BaylorBusiness
Hankamer School of Business

Working Paper Series

GLOBAL PATENT PROTECTION: CHANNELS OF NORTH & SOUTH WELFARE GAIN

Earl Grinols and Hwan C. Lin
Baylor University and University of North Carolina at Charlotte
Earl_Grinols@baylor.edu

2004-050-ECO

BAYLOR
UNIVERSITY

GLOBAL PATENT PROTECTION: CHANNELS OF NORTH & SOUTH WELFARE GAIN

By Earl Grinols* and Hwan C. Lin**

May 2004
Revised October 2004

Abstract

Much of the dynamic literature on intellectual property protection (IPP) arrays goods along a segment of the real line, one endpoint of which expands with innovation. A single margin of innovation brings computational clarity, but implies that the innovating region cannot reassign its research and development efforts among multiple sectors. This leads to special results. This paper expands innovation to two dimensions and re-examines the question of North and South intellectual property protection. The model includes many of the features of earlier models but predicts avenues of cooperation and mutual interest that were previously unavailable. For example, the South may benefit from equal or even higher standards of IPP protection than in the North, and it is possible that the North *gains* from differentially weaker IPP enforcement in the South. The source of the different conclusions is traced to different channels of welfare influence that support the findings. Monopoly power is less important in explaining them than resource shifting between innovation sectors. Key features not previously found include the ability of lower Southern IPP to spur innovation of Northern goods and to make available greater resources for Northern production of current consumption.

Key Words: Intellectual Property Protection, Innovation, Channels of Welfare, North, South.
JEL Classification: F13

---

*Department of Economics, Baylor University, One Bear Place #98003, Waco, Texas 76798-8003.

**Department of Economics, University of North Carolina at Charlotte, Charlotte, North Carolina 28223.

1 INTRODUCTION

The proper enforcement of intellectual property protection (IPP) depends on the effect that protection has on the market-driven dynamic processes of innovation and growth. These processes depend on rates of return to innovation and on forward-looking decisions by firms and households. The element of monopoly power is present because patented goods are granted government protection. A complete analysis of IPP, therefore, requires a dynamic setting and must consider channels of welfare influence due to the degree of monopoly power, the terms of trade, rates of innovation, and, if multiple innovation sectors are present, to resource allocation between them. To model dynamic innovation the literature on IPP developed models based on an ever-expanding unidimensional list of goods. In this world, a single margin of expansion is determined by the process of innovation. The framework was comprehensive enough to incorporate key features and of low enough dimensionality to be mathematically manageable. Many papers developed and worked from the unidimensional framework of Krugman (1979), Dollar (1986), Jensen and Thursby (1987), Romer (1990), and others.

One drawback of unidimensionality, however, is the reliance that it places on a single margin of innovation. When an innovating region, the North, and a non-innovating region, the South, are linked in trade and their consumption of the same linear array of goods, it is not possible for the North to adjust its innovation efforts in response to events in one region without simultaneously fixing the margin of innovation on goods for the other. This leads to special conclusions about the effects of IPP that are due to the model more than to the real trade environment. For example, the unidimensional model predicts that it necessarily disadvantages the South—which does not innovate and must pay higher prices for imported goods still under patent—to favor high standards of intellectual property rights protection when Southern firms can produce copied (pirated) products at lower prices than they can import them. We show in the present paper that relaxing the assumption of a one dimensional array of goods leads to the conclusion that the South can gain by higher intellectual property protection and that the North can often be *better off* if there is less, or even no, protection of intellectual property in the South. This latter feature does not derive from the oft remarked finding that the North can "overdo" its patent protection and that by reducing the degree of monopoly power it helps itself. It comes instead from the dynamic adjustment of resources from one margin of innovation to another and the implications that this has for Northern consumption. The contribution of this paper therefore is to make evident the presence of these different channels of welare influence in a fully articulated dynamic model that nests the earlier framework as a special case, but also expands to include a double margin of innovation.

Patent protection is dependent on enforcement effort in the market of purchase. A good that is under patent in one region of the world may find that another region tolerates its imitation and sale within its domestic market. In this paper, the non-innovating region enforces patent protection for some goods (x goods) but chooses to apply differential standards to infringements that affect goods more central to its interests (y goods). Imitators might be allowed to infringe patents on drugs used by Southern populations, for example, while patents for less critical products continue to be locally enforced. Thus the model consists of two regions, each of which selects a level of intellectual property protection. Certainly the South can enforce lower standards for y goods that are sold only in its market if it chooses. Would it ever want to enforce higher standards? We also examine this case in what follows. It is possible for the South to harm itself by unilateral lax enforcement of intellectual property rights, or, what is the same thing, to help itself by voluntarily adopting high or higher standards of IPP compared to the rest of the world.

A few previous papers have considered the issue of differential or asymmetric intellectual property protection across countries. Chin and Grossmam (1990) and Deardorf (1992) are interested in the efficiency incentives for extending northern levels of IPP to the rest of the world. They treat innovation as a one-time static decision, however, and so are not able to investigate intertemporal channels of welfare influence. Diwan and Rodrick (1991) emphasize the effect that different distributions of tastes for goods between regions has on the innovated goods mix and its utility to different regions. Their model is static, but has similarities in motivation to this paper to which we will return briefly in section 4. Grinols and Lin (1997) considered the separate choice of IPP by trade partners in a dynamic setting with two innovation sectors, but considered only the special case where the South drops all intellectual property protection. In Grinols and Lin (1997) the results are qualitatively similar to those found here. Grossman and Lai (2004) consider the case where both regions are capable of conducting innovation and imitation in a dynamic context. We will compare and contrast their findings in section 4. To our knowledge, the present paper is the only one that identifies channels of welfare influence with continuous choices of IPP by North and South that includes two sectors of innovation and intertemporal innovation.

In the remainder of the paper, Section 2 presents the elements of the model. Section 3 discusses the impact of asymmetric IPP on its solution in steady state, including the analysis of each region's optimal choice of IPP and the North-South Nash equilibrium in patent life. We find that it may be in the South's interest to offer more or less IPP than the North. Section 4 demonstrates that the effects found in steady state are present in transitional equilibria by solving the model for the case of a transitional welfare change starting from steady state where the South changes its level of IPP. The conclusions found in Section 3—for example that the North may gain from lower IPP in the South due to the effect of shifting resources between innovating sectors—are present when welfare along the transition path to steady state is taken into account. Section 5 concludes.

2 THE MODEL

Assume that a list of goods x are consumed in two regions, North and South, and are indexed from 0 to n_x. In addition, assume that there is a second set of goods y, indexed from 0 to n_y, that are special to the South and are consumed only there. The creation of new goods of either type takes place in the innovating North where they are initially produced under monopolistic conditions while "under patent." The probabilities, really hazard rates, that the market will learn to imitate a given patented good over the next instant are m_x and m_y. m_x is set by the North and m_y is set by the South. In each country, a higher level of intellectual property protection is associated with a lower hazard rate. The expected patent life for each type of good is therefore $1/m_x$ and $1/m_y$, respectively. Once a good is imitated, it is "out of patent." This means that its technology is commonly known. In our model, production of out-of-patent goods shifts to the non-innovating South where technology is the same, but the wage rate is lower. One unit of labor, the only factor, produces one unit of any product in either the North or the South.

