Preliminary Draft

Intellectual Property Protection and Innovation

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Well-designed and enforceable intellectual property rights (IPRs) provide economic incentives for research and development (R&D) and are, therefore, regarded as important determinants of technological progress and economic growth. Despite the apparent benefits to the existence of strong IPRs, many countries have a poor record in IPR protection (Helpman, 1993; Richardson and Gaisford, 1994).

This is especially true in the developing world (Helpman, 1993) with prime examples being Argentina (where 50-80% of Roundup Ready soybean seeds grown are not purchased from the property right holder) and China (where Procter & Gamble estimates its annual losses due to counterfeiting to US$150 million). The estimates of annual costs of infringement to US firms vary between $24 billion for 1986 (U.S. International Trade Commission, 1988) and $2.3 billion (Feinberg and Rousslang, 1990). At the same time, private research in the agricultural sector has increased vastly compared to the public sector, thus showing the need for effective IPR protection (Moschini and Lapan, 1997). The importance of IPR infringement has been recognized and the issue has taken central stage in the Agreement on Trade Related Aspects of Intellectual Property (TRIPs). Under the TRIPs agreement, countries can retaliate and penalize violations of their innovating firms' IPRs in other countries.

The issue of IPR infringement has inspired a number of studies on its economic ramifications. A case in point is the paper by Giannakas (2002) that develops a game-theoretic model of heterogeneous producers to analyze the economic causes of IPR infringement and its consequences for the welfare of the groups involved, the pricing and adoption of an *existing* innovation. Giannakas' analysis allows gauging the optimal enforcement policy of the government, the pricing strategy of the innovators and technology adoption decisions when the technology in question has already been developed.

Motivated by the effect of IPR protection on the incentives to innovate, this paper extends the framework of analysis developed in Giannakas (2002) by endogenizing the innovators' decision to innovate. In particular, rather than taking the innovation as given, this paper explicitly considers the ramifications of IPR enforcement policies on the allocation of investment capital in R&D activity.

The strategic interaction between the innovator, the government and the potential users of the new technology is modeled as a four stage sequential game. In stage 1 the innovator decides whether to invest in R&D and, if so, by how much. In stage 2, the government determines the level of protection it will provide to the innovating firm. Once the enforcement policy of the government has been determined, the innovator decides on the pricing of the new technology in stage 3. Finally, in stage 4, the potential users of the new technology decide whether to adopt this technology and, if so, whether to infringe on the innovator's IPRs observing the enforcement policy in place as well as the nature and pricing of the new technology. To avoid Nash equilibria involving non-credible strategies, the game is solved using backward induction (Gibbons, 1992) with the corresponding outcome providing the subgame perfect equilibrium investment in R&D, enforcement of IPRs, pricing and adoption of the new technology.

The rest of the paper is organized as follows. The next section introduces the basic model with perfect enforcement. The second part of the paper extends the baseline model by incorporating infringement into the analysis and compares the resulting equilibrium to that of the analysis of the case where the innovator cannot price discriminate between different countries. The last part considers the use of IPR protection as a strategic trade policy tool.

Perfect Enforcement

The baseline model uses the assumption of profit maximizing behavior of producers and innovators and the welfare optimization by the government to derive a sub-game perfect Nash equilibrium. To begin, consider the problem of the producer.

Producer's problem

Producers have to decide on whether to grow the genetically modified (GM) or the conventional crop. Producers are assumed to differ in term of the returns they receive from the production of the two crops. Let $A \in [0,1]$ be the attribute that differentiates the producers. The producer with differentiating attribute A has the following net return function:

$\Pi_t = p_t - p_t^s + \gamma A$ **<u>if</u>** conventional crop is produced

$\Pi_{gm} = p_{gm} - p_{gm}^s + \phi A$ **<u>if</u>** GM crop is produced

where the subscripts t and gm stand for traditional and genetically modified goods respectively. The prices p_t and p_{gm} are the prices of the farm output of traditional and genetically modified crops, respectively net of all costs except the cost of seeds. The superscript s on the price then denotes the price of the seed. The parameters γ and Φ are the return premium factors of conventional and GM crops depending on the type of the individual producer. Better producers will be able to achieve larger profits, regardless of the type of crop they are planting. The relative gains for a better producer, however, differ between the GM crop and the conventional crop, represented by the difference in the return premium factors. Producers' types are assumed to be uniformly distributed between 0 and 1. The assumption of a uniform distribution simplifies the analysis significantly without diminishing the generalizability of the results. Typically the market price of conventional crops is higher than the price of GM crops, but at the same time also the cost of conventional seeds is higher. In order to assure a positive quantity of both traditional and genetically modified product we assume $\gamma - \phi > \left(p_{gm} - p_{gm}^{s}\right) - \left(p_t - p_t^{s}\right) > 0$. The producer with differentiating attribute $A_I : \prod_t = \prod_{gm}$ is indifferent between the two products where

$$A_I = \frac{(p_{gm} - p_{gm}^{s}) - (p_t - p_t^{s})}{\gamma - \phi}$$

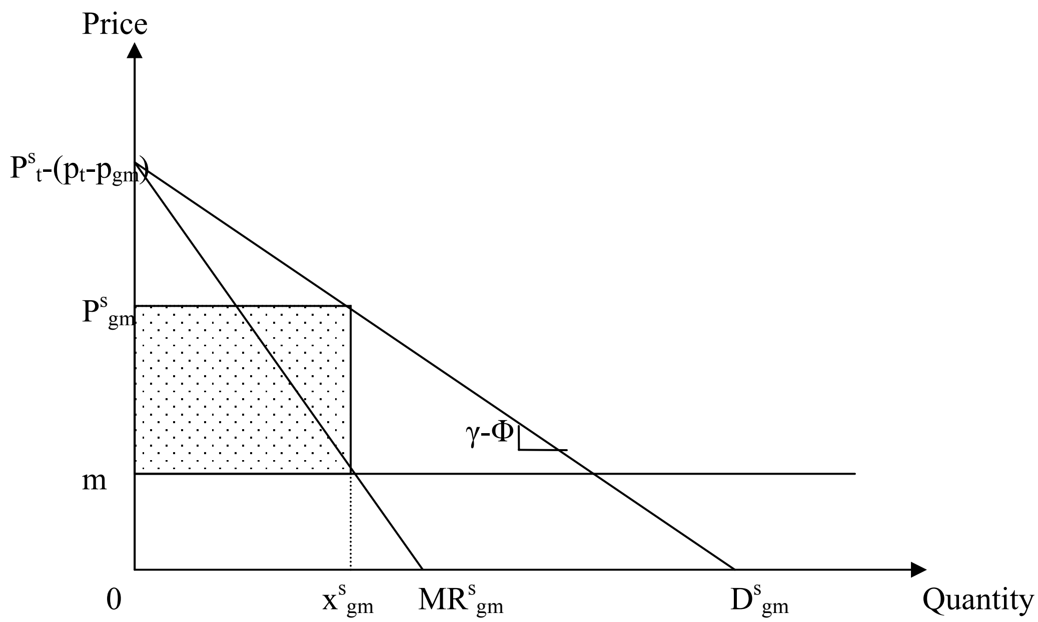
The parameter A_I also gives the market share of the GM product while 1- A_I is the market share of the conventional product, as producers between type 'A_I' and type '1' will prefer to produce the traditional product and producers between type '0' and type 'A_I' will prefer to produce the GM product. Assuming that each producer produces only one unit, we can calculate the total supply of the GM product by simply multiplying the market share by the number of producers (H) in the market.

Innovator's problem

Assuming fixed proportions between inputs and outputs, the supply of the GM product also gives the derived demand for GM seed (see Giannakas, 2002). The innovator maximizes profits by choosing a seed price that equates marginal revenue with marginal costs, if producing the GM seed:

$$\max_{p^s_{gm}} \pi = \left(p^s_{gm} - m\right)x_{gm}$$

Figure 1



Assuming constant marginal costs the maximization yields following price/ quantity combination:

$$p^s_{gm} = \frac{\left[p^s_t - \left(p_t - p_{gm}\right)\right] + m}{2}$$

$$x^s_{gm} = H_1 \frac{\left[p^s_t - \left(p_t - p_{gm}\right)\right] - m}{2\left(\gamma - \phi\right)}$$

Innovation decision

The government does not enter as an active player in this scenario since we assumed perfect enforcement. Contrary to the model in Giannakas (2002) the innovation decision is now endogenous. The paper by Giannakas assumed that innovation already took place and the innovator only decides on price and quantity. This model goes one step further by arguing that the innovator can foresee the reaction by government and producers and will choose accordingly whether to innovate or not. This is an important extension because it explains from within the model why innovations might not occur. The decision of the innovator on whether to invest in R&D, is based on the comparison of expected payoff under investment and non-investment.[1] The innovator's problem on this stage of the game can thus be expressed as:

$$\max_{d} \text{IR} = \begin{cases} 0 & if \quad d = ni \\ H\dfrac{\left(\left[p_t^s - \left(p_t - p_{gm}\right)\right] - m\right)^2}{4(\gamma - \phi)} - R\,\&\,D & if \;\; p_{gm}^{s*} < p_t^s - \left(p_t - p_{gm}\right) and \;\; d = i \\ < 0 & if \;\; p_{gm}^{s*} > p_t^s - \left(p_t - p_{gm}\right) and \;\; d = i \end{cases}$$

The innovator maximizes profits by deciding ($d \in [i, ni]$) on whether to innovate (d=i) or not to innovate (d=ni). If the innovator decides not to innovate the profits will be zero. Innovation brings the innovator a positive profit if the equilibrium pricing p_{gm}^{s*} for the innovator is such that staying in the market is profitable (e.g. $p_{gm}^{s*} < p_t^s - \left(p_t - p_{gm}\right)$) and the innovator rent is large enough to cover the fixed costs of innovation (e.g. $H\dfrac{\left(\left[p_t^s - \left(p_t - p_{gm}\right)\right] - m\right)^2}{4(\gamma - \phi)} > R\,\&\,D$), otherwise the innovator will loose and is better off not spending resources on innovation in the first place.

