.0154)	4.1016	4.4158	72.6937	74.1337
m^{**} (=.0162)				
$1.05m^{**}$ (=.0170)	4.1385	3.8131	70.8480	69.1279
$1.10m^{**}$ (=.0178)	4.1562	3.4904	69.9673	66.1767

Notes: m^{**} is the critical imitation rate at which the regime switch does not alter the initial steady-state equilibrium. Other than m and ρ, the simulations use these parameter values: $L^N = 1$, $L^S = 12$, $a = 3$, $\varepsilon = 3$

4.4.1 Northern Welfare: Embargo Case

Inspection of the system steady states for equations (18)-(19) and equations (32)-(34) shows that x innovation growth rates can be higher or lower in the regime of asymmetric IPR enforcement with embargo compared to the symmetric regime. Figure 2 plots the relationship between the imitation rate and steady state innovation growth for the two regimes of symmetric IPR enforcement and asymmetric enforcement with embargo. The results are summarized in Table 2 for three choices of the subjective discount rate (.25%, 1.5%, and 3%).[12] As shown there, steady state innovation is higher in the asymmetric regime, $g_1 > g_0$ when the rate of imitation is below m^{**}. When the rate of imitation is high, the steady state x innovation rate drops below the corresponding rate of the symmetric regime. A higher innovation growth rate is associated with a higher equilibrium share of products under patent, as shown in the two right hand columns of Table 2.

Returning to Figure 2, we see that a sufficiently high imitation rate (in the case of $\rho = .015$, for example, this rate is $m \geq m^* = .0341$) causes the x innovation rate to fall to zero after the South drops IPR protection. When the Southern market was available, Northern innovation was sustainable, even in the face of high imitation, because the combined market was large enough to provide the profits needed by innovators.

[12]The same procedure is used for Table 2 as was used to generate Table 1.

When the market for innovated products is confined solely to the smaller North in this case, innovation is not supportable. In the presence of high imitation rates therefore, we expect Northern welfare to drop after the regime switch because the North experiences lower innovation and worsened terms of trade.

Using equation (14), present value of the North's per-capita utility (discounted from $t = 0$ to infinity) in the initial regime of symmetric IPR enforcement is

$$\begin{aligned} U_0^N &= \int_0^\infty e^{-\rho t} \log u_o^N(t) dt \\ &= \frac{1}{\varepsilon - 1} \int_0^\infty e^{-\rho t} \log \left[n_x(0) e^{g_0 t} \right] dt + \frac{1}{\varepsilon - 1} \int_0^\infty e^{-\rho t} \log \left[\zeta_0 + (1 - \zeta_0) \left(\frac{p_0^N}{p_0^S} \right)^{\varepsilon - 1} \right] dt \\ &+ \int_0^\infty e^{-\rho t} \log \left[1 - \frac{2ag_0}{L^N} \right] dt \end{aligned} \tag{38}$$

where $\frac{2ag_0}{L_N}$ is the share of labor devoted to innovation activities, a measure of savings in the economy. $\log \left[1 - \frac{2ag_0}{L^N}\right]$ therefore measures the logarithm of labor devoted to producing current consumption goods. In the asymmetric regime, discounted present value of future welfare is (see Appendix for details)

$$\begin{aligned} U_1^N &= \int_0^\infty e^{-\rho t} \log u_1^N(t) dt \\ &= \frac{1}{\varepsilon - 1} \int_0^\infty e^{-\rho t} \log \left[n_x(0) e^{g_x(t) t} \right] dt \\ &+ \frac{1}{\varepsilon - 1} \int_0^\infty e^{-\rho t} \log \left[\zeta_x(t) + (1 - \zeta_x(t)) \left(\frac{p_1^N}{p_1^S} \right)^{\varepsilon - 1} \right] dt \\ &+ \int_0^\infty e^{-\rho t} \log \left[1 - \frac{2ag_x(t)}{L^N} \right] dt \\ &+ \int_0^\infty e^{-\rho t} \log \left[\frac{\varepsilon - 1}{\varepsilon - 1 + \gamma_x(t)} \right] dt \end{aligned} \tag{39}$$

where $g_x(t)$, $\zeta_x(t)$, and $\gamma_x(t)$ are time dependent, subject to system (32)-(34), and will converge to g_1, ζ_1, γ_1 in steady state.[13] Subtracting (38) from (39) yields