The assumption, referred to in the introduction, that m_x is controlled in the North and m_y in the South requires further explanation to see why it is an object of particular interest in the present paper. The legal view of patents is that they embody legislatively set durations within which exclusive use of a product is granted to the patentee, after which exclusivity falls to zero and access is universal. In reality, patents, like contracts, are not all or nothing impositions. Every contract contains within it the implicit understanding that a party may choose to violate it if the damage caused by adhering to the contract becomes greatly out of proportion to the originally foreseen benefits of the agreement and the consequences of abrogation. Naturally penalties must be prescribed in law for contract violations. At the same time it is recognized that it is a cost-benefit decision whether the contract will be honored. Similarly, the firm's violation of a patent is a decision based on the relative benefits and costs, where costs include physical discovery costs regarding learning the secrets of production for the good in question, but also includes the expected costs of legal consequences. In this regard, one can imagine that a country might be less diligent to enforce patent laws on a local enterprise engaged in distributing a critical AIDS drug to its citizenry in violation of patent, when for other goods it does not feel the same need for exception. By selectively choosing the degree of diligence in enforcing international patent rules for y goods but not x, the South determines the effective degree of patent protection. The purpose of the present paper is to examine the case where the South is bound by its international agreements to the enforcement of patents (x goods), but because of its special position with respect to some goods chooses to "select" its own degree of patent enforcement for y goods. We show that it nevertheless is not necessarily the case that the South would therefore want to choose less stringent IPP. Further, it may not be in the North's interest that the South enforce high IPP standards on y goods. Understanding these features is the purpose of the present investigation.

Continuing with the model, utility in each region is given by

$$u(t) = \int_t^\infty e^{-\rho(s-t)} \log \eta(s) ds \tag{1}$$

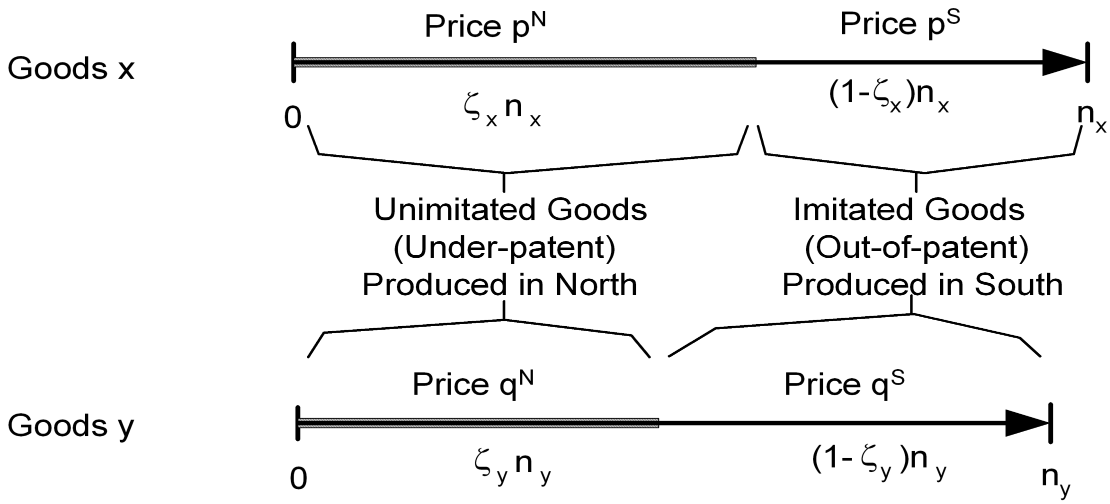
where ρ is the subjective discount rate and $\eta(s)$ is the flow of utility at time s given by

$$\eta^N(s) = C_x^N(s) \qquad \text{in the North, and} \tag{2}$$

$$\eta^S(s) = [C_x^S(s)]^b [C_y^S(s)]^{1-b} \qquad \text{in the South.} \tag{3}$$

b is a constant between zero and 1 that equals the share of Southern income spent on goods

Figure 1: Under-patent and Out-of-patent Goods



x, and C is a CES consumption index of goods x or y,

$$C_k = \left[\int_0^{n_k} c_k(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \qquad k = x, y, \quad \varepsilon > 1, \tag{4}$$

Constant ε is the price elasticity of demand.

Figure 1 describes the prices and availability of goods. Goods x have market prices p; goods y have market prices q. Superscript S refers to a good produced in the South; superscript N to a good produced in the North. The fractions of goods x and y that are under-patent are given by ζ_x and ζ_y, respectively. The shaded portion of the lines in Figure 1, therefore, represents the range of goods that are Northern-produced and under patent, while the goods further to the right are Southern-produced goods that are out of patent. In equilibrium the North sells some of its production (i.e. under-patent x goods) to Northern markets and some of its production (under-patent x and y goods) to Southern markets. The South similarly sells some of its output (out-of-patent x goods) to the North and some of its output (out-of-patent y goods) to the South.

The model has two dynamic processes. One describes the innovation of new goods and the other describes products leaving patent. The North devotes part of its labor force to innovating new products, increasing n_x at rate $\frac{\dot{n_x}}{n_x} \equiv g_x$ and n_y at rate $\frac{\dot{n_y}}{n_y} \equiv g_y$. This lengthens the lines in Figure 1. The margin of imitated goods also expands as more goods move from the in-patent state to the out-of-patent state.

2.1 The Static System

Given production of under-patent goods by the North and out-of-patent goods by the South, the fact that the two regions have the same demand structures means that the price of under-patent goods ultimately will be the same in the two regions, and similarly for the price of out-of-patent goods, $p^N(i) = p^N = q^N = q^N(j)$ and $p^S(i) = p^S = q^S = q^S(j)$ for $i \in [0, n_x]$ and $j \in [0, n_y]$. Formally, the demands for goods corresponding to CES utility (4) are

$$c_x^N(i) = \frac{1}{p(i)}\left(\frac{p(i)}{P}\right)^{1-\varepsilon} E^N \tag{5}$$

$$c_x^S(i) = \frac{1}{p(i)}\left(\frac{p(i)}{P}\right)^{1-\varepsilon} bE^S \tag{6}$$

$$c_y^S(j) = \frac{1}{q(j)}\left(\frac{q(j)}{Q}\right)^{1-\varepsilon} (1-b)E^S \tag{7}$$

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

$$\begin{aligned} P &= \left(\int_0^{n_x} p(i)^{1-\varepsilon} di\right)^{\frac{1}{1-\varepsilon}} \\ &= n_x^{\frac{1}{1-\varepsilon}}[(1-\zeta_x)(p^S)^{1-\varepsilon} + \zeta_x(p^N)^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}} \qquad (8) \\ Q &= n_y^{\frac{1}{1-\varepsilon}}[(1-\zeta_y)(q^S)^{1-\varepsilon} + \zeta_y(q^N)^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}}. \qquad (9) \end{aligned}$$

Profit maximization by monopolistic suppliers of each under-patent variety implies,

$$p^N = \frac{\varepsilon w^N}{\varepsilon - 1} \tag{10}$$

where w^N is the Northern wage rate. For each out-of-patent good,

$$p^S = w^S, \tag{11}$$

where wage rate w^S ($w^S < w^N$) applies in the South. Henceforth, we can drop reference to q^N, q^S since they equal p^N, p^S. As explained earlier, under-patent goods are not made in the South because the technology does not become known to Southern producers until the good is out of patent.

Because one unit of labor produces one unit of output, the number of units of labor input equals the quantity of output. We will show in the next section that $a(g_x + g_y)$ equals the number of units of labor devoted to innovation of goods x and y, where a is a constant that relates the use of labor in innovation activity to the innovation rates g_x, g_y. L^N is Northern labor supply, L^S is Southern labor supply. Equation (12) says that the amount of income in the North devoted to purchase of consumption goods equals the national income $p^N L^N$ less the cost of labor devoted to innovation. Equation (13) says that the amount the South spends on consumption goods equals Southern income $p^S L^S$.

$$E^N = p^N(L^N - ag_x - ag_y) \tag{12}$$

$$E^S = p^S L^S \tag{13}$$

The static system is closed by the market clearing condition that expenditure equals available income.

$$E^N = \left(\frac{p^N}{P}\right)^{1-\varepsilon} \zeta_x n_x(E^N + bE^S) + \left(\frac{p^N}{Q}\right)^{1-\varepsilon} \zeta_y n_y((1-b)E^S) \tag{14}$$

$$E^S = \left(\frac{p^S}{P}\right)^{1-\varepsilon} (1-\zeta_x)n_x(E^N + bE^S) + \left(\frac{p^S}{Q}\right)^{1-\varepsilon} (1-\zeta_y)n_y((1-b)E^S) \tag{15}$$

The first term on the right of (14) is the North's earnings from sale of under-patent x goods. The second term is the North's earnings from the sale of under-patent y goods. A similar interpretation for out-of-patent goods applies to equation (15) for the South. Either (14) or (15) is redundant by Walras' Law.