[1] Most studies confirm that higher IPRs encourage more R&D spending (Lesser, 1997). One exception is Levin et al. (1987).

Imperfect Enforcement

Under imperfect enforcement the producer has the additional choice to obtain the GM seed illegally by either retaining it from past harvest or buying it from the black market. For simplicity, we assume that the cost of seed in this case is negligible and can be set to zero. Engaging in illegal activities, however, can result in detection and subsequent fines. The detection probability and the fine are denoted as δ and ρ. The detection probability is assumed to increase with the characteristic of the producer. The reasoning for this is that better producers are located in more accessible regions, have more unified parcels and are more attractive targets for tax revisions and other scrutiny due to their success. However, the actual detection probability is not only determined by the particular characteristic of the producer, but also by the resources (R) spent by the government. The more resources the government spends, the higher is the base detection probability. The respective profit functions for the producers are then

$\pi_t = p_t - p_t^s + \gamma A$ **<u>if</u>** conventional crop is produced

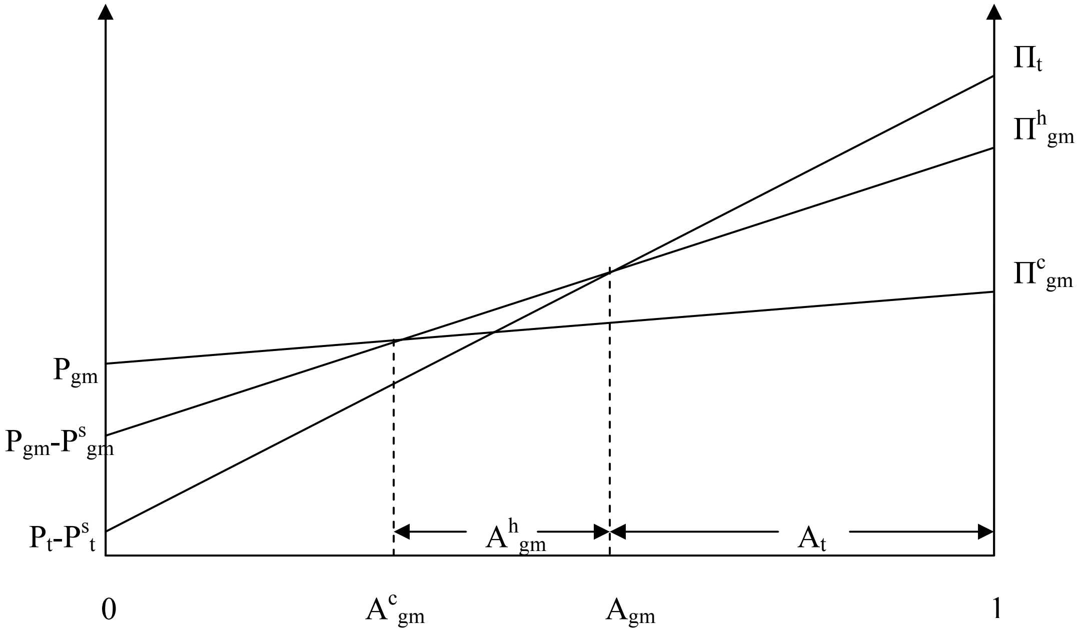
$\pi_{gm}^h = p_{gm} - p_{gm}^s + \phi A$ **<u>if</u>** GM crop is produced with seeds obtained legally

$\pi_{gm}^c = p_{gm} - \delta\rho + \phi A$ **<u>if</u>** GM crop is produced with seeds obtained illegally

$where \quad \delta = \delta_0(R) \cdot A$

Figure two graphs the net return functions and depicts the determination of market shares of conventional crops (A_t), GM crops produced with seeds obtained legally (A^h_{gm}) and illegally (0 to A^c_{gm}).

Figure 2



Similar to the perfect enforcement case, the producer who is indifferent between the GM and conventional crops has the differentiating attribute:

$$A_I : \pi_{gm}^{h} = \pi_t$$

$$\Rightarrow A_I = A_{gm} = \frac{(p_{gm} - p_{gm}^{s}) - (p_t - p_t^{s})}{\gamma - \phi} \cdot$$

Assuming fixed proportions between inputs and outputs the derived demand for the GM seeds is then calculated as the difference between the total amount of GM crops produced (i.e. $x_{gm} = H \cdot A_{gm} = H \frac{(p_{gm} - p_{gm}^{s}) - (p_t - p_t^{s})}{\gamma - \phi}$) and the GM crops produced with infringement (i.e. $x_{gm}^{c} = H \frac{p_{gm}^{s}}{\delta_0 \rho}$). This gives

$x_{gm}^{s} = x_{gm}^{h} = H\frac{\delta_0 \rho\left(p_t^s - \left(p_t - p_{gm}\right)\right) - \left[\gamma - \phi + \delta_0 \rho\right] p_{gm}^s}{\delta_0 \rho\left(\gamma - \phi\right)}$. The innovator's problem is therefore:

$$\max_{p_{gm}^s} \pi = \left(p_{gm}^s - m\right) x_{gm}^s$$

$$s.t. \qquad x_{gm}^s \geq 0 \Rightarrow$$

$$p_{gm}^s \leq \frac{\delta_0 \rho\left[p_t^s - \left(p_t - p_{gm}\right)\right]}{\gamma - \phi + \delta_0 \rho}$$

The resulting price and quantity combination

$$p_{gm}^s = \frac{\delta_0 \rho}{\gamma - \phi + \delta_0 \rho} \times \frac{\left[p_t^s - \left(p_t - p_{gm}\right)\right]}{2} + \frac{m}{2}$$

$$x_{gm}^s = H\frac{p_t^s - \left(p_t - p_{gm}\right) - m}{2\left(\gamma - \phi\right)} - \frac{m}{2\delta_0 \rho} = H\frac{\delta_0 \rho\left[p_t^s - \left(p_t - p_{gm}\right) - m\right] - \left(\gamma - \phi\right) m}{2\delta_0 \rho\left(\gamma - \phi\right)}$$

show the equilibrium price charged by the innovator, as a function of the level of IPR protection and the respective quantity of legally purchased GM seeds. The quantity of seeds obtained illegally can then be calculated as

$$x_{gm}^c = H\frac{\delta_0 \rho\left[p_t^s - \left(p_t - p_{gm}\right) + m\right] + \left(\gamma - \phi\right) m}{2\delta_0 \rho\left(\gamma - \phi + \delta_0 \rho\right)}.$$

If the innovator is forced to exit the market it leaves a quantity for illegal seeds of

$$x_{gm}^c = H\frac{p_t^s - p_t + p_{gm}}{\gamma - \phi + \delta_0 \rho}.$$

With imperfect enforcement, the enforcement of the government has to be taken into consideration to determine the outcome in the market. Assuming that the enforcement costs are not too high, the government wants to make sure that the innovator is innovating, because domestic welfare is larger with innovation than without. Therefore it has to assure the innovator a payoff that covers not only the variable costs of production, but also at least some of the sunk costs of innovation. The maximization problem of the government can be written as[2]

$$\max_{\delta_0} W = PS - TC + CS + REP$$

$$s.t. \qquad \sum_{i}^{n} IR^i \geq \overline{IR} = R\,\&\,D$$

$$W \geq W\Big|_{\frac{\partial TC}{\partial \delta_0} = \frac{\partial REP}{\partial \delta_0}}$$

where PS, TC, CS, REP, IR stand for producer surplus, taxpayer cost, consumer surplus, reputation cost and innovators' rent respectively. Taxpayer cost is assumed to increase with an increase in protection as more resources have to be committed to the auditing process (Feinberg and Rousslang, 1990). Complete protection is almost impossible (Levin et al. 1987), indicating the rapid increase in cost for improved auditing. Reputation is a positive function of protection and captures the benefits of being seen as a lawful nation by other countries. Benefits can be realized through better trade agreements with other countries, more development aid, better investment grading etc. The first constraint is given to indicate that all governments together have to provide enough profits to at least cover some minimum innovators' rent, in this case assumed to be equal to the R&D cost incurred by the innovator. Each government can have a different conjecture about the effect of changes in IPR protection in the home country on the

[2] It is assumed that the government chooses to affect infringement primarily through auditing probability and not through changing the fines being charged. Due to justice considerations, the size of fines is determined by the severity of the crime (Stigler, 1970). Furthermore, Ostergard (2000) argues that looking at the actual enforcement of laws is more important than analyzing the law itself.

behavior of the rest of the world. Specifically, each government considers $\frac{\partial \delta_{0j}}{\partial \delta_{0i}} = \eta$.