[13] According to (27), $\lim_{t\to\infty} \gamma_x(t) = \frac{1-\zeta_1}{1-\zeta_1+\zeta_1 a^{\varepsilon-1}}$.

$$
\begin{aligned}
\triangle U^N &= U_1^N - U_0^N \\
&= \triangle^N_{Prod.-availability} + \triangle^N_{Terms-of-trade} + \triangle^N_{Mkt-power} \qquad (40)\\
&\quad + \triangle^N_{Prod.-location} + \triangle^N_{Saving}
\end{aligned}
$$

where

$$\triangle^N_{Prod.-availability} = \frac{1}{\varepsilon - 1}\int_0^\infty e^{-\rho t}\left(g_x(t) - g_0\right) t dt$$

$$\triangle^N_{Terms-of-trade} = \frac{1}{\varepsilon - 1}\int_0^\infty e^{-\rho t}\log\left[\frac{\zeta_0 + (1-\zeta_0)\left(\frac{p_1^N}{p_1^S}\right)^{\varepsilon-1}}{\zeta_0 + (1-\zeta_0)\left(\frac{p_0^N}{p_0^S}\right)^{\varepsilon-1}}\right] dt$$

$$\triangle^N_{Mkt-power} = \frac{1}{\varepsilon - 1}\int_0^\infty e^{-\rho t}\log\left[\frac{\zeta_x(t) + (1-\zeta_x(t))\left(\frac{p_1^N}{p_1^S}\right)^{\varepsilon-1}}{\zeta_0 + (1-\zeta_0)\left(\frac{p_1^N}{p_1^S}\right)^{\varepsilon-1}}\right] dt$$

$$\triangle^N_{Prod.-location} = \int_0^\infty e^{-\rho t}\log\left[\frac{\varepsilon - 1}{\varepsilon - 1 + \gamma_x(t)}\right] dt$$

$$\triangle^N_{Saving} = \int_0^\infty e^{-\rho t}\log\left[\frac{1 - a g_x(t)/L^N}{1 - 2a g_0/L^N}\right] dt$$

Inspection of each term reveals under what conditions it is positive or negative. The sign of the product availability term is negative if $g_x(t) < g_0$. The term-of-trade term is always negative since $p_1^N/p_1^S < p_0^N/p_0^S$ (see (7) and (20)). It measures change in welfare due to the worsened terms-of-trade the North faces after the regime switch with the same mix of goods under-patent and out-of-patent. The market power term, relating to the fraction of goods monopolistically supplied, is negative if the share of Northern goods under patent rises, ceteris paribus, $\zeta_x(t) > \zeta_0$ because of the monopoly element. The production location term is uniformly negative when the North produces some goods perfectly competitively (as is the case, $\gamma_x(t) > 0$) since it represents a reduction in associated profits to those firms compared to monopolistic market structure. The final savings term is negative if $a g_x(t)/L^N > 2a g_0/L^N$. The explanation here is that when the share of labor devoted to the innovation sector is greater after the regime switch than before, more current resources are