Equations (8)–(15) give seven independent relations in the eight unknown variables p^N, p^S, w^N, w^S, P, Q, E^N, E^S. Choosing $p^S = 1$ as numeraire, or, equivalently, solving for the terms of trade, $\tau \equiv p^N/p^S$, closes the system. We now turn to the determination of $\zeta_x, \zeta_y, g_x, g_y, n_x, n_y$ using the economy's dynamic equations.

2.2 Dynamics

Innovation uses L_k, $k = x, y$, labor hours to produce $\frac{1}{a} n_k L_k = \dot{n}_k$ new products per unit time where n_k is the cumulative stock of knowledge and a is a productivity parameter. This implies that the growth rate of new goods is given by $\frac{\dot{n}_k}{n_k} \equiv g_k = \frac{1}{a} L_k$. Thus, the total amount of labor devoted to innovation activity is $L_x + L_y = a(g_x + g_y)$ as stated in the previous section.

The amount of innovation depends on the market value of newly innovated products v_k, $k = x, y$. Innovation value must cover development costs, or innovation will be unprofitable, and cannot more than cover costs or demand for labor in the innovation sector would become unbounded. Thus $v_k \dot{n}_k - w^N L_k = 0$ or

$$v_k = \frac{w^N L_k}{\dot{n}_k} = \frac{w^N a}{n_k} \qquad k = x, y. \tag{16}$$

Equation (16) can be interpreted by saying that v_k equals the cost of getting one more patent. Using (10), operating profits from producing and selling a product under patent are

$$\pi_k = \frac{1}{\varepsilon} p^N k^N \qquad k = x, y \tag{17}$$

where $k^N = x^N$ or y^N is the quantity produced by the firm.[1] Operating profits are zero once imitation has occurred.

Assuming functioning capital markets, the return to a firm that operates over the instant dt is

$$\pi dt + (1 - m\,dt)\,\dot{v}\,dt - m\,dt\,v$$

where $\dot{v}\,dt$ is the capital gain to the firm if the firm is not imitated during the instant (the probability of being imitated is $m\,dt$) plus the loss in firm value if the firm is imitated. Against this return, the firm could sell its shares and earn $rv\,dt$ over the instant where r is the Northern interest rate. Dividing both terms by dt, and taking the limit as dt approaches zero implies $rv = \pi + \dot{v} - mv$ or

$$r = \frac{\pi_k}{v_k} + \frac{\dot{v}_k}{v_k} - m_k \qquad k = x, y. \tag{18}$$

From (10), (16), (17),

$$\begin{aligned} \frac{\dot{v}_k}{v_k} &= \frac{\dot{w}^N}{w^N} - \frac{\dot{n}_k}{n_k} = \frac{\dot{p}^N}{p^N} - g_k, \qquad \text{and} \\ \frac{\pi_k}{v_k} &= \frac{1}{a(\varepsilon - 1)} \frac{\gamma_k}{\zeta_k} \left(L^N - a(g_x + g_y)\right) \qquad k = x, y \end{aligned}$$

[1]We drop the variety identifiers since $x^N(i) = x^N$ for all i under patent. The same applies to $y^N(j)$.

where γ_x is defined as the fraction of non-research labor in the North devoted to production of under-patent goods x. Using the fact that $p^N x^N = (\frac{p^N}{P})^{1-\varepsilon}(E^N + bE^S)$,

$$\begin{aligned}
\gamma_x &\equiv \frac{\zeta_x n_x x^N}{L^N - a(g_x + g_y)}. \\
&= \left[1 + \frac{b}{\tau}\left(\frac{L^S}{L^N - a(g_x + g_y)}\right)\right]\left[\frac{\zeta_x}{(1-\zeta_x)\tau^{\varepsilon-1} + \zeta_x}\right] \equiv f_x(z) \qquad (19)
\end{aligned}$$

where z is a column vector of components $(\zeta_x, \zeta_y, g_x, g_y, \tau)$. The simplifying notation $f_x(z)$ for the right hand side of (19) will be used in equations (23) and (24) below. The share of non-research northern labor devoted to production of y goods is therefore $\gamma_y = 1 - \gamma_x$ and we define $f_y(z) \equiv 1 - f_x(z)$.

Differentiating (12) with respect to time and using the relation that expenditures by a Northern consumer with preferences given by (1), (2) and (4) satisfy $\dot{E}^N/E^N = r - \rho$ implies

$$r - \rho = \frac{\dot{p}^N}{p^N} - \frac{a(\dot{g}_x + \dot{g}_y)}{L^N - a(g_x + g_y)}. \qquad (20)$$

To solve for the model's dynamics, note that the measure of goods going out of patent over instant dt is given by $[(1-\zeta_k)\dot{n}_k - n_k\dot{\zeta}_k]\, dt$, from the time derivative of $(1-\zeta_k)n_k$, $k = x, y$. As a proportion of goods under patent, this gives $m_k = \frac{(1-\zeta_k)\dot{n}_k - n_k\dot{\zeta}_k}{\zeta_k n_k}$ or

$$\begin{aligned}
\dot{\zeta}_x &= g_x - (g_x + m_x)\zeta_x \qquad (21)\\
\dot{\zeta}_y &= g_y - (g_y + m_y)\zeta_y. \qquad (22)
\end{aligned}$$

Next, replace $\frac{\pi_k}{v_k}$ and $\frac{\dot{v}_k}{v_k}$ in (18). This gives two expressions for required profitability in the x and y sectors relative to the interest rate r. Using (20) to eliminate r, gives

$$\dot{g}_x + \dot{g}_y = \left[\frac{L^N}{a} - (g_x + g_y)\right]\left[\rho + g_k + m_k - \frac{1}{\varepsilon - 1}\left(\frac{L^N}{a} - (g_x + g_y)\right)\frac{f_k(z)}{\zeta_k}\right],\ k = x, y. \qquad (23)$$

and eliminating $\dot{g}_x + \dot{g}_y$ by setting the two expressions equal to one another implies,

$$0 = g_x - g_y + m_x - m_y - \frac{1}{\varepsilon - 1}\left(\frac{L^N}{a} - (g_x + g_y)\right)\left(\frac{f_x(z)}{\zeta_x} - \frac{(1 - f_x(z))}{\zeta_y}\right). \qquad (24)$$

Using (8) and (9) to replace P and Q in (14) and using (12) and (13) to replace E^N and E^S gives the final relation for the terms of trade, τ, in terms of the other variables $(\zeta_x, \zeta_y, g_x, g_y)$,

$$0 = \tau^\varepsilon - \left\{b\left[\frac{\zeta_x}{\zeta_y}\right] + (1-b)\left[\frac{(1-\zeta_x)\tau^{\varepsilon-1} + \zeta_x}{(1-\zeta_y)\tau^{\varepsilon-1} + \zeta_y}\right]\right\}\left[\frac{\zeta_y}{1-\zeta_x}\right]\left[\frac{L^S}{L^N - a(g_x + g_y)}\right]. \qquad (25)$$

Once τ is known, the rest of the static system follows from (8)-(15), recursively.

Equations (21), (22), (23) and the time derivatives of (24) and (25) are five linear relations in $(\dot{\zeta}_x, \dot{\zeta}_y, \dot{g}_x + \dot{g}_y, \dot{g}_x - \dot{g}_y, \dot{\tau})$. $g_x + g_y$ and $g_x - g_y$ are the logically equivalent dynamic variables to g_x, g_y. However, since we need g_x and g_y separately in computing Northern and Southern welfare, we solve for the autonomous system $\dot{z} = A(z)$ for column vector $z = (\zeta_x, \zeta_y, g_x, g_y, \tau)$, for which the local stability in steady state can be checked in terms of the Jacobian of $A(z)$.[2] Of the five variables, ζ_x, ζ_y are time-continuous state variables, while g_x, g_y, τ are jump variables.