Furthermore, countries can be either small countries or large countries, depending on which a change in innovator rent accruing from the domestic market will have a different impact on total innovator rent $\frac{\partial \sum IR}{\partial IR_i} = \lambda(\eta)$. λ depends on η because the effect of country size is influenced by the behavioral conjecture. Different λ imply different conjectures:

$$\lambda = \begin{cases} \lambda = 0 & \textit{small country or free rider} \\ \text{"}0 < \lambda < \varepsilon & \textit{small country with cooperation}\text{"} \\ \lambda = 1 & l\arg e \textit{ country, no cooperation} \\ \lambda > 1 & l\arg e \textit{ country with cooperation} \end{cases}$$

With λ=0 the government either believes that its country is too small to matter, or a decrease in the innovator's rent domestically will be substituted by an equal increase abroad. A conjecture of 0<λ<1 implies that the country is too small to matter itself, but a change in its innovator's rent causes other countries to follow suit. This case is rather unlikely as typically only a large country can act as a leader in the market and we ignore it for the further analysis. A λ=1 implies that an increase in innovator's rent in that country will increase the total innovator's rent by the same margin. This occurs when the country under consideration is a large country and there is no cooperation occurring. Lastly, when λ is larger than one, a change in the innovator's rent not only increases the total innovator's rent by the same margin, but also causes other government to act in a cooperative way, thus increasing the total innovator's rent further.

The innovator's rent is not part of the maximization process, since the analysis is about a developing country with presumably no domestic innovators. The second constraint indicates that the government will provide sufficient protection for innovation only if it achieves a welfare gain over the welfare obtained under the optimal no-innovation level of protection, found by equating marginal gain from reputation to marginal cost from enforcement.

Given that the innovator actually is in the market, the producer surplus is given by

$$PS = H\left\{ p_t - p_t^s + H\frac{\gamma}{2} + \frac{P_{gm}^s\left[-\left(\delta_0\rho - (\gamma-\phi)B\right) - \left(\gamma - \phi + \delta_0\rho\right)HB\right] + HP_{gm}^{s^2}\left(\gamma - \phi + \delta_0\rho\right) + B^2\delta_0\rho}{2\delta_0\rho(\gamma-\phi)} \right\}.$$

For the calculation of the consumer surplus we assume heterogeneous consumers with $c \in [0,1]$ being the attribute that differentiates the consumers. Higher values of c signify higher aversion towards GM products.

$$CS = \int_0^{x_{gm}} \left(U(c) - P_{gm}\right) dc = \frac{U(0) - P_{gm}}{2} x_{gm}$$

U(c) is the willingness to pay of the consumer with attribute c and is assumed to be linearly decreasing in c. Assuming that both GM and conventional product exist in the market, the integral is equivalent to the average difference between the willingness to pay and the market price multiplied by the quantity consumed. We can show that producer surplus is decreasing in the detection probability (e.g. $\frac{\partial PS}{\partial \delta_0} < 0$). Further, an increase in IPR protection decreases the quantity of the GM product sold in the market ($\frac{\partial x_{gm}}{\partial \delta_0} < 0$), which will increase the price of the GM product ($\frac{\partial P_{gm}}{\partial \delta_0} > 0$). This implies that consumer surplus will also decrease with an increase in IPR protection:

$$\frac{\partial CS}{\partial \delta_0} = -\frac{\partial P_{gm}}{\partial \delta_0} x_{gm} + \frac{U(0) - P_{gm}}{2} \frac{\partial x_{gm}}{\partial \delta_0} < 0$$

Both producer surplus as well as consumer surplus is negatively affected by increases in IPR protection. Explicitly taking the consumer surplus into consideration adds significantly to the complexity of the analysis because changes in the price of GM products will have an effect on producers' decision to produce. Therefore, since no additional qualitative insights are gained, we henceforth (until the extension with trade) do not explicitly consider the consumer in the model.

The innovator's rent equals

$$IR = H \frac{\left[\delta_0 \rho (B - m) - (\gamma - \phi) m\right]^2}{4 \delta_0 \rho (\gamma - \phi)(\gamma - \phi + \delta_0 \rho)}$$

where $B = p_{gm} - \left(p_t - p_t^s\right)$

We can show that the innovator's rent is increasing in auditing probability (e.g. $\frac{\partial IR}{\partial \delta_0} > 0$). If the innovator does not enter the market (e.g. when $\delta_0 \rho < \frac{(\gamma - \phi) m}{p_t^s - (p_t - p_{gm}) - m}$),

its rent is zero and producer surplus can be calculated

as $PS = H\left(p_t - p_t^s + \frac{\gamma}{2} + \frac{B^2}{2(\gamma - \phi + \delta_0 \rho)} \right)$.

If reputation costs are not significant (and for developing countries they do not seem to be very large), the government of a small country has no incentive to provide any IPR protection. This maximizes producer surplus (and consumer surplus) and minimizes taxpayer costs. At the same time the lack of protection will not influence the innovator's decision to invest in R&D, since the contribution to the total innovator's rent is insignificant. This explains, why many developing countries offer very little IPR protection. For the large country, the optimal behavior depends on the conjecture they have about the behavior of the rest of the world. If the large country has a conjecture of $\lambda=0$, the optimal behavior is to free ride and reduce its own IPR protection to a minimum level. The expectation is that the rest of the world will make up for the loss in innovator's rent, by increasing their IPR protection.[3] With a conjecture of $\lambda=1$ the large country will have no incentive to change its IPR protection if the minimum innovator's rent is exactly obtained. If more than the minimum innovator's rent is provided, the large country will decide to decrease its IPR protection[4] and *vice versa*.[5] If the large country expects cooperation, i.e. $\lambda>0$, it will have an incentive to increase IPR protection if the innovator's rent is below the minimum level required for innovation. The country will do so even if by itself it cannot provide sufficient innovator's rent to enable the innovator to cover R&D costs.

The above analysis provides a framework for explaining the observed distribution of protection in the real world (e.g. developed countries protecting much, whereas developing countries protecting little). Most developing countries are small countries and thus have an incentive to choose very small rates of IPR protection. Developed countries are mostly large countries, but differ with regard to their conjectures. This explains why there is no uniform degree of IPR protection across countries. Another factor explaining the unequal distribution of IPR protection is, of course, that the reputation effect is much higher for developed countries than for developing countries and, thus, forces developed

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[3] Compare also to Yang (1998). He argues that Southern countries have the incentives to wait and see what the other countries are doing before deciding on a level of protection. If one country is forced to protect more, the other countries have incentive to protect less.

[4] If reputation costs are not too significant

[5] As long as taxpayer costs do not overcompensate the gain from enabling innovation

countries to protect more than they otherwise would. Furthermore, governments of developed countries consider the innovator's rent in their welfare maximization, which might induce higher protection as well.

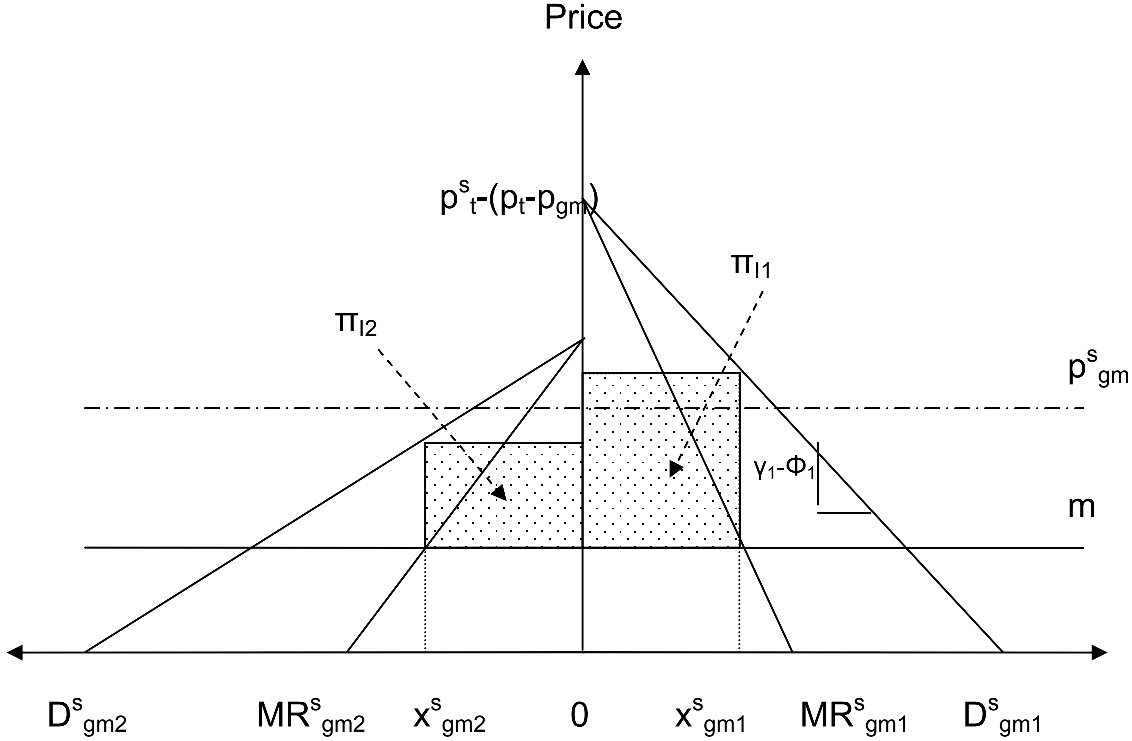
No Price Discrimination

The previous analysis assumes that the innovator can successfully price discriminate between producers from different countries. We will now consider the case where the innovator is unable to prevent resale of its technology between countries and is therefore unable to price discriminate. The producer faces the same decision as before, namely to produce the traditional crop, purchase the GM seed legally, or obtain the seed through some illegal channel. The innovator knows the optimal response by the producers and decides accordingly on the optimal price across countries. For the case of perfect enforcement this problem can be graphically illustrated for a two country case as shown in figure 3. The no-discrimination equilibrium price (p^s_{gm}) is a weighted average of the prices the innovator would have chosen for each country under price discrimination.