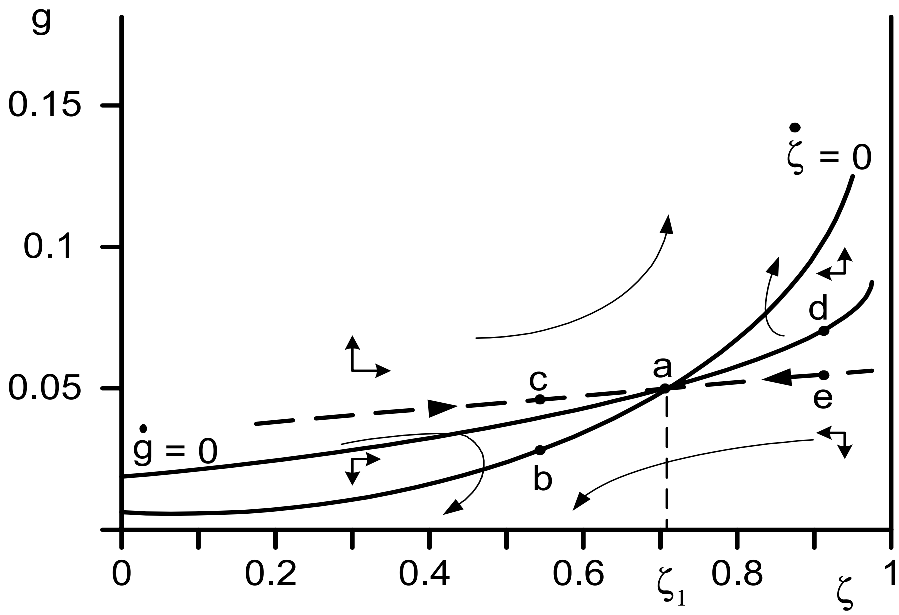

Figure 3: PHASE DIAGRAM

devoted to innovation than to production of current consumption goods. Increased saving activity therefore diminishes current consumption.

With different avenues of welfare influence operating we need to determine whether $g_x(t)$ is greater than or less than g_0. Figure 3 draws the phase diagram for the model of Table 2, showing the stable arms with directional arrows.[14] The locus $\dot{\zeta} = 0$ is unchanged in the regime switch. Thus two outcomes are possible. If the new steady state is such that $g_1 > g_0$ the regime switch causes g to jump to the stable arm as from point b to c and travel northeast to the new steady state. At the same time, $\zeta_x(t)$ increases steadily to its new value ζ_1. Thus the regime switch causes both $g_x(t)$ and $\zeta_x(t)$ to be uniformly above their initial value. If $g_1 < g_0$ the reverse is true; $g_x(t)$ takes an initial jump downward after the regime switch as from point d to e. Thereafter, both $g_x(t)$ and $\zeta_x(t)$ decline uniformly to g_1 and ζ_1 respectively. The sign of each of the components of Northern welfare can be determined based on the path of $g_x(t)$ and $\zeta_x(t)$. In no case, however, are all terms of (40) the same sign. To see whether Northern welfare gains are possible we examine the model of Figure 2 and Tables 2-3 in the neighborhood of the crossover point a.

Table 3 computes the components of Northern welfare change for the values of Table 2. As shown there, Northern welfare can rise or fall. In each case the terms-of-trade component (column 2) shows welfare losses, as expected. The less discounting of the future, the greater the present value of terms-trade losses is. The product availability and market power terms lead to Northern welfare grains of losses according to whether

[14]Parameter values for the diagram in Figure 3 are: $L^N = 1$, $L^S = 12$, $a = 3$, $\varepsilon = 3$, $\alpha = 2/3$, $\rho = .015$, $m = .0202$.

Table 3: NORTHERN WELFARE:
Regime of Symmetric IPR Enforcement to No IPR Enforcement in South
(The North enforces a Section-337 type embargo)

Rate of Imitation, m	Product Availability Gain	Terms of Trade Gain	Market Power Gain	Location of Prod. Gain	Saving Gain	Total Welfare Change
		$\rho = .0025$				
$.90m^{**}$ (=.0215)	446.93	-231.17	-3.46	-80.85	78.73	210.17
$.95m^{**}$ (=.0227)	223.59	-229.05	-1.80	-84.87	82.77	-9.36
m^{**} (=.0239)						
$1.05m^{**}$(=.0251)	-223.86	-224.57	1.76	-92.76	90.73	-448.70
$1.10m^{**}$(=.0263)	-448.02	-222.60	4.04	-96.65	94.64	-668.59
		$\rho = .015$				
$.90m^{**}$ (=.0182)	13.14	-37.85	-0.51	-13.21	11.14	-27.30
$.95m^{**}$ (=.0192)	6.61	-37.54	-0.26	-13.84	11.80	-33.24
m^{**} (=.0202)						
$1.05m^{**}$(=.0212)	-6.72	-36.91	0.28	-15.07	13.08	-45.34
$1.10m^{**}$(=.0222)	-13.56	-36.59	0.59	-15.67	13.70	-51.53
		$\rho = .03$				
$.90m^{**}$ (=.0145)	3.77	-18.53	-0.22	-6.45	4.45	-16.98
$.95m^{**}$ (=.0154)	1.93	-18.40	-0.11	-6.74	4.76	-18.56
m^{**} (=.0162)						
$1.05m^{**}$(=.0170)	-2.06	-18.13	0.12	-7.30	5.36	-22.01
$1.10m^{**}$(=.0178)	-4.29	-17.99	0.24	-7.57	5.66	-23.95

Notes: m^{**} is the critical imitation rate at which the regime switch does not alter the initial steady-state equilibrium. Other than m and ρ, the simulations use these parameter values: $L^N = 1$, $L^S = 12$, $a = 3$, $\varepsilon = 3$

the new regime results in higher or lower product innovation, as described above.