3 STEADY STATE & THE CHOICE OF IPP REGIME

In section 2 we solved the model for intertemporal dynamics, characterized by equations (21)–(25), and static equilibrium, characterized by equations (8)–(15). We now examine the model for its implications regarding selection of the IPP regime in steady state. The main purpose is to show that once Northern innovations are differentiated for regional markets, the non-innovating region can surprisingly gain from enforcing a level of IPP higher than that of the innovating region. We also demonstrate that the North, in contrast, may gain from weaker IPP in the South. This result is explained in the next section using the decomposition of welfare introduced in this section.

---

[2]Let functions $a(z)$—$e(z)$ represent the right hand sides of equations (21)—(25), respectively, and let subscripts denote derivatives with respect to the elements of z. Then $A(z) = G(z)^{-1}H(z)$ where $G(z) = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ d_1(z) & d_2(z) & d_3(z) & d_4(z) & d_5(z) \\ e_1(z) & e_2(z) & e_3(z) & e_4(z) & e_5(z) \end{pmatrix}$ and $H(z) = \begin{pmatrix} a(z) \\ b(z) \\ c(z) \\ 0 \\ 0 \end{pmatrix}$. Local stability holds if the Jacobian of $A(z)$ at the steady state being examined z_0 has two or more eigenvalues with negative real parts, a condition which is satisfied by the model.

3.1 Welfare Decompositions

To begin, using the indirect utility function based on equations (1)–(4) we first derive the present value of per capita consumption for each region,

$$\begin{aligned} W^N &= \int_0^\infty e^{-\rho s}\left[\log \frac{E^N(s)}{L^N} - \log P(s)\right] ds \\ &= \int_0^\infty e^{-\rho s}\left[\log \frac{p^N(s)(L^N - ag_x(s) - ag_y(s))}{L^N} - \log P(s)\right] ds \\ &= \int_0^\infty \frac{e^{-\rho s}}{\varepsilon - 1}\left[\log\left(\zeta_x(s) + (1-\zeta_x(s))\left(\frac{p^N(s)}{p^S(s)}\right)^{\varepsilon-1}\right) + \log n_x(s)\right] ds + \\ &\quad \int_0^\infty e^{-\rho s} \log\left[1 - \frac{ag_x(s) + ag_y(s)}{L^N}\right] ds, \end{aligned} \tag{26}$$

$$\begin{aligned} W^S &= \int_0^\infty e^{-\rho s} b\left[\log \frac{bE^S(s)}{L^S} - \log P(s)\right] ds + \int_0^\infty e^{-\rho s}(1-b)\left[\log \frac{(1-b)E^S(s)}{L^S} - \log Q(s)\right] ds \\ &= \int_0^\infty \frac{e^{-\rho s}}{\varepsilon - 1} b\left[\log\left(\zeta_x(s)\left(\frac{p^S(s)}{p^N(s)}\right)^{\varepsilon-1} + 1 - \zeta_x(s)\right) + \log n_x(s)\right] ds + \\ &\quad \int_0^\infty \frac{e^{-\rho s}}{\varepsilon - 1}(1-b)\left[\log\left(\zeta_y(s)\left(\frac{p^S(s)}{p^N(s)}\right)^{\varepsilon-1} + 1 - \zeta_y(s)\right) + \log n_y(s)\right] ds \\ &\quad + \frac{1}{\rho}\log[b^b(1-b)^{(1-b)}]. \end{aligned} \tag{27}$$

According to (27), the South favors higher growth rates g_y, g_x that raise $n_x(s), n_y(s)$, improved terms of trade (i.e. $\tau = p^N/p^S$ lower), and reduced share of goods under patent ζ_x, ζ_y.

Equations (21)—(25) with $\dot{\zeta}_y, \dot{\zeta}_x, \dot{g}_y, \dot{g}_x$ set to zero determine steady state. Table 1 solves the model starting from a symmetrical economy where the expected patent life is 20 years for both North and South, $g_x = g_y$, and $\zeta_x = \zeta_y$.

We run two experiments: a uniform one percent reduction of expected patent life from 20 years to 19.8 years by North and South, and a unilateral one percent reduction of patent life by the South only. A uniform reduction in patent life leads to an improvement in Southern terms of trade (τ falls), reduction in the share of y goods under patent (ζ_y falls), increase in the innovation rate for y goods (g_y rises,) and an increase in Southern welfare.[3]

[3]This steady-state welfare result is similar to Helpman (1993, Theorem 1). But here we show that the

Table 1: **Steady State Southern and Northern Welfare with Differential IPP**

Expected Patent Life (Years) North	Expected Patent Life (Years) South	b	ζ_y	ζ_x	g_y	g_x	W^S	W^N	w^N/w^S	Terms of Trade τ
20	20	0	76.37	76.37	16.16	16.16	770.4	790.0	1.198	1.797
19.8	19.8		76.25	76.12	16.22	16.10	773.6	787.2	1.194	1.791
20	19.8		76.12	76.43	16.10	16.21	767.9	792.7	1.196	1.795
20	20	.25	60.04	83.26	7.51	24.87	561.9	1219.9	1.195	1.792
19.8	19.8		59.90	83.10	7.54	24.84	562.9	1218.4	1.191	1.786
20	19.8		59.58	83.30	7.44	24.94	560.5	1223.4	1.193	1.789
20	20	.50	$4.7\ 10^{-8}$	86.76	$2.3\ 10^{-9}$	32.76	795.8	1611.2	1.206	1.810
19.8	19.8		$5.9\ 10^{-8}$	86.64	$3.0\ 10^{-9}$	32.76	796.0	1611.3	1.202	1.804
20	19.8		$2.2\ 10^{-8}$	86.76	$1.1\ 10^{-9}$	32.76	795.8	1611.2	1.206	1.810
20	20	1.00	0.0	86.76	0.0	32.76	1577.4	1620.2	1.520	2.280
19.8	19.8		0.0	86.64	0.0	32.76	1577.8	1620.2	1.515	2.272
20	19.8		0.0	86.76	0.0	32.76	1577.4	1620.2	1.520	2.280

Notes: 1. $1/m_x$ = Expected Northern patent life in years;
$1/m_y$ = Expected Southern patent life in years.
2. $L^N = 1, L^S = 1.2167, \rho = .01, a = 1, \varepsilon = 3$. $\zeta_x, \zeta_y, g_y, g_x$ are in percent.
3. The terms of trade is proportional to the relative wage: $\tau = \frac{\varepsilon}{\varepsilon - 1}\ w^N/w^S$

This might seem to imply that the South would benefit by enforcing lower intellectual property rights standards than the North, and that the North would be harmed. Such a conclusion is false. When y goods are important to Southern consumption and Northern innovation of y goods is viable—for example when $b = 0, .25$ or $.50$—Table 1 shows that unilateral reduction of patent life in the South improves Southern terms of trade and lowers the share of y goods under patent, but diminishes innovation of new goods, and causes a *reduction* in Southern welfare. It is equally interesting that Northern welfare rises!