Mathematically, the innovator's problem can be written as

$$\max_{p^s_{gm}} \pi = \left(p^s_{gm} - m\right)\left(x_1 + x_2\right)$$
$$= \left(p^s_{gm} - m\right)\left(H_1 \frac{\left(p_{gm1} - p^s_{gm}\right) - \left(p_{t1} - p^s_{t1}\right)}{\gamma_1 - \phi_1} + H_2 \frac{\left(p_{gm2} - p^s_{gm}\right) - \left(p_{t2} - p^s_{t2}\right)}{\gamma_2 - \phi_2}\right)$$

Figure 3



The price and quantity solutions to this problem then are:

$$p_{gm}^{s} = \frac{(\gamma_2 - \phi_2)H_1B_1 + (\gamma_1 - \phi_1)H_2B_2 + m(H_1(\gamma_2 - \phi_2) + H_2(\gamma_1 - \phi_1))}{2(H_1(\gamma_2 - \phi_2) + H_2(\gamma_1 - \phi_1))}$$

$$x_{gm1}^{s} = H_1\left[\frac{B_1}{\gamma_1 - \phi_1} - \frac{(\gamma_2 - \phi_2)H_1B_1 + (\gamma_1 - \phi_1)H_2B_2 + m(H_1(\gamma_2 - \phi_2) + H_2(\gamma_1 - \phi_1))}{2(\gamma_1 - \phi_1)(H_1(\gamma_2 - \phi_2) + H_2(\gamma_1 - \phi_1))}\right]$$

$$x_{gm2}^{s} = H_2\left[\frac{B_2}{\gamma_2 - \phi_2} - \frac{(\gamma_2 - \phi_2)H_1B_1 + (\gamma_1 - \phi_1)H_2B_2 + m(H_1(\gamma_2 - \phi_2) + H_2(\gamma_1 - \phi_1))}{2(\gamma_2 - \phi_2)(H_1(\gamma_2 - \phi_2) + H_2(\gamma_1 - \phi_1))}\right].$$

The difference between the price charged by the innovator under no price discrimination and with price discrimination can be calculated as

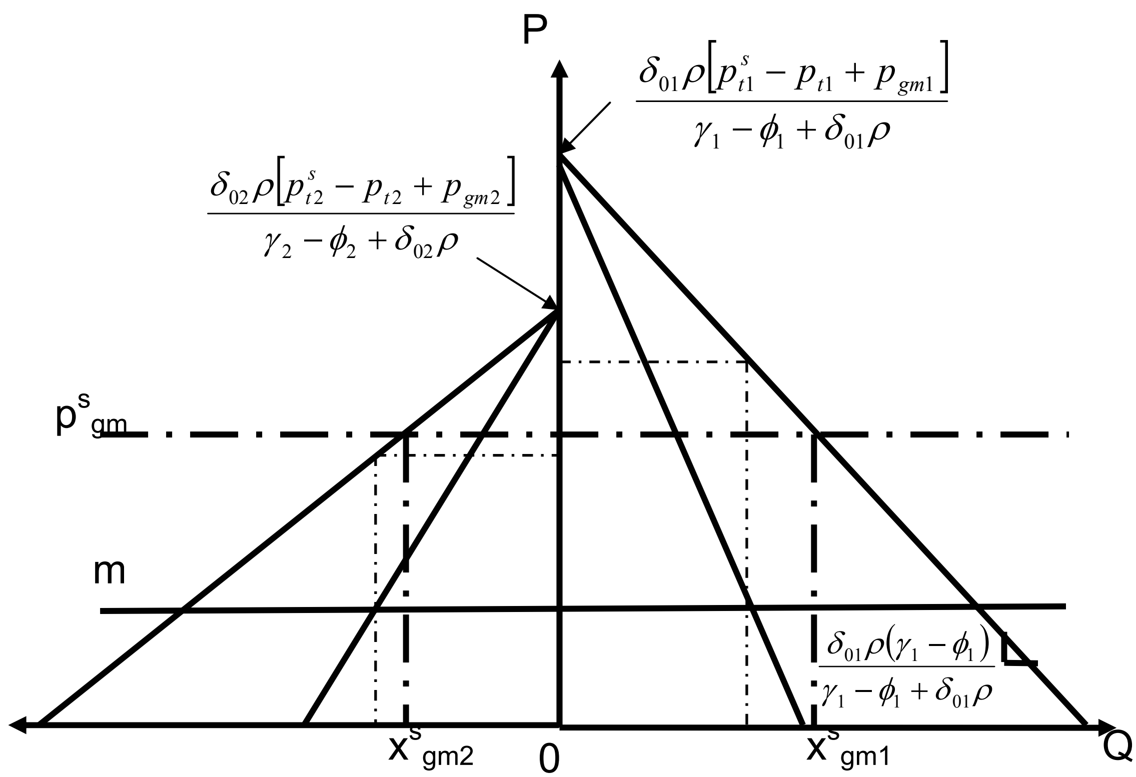
$$P^{nodisc} - P_1^{disc} = \frac{(B_2 - B_1)(\gamma_1 - \phi_1)H_2B_2}{2(H_1(\gamma_2 - \phi_2) + H_2(\gamma_1 - \phi_1))}$$

As expected, the price will be higher for country one than with price discrimination, if the maximum price charged (B) in country two is relatively higher than in country one. Consequently, the country with the larger relative return premium will sell a lower quantity relative to the price discrimination:

$$x_{gm1}^{nodisc} - x_{gm1}^{disc} = \frac{(B_1 - B_2)H_2H_1}{2(H_1(\gamma_2 - \phi_2) + H_2(\gamma_1 - \phi_1))} > 0$$

More interesting in the context of this paper is to look at the case with imperfect enforcement. Figure 4 depicts the equilibrium conditions in the markets under imperfect enforcement of the innovator's IPRs.

Figure 4



Mathematically, the innovator's problem can be stated as:

$$\max_{p_{gm}^s} \pi = \left(p_{gm}^s - m\right)\left(x_{gm1}^s + x_{gm2}^s\right)$$

$$s.t. \qquad x_{gmi}^s \geq 0 \Rightarrow$$

$$p_{gm}^s \leq \frac{\delta_{0i}\rho_i\left[p_{ti}^s - \left(p_{ti} - p_{gmi}\right)\right]}{\gamma_i - \phi_i + \delta_{0i}\rho_i}$$

The first order condition for the profit maximizing price then is

$$\sum_i \left(H_i \frac{\delta_{0i}\rho_i\left[p_{si}^d - (p_{si} - p_{Ii})\right] - \left[\gamma_i - \phi_i + \delta_{0i}\rho_i\right]p_I^d}{\delta_{0i}\rho_i\left(\gamma_i - \phi_i\right)} \right) - (p_{gm}^s - m)\sum_i \left[H_i \frac{\gamma_i - \phi_i + \delta_{0i}\rho_i}{\delta_{0i}\rho_i\left(\gamma_i - \phi_i\right)} \right] = 0,$$

which can be solved for the optimal price and quantity (for each country).

$$p_{gm}^s = \frac{H_1\delta_{02}\rho_2\left(\gamma_2 - \phi_2\right)\delta_{01}\rho_1 B_1 + H_2\delta_{01}\rho_1\left(\gamma_1 - \phi_1\right)\delta_{02}\rho_2 B_2}{2\left[\left(\gamma_1 - \phi_1 + \delta_{01}\rho_1\right)H_1\delta_{02}\rho_2\left(\gamma_2 - \phi_2\right) + H_2\delta_{01}\rho_1\left(\gamma_1 - \phi_1\right)\left(\gamma_2 - \phi_2 + \delta_{02}\rho_2\right)\right]} + \frac{m}{2}$$

$$x_{gm1}^h = H_1 \frac{\theta_1\psi_1\delta_{01}\rho_1 B_1 + 2\theta_2\psi_2\delta_{01}\rho_1 B_1 - \theta_1\psi_2\delta_{02}\rho_2 B_2 - \theta_1 m\left(\theta_1\psi_1 + \theta_2\psi_2\right)}{\delta_{01}\rho_1\left(\gamma_1 - \phi_1\right)2\left(\theta_1\psi_1 + \theta_2\psi_2\right)}$$

$$where\ \theta_i := \left(\gamma_i - \phi_i + \delta_{0i}\rho_i\right)\ and\ \psi_1 := H_1\delta_{02}\rho_2\left(\gamma_2 - \phi_2\right), \psi_2 := H_2\delta_{01}\rho_1\left(\gamma_1 - \phi_1\right)$$

Similar to the case of perfect enforcement, the price of GM seeds in country one will be higher than under price discrimination, if the maximum possible price charged by the innovator is larger in county two than in country one. Higher price results in lower quantity compared to the price discrimination case.

Comparative statics allow us to calculate the effect of an increase in protection in one country on the price charged by the innovator. Specifically, and increase in the audit probability results in increased prices charged by the innovator, i.e.,

$$\frac{\partial p_{gm}^s}{\partial \delta_{01}} = \frac{H_1\rho_1\left(\delta_{02}\rho_2\right)^2\left(\gamma_2 - \phi_2\right)\left(\gamma_1 - \phi_1\right)\left(H_2\left(\gamma_1 - \phi_1\right)B_2 + H_1\left(\gamma_2 - \phi_2\right)B_1\right)}{2\left[\left(\gamma_1 - \phi_1 + \delta_{01}\rho_1\right)H_1\delta_{02}\rho_2\left(\gamma_2 - \phi_2\right) + H_2\delta_{01}\rho_1\left(\gamma_1 - \phi_1\right)\left(\gamma_2 - \phi_2 + \delta_{02}\rho_2\right)\right]^2} > 0$$

The intuition behind this result is that an increase in protection in country one will increase the relative profitability of purchasing genetically modified seeds legally in that country. This in turn will increase the innovator's derived demand (pivotal shift of the demand schedule to the right) which will increase the innovator's profit maximizing price in that country. This causes the innovator to charge a higher international price, regardless of whether the country previously had a lower or higher price relative to the other countries. At the same time the quantity sold by the innovator will also increase,

i.e., $$\frac{\partial x^h_{gm1}}{\partial \delta_{01}} = H_1\left[\frac{p^s_{gm1}\rho_1(\gamma_1-\phi_1)^2}{[\delta_{01}\rho_1(\gamma_1-\phi_1)]^2} - \frac{[\gamma_1-\phi_1+\delta_{01}\rho_1]\frac{\partial p^s_{gm1}}{\partial \delta_{01}}}{[\delta_{01}\rho_1(\gamma_1-\phi_1)]}\right] > 0$$

The reason for this is that the increase in equilibrium quantity due to the increase in demand more than offsets the quantity reduction due to the price increase.