In each of the cases shown, the North loses welfare overall due to loss of IPR protection in the South. The single expectation is the first row of Table 3 where the subjective discount rate and the rate of imitation are both low. In this case the route to gains – the savings effect and the product availability effect – is that the new regime resulted in higher x innovation and at the same time released resources from the y innovation sector so that greater resources were available for current consumption of x goods. The surprising possibility that the North might actually gain in present value terms from the dynamic consequences of the loss of IPR protection in the South is therefore demonstrated.

We next describe Northern welfare in the no embargo case before summarizing our findings.

4.4.2 Northern Welfare: No Embargo Case

As described above, in the absence of a Northern embargo equilibrium is characterized by no innovation of x or y goods and all goods are produced under conditions of perfect competition:

$$q_1^N = q_1^S = p_1^N = q_1^S = w_1^N = w_1^S \tag{41}$$

$$g_x = g_y = g_1 = \zeta_x = \zeta_y = \zeta_1 = 1 - \gamma_x = 0 \tag{42}$$

The components of Northern welfare change compared to the regime of symmetric IPR enforcement are

$$\begin{aligned}\triangle^N_{Prod.-availability} &= \frac{1}{\varepsilon - 1}\int_0^\infty e^{-\rho t}(g_1 - g_0)t dt \\ &= \frac{-g_0}{(\varepsilon-1)\rho^2} < 0\end{aligned}$$

$$\begin{aligned}\triangle^N_{Terms-of-trade} &= \frac{1}{\varepsilon - 1}\int_0^\infty e^{-\rho t}\log\left[\frac{\zeta_0 + (1-\zeta_0)(1)^{\varepsilon-1}}{\zeta_0 + (1-\zeta_0)\left(\frac{p_0^N}{p_0^S}\right)^{\varepsilon-1}}\right]dt \\ &= \frac{-1}{\varepsilon-1}\int_0^\infty \log\left[\zeta_0 + (1-\zeta_0)\left(\frac{p_0^N}{p_0^S}\right)^{\varepsilon-1}\right] < 0\end{aligned}$$

$$\begin{aligned}\triangle^N_{Mkt-power} &= \frac{1}{\varepsilon - 1}\int_0^\infty e^{-\rho t}\log\left[\frac{\zeta_1 + (1-\zeta_1)(1)^{\varepsilon-1}}{\zeta_0 + (1-\zeta_0)(1)^{\varepsilon-1}}\right]dt \\ &= \frac{1}{\rho}\log\left[\frac{\varepsilon-1}{\varepsilon}\right] < 0\end{aligned}$$

$$\begin{aligned}\triangle^N_{Saving} &= \int_0^\infty e^{-\rho t}\log\left[\frac{1 - ag_1/L^N}{1 - 2ag_0/L^N}\right]dt \\ &= \frac{-1}{\rho}\log\left[1 - 2ag_0/L^N\right] > 0\end{aligned}$$

It follows that the North is worse off because of the failure to innovate new x products, its worsened terms-of-trade, and the loss of monopoly profits from the shift in production location. Its only source of gain is the saving term since resources leave the x and y innovation sectors for use in producing current consumption. Table 4 confirms that Northern welfare is reduced in each of the cases examined, both in comparison to the initial regime and in comparison to the regime where the North imposes an embargo on

Table 4: NORTHERN WELFARE:
Regime of Symmetric IPR Enforcement to No IPR Enforcement in South
(The North does not enforce a Section-337 type embargo)

