SHOULD EUROPE FURTHER STRENGTHEN INTELLECTUAL PROPERTY FOR PLANT BREEDERS? AN ANALYSIS OF SEED INDUSTRY PROPOSALS

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Paper prepared for presentation at the XI[th] International Congress of the EAAE
(European Association of Agricultural Economists),
'The Future of Rural Europe in the Global Agri-Food System'
Copenhagen, Denmark, August 24-27, 2005

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Abstract

This paper illustrates the potential negative effects of increasing the scope of plant breeders' rights (PBR) protection, as has been proposed for Europe by leading plant breeding firms. Such a policy could increase the costs for varietal development for breeding companies, particularly if their access to varieties of the market leader is constrained. This is represented as an asymmetrical increase in breeders' cost functions in a simple model of endogenous quality choice under price competition. Increased scope of IPR protection leads to increased profits for the leading breeding company but decreases in varietal quality and both farm and overall profits.

Keywords:
Intellectual Property Rights, Product Differentiation, Plant Breeding, Genetic Diversity.

JEL Classification: L13, O34, Q16

1. Introduction

This paper develops a theoretical model to analyse the impacts of intellectual property rights (IPRs) policy options on innovation in the plant breeding sector and social welfare. The U.S. and the E.U. are pursuing separate policies with respect to the patenting of innovation in the plant breeding sector. In contrast to the stronger patenting approach of the U.S., the E.C. Directive 98/44/EC on the legal protection of biotechnological inventions only allows plant breeder's rights (PBR) for plant varieties, while patent protection is to be available for biotechnological inventions such the use of genetic transformation techniques in plants. Many developing countries and economies in transition, in the fulfillment of their TRIPS obligations, have passed PBR legislation, and are now in the stages of institutional implementation. These countries are generally less advanced in their corresponding patent obligations for biotechnology inventions.

The principal motivation for this paper is the proposal by some large plant breeding companies in the private sector to increase the scope of PBR protection particulary in Europe, and eventually in developing countries through adjustments to the treaty of the International Union for the Protection of New Varieties of Plants (UPOV). UPOV is an international agreement on the technical requirements for PBR protection as well as the resulting scope of protection. Both of the two most recent versions of the treaty, referred to as the 1978 Act and the 1991 Act, include a "breeders' exemption" which means that protected varieties may be used by competitors as material in their breeding programs, without any obligation to the original right holder. (The 1991 Act of UPOV introduced the exclusion to the breeders' exemption for "essentially-derived varieties" (EDV)). PBR protection, which is an IPR tailored to the specific characteristics of the agricultural plant breeding sector, has largely been replaced in the U.S.by the availability of utility patents for plant varieties.

Recently, Pioneer Hi-bred proposed a phasing-in of the the breeders' exemption after a certain number of years, determined per crop according to factors such as the length of the breeding cycle and the product lifetime (Donnenwirth et al., 2004; the proposal was also made by R. McConnell, CEO of Pioneer Hi-Bred in a presentation to the International Seed Federation (ISF) Seminar on Intellectual Property Rights and Access to Plant Genetic Resources, held in Berlin, 27-28 May 2004). This period would obviously be shorter than the duration of PBR protection e.g. 10 years. Under such an arrangement, competing breeders would have to wait for these first 10 years to pass before being able to use a protected variety in their breeding programmes, without permission of the rightholder.

The alternatives for IPR protection of plant varieties can now be viewed as a continuum from PBRs to patents. In between these two options, a phased-in breeders' exemption would be an intermediate option to strengthening the scope of protection of PBRs. At the extreme, if the breeders exemption is not phased in until the expiry of the PBR, then the protection is quite comparable to that of patents, ignoring the requirements for obtaining protection.

The question for policymakers is what is the effect of increased protection on innovation incentives, including the indirect effects arising from changes in market structure. Ultimately, policy should be chosen to maximize the resulting welfare outcome. But another policy objective has also been added to the list recently and concerns the use and maintenance of genetic diversity. On the one hand, increasing concentration that could result from broader IPR protection, could lead to a more limited range of crop varieties being available. On the other hand, for crops such as maize, Pioneer argues that increased appropriation by breeders of benefits is necessary to finance the greater R&D investments necessary in order to incorporate a broader range of genetic material, such as wild relatives, into their breeding programmes (Donnenwirth et al., 2004).