It is also interesting to look at the effect of an increase in the effective total demand for traditional and GM crop. This might be caused by a general increase in income for the country under consideration or by a population increase.

$$\frac{\partial p^s_{gm}}{\partial H_1} = \frac{\left[\frac{B_1\delta_{01}\rho_1}{(\gamma_1-\phi_1+\delta_{01}\rho_1)} - \frac{B_2\delta_{02}\rho_2}{(\gamma_2-\phi_2+\delta_{02}\rho_2)}\right](\gamma_1-\phi_1+\delta_{01}\rho_1)(\gamma_2-\phi_2+\delta_{02}\rho_2)\delta_{02}\rho_2(\gamma_2-\phi_2)\delta_{01}\rho_1H_2(\gamma_1-\phi_1)}{2[(\gamma_1-\phi_1+\delta_{01}\rho_1)H_1\delta_{02}\rho_2(\gamma_2-\phi_2)+H_2\delta_{01}\rho_1(\gamma_1-\phi_1)(\gamma_2-\phi_2+\delta_{02}\rho_2)]^2}$$

An increase in the total demand in country one will increase prices charged by the innovator if the maximum price the innovator can charge in each country, $\frac{B_i\delta_{0i}\rho_i}{(\gamma_i-\phi_i+\delta_{0i}\rho_i)}$, is larger in country one than in country two. This is the case because a larger maximum price implies, *ceteris paribus*, a greater innovator surplus created within that country. This causes the innovator to place more weight on that country for the estimation of the international equilibrium price, and therefore lower the international equilibrium price if the domestic equilibrium price was lower and increase the international equilibrium price if the domestic equilibrium price was higher.

Similar to the price discrimination case the problem of the government is to determine the level of enforcement that maximizes domestic welfare subject to the minimum innovator's rent. The innovator's rent can be shown to equal:

$$IR = \sum_i IR_i = \sum_i \left(p^s_{gm} - m\right)x^s_{gmi}$$

$$IR_1 = \left(p^s_{gm} - m\right)x^s_{gm1} = H_1 \frac{\theta_1\psi_1\delta_{01}\rho_1 B_1 + 2\theta_2\psi_2\delta_{01}\rho_1 B_1 - \theta_1\psi_2\delta_{02}\rho_2 B_2 - \theta_1 m\left(\theta_1\psi_1 + \theta_2\psi_2\right)}{\delta_{01}\rho_1\left(\gamma_1 - \phi_1\right)2\left(\theta_1\psi_1 + \theta_2\psi_2\right)}$$

$$\cdot\left(\frac{\psi_1\delta_{01}\rho_1 B_1 + \psi_2\delta_{02}\rho_2 B_2}{2\left(\theta_1\psi_1 + \theta_2\psi_2\right)} + \frac{m}{2} - m\right)$$

$$= H_1 \frac{B_1^{\,2}\mu + B_2^{\,2}\nu + B_1 B_2 o + B_1\varpi + m^2\vartheta}{4\delta_{01}\rho_1\left(\gamma_1 - \phi_1\right)\left(\theta_1\psi_1 + \theta_2\psi_2\right)^2}$$

where

$$\mu := \delta_{01}^2\rho_1^2\psi_1\left(\theta_1\psi_1 + 2\theta_2\psi_2\right)$$

$$\nu := -\psi_2^2\delta_{02}^2\rho_2^2\theta_1$$

$$o := \delta_{01}\rho_1\delta_{02}\rho_2\psi_2^2 2\theta_2$$

$$\varpi := 2m\delta_{01}\rho_1\left(\theta_1\psi_1 + \theta_2\psi_2\right)^2$$

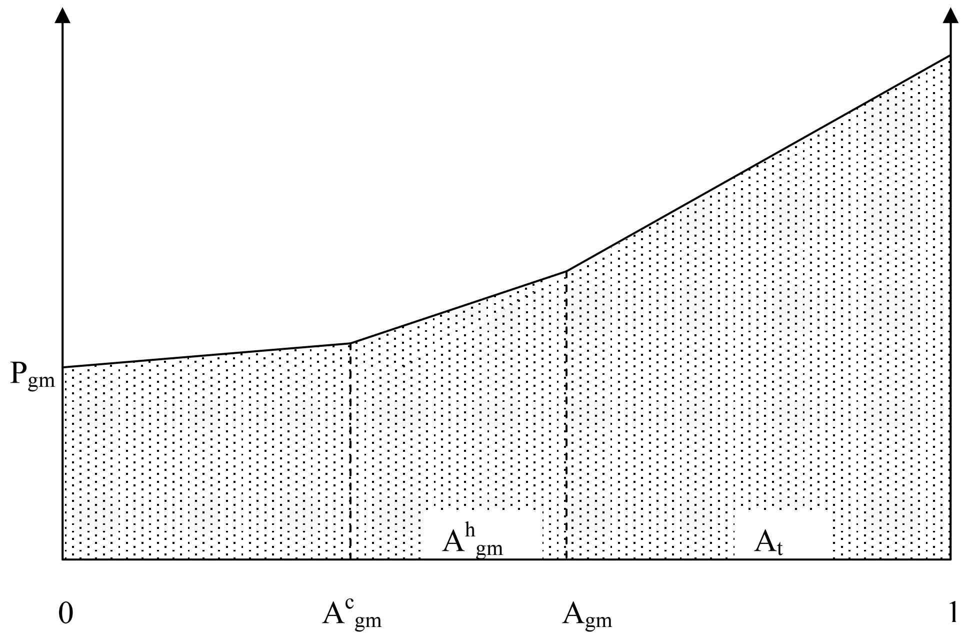
$$\vartheta := \theta_1\left(\theta_1\psi_1 + \theta_2\psi_2\right)^2$$

IR_2 follows symmetrically and is not explicitly derived here. The producer surplus is derived as the area under the double kinked curve in figure 5 with the respective share being multiplied by the total population in that country. Mathematically, this can be shown for country one to equal

$$PS = H_1\left(P_{t1} - P^s_{t1}\right) + \frac{1}{2}H_1^{\,2}\gamma_1$$

$$+ H_1 \frac{P^s_{gm}\left[-\left(\delta_{01}\rho_1 - \left(\gamma_1 - \phi_1\right)B_1\right) - \left(\gamma_1 - \phi_1 + \delta_{01}\rho_1\right)H_1 B_1\right] + H_1 P^{s^2}_{gm}\left(\gamma_1 - \phi_1 + \delta_{01}\rho_1\right) + B_1^2\delta_{01}\rho_1}{2\delta_{01}\rho_1\left(\gamma_1 - \phi_1\right)}$$

Figure 5



Consistent with a priori expectations, the producer surplus is increased under price discrimination if the price is lower than that under no price discrimination. The increase in producer surplus is then given by:

$$\Delta PS = \frac{H_1\left(P^s_{gm} - P^s_{gm1}\right)\left[-\left(\delta_{01}\rho_1 - (\gamma_1 - \phi_1)B_1\right) - (\gamma_1 - \phi_1 + \delta_{01}\rho_1)H_1B_1\right] + H_1^2\left(P^{s^2}_{gm} - P^{s^2}_{gm1}\right)(\gamma_1 - \phi_1 + \delta_{01}\rho_1) + B_1^2\delta_{01}\rho_1}{2\delta_{01}\rho_1(\gamma_1 - \phi_1)}$$

Similar to the price discrimination case, an increase in protection will lead to an increase in innovator's rent through increases in quantity and price. The increased price charged by the innovator causes the producer surplus to fall. Relative to the price discrimination case, producer surplus is less responsive to a change in protection[6], making the reputation effect and the enforcement costs relatively more important for the government decision. It should be noted that the previous discussion assumes that we

[6] due to the relatively smaller price change of GM seeds by the innovator

deal with a large country, as the innovator would otherwise not take the level of protection of that country into consideration for its profit maximizing price. It follows that a small country cannot affect the price of the GM seed by providing a different amount of protection. The producers still benefit, however, since infringing becomes cheaper. Due to the decreased cost of infringement, more producers choose to obtain GM seeds illegally, which consequently leads to a decreased market share of the innovator relative to the benchmark case of price discrimination. Producers also lose compared to the benchmark case, due to the decreased price responsiveness of the innovator.