To further investigate the source of these outcomes, let subscripts $0, 1$ denote initial and final values, respectively, and decompose the change in welfare from an initial steady state

result can be carried over to a North-South model with regionally differentiated innovations, provided a uniform IPP level is enforced worldwide.

into its economic components. In steady state, $n_k(s) = n_k(0)e^{g_k(0)s}$, $\zeta_k(s) = \zeta_k(0)$, for $k = x, y$, and $p^N(s)/p^S(s) = p_0^N/p_0^S$. Subtracting W_0^N from (26) yields,

$$\begin{aligned} \Delta W^N &= W_1^N - W_0^N \\ &= \Delta^N_{Prod.-availability} + \Delta^N_{Terms-of-Trade} + \Delta^N_{Mkt-power} + \Delta^N_{Saving} \end{aligned} \quad (28)$$

where

$$\begin{aligned} \Delta^N_{Prod.-availability} &= \int_0^\infty \frac{e^{-\rho t}}{\varepsilon - 1}(g_x(s) - g_x(0))sds \\ \Delta^N_{Terms-of-trade} &= \int_0^\infty \frac{e^{-\rho t}}{\varepsilon - 1} \log \left[\frac{\zeta_x(0) + (1 - \zeta_x(0)) \left(\frac{p_1^N(s)}{p_1^S(s)} \right)^{\varepsilon - 1}}{\zeta_x(0) + (1 - \zeta_x(0)) \left(\frac{p_0^N}{p_0^S} \right)^{\varepsilon - 1}} \right] ds \\ \Delta^N_{Mkt-power} &= \int_0^\infty \frac{e^{-\rho t}}{\varepsilon - 1} \log \left[\frac{\zeta_x(s) + (1 - \zeta_x(s)) \left(\frac{p_1^N(s)}{p_1^S(s)} \right)^{\varepsilon - 1}}{\zeta_x(0) + (1 - \zeta_x(0)) \left(\frac{p_1^N(s)}{p_1^S(s)} \right)^{\varepsilon - 1}} \right] ds \\ \Delta^N_{Saving} &= \int_0^\infty e^{-\rho s} \log \left[\frac{1 - a(g_x(s) + g_y(s))/L^N}{1 - a(g_x(0) + g_y(0))/L^N} \right] ds. \end{aligned}$$

Inspection of each term reveals under what conditions it is positive or negative. The sign of the product availability term is negative if $g_x(t) < g_x(0)$. The terms-of-trade term is always negative if $p_1^N(s)/p_1^S(s) < p_0^N/p_0^S$. It measures change in welfare due to changed terms-of-trade that the North faces. 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*, $\zeta_x(s) > \zeta_x(0)$. The final saving term is negative if $ag_x(s) + ag_y(s) > ag_x(0) + ag_y(0)$. 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 devoted to innovation than to production of consumption goods. Increased innovation therefore diminishes current consumption.

For the South,

$$\begin{aligned} \Delta W^S &= W_1^S - W_0^S \\ &= \Delta^S_{Prod.-availability} + \Delta^S_{Terms-of-Trade} + \Delta^S_{Mkt-power} \end{aligned} \quad (29)$$

where

$$\Delta^S_{Prod.-availability} = \int_0^\infty \frac{e^{-\rho s}}{\varepsilon - 1} \left[b(g_x(s) - g_x(0)) + (1 - b)(g_y(s) - g_y(0)) \right] sds$$

$$
\begin{aligned}
\Delta^S_{Terms-of-trade} &= b\int_0^\infty \frac{e^{-\rho s}}{\varepsilon-1}\log\left[\frac{\zeta_x(0)\left(\frac{p_1^S(s)}{p_1^N(s)}\right)^{\varepsilon-1}+1-\zeta_x(0)}{\zeta_x(0)\left(\frac{p_0^S}{p_0^N}\right)^{\varepsilon-1}+1-\zeta_x(0)}\right]ds \\
&\quad + (1-b)\int_0^\infty \frac{e^{-\rho s}}{\varepsilon-1}\log\left[\frac{\zeta_y(0)\left(\frac{p_1^S(s)}{p_1^N(s)}\right)^{\varepsilon-1}+1-\zeta_y(0)}{\zeta_y(0)\left(\frac{p_0^S}{p_0^N}\right)^{\varepsilon-1}+1-\zeta_y(0)}\right]ds \\
\Delta^S_{Mkt-power} &= b\int_0^\infty \frac{e^{-\rho s}}{\varepsilon-1}\log\left[\frac{\zeta_x(s)\left(\frac{p_1^S(s)}{p_1^N(s)}\right)^{\varepsilon-1}+1-\zeta_x(s)}{\zeta_x(0)\left(\frac{p_1^S(s)}{p_1^N(s)}\right)^{\varepsilon-1}+1-\zeta_x(0)}\right]ds \\
&\quad + (1-b)\int_0^\infty \frac{e^{-\rho s}}{\varepsilon-1}\log\left[\frac{\zeta_y(s)\left(\frac{p_1^S(s)}{p_1^N(s)}\right)^{\varepsilon-1}+1-\zeta_y(s)}{\zeta_y(0)\left(\frac{p_1^S(s)}{p_1^N(s)}\right)^{\varepsilon-1}+1-\zeta_y(0)}\right]ds.
\end{aligned}
$$

Changes in the terms of trade affect the South in the opposite direction than they do the North. Southern welfare differs from the North's in two other ways. Southern welfare depends on a weighted average of effects operating through x goods and y goods with weights b and $1-b$, and, since the South does not devote labor to investment in innovation, the savings term is absent.

Table 2 displays the decomposition of Southern welfare change for the first three rows of Table 1 into the product availability gain which shows the benefit to the South of a higher growth rate of innovated goods y, terms of trade gains, and market power gain which has to do with the share of goods that are under patent at any one time. Reducing patent protection provides an improvement in welfare related to market power for either of the alternatives in Table 2 because the degree of monopoly in goods y is diminished. Also, as we expect, the South's terms of trade are improved by less IPP. However, these gains are swamped by the loss in product availability in the case when the South unilaterally lowers IPP. It follows that the South harms itself by lower IPP in this example.

Table 1 showed that less enforcement of intellectual property rights in the South than in the North can raise Northern steady state welfare. We postpone a decomposition of Northern welfare in a fashion similar to Table 2 to the next section where we show that the same conclusions found in steady state apply in the transition from one steady state to another. Verifying that the economic effects on North and South of differential IPP

Table 2: **Decomposition of Change in Southern Welfare**

Expected Patent Life (Years) North	Expected Patent Life (Years) South	Product Availability Gain	Terms of Trade Gain	Market Power Gain	Total Welfare Change
20	20	0	0	0	0
19.8	19.8	2.97	.166	.084	3.2
20	19.8	-2.79	.083	.178	-2.5

Note: The change in welfare is measured compared to line 1 in Table 1.

enforcement are not just an artifact of the transition to steady state only or of steady state only, but are found in the former and can persist in the latter is important information about the nature of the avenues of welfare impact. We conclude this section by providing an example where the South and North optimally select their IPP levels.

3.2 Optimal IPP

We now consider a more flexible version of our model that allows each of the two countries to optimally set imitation rates for the two goods. In selecting the optimal level of IPP, some recognition of enforcement costs must play a role to avoid the unrealistic implication that higher levels of IPP are as easy to provide as none. Since we have a greater focus on Southern IPP interests, we consider the South first. Stricter IPP induces more resources to be devoted to the innovation of Southern goods, but incurs real costs to the South. In our model, the only input is labor, hence real enforcement costs must be reflected in labor. We assume, therefore, that the share of labor in the South devoted to IPP strictly rises with increases in expected patent life. This assumption guarantees that some labor must be devoted to IPP enforcement. The remaining labor $\widetilde{L}^S$ for use in production is,

$$\widetilde{L}^S = L^S e^{-\Theta_y/\mu}$$

where Θ_y (=$1/m_y$) is expected patent life, and $\mu$is a positive free parameter. Effective labor supply decreases as more resources are directed toward non-productive use.