Rate of Imitation, m	Product Availability Gain	Terms of Trade Gain	Market Power Gain	Location of Prod. Gain	Saving Gain	Total Welfare Change
		$\rho = .0025$				
.90m** (=.0215)	-4348.94	-291.89	0.0	-162.18	46.04	-4756.98
.95m** (=.0227)	-4350.41	-291.79	0.0	-162.18	46.05	-4760.33
m** (=.0239)						
1.05 m** (=.0251)	-4353.22	-291.39	0.0	-162.18	46.08	-4760.63
1.10 m** (=.0263)	4354.56	-290.95	0.0	-162.18	46.10	-4761.60
		$\rho = .015$				
.90m** (=.0182)	-107.32	-47.68	0.0	-27.03	6.77	-175.26
.95m** (=.0192)	-107.55	-47.69	0.0	-27.03	6.78	-175.49
m** (=.0202)						
1.05 m** (=.0212)	-108.00	-47.66	0.0	-27.03	6.81	-175.88
1.10 m** (=.0222)	-108.21	-47.63	0.0	-27.03	6.83	-176.05
		$\rho = .03$				
.90m** (=.0145)	-22.67	-23.27	0.0	-13.51	2.83	-56.63
.95m** (=.0154)	-22.78	-23.29	0.0	-13.51	2.85	-56.74
m** (=.0162)						
1.05 m** (=.0170)	-22.99	-23.31	0.0	-13.51	2.88	-56.93
1.10 m** (=.0178)	-23.09	-23.30	0.0	-13.51	2.89	-57.02

Notes: m^{**} is the critical imitation rate at which the regime switch does not alter the initial steady-state equilibrium. Other than m and ρ, the simulations use these parameter values: $L^N = 1$, $L^S = 12$, $a = 3$, $\varepsilon = 3$.

imports of newly-copied x goods from the South.

Expect in cases of extremely high subjective discounting of the future by the North,[15] we expect an embargo to be the higher welfare alternative for the North in response to Southern failure to enforce IPR. We summarize our conclusion about Northern welfare in the embargo case in the following proposition.

Proposition 2 (Northern Welfare): For economies that begin in steady state with symmetric IPR enforcement, dropping IPR enforcement in the South may lead to higher or lower Northern innovation and welfare.

[15] As $\rho \to \infty$ the change in Northern welfare approaches zero, implying that the North is better off without an embargo in cases where Table 2 shows overall welfare loss

5 SUMMARY AND EVALUATION

The classic dilemma between protecting intellectual property rights to induce future innovation or allowing fuller dissemination of technology to foment competition in production raises special questions when one region, call this the North, innovates and another region, call this the South, purchases the innovated product. Clearly the North and South have a common interest in selecting IPR enforcement that is not too strict; both lose by virtue of the inefficiencies introduced by monopoly elements in competition. At issue is whether there is interest in enforcing common intellectual property rights that are not too low. A positive answer is significant because self-interest is a powerful motivating force in working toward international cooperation.

This paper examined the welfare effects of failure to enforce IPR in the South, starting from a regime of symmetrical IPR enforcement by both North and South. We showed that failure to enforce intellectual property rights by the South changes the direction of Northern innovation: Absence of Southern IPR rights enforcement causes the North to innovate for Northern markets but not for the Southern market. We found that the dynamic losses to the South from a smaller range of future goods can outweigh the terms-of-trade and price-related gains from producing copied Northern goods at lower cost.

An important feature in this scenario is that Northern and Southern goods were not assumed to be perfect substitutes. Relaxing the perfect substitutes assumption allowed for some Northern innovation to be differentially directed toward Southern markets. Failure to provide Southern IPR would therefore hinder the innovation process, the consequences of which could fall more heavily Southern consumers. In the present model Northern and Southern goods have zero substitutability so the consequences were sharp: Innovation of new Southern goods ceased without Southern IPR protection. Models with different degrees of substitutability between Northern and Southern goods, however, would also allow for the effects of failure to provide IPR to fall more heavily on one region or group of goods than another.

We also evaluated the effect of Southern failure to enforce IPR on Northern welfare. The impact on Northern welfare operated through five channels. Northern welfare was affected by a different rate of innovation of Northern goods, leading to different product in the future. The degree to which the North's terms-of-trade worsened as a result of lower prices for goods that it had once sold to the South in the symmetric regime as unimitated products also affected its welfare. The range of goods which shifted from monopoly to perfect competition in provision raised Northern welfare by eliminating monopoly inefficiencies. On the production side, the production location effect altered Northern welfare according to the lost profit associated with resources that the North devoted to zero-profit industries compared to positive-profit industries previously . Finally, Northern welfare was helped by a saving effect, meaning the releasing of resources to other Northern assignments that were previously devoted to innovating for the Southern market. Each channel was identified with a term in the overall welfare change formula.