International Trade

The next part of the paper focuses on the effect of IPR protection on international trade. Specifically, the analysis focuses on whether protection can be used as a strategic trade policy tool to increase exports.[7] In the following analysis we assume that we deal with a small sector; goods are traded internationally, but a change in net-exports does not result in changes in the terms-of-trade. This allows to model international trade as a simple one-sector international demand and supply model. As before, we choose a sector with some crops being produced using traditional seeds and others being produced using GM seeds. Note that the goods traded are now consumer goods[8], not seeds, and thus the analysis focuses on the producer level, not input suppliers' level. We assume that the trading sector is perfectly competitive and that trading costs are negligible. To further simplify the analysis, we also assume that countries are similar in all but the level of protection of GM products. The careful reader will notice that the previous sections of the paper imply

[7] For a similar analysis on strategic labeling see Veyssiere and Giannakas (2004)
[8] created in fixed proportions from crops

that if countries are similar they also will choose similar levels of protection. Allowing for this inconsistency enables us, however, to more clearly gauge the effect of changes in property right protection. Similar to Chichilnisky (1994), we can now demonstrate that trade can be caused by differences in IPR protection itself.

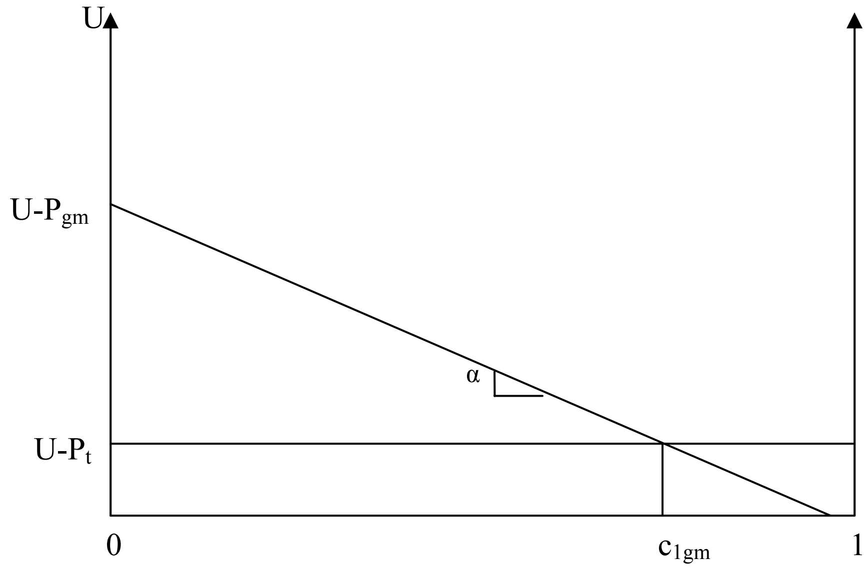
Consumers now have to be modeled explicitly, as international demand and supply jointly determine trade flows. The analysis of the consumers follows closely the discussion in Giannakas and Fulton (2002) and Fulton and Giannakas (2004). Each consumer is assumed to consume one unit of either the GM or the conventional product and the expenditure for this consumption represents only a small part of her budget. Let $c \in [0,1]$ be the attribute that differentiates the consumers. The consumer with differentiating attribute c has the following utility function:

$$U_{gm} = U - P_{gm} - \alpha c$$
$$U_t = U - P_t$$

Subscripts gm and t on U represent the utility of consuming the product produced with GM crops and the product produced with conventional crops respectively. Similarly, these subscripts on P represent the price the consumer has to pay for the respective product. U is the base utility the consumer gains from consuming the product, whereas α is the positive utility discount factor associated with the consumption of the GM product.

As shown in figure 6, given equal prices, consumers prefer the conventional over the GM product (i.e. conventional and GM products are vertically differentiated). The GM product is cheaper, however, which leads some consumers to demand GM products, whereas others demand the conventional product.

Figure 6



The indifferent consumer is located at

$$c_{1gm} : U_{gm} = U_t \Rightarrow c_{1gm} = \frac{P_t - P_{gm}}{\alpha}$$

The total demand in each country is then $D_{gm}^{1} = H_1 \cdot \frac{P_t - P_{gm}}{\alpha}$ and $D_t^{1} = H_1 \cdot \frac{\alpha - P_t + P_{gm}}{\alpha}$.

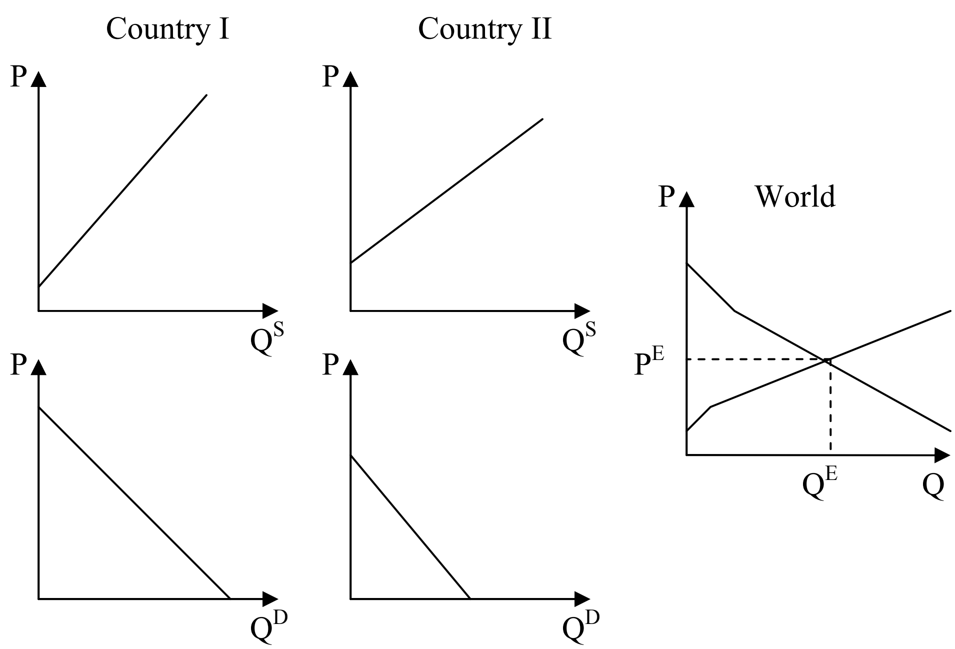
This allows calculating the world demand as simply the summation of the individual country demands. Assuming equal α across countries, the two country case thus would lead to a world demand of

$$D_{gm}^{tot} = D_{gm}^{1} + D_{gm}^{2} = (H_1 + H_1) \cdot \frac{P_t - P_{gm}}{\alpha}$$
$$D_t^{tot} = D_t^{1} + D_t^{2} = (H_1 + H_1) \cdot \frac{\alpha - P_t + P_{gm}}{\alpha}$$

International trade with perfect enforcement

Total supply of genetically modified products across countries is the sum of the total amounts of genetically modified products produced in each country, with seeds obtained either through infringement or legal purchases. Similarly, total supply for the traditional product is the sum of the supplies from each country.

Figure 7



With similar conditions in both countries the supply curves for the GM product and the conventional product under perfect enforcement are:

$$S_{gm}^{tot} = S_{gm}^{1} + S_{gm}^{2} = \left(H_1 + H_2\right)\frac{\left[p_t^s - \left(p_t - p_{gm}\right)\right] - m}{2(\gamma - \phi)}$$

$$S_t^{tot} = S_t^1 + S_t^2 = \left(H_1 + H_2\right)\frac{2(\gamma - \phi) - \left[p_t^s - \left(p_t - p_{gm}\right)\right] + m}{2(\gamma - \phi)}$$

The inverse demand and supply functions then are:

$$P_{gm} = P_t - \frac{\alpha}{(H_1 + H_2)} D_{gm}^{tot}$$

$$P_t = \alpha + P_{gm} - \frac{\alpha}{(H_1 + H_2)} D_t^{tot}$$

$$p_{gm} = p_t - p_t^s + m + \frac{2(\gamma - \phi)}{(H_1 + H_2)} S_{gm}^{tot}$$

$$p_t = p_t^s + p_{gm} - 2(\gamma - \phi) - m + \frac{2(\gamma - \phi)}{(H_1 + H_2)} S_t^{tot}$$

which allows to derive equilibrium prices and quantities as:

$$Q_{gm}^{tot} = (p_t^s - m)\frac{(H_1 + H_2)}{2(\gamma - \phi) + \alpha}$$

$$Q_t^{tot} = (-p_t^s + 2(\gamma - \phi) + m + \alpha)\frac{(H_1 + H_2)}{2(\gamma - \phi) + \alpha}$$

$$P_{gm} = P_t - \frac{\alpha}{2(\gamma - \phi) + \alpha}(p_t^s - m)$$

$$P_t = P_{gm} - \frac{\alpha}{2(\gamma - \phi) + \alpha}(-p_t^s + m)$$

The amount exported/imported by each respective country can then be calculated as the difference between the quantity supplied by a country at the equilibrium price and the quantity demanded at that price:

$$S_{gm}^1 = H_1 \frac{(p_t^s - m)}{2(\gamma - \phi) + \alpha}$$

$$D_{gm}^1 = H_1 \frac{(p_t^s - m)}{2(\gamma - \phi) + \alpha}$$

$$Q_{trade} = S_{gm}^1 - D_{gm}^1 = 0$$

Since all countries are the same and world price is equal to the domestic price there is no international trade in this scenario.