We do not need to adjust the earlier equations of static and dynamic equilibrium in Sections 2, 3.1, and 3.2, except to replace L^S with $\widetilde{L^S}$ and to note that Southern welfare per capita reflects the loss of resources arising from IPP enforcement. Revised W^S becomes,[4]

$$W^S = \frac{\log[b^b(1-b)^{1-b}]}{\rho} + \sum_{k=x,y} b_k \int_0^\infty \frac{e^{-\rho s}}{\varepsilon - 1} \left[\log\left(\zeta_k(s)\tau(s)^{1-\varepsilon} + 1 - \zeta_k(s)\right) + \log n_k(s) + \log e^{-\Theta_k/\mu}\right] ds$$

where $b_k = b$ if $k = x$ and $b_k = 1 - b$ if $k = y$. This equation reduces to

$$W^S = \frac{1}{\rho(\varepsilon - 1)} \sum_{k=x,y} b_k \left[\log\left(\zeta_k \tau^{1-\varepsilon} + 1 - \zeta_k\right) + \frac{g_k}{\rho} - \frac{(\varepsilon - 1)\Theta_k}{\mu}\right] + \frac{\log[b^b(1-b)^{1-b}]}{\rho}$$

in steady state. Stronger IPP affects welfare directly through $\frac{\Theta_y}{\mu}$, as well as indirectly through its effects on ζ_k, τ, and g_k, $k = x, y$.

Solving the model for different values of Southern patent life, assuming northern patent life of 20 years, results in Table 3. Southern welfare is highest when it selects a patent life of $\Theta_y = 22$ or 28.5 years—in both cases, higher protection than offered in the North. Thus, there is no general presumption that lower IPP standards than in the North are necessarily in the South's best interest. Further, in the former case the terms of trade improve for the South (τ falls from 1.809 to 1.805) and growth of y good falls, while in the latter case the terms of trade deteriorate (1.803 to 1.806) and growth of y rises. Thus, the South must consult all of the components of (29) that determine its circumstances and optimal IPP. It is not hard to show that if μ is sufficiently small, the reverse case can occur where the optimal level of Southern IPP is lower than in the North. The lower optimal patent life in the upper panel of Table 3 (22 years) can be explained as follows. As y goods becomes more important to Southern consumption, keeping them under patent with higher prices for long periods becomes a greater burden on consumption so the optimal patent life diminishes.

[4] Per worker spending $\frac{E^S}{L^S}$ now equals $\frac{p^S \widetilde{L^S}}{L^S}$ instead of $\frac{p^S L^S}{L^S}$ $(= p^S)$; see equation (27).

Table 3: **Optimal IPP Enforcement in Steady State: South**

b	Patent Life (Years) North	Patent Life (Years) South	ζ_y	ζ_x	g_y	g_x	W^S	W^N	$\frac{w^N}{w^S}$	Terms of Trade τ
0	20	24	79.7	76.1	16.4	15.9	737.3	779.8	1.206	1.809
	20	22*	78.2	76.2	16.3	16.0	738.7*	783.3	1.204	1.805
	20	20	76.4	76.4	16.2	16.2	737.1	790.0	1.198	1.797
	20	30	72.9	82.4	8.8	23.3	484.7	1144.3	1.202	1.803
.25	20	28.5*	71.6	82.4	8.9	23.5	485.0*	1150.3	1.204	1.806
	20	24	66.6	82.8	8.3	24.0	481.8	1178.8	1.204	1.805

Notes: 1. Asterisk (*) indicates the optimal Southern expected patent life ($1/m_y$) in years.
2. $L^N = 1, L^S = 1.69808, \mu = 60, \rho = .01, a = 1, \varepsilon = 3$. These values match Table 1 because the implied effective labor supply is $\tilde{L}^S = 1.2167$. Expected Northern patent life is assumed to be fixed at 20 years. $\zeta_x, \zeta_y, g_y, g_x$ are in percent.

If patent life is optimally chosen by the North, would it still be possible that the South prefers higher protection?[5] Consider the Nash equilibrium that results when both the North and South optimally select their levels of IPP. As before assume that L^N for use in production is replaced by $\widetilde{L}^N = L^N e^{-\Theta_x/\mu}$ where Θ_x (=$1/m_x$) is expected patent life. Welfare for the North becomes

$$W^N = \frac{1}{\rho(\varepsilon-1)}\left[\log\left(\zeta_x + (1-\zeta_x)\tau^{\varepsilon-1}\right) + \frac{g_x}{\rho}\right] + \frac{1}{\rho}\log\left[e^{-\frac{\Theta_x}{\mu}} - \frac{ag_x + ag_y}{L^N}\right].^{6}$$

Table 4 shows the resulting reaction curves in Θ_x and Θ_y and displayed as Figure 2 for the case of $b = .25$. Equilibrium is stable if the slope of the South's reaction curve is smaller than that of the North's in absolute value, a condition that is satisfied by the model.

The South's optimal selection of patent life in Nash equilibrium is higher than the North's in both cases: 24.5 years compared to the North's 23.1 in one, and 28.85 years to the North's 20.67 in the other. The comparative statics can be seen in Figure 2 where the North and South's reaction curves are drawn. Nash equilibrium is point e which lies above the 45 degree line (South has higher patent protection than in the North). We can also consider cases at other points such as a, b, c. At point a both North and South have 20 year patent lives. A

[5]We thank the referee for suggesting this question.

[6]As before, per worker spending $\frac{E^N}{L^N}$ now equals $\frac{p^N\widetilde{L^N}}{L^N}$ instead of $\frac{p^N L^N}{L^N}$ ($= p^N$); see equation (26).

Table 4: North and South's Optimal Patent Life Response (Years)

b=0	Θ_x	15	20	23.10*	25	30	35	40
	South's Response	20.3	22.0	24.50*	23.2	24	24.6	25.2
	Θ_y	15	20	24.50*	25	30	35	40
	North's Response	25.1	25	23.10*	24.3	23	21.8	20.6
b= 0.25	Θ_x	15	20	20.67*	25	30	35	40
	South's Response	26.3	28.6	28.85*	30.3	31.6	32.5	33.1
	Θ_y	15	20	25	28.85*	30	35	40
	North's Response	23.1	22.7	21.7	20.67*	20.4	19	17.7

Notes: Use the same set of parameter values as Table 3. Asterisk (*) indicates Nash equilibrium values.

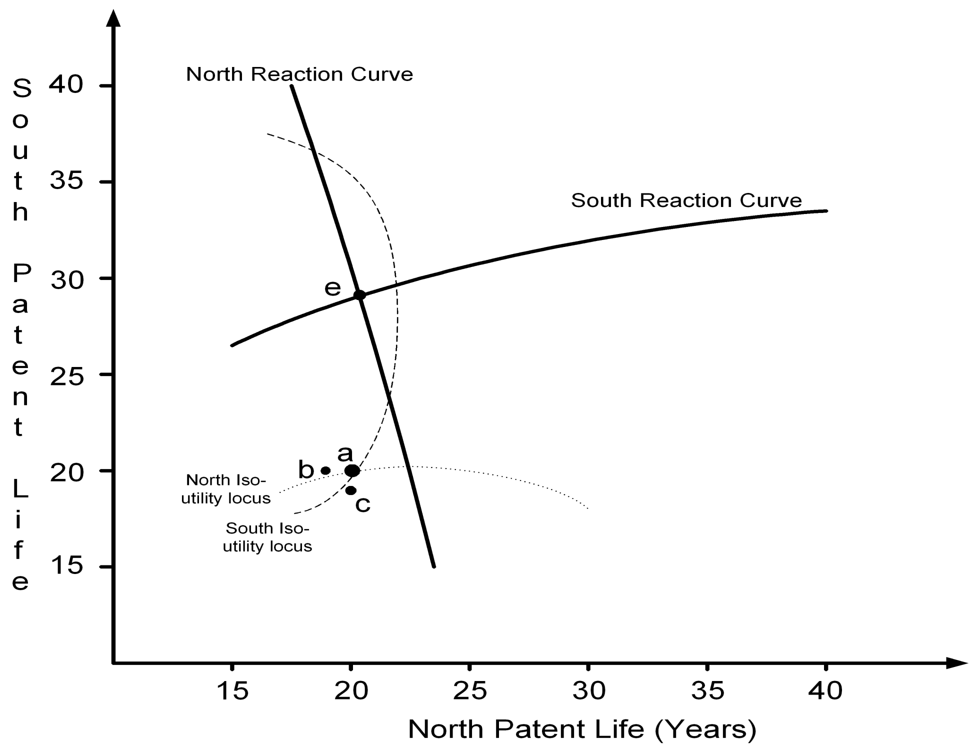
reduction in patent life by the North moves equilibrium from point a to b, which lies to the left of the North's iso-utility curve and therefore lowers Northern welfare while helping the South. The unilateral reduction in Southern patent protection which moves a to c does the reverse. In this case the North gains from lower IPP in the South which we have already discussed in terms of Table 1.