To protect its innovation sector the North responded to lack of Southern IPR protection by the conventional trade law remedy of imposing an embargo on imports of goods that were under patent at the time of the regime switch. We examined the case where the North did not impose an embargo, confirming that Northern welfare is higher with embargo than without.

We expected that the combination of worsened terms-of-trade for the North and a smaller market for innovated products would guarantee lower innovation rates and net welfare losses. The analysis surprised us on both counts. Not only did we find that Northern innovation could be higher after the regime switch, but the model showed that Northern welfare paradoxically might rise, due primarily to the beneficial effects of the saving gain and increased innovation of Northern products after the regime switch. In the usual case, however, Northern welfare suffered due to Southern dropping of IPR protection.

What lessons can we draw? There appear to be at least two. First, asymmetry is a key aspect of the innovation process. Failure to provide intellectual property rights may lead to consequences that fall more heavily on one sector or country than another. That country can be North or South. While a model with asymmetries is often more computationally intensive, we believe that its insights will ultimately prove critical to a full understanding of the international ramifications of intellectual property rights enforcement. Second, failure to provide IPR in the South appears to harm the North primarily through worsened terms-of-trade and adverse effects on its future innovation as intuition would suggest. However, the paradoxical case where Northern welfare rises after the regime switch is possible. The paradox was explained in terms of the several routes for welfare change examined here. Knowing better how to predict or rule out such a seemingly unusual outcome is a topic for further investigation.

Appendix

A Derivation of the North's intertemporal welfare (39) in the asymmetric regime

From (26), the North's per capita expenditure is given by

$$\frac{E^N}{L^N} = \left(\frac{\varepsilon - 1}{\varepsilon - 1 + \gamma_x}\right) p^N \left(1 - \frac{ag_x}{L^N}\right) \tag{A.1}$$

As described in the text, in the asymmetric regime Northern and Southern firms have the same technology and costs for out-of-patent goods. Thus, without loss of generality, assume that Northern firms in the asymmetric regime produce all out-of-patent products, equal in number to $(1-\zeta_x)n_x$. The price index (4) in the text becomes

$$P = \left(\int_0^{(1-\zeta_x)n_x} \left(p^S\right)^{1-\varepsilon} di + \int_{(1-\zeta_x)n_x}^{n_x} \left(p^N\right)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}$$

$$\left[\left((1-\zeta_x)n_x\right) \left(p^S\right)^{1-\varepsilon} + \zeta_x n_x \left(p^N\right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{A.2}$$

where p^S denotes the price of out-of-patent goods. Using (A.1) and (A.2), the logarithm of the North's per-capita utility flow is given by

$$\begin{aligned}
\log\, u_1^N &= \left(\log \frac{E^N}{L^N}\right) - (\log\, P) \\
&= \left(\log\left(\frac{\varepsilon - 1}{\varepsilon - 1 + \gamma_x}\right) + \log\, p^N + \log\left(1 - \frac{a g_x}{L^N}\right)\right) \\
&\quad -\frac{1}{1-\varepsilon}\left(\log\, n_x + (1-\varepsilon)\log\, p^N + \log\left[(1-\zeta_x)\left(\frac{p^S}{p^N}\right)^{1-\varepsilon} + \zeta_x\right]\right) \\
&= \log\left(\frac{\varepsilon - 1}{\varepsilon - 1 + \gamma_x}\right) + \log\left(1 - \frac{a g_x}{L^N}\right) + \frac{1}{\varepsilon - 1}\log\, n_x \\
&\quad +\frac{1}{\varepsilon - 1}\log\left[(1-\zeta_x)\left(\frac{p^S}{p^N}\right)^{1-\varepsilon} + \zeta_x\right]
\end{aligned} \tag{A.3}$$

where n_x grows at the rate g_x of innovation. (A.3) yields equation (38) of the text.

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