International trade with infringement

The next step is to consider the case in which producers actually infringe. In this case, the demand analysis remains the same, but world supply becomes:

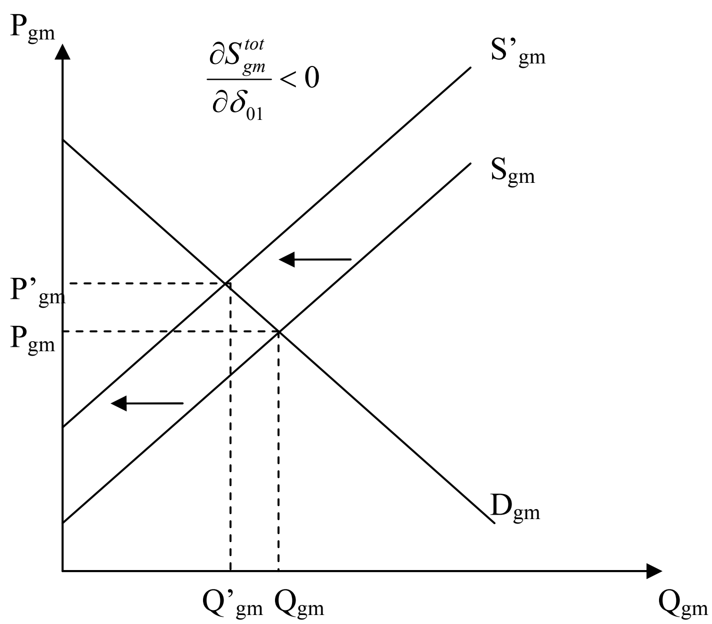
$$S_{gm}^{tot} = S_{1gm}^{tot} + S_{2gm}^{tot} = H_1 \frac{(\gamma-\phi)B + (\gamma-\phi+\delta_{01}\rho)(B-m)}{2(\gamma-\phi+\delta_{01}\rho)(\gamma-\phi)} + H_2 \frac{(\gamma-\phi)B + (\gamma-\phi+\delta_{02}\rho)(B-m)}{2(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi)}$$

$$S_t^{tot} = S_{1t}^{tot} + S_{2t}^{tot} = H_1 \frac{(\gamma-\phi)(2(\gamma-\phi+\delta_{01}\rho)-B)-(\gamma-\phi+\delta_{01}\rho)(B-m)}{2(\gamma-\phi+\delta_{01}\rho)(\gamma-\phi)}$$
$$+ H_2 \frac{(\gamma-\phi)(2(\gamma-\phi+\delta_{02}\rho)-B)-(\gamma-\phi+\delta_{02}\rho)(B-m)}{2(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi)}$$

Clearly, world supply of the GM product depends negatively on the degree of intellectual property protection in each country,

$$\frac{\partial S_{gm}^{tot}}{\partial \delta_{01}} = H_1 \frac{-2\rho(\gamma-\phi)^2 B}{[2(\gamma-\phi+\delta_{01}\rho)(\gamma-\phi)]^2} < 0$$

<u>Figure 8</u>



World supply of the traditional product, on the other hand, depends positively on the degree of IPR protection in each country (e.g. $\frac{\partial S_t^{tot}}{\partial \delta_{01}} > 0$). An increase in the IPR protection in any country is, thus, equivalent to a left shift of the world supply curve of GM crops. This will increase world price for genetically modified food and decrease the equilibrium quantity in the market. The inverse world supply of the GM product is then:

$$p_{gm} = p_t - p_t^s + \frac{m(H_1 + H_2)(\gamma - \phi + \delta_{01}\rho)(\gamma - \phi + \delta_{02}\rho)}{\left[H_1(\gamma - \phi + \delta_{02}\rho)(2(\gamma - \phi) + \delta_{01}\rho) + H_2(\gamma - \phi + \delta_{01}\rho)(2(\gamma - \phi) + \delta_{02}\rho)\right]}$$
$$+ \frac{2(\gamma - \phi + \delta_{02}\rho)(\gamma - \phi + \delta_{01}\rho)(\gamma - \phi)}{\left[H_1(\gamma - \phi + \delta_{02}\rho)(2(\gamma - \phi) + \delta_{01}\rho) + H_2(\gamma - \phi + \delta_{01}\rho)(2(\gamma - \phi) + \delta_{02}\rho)\right]} S_{gm}^{tot}$$

Equating this to world demand for the GM product yields equilibrium quantities and prices of:

$$Q_{gm}^{equ} = \frac{(H_1 + H_2)\left[H_1(\Omega + \Delta_{02})(2\Omega + \Delta_{01}) + H_2(\Omega + \Delta_{01})(2\Omega + \Delta_{02})\right]p_t^s}{2(H_1 + H_2)(\Omega + \Delta_{02})(\Omega + \Delta_{01})\Omega + \alpha\left[H_1(\Omega + \Delta_{02})(2\Omega + \Delta_{01}) + H_2(\Omega + \Delta_{01})(2\Omega + \Delta_{02})\right]}$$
$$- \frac{m(H_1 + H_2)^2(\Omega + \Delta_{01})(\Omega + \Delta_{02})}{\left[2(H_1 + H_2)(\Omega + \Delta_{02})(\Omega + \Delta_{01})\Omega + \alpha\left[H_1(\Omega + \Delta_{02})(2\Omega + \Delta_{01}) + H_2(\Omega + \Delta_{01})(2\Omega + \Delta_{02})\right]\right]}$$
$$where \quad \Omega = \gamma - \phi; \quad \Delta_i = \delta_{0i}\rho$$

$$P_{gm}^{equ} = P_t - \frac{\alpha\left[H_1(\Omega + \Delta_{02})(2\Omega + \Delta_{01}) + H_2(\Omega + \Delta_{01})(2\Omega + \Delta_{02})\right]p_t^s}{\left[2(H_1 + H_2)(\Omega + \Delta_{02})(\Omega + \Delta_{01})\Omega + \alpha\left[H_1(\Omega + \Delta_{02})(2\Omega + \Delta_{01}) + H_2(\Omega + \Delta_{01})(2\Omega + \Delta_{02})\right]\right]}$$
$$+ \frac{\alpha m(H_1 + H_2)(\Omega + \Delta_{01})(\Omega + \Delta_{02})}{\left[2(H_1 + H_2)(\Omega + \Delta_{02})(\Omega + \Delta_{01})\Omega + \alpha\left[H_1(\Omega + \Delta_{02})(2\Omega + \Delta_{01}) + H_2(\Omega + \Delta_{01})(2\Omega + \Delta_{02})\right]\right]}$$

The quantity exported by a country then can be calculated by subtracting domestic demand at from the domestic supply the world price.

$$D: Q_{gm}^{1} = H_1 \frac{\left[H_1(\Omega+\Delta_{02})(2\Omega+\Delta_{01}) + H_2(\Omega+\Delta_{01})(2\Omega+\Delta_{02})\right]p_t^s}{2(H_1+H_2)(\Omega+\Delta_{02})(\Omega+\Delta_{01})\Omega + \alpha\left[H_1(\Omega+\Delta_{02})(2\Omega+\Delta_{01}) + H_2(\Omega+\Delta_{01})(2\Omega+\Delta_{02})\right]}$$

$$- H_1 \frac{m(H_1+H_2)(\Omega+\Delta_{01})(\Omega+\Delta_{02})}{\left[2(H_1+H_2)(\Omega+\Delta_{02})(\Omega+\Delta_{01})\Omega + \alpha\left[H_1(\Omega+\Delta_{02})(2\Omega+\Delta_{01}) + H_2(\Omega+\Delta_{01})(2\Omega+\Delta_{02})\right]\right]}$$

$$S: Q_{gm}^{1} = \frac{H_1(2\Omega+\Delta_{01})p_t^s\left[2(H_1+H_2)(\Omega+\Delta_{02})(\Omega+\Delta_{01})\Omega\right]}{2\Omega(\Omega+\Delta_{01})\left[2(H_1+H_2)(\Omega+\Delta_{02})(\Omega+\Delta_{01})\Omega + \alpha\left[H_1(\Omega+\Delta_{02})(2\Omega+\Delta_{01}) + H_2(\Omega+\Delta_{01})(2\Omega+\Delta_{02})\right]\right]}$$

$$- \frac{H_1 m(\Omega+\Delta_{01})\left[2(H_1+H_2)(\Omega+\Delta_{02})(\Omega+\Delta_{01})\Omega + \alpha H_2 \Omega(\Delta_{01}-\Delta_{02})\right]}{2\Omega(\Omega+\Delta_{01})\left[2(H_1+H_2)(\Omega+\Delta_{02})(\Omega+\Delta_{01})\Omega + \alpha\left[H_1(\Omega+\Delta_{02})(2\Omega+\Delta_{01}) + H_2(\Omega+\Delta_{01})(2\Omega+\Delta_{02})\right]\right]}$$

$$Net\exp ort = \frac{\left[\Delta_{02}-\Delta_{01}\right]H_2 H_1\left(2\Omega p_t^s - \alpha m\right)}{2\left[2(H_1+H_2)(\Omega+\Delta_{02})(\Omega+\Delta_{01})\Omega + \alpha\left[H_1(\Omega+\Delta_{02})(2\Omega+\Delta_{01}) + H_2(\Omega+\Delta_{01})(2\Omega+\Delta_{02})\right]\right]}$$