Neither region wants patent protection that is too high because it implies that goods are monopolistically supplied for periods that are too long. As we have discussed in section 3.1, the natural refinement to Figure 2 involves decomposing the welfare change into its component parts and evaluating the relevant effects on terms of trade, product availability, market power, and, for the North, innovation effects.

4 WELFARE IN TRANSITION TO STEADY STATE

In this section we provide information about Northern and Southern welfare in the transition to steady state. We find the same channels of welfare influence in operation as described in Section 3. We base the analysis of transitional dynamics on the same set of parameter values we have used for Tables 1 and 2. But here the analysis is confined to the specific case of b = 0.25. Initially, we assume that the South has laxer protection of intellectual property (with expected patent life $1/m_y$ = 19.8 years) than the North (with expected patent life

Figure 2: Nash Equilibrium in Patent Life



$1/m_x = 20$ years). We then perturb the initial steady state by increasing IPP in the South from $1/m_y = 19.8$ years to $1/m_y = 20$ years and follow the transitional dynamics. Therefore, the third row of the second panel of Table 1 corresponds to the initial steady state of our transitional dynamics experiments and the first row of it corresponds to the new steady state. The earlier conclusion from the steady-state analysis of Section 3.1 that the North may be harmed and the South may be helped by increased IPP in the South continues to apply when transitional welfare effects are considered. In the appendix we briefly describe how we solved the dynamic system.

4.1 Raising Southern IPP and Transitional Dynamics

The time paths of $\zeta_x(t)$ and $g_x(t)$ can be determined from $z(t) = (\zeta_x(t), \zeta_y(t), g_x(t), g_y(t), \tau(t))$ starting from $t = 0$ when the South unilaterally increases $1/m_y$. After the South raises its IPP standard, the share of x goods monopolistically supplied ($\zeta_x(t)$) falls continuously to its new steady-state level. The share of y goods monopolistically supplied ($\zeta_y(t)$) likewise can be shown to rise continuously to a higher steady-state level. The innovation rate of x goods, however, takes an initial jump downward at time 0, thereafter falling continuously to a lower steady state level. The innovation rate of y goods does the reverse, jumping up at time 0 and rising continuously thereafter to a higher steady state level. The behavior of Northern innovation in x goods is significant. It indicates that lower IPP in the South is often associated with a shift of resources from one innovation margin (in this case y goods) to another (x goods) that may represent a welfare gain to Northern welfare. This avenue of welfare advantage is distinct from channels that operate through Northern market (monopoly) power and through the terms of trade. The change in g_x occurs through a reassignment of innovation effort to the x sector when y goods receive different protection. Here, by working the experiment in reverse, we see that reduced IPP in the South diminishes innovation in y goods, but shifts resources to x innovation. In the forward direction of the experiment, unilateral tightening of Southern IPP encourages Northern resources to migrate from the x-goods sector to the y-goods sector, not only in manufacturing activity but also in innovative activity.

The finding in transition to steady state that raising IPP in the South spurs innovation in the North for Southern goods and weakens innovation in the North for Northern goods is consistent with the earlier steady-state analysis (see Table 1), but is missing in the IPP-innovation-growth literature. Finally, raising IPP in the South worsens the South's term of trade as have seen in our steady-state analysis. The terms of trade jump upward at time 0 and rise continuously to its new steady state level. This harms the South and benefits the North. The effects on innovation mentioned above help the South but harm the North. How these channels combine to impact each region in the short-term and long-term is the next focus.

4.2 Channels of Welfare Change and Transitional Dynamics

To compare welfare, we substitute the time paths of $\zeta_x(t), \zeta_y(t), g_x(t), g_y(t)$ and $\tau(t)$ for $t \geq 0$ into $W(t)$ and $dW(t)/dt$ based on equations (26) and (27). $W(t)$ is the integral (26) with the upper limit replaced by time t. Thus, for each region $dW(t)/dt$ measures the present value of the instantaneous flow of utility per capita at time t and $W(t)$ measures the present value of future utility per capita for utility from time 0 out to time t. For each welfare measure and region, we then compute the difference between two trajectories. One trajectory is the initial steady state and the other is the trajectory to the new steady state. A positive difference means that there is an increase in the present value of future instantaneous utility or the present value of future utility from time 0 to time t. The results are reported in Table 5.

Table 5: Welfare Comparisons in Transition

Time	Change in Instantaneous Utility $\Delta(dW^S/dt)$	Change in PV of Utility Summed Over Time 0—t ΔW^S	Change in Instantaneous Utility $\Delta(dW^N/dt)$	Change in PV of Utility Summed Over Time 0—t ΔW^N
0	−0.000043	0.00000	−0.00033	0.00000
4	−0.00033	−0.00090	−0.00054	−0.00148
8	−0.00025	−0.00217	−0.00132	−0.00510
12	−0.00001	−0.00271	−0.00236	−0.01243
16	0.00038	−0.00195	−0.00346	−0.02408
20	0.00079	0.00039	−0.00454	−0.04010
50	0.00350	0.06816	−0.01016	−0.27164
100	0.00521	0.29778	−0.01277	−0.86832
500	0.00055	1.37034	−0.00120	−3.31622

These results indicate two important points. First, the North would prefer that the South maintain lower intellectual property protection than itself. A unilateral increase in IPP in the South reduces Northern welfare uniformly along the transition to the new steady state. A decomposition of the North's welfare (see Table 5) reveals that this loss to the North is primarily due to the worsened product availability in the North when better Southern IPP draws resources into the y innovation sector and out of the x sector. This effect is roughly ten times the effect due to changes in the terms of trade and in Northern market power. This channel of welfare influence can arise, as it does here, when there are multiple innovation margins or sectors present. The traditional monopoly power and terms-of-trade channels of welfare influence are also present—the terms-of-trade effect is welfare improving for the North in this case—but they are outweighed by the adverse innovation sectoral effects that work

Table 6: Decomposition of Northern Welfare in Transition: $\Delta W^N \times 10^3$ Evaluated from Time t = 0 to 50.

Product Availability	Term of Trade	Market Power	Saving	Total
-300.40	21.19	9.49	-1.93	-271.64

against the innovating North. Instantaneous welfare $dW^S(t)/dt$ in the South is worse off in the short run due to the harmful terms of trade effect of its higher IPP. Southern utility turns positive in the future due to increased innovation and greater product availability. According to Table 4, the South suffers welfare losses until the twelfth year [at t =12, $\Delta dW^S(t)/dt$ turns positive for the first time]. Not until 8 more years have passed and the present value of 20 years of utility have been realized, does the South's gains exceed the initial utility losses.

Our findings are consistent with others such as Diwan and Rodrik (1991) who have also suggested that the South tends to benefit from enforcing high levels of IPP when the country stands to gain on the consumption side from new inventions. We confirm their result in a dynamic context, though not all of their conclusions carry over. For example, Diwan and Rodrik found that an increase in the relative size of the Southern market affects innovation in the same fashion as an increase in Southern protection. In our model, a larger South leads to higher g_y, but in a different fashion than changing m_y. They also find that world welfare is maximized with equal protection rates which does not carry over to our model.