In this paper, we develop a simple theoretical model to illuminate some of the tradeoffs between innovation incentives and product quality/diversity, arising from the effects of changes in IPR protection. Our model is a modest adaptation of a standard model elaborated by Motta (1993) of vertical product differentiation with endogenous quality choice, based on an earlier and well-known contribution by Shaked and Sutton (1982). The following section briefly reviews some relevant strands of literature on the scope of IPR protection. We then present the theoretical model in which we interpret a phased-in breeders' exemption as affecting the cost functions for breeders. Numerical simulations in the subsequent section illustrate how a phased-in breeders exemption may drive competitors out of the market while still leaving the leading firm with little incentive to increase investment. In the concluding remarks, we comment on the possibilities for undertaking further empirical and theoretical research on this issue.

2. Approaches to Analyzing the Scope of IPR Protection

In this section we review relevant literature on the scope of IPR protection. There have been relatively few attempts to model PBRs as an explicit form of IPR (Lesser, 1997). Alston and Venner (2002) developed a model of partial appropriability for a monopolistic breeding sector with the breeders' exemption mentioned as one of the explanations for the relatively weak appropriability provided by PBRs in the U.S. Patents, in contrast, have received considerable attention from economists in terms of both theoretical and empirical research. The issue of interest here is to what extent the findings of this research are applicable for the phased-in breeders' exemption issue.

The option of a phased-in breeders' exemption suggests a continuum of increasing protection, similar to the concept of breadth of patent protection where breadth is one dimension of the scope of patent protection. O'Donoghue (1998) distinguishes between lagging breadth, which describes the extent of protection against imitators, and leading breadth, which is the extent of protection against subsequent innovators. Denicolo (2002) uses the term "forward protection" for leading breadth and earlier terms include "height" (Klemperer, 1990; Van Dijk, 1996). (O'Donoghue (1998) provides a clear discussion of the relationship between these various concepts of patent breadth.) It is possible to interpret a phased-in breeders' exemption has extending the breadth of patent-like protection. Broader protection means that subsequent breeders must invest more to develop a variety with greater benefits for farmers, without infringing the existing variety.

The last 15 years has seen a steady progression in the complexity of models developed to analyse the breadth of patent protection. Earlier work concentrated on a two-stage framework and the need for broad patent protection and licensing provisions to transfer benefits from a subsequent innovator back to a first-innovator (e.g. Scotchmer 1991, Scotchmer 1996). More recent work has extended the analysis to an infinite-stage setting of sequential innovation, highighting a need to balance upstream and downstream incentives (O'Donoghue et al., 1998; Bessen and Maskin, 2000) and making a link with the quality ladders framework of endogenous growth (O'Donoghue, 1998).

The patent scope literature has not yet examined all the important aspects of the problem. Market structure and power are not captured in such frameworks where the most recently developed product enjoys a monopoly position until replaced by the subsequent generation. A good deal of the debate surrounding the PBR-patent issue in plant breeding, concerns the potential effects of broader IPR protection in terms of greater concentration and the ability of other firms to continue competing with a leader. More specifically, a phased-in breeders' exemption, or even patent protection, could result in a carving up of the germplasm pool among a very limited number of breeders remaining in the market (a manifestation of the "carving up the commons" phenomenon; see Falcon and Fowler, 2002).

This germplasm pool issue reflects a specific characteristic of the plant breeding sector. Plant breeding differs from many other forms of cumulative innovation in that further innovation (breeding) is not possible without physical access to previous innovations. This is arguably the principal reason why PBRs were developed in the first place, as an alternative to utility patents for which their publication releases (in principal) the knowledge behind the innovation to competitors and researchers. There is no parallel to this information disclosure with PBR as it is effectively included only in the variety's genetic sequence.

There are various approaches available for representing the germplasm pool issue. Spillovers in R&D offer one possibility that could be further explored, building on the d'Aspremont and Jacquemin (1988) framework (see also Amir, 2000 for a summary of recent developments). In this paper, we choose a vertical product differentiation framework in order to also incorporate a representation of varietal diversity, as well as the notion of absolute improvements to plant varieties. A range of available plant varieties is beneficial to the extent that farms are heterogeneous. Furthermore, a greater number of plant varieties is likely to entail a broader range of genetic material being used which helps attain conservation objectives. (There is some controversy as to the extent to which *in situ* as well as *ex situ* conservation is necessary, as well as the extent to which diversity should be present in commercial fields, particulary if this involves a tradeoff with (current) productivity (e.g Wright 1997). But there is less controversy over the fact that conservation without use has little purpose.)

A well-known approach to modelling a duopoly in which firms endogenously choose their quality levels was developed by Shaked and Sutton (1982). With symmetric firms, they show that the equilibrium solution will entail one firm supplying a higher quality than the other, in order to ease price competition. Their analysis was restricted to where costs of quality improvements were fixed. Motta (1993) allows variable cost functions for quality and analyses Bertrand vs Cournot competition, confirming that product differentiation arises in a symmetric duopoly. In the model presented below, we modestly extend Motta's formulation of the model.