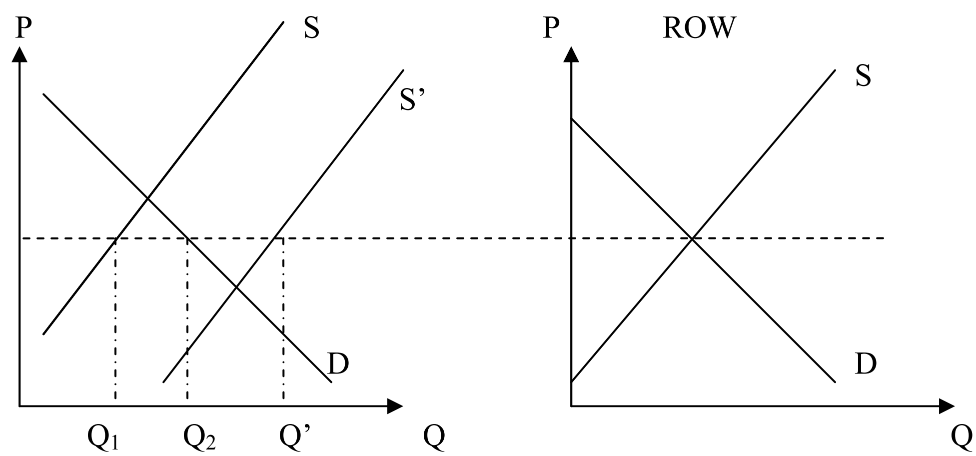
As we can see, this expression is positive as long as levels of protection are higher in country 2 than in the home country. The intuitive explanation is that higher levels of IPR protection increase the cost to the producers as they have to purchase the respective good from the innovator rather than simply copy it. This increase in the cost of production reduces production and exports to the world market (see also Lesser, 1997). This is equivalent to a negative first derivative of net-exports with respect to the protection probability:

$$\frac{\partial Net\exp ort}{\partial \delta_{01}} = -\frac{\rho H_2 H_1\left(2\Omega p_t^s - \alpha m\right)(H_1+H_2)(\Omega+\Delta_{02})\left[(\Omega+\Delta_{02})2\Omega + (2\Omega+\Delta_{02})\alpha\right]}{2\left[2(H_1+H_2)(\Omega+\Delta_{02})(\Omega+\Delta_{01})\Omega + \alpha\left[H_1(\Omega+\Delta_{02})(2\Omega+\Delta_{01}) + H_2(\Omega+\Delta_{01})(2\Omega+\Delta_{02})\right]\right]^2} < 0$$

Small Open Economy

For a small open economy the domestic price is determined by the world price. In the two country case, this implies that the world price is equal to the price level determined by demand and supply relationships in the large country (country two). Figure 9 shows the effect of a decrease in IPR protection on exports on country one. In the original position the home country had a level of protection that caused a supply schedule of S. With the given world price determined by country two, the quantity produced domestically is Q_1 and the quantity demanded is Q_2. Country one is therefore a net-importer. After the decrease in protection, however, the supply schedule in country one shifts to the right and increases the amount produced domestically to Q'. This implies that the country becomes now a net-exporter, with exports being the difference between Q' and Q_2.

Figure 9



Mathematically, the world price can be calculated by equating demand and supply:

$$D_{gm}^{2} = H_2 \cdot \frac{P_t - P_{gm}}{\alpha} = H_2 \frac{(\gamma-\phi)B + (\gamma-\phi+\delta_{02}\rho)(B-m)}{2(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi)} = S_{2gm}^{tot}$$

which gives rise to

$$P_{gm} = P_t + \frac{(\gamma-\phi+\delta_{02}\rho)\alpha m - \alpha\left(2(\gamma-\phi)+\delta_{02}\rho\right)P_t^{s}}{\left[\alpha\left(2(\gamma-\phi)+\delta_{02}\rho\right)+2(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi)\right]}$$

Using the world price to determine the supply and demand in the home country, we get:

$$S_{gm}^{1} = H_1 \frac{2(2(\gamma-\phi)+\delta_{01}\rho)(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi)P_t^s}{[\alpha(2(\gamma-\phi)+\delta_{02}\rho)+2(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi)]2(\gamma-\phi+\delta_{01}\rho)(\gamma-\phi)}$$
$$-H_1 \frac{[\alpha(\delta_{02}\rho-\delta_{01}\rho)+2(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi+\delta_{01}\rho)](\gamma-\phi)m}{2(\gamma-\phi+\delta_{01}\rho)(\gamma-\phi)[\alpha(2(\gamma-\phi)+\delta_{02}\rho)+2(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi)]}$$

$$D_{gm}^{1} = H_1 \cdot \frac{(2(\gamma-\phi)+\delta_{02}\rho)P_t^s-(\gamma-\phi+\delta_{02}\rho)m}{[\alpha(2(\gamma-\phi)+\delta_{02}\rho)+2(\gamma-\phi+\delta_{02}\rho)(\gamma-\phi)]}$$

$$\Rightarrow S_{1gm}^{tot} - D_{gm}^{1} : Net\exp ort = H_1 \frac{(\aleph_{02}-\aleph_{01})(2(\gamma-\phi)P_t^s-\alpha m)}{[\alpha(2\Im+\aleph_{02})+2(\Im+\aleph_{02})\Im]2(\Im+\aleph_{01})}$$

Similar to the large country case, net-exports are positive as long as protection in the rest of the world is higher than in the home country. Furthermore, net-exports will decrease with an increase in IPR protection.

$$\frac{\partial Net\exp ort}{\partial \delta_{01}} = -\frac{H_1\rho(2(\gamma-\phi)P_t^s-\alpha m)(\Im+\aleph_{02})}{[\alpha(2\Im+\aleph_{02})+2(\Im+\aleph_{02})\Im]2(\Im+\aleph_{01})^2} < 0$$

Comparing the small open economy and the large country case, we can observe that net-exports (imports)[9] are higher in a small open economy. This can easily be explained by the fact that, if a large country decreases the IPR protection, the increase in the total quantity produced affects the world price which alleviates the benefit from increasing the quantity in the first place. This will lead to a smaller supply response by large countries than smaller countries.

[9] If IPR protection is lower in the small country than the rest of the world, the small country will have net-exports. In that case the net-exports are higher than with a large country with comparable market conditions. If IPR protection is higher in the small country than the rest of the world, the small country will have net-imports, again higher than a large country with comparable market conditions.

Effectiveness of IPR protection without price discrimination

The effect of a change in IPR protection on trade flows, when the innovator is unable to price discriminate, can be deduced from results obtained in the previous sections of this paper. If price discrimination is not possible for the innovator, a change in IPR protection cannot change net-exports when market conditions are similar across countries. Without price discrimination, the innovator will react to a decrease in IPR protection in a large country by reducing the GM seed price in all countries. Consequently, all producers benefit from the price reduction and expand their production. This will lead to an increase in world supply which will result in a decrease in world price for GM crops. Since the effect is symmetric for all countries (since they all have similar market conditions), there is an increase in the world quantity of GM crops, but not a change in the quantity exported. Despite the ineffectiveness with regard to net-exports a reduction in IPR protection still benefits the domestic producers, because infringement becomes cheaper. Producer surplus is therefore larger. Obviously, a change of IPR protection in a small country has no effect on the pricing decision of the innovator and therefore will not change the total supply and world price for GM crops.

If IPR protection goes below the threshold of $\delta_0 \rho < \frac{(\gamma - \phi)m}{p_t^s - (p_t - p_{gm}) - m}$, however, the innovator exits the market and a positive net effect on exports can be observed. Even if the innovator is not forced to exit the market, producers can still benefit from a decrease in IPR protection. Due to the reduction in infringement cost, a larger quantity of the GM crop is produced with seeds obtained illegally. The reason is, of course, that it is now cheaper for the producer to do so. At the same time, the overall quantity does not increase as the increase in GM crops produced with illegally obtained seeds is exactly offset by a reduction in seeds obtained legally. This implies that protection does not have an effect on total exports or imports, but will increase the profitability of production.

Conclusion

This paper builds on the research presented in Giannakas (2002). The first extension is to endogenize the innovation decision of the innovator. Innovators will only engage in R&D activity if the expected payoff is sufficiently large. The government has to take this into consideration when deciding on the optimal level of protection. It is shown that the optimal choice of the government depends not only on the pricing decision of the innovator, but also on its conjecture about the policy of other governments and its country size. It turns out that for a small country a minimum level of protection is optimal.[10] For a large country, the choice of protection depends on the conjecture about other countries' behavior. If the large country expects other countries to behave cooperatively it has an incentive to free ride. Otherwise the large country will decide to contribute to the total innovator's rent, depending on the starting position.

The second extension analyses the effect of assuming the inability of the innovator to price discrimination between countries. The analysis shows that, similar to before, an increase in IPR protection will cause the innovator to increase prices. This only happens, however, if the country under consideration is a large country in the sense that it affects the innovator's rent. One of the most interesting results is that an increase in the effective demand for seeds will result in increased (decreased) GM seed prices over time, if the starting markup difference between GM seed and traditional seed is smaller (larger) than in other countries.

The last extension introduces international trade into the analysis. More specifically it analyzes whether IPR protection can be used as a strategic trade policy tool

[10] This supports the conclusion of a more complex model introduced by Helpman (1993)

as suggested by Giannakas (2002). Results show that a decrease in IPR protection will lead to a smaller price charged by the innovator, which will increase the production of GM products. If the country under consideration is a large country, this will increase world supply and thus lower the world price of the GM product. This will alleviate the net-effect on supply. Independently of whether the country is small or large, however, a decrease in IPR protection will lead to an increase in net-exports. If price discrimination is possible, IPR protection can therefore be used as a strategic trade tool.[11]

If price discrimination is not possible for the innovator, a change in IPR protection cannot change net-exports as long as market conditions are similar across countries. Without price discrimination the innovator will react to a decrease in IPR protection in a large country by reducing the GM seed price in all countries. Due to the symmetry assumed in this model, there is an increase in the world quantity of GM crops, but not a change in the amount exported. Producer surplus increases, however, since infringing becomes cheaper. A change of IPR protection in a small country has no effect on the pricing decision of the innovator. This is implies that world supply for GM crops will not change and thus world price of GM crops will stay the same. Within the small country there is simply a shift from legally purchased seeds to illegally obtained seeds without a change in net-exports.

We can conclude therefore that intellectual property right protection can only be used effectively to boost exports if the innovator can price discriminate. However, regardless of the price discrimination ability of the innovator, a decrease in IPR protection will always increase producer surplus.

[11] A similar result has been shown by Taylor (1993)

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