We can also compare and contrast our results to Grossman and Lai's (2002) (GL) dynamic model of the choice of IPP by two regions. Obvious differences are that GL allow goods to become obsolete over time whereas goods are long-lived in the present setting. More importantly for interpretation of results, however, is that GL allow both economies to innovate, while this paper emphasizes dynamic innovation of goods to meet international preference differences. In a non-cooperative game, GL find that the economy with the lesser ability to innovate grants a shorter patent life than the economy with the greater ability. This does not carry over into our model because there are multiple sectors of innovation and therefore different avenues through which patent life affects the non-innovating South's interests. In our model, the South cannot "free ride" on the North's need to innovate y goods for itself, but must select patent protection to induce the rate of flow of new goods that is best for itself when balanced against their monopoly provision price and the range of goods subject to monopoly market structure. These are the three channels of welfare influence identified in section 3. The influence on Northern welfare operating through the resource shifting effect between x innovation and current production on one hand, and innovation of y goods for foreign sale on the other has no counterpart in a model with a single set of x goods being innovated. The two models therefore emphasize different features which explains their different results.

5 SUMMARY AND EVALUATIVE DISCUSSION

The dilemma between protecting intellectual property rights to induce future innovation or allowing fuller disemmination 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. The North and South have a common interest in selecting IPP that is not too strict because 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 as suggested here is significant because self-interest is a powerful motivating force in working toward international cooperation.

This paper examined the welfare consequences of enforcement of intellectual property rights standards in the South in a dynamic context where savings-investment rates and growth rates are endogenously determined by forward looking agents, starting from a regime of symmetrical IPP enforcement by both North and South. 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, leading to welfare losses to the South. The South's interests dictate that its optimal IPP could be higher or lower than in the North. This result augments standard conclusions derived in a setting where there is a one dimensional class of goods consumed by North and South.

We also evaluated the effect of lower Southern IPP on Northern welfare. 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. We found instead that Northern innovation could be higher or lower after the regime switch, and Northern welfare might rise both in steady state and in transition to steady state due to the beneficial effects of the freeing of resources previously devoted to innovating Southern goods and the increased innovation of Northern products after the regime switch.

The impact on Northern welfare operated through four channels. Northern welfare was most affected by a shifting of resources between innovation sectors leading to a different rate of innovation of Northern goods and a different set of products in the future. To a lesser extent, 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 frpm monopoly to perfect competition in provision raised Northern welfare by eliminating monopoly inefficiencies. Finally, Northern welfare was helped by a saving effect, meaning the releasing of resources to other Northern assignments that were previously devoted to innovating.

There appear to be two main lessons. First, moving beyond unidimensionality in innovated goods is a key aspect of the innovation process. Failure to provide IPP may lead to consequences that fall more heavily on one sector or country than another. That country can be North or South. While a dynamic model with multiple innovation sectors is often more computationally intensive, we believe that its insights are necessary to a complete understanding of the international ramifications of intellectual property protection. Failure to provide IPP 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 second lesson is that the paradoxical case where Northern welfare rises with lower Southern IPP is possible. The paradox was explained in terms of the channels of welfare ionfluence examined here. One unanticipated result of the analysis was the finding that the transfer of resources from innovation in one sector to innovation in another or to production of current consumer goods is a major consideration in the proper evaluation of intellectual property rights protection.

Appendix: Derivation of dynamic system in the case where the South raises IPP

Fist, we derived the nonlinear autonomous system, $\dot{z}(t) = A(z(t))$ with $z(t) = (\zeta_x(t), \zeta_y(t), g_x(t), g_y(t), \tau(t))$, from equations (21) - (25). See footnote 2 for the procedure for deriving the system from (21)-(25). We used Mathematica command $D[\cdot, \cdot]$ to simplify the tedious derivations. We then linearized the system by forming the Jacobian $\frac{\partial A(z(t))}{\partial z(t)}$ evaluated at the steady state $\bar{z} = (\bar{\zeta}_x, \bar{\zeta}_y, \bar{g}_x, \bar{g}_y, \bar{\tau})$ associated with $1/m_y = 1/m_x = 20$ years. We solved the system to obtain closed-form solutions for the time paths of $z(t)^T = \sum_{i=1}^{5} \nu_i \cdot c_i e^{\lambda_i t} + \bar{z}^T$ for $t \,\epsilon\, [0, \infty)$ where T represents the transpose of a row vector. $(\lambda_1, \lambda_2, ..., \lambda_5)$ are the eigenvalues of the Jacobian, all distinct real roots $(-.2815, -.1000, -5.8156 * 10^{-17}, -7.9047 * 10^{-18}, .5862)$. ν_i is the eigenvector corresponding to λ_i, and c_i's are the coefficients to be determined. Both eigenvalues and eigenvectors were computed using Mathematica command Eigensystem$[\cdot, \cdot]$ and were rounded up. Since the system has a saddle point $(\lambda_5 > 0 > \lambda_1, \lambda_2, \lambda_3, \lambda_4)$, we set c_5 equal to zero to ensure that the system stays on its stable manifold. We uniquely solved for the four coefficients c_1, c_2, c_3, c_4 using the two initial value conditions given by $(\zeta_x(0), \zeta_y(0)$ which are predetermined, and two other nonlinear constraints represented by equations (24) and (25) which hold in transition and in steady state.

References

Chin, Judith C., and Gene M. Grossman (1990). "Intellectual Property Rights and North-South Trade," in *The Political Economy of International Trade: Essays in Honor of Robert E. Baldwin*, ed. by Ronald W. Jones and Anne O. Krueger. Cambridge, MA: Basil Blackwell.

Deardorff, Alan V. (1992). "Welfare Effects of Global Patent Protection," *Economica*, 59, 35-51.

Diwan, Ishac, and Dani Rodrik (1991). "Patents, Appropriate Technology, and North-South Trade," *Journal of International Economics*, 30, 27-47.

Dollar, David (1986). "Technological Innovation, Capital Mobility, and Product Cycle in North-South Trade," *American Economic Review*, 76, 177-190.

Grinols, Earl L. and Hwan C. Lin (1997). "Asymmetric Intellectual Property Rights Protection and North-South Welfare," Bureau of Economic and Business Research Working Paper No. 98-0106, University of Illinois, September 1997, also posted in the Social Science Research Network Electronic Library (http://papers.ssrn.com/sol3/papers.cfm?abstract_id-150735).

Grossman, Gene M. and Edwin Lai (2004). "International Protection of Intellectual Property" Center Economic Studies and ifo Institue for Economic Research Working Paper No. 790, October 2002 (forthcoming *American Economic Review*).

Helpman, Elhanan, (1993). "Innovation, Imitation, and Intellectual Property Rights," *Econometrica*, 61, 1247-1290.

Jensen, Richard, and Marie Thursby (1987). "A Decision-Theoretical Model of Innovation, Technology Transfer, and Trade," *Review of Economic Studies*, LIV, 631-647.

Krugman, Paul R. (1979). "A Model of Innovation, Technology Transfer, and the World Distribution of Income," *Journal of Political Economy*, 87, 253-266.

Lai, Edwin L. C. (1998). "International Intellectual Property Rights Protection and the Rate of Innovation," *Journal of Development Economics*, 55, 133-153.

Maskus, Keith E. (2000a). *Intellectual Property righs in the Global Economy.* Washington, DC: The Institute for International Economics.

McCalman, Phillip (2001). "Reaping What you Sow: An Empirical Analysis of International Patent Harmonization," *Journal of International Economics*, 55, 161-185.

Nordhaus, William D. (1969). *Invention, Growth and Welfare: A Theoretical Treatment of Technological Change*, Cambridge, MA: The MIT Press.

Romer, Paul N. (1990). "Endogenous Technological Change," *Journal of Political Economy*, 98, 5, S71-S102.

Turnovsky, Stephen (1994). "TRIPS, Trade, and Growth," *International Economic Review*, 35, 361-381.

Turnovsky, Stephen (1997). *International Macroeconomic Dynamics.* Cambridge: MIT Press.

Turnovsky, Stephen (1999). *Economic Growth in Open Economies*, *Journal of Economic Dynamics and Control*, ed. Special Issue.

Yang, Yong (1998). "Why Do Southern Countries Have Little Incentive to Protect Northern Intellectual Property Rights?" *Canadian Journal of Economics*, 31, 800-816.