3. An Oligopolistic Model of Plant Breeding

To analyse the effects of restricting the breeders' exemption, we develop a model of vertical product differentation for the plant breeding sector in which two plant breeding firms choose the quality and then the price of their respective seed varieties in a two-stage game. This model of endogenous quality choice is an extension of the paper by Motta (1993). The difference here is that we allow for asymmetric cost functions at the R&D, or quality, stage as a means of representing the effects of a phased-in breeders' exemption. As will be seen below, our logic for such an approach is based on the representation of plant breeding within a search-theoretic framework by Evenson (1998).

We begin with the basic structure of the model. For simplicity, the farming sector is modelled analogously to consumers in a model of vertical product differentiation. Farms compete in a competitive output market as price takers. Seed is their only input and their profit is given by $V = vu - p$, where u and p are respectively, the quality and price of seed. Farms differ in the characteristics of their land and local growing conditions which are captured in the parameter $v \in [v_{min}, v_{max}]$, with v being uniformly distributed with unit density. As is typical with such models, we normalize the quantity purchased such that each farm buys one unit of seed unless $vu - p < 0$, in which case they neither purchase nor produce. We assume that the market is not covered, as in Motta (1993) who discusses the implications of assuming full or partial market coverage. Full market coverage would affect our specific numerical results but not their qualitative interpretation. Given the extent of competition in the seed sector and the predominance of farm-saved seed in many countries, partial market coverage seems more compelling although Wauthy (1996) has generalized this class of models to allow for endogenous determination of market coverage.

We assume that there are only two firms that play a two-stage game, with each firm producing one variety of seed. In the first stage, firms must choose the quality, u_1 and u_2 respectively, of their variety, with $u_1, u_2 \geq 1$. This lower bound of quality could be interpreted as a legal minimum standard (e.g. seed certification requirements) or as the existing quality level on which firms have to improve. We interpret this first stage as an R&D stage in which firms incur fixed costs to achieve a chosen quality level, as suggested by Motta (1993). In the second stage, Bertrand price competition takes place. For simplicity and without loss of generality, we assume that the costs of producing seed are zero. A sub-game perfect Nash equilibrium is solved through backward induction.

Firm 1 is the quality leader and firm 2 is a follower: $u_1 \geq u_2$. Farm v_{12} earns equal profits from variety 1 as it does from variety 2, so $v_{12} = (p_1 - p_2)/(u_1 - u_2)$. Farm v_{02} earns zero profits from variety 2: $v_{02} = p_2/u_2$. Thus farms distributed between $v_{12} \leq v \leq v_{\max}$ will purchase variety 1; and farms distributed between $v_{02} \leq v \leq v_{12}$, variety 2. This leads to the following simple inverse demand functions:

$$\begin{aligned} q_1 &= v_{\max} - (p_1 - p_2)/(u_1 - u_2) \\ q_2 &= (p_1 - p_2)/(u_1 - u_2) - (p_2 / u_2) \end{aligned} \tag{1}$$

Given their quality choices (u_1, u_2), firms seek to maximize their profits, $\Pi_i = p_i q_i$, in the second stage by setting price. The first order conditions for profit maximization are

$$\begin{aligned} \partial\Pi_1 / \partial p_1 &= v_{\max} + (p_2 - 2p_1)/(u_1 - u_2) = 0 \\ \partial\Pi_2 / \partial p_2 &= (p_2 - 2p_1)/(u_1 - u_2) - 2p_2/u_2 = 0 \end{aligned} \tag{2}$$

Solving for equilibrium prices yields,

$$\begin{aligned} p_1 &= 2v_{\max} u_1 (u_1 - u_2)/(4u_1 - u_2) \\ p_2 &= v_{\max} u_2 (u_1 - u_2)/(4u_1 - u_2) \end{aligned} \tag{3}$$

and profits in the second stage are,

$$\begin{aligned} \Pi_1(u_1, u_2) &= 4(u_1 - u_2)[v_{\max} u_1 (4u_1 - u_2)]^2 \\ \Pi_2(u_1, u_2) &= u_1 u_2 (u_1 - u_2)[v_{\max} / (4u_1 - u_2)]^2 \end{aligned} \tag{4}$$

The first stage quality game is then solved by firms choosing their quality levels to maximize profits which now incorporate the cost functions. This R&D cost function is taken to be a quadratic function of quality which was the original suggestion of d'Aspremont et al. (1979) in their analysis of Hotelling's (1929) model of spatial competition. The quadratic cost function is also a common functional form in the literature on R&D. We feel that in this case, its choice can also be justified by the work of Evenson and Kislev (1976) and Evenson (1998) on plant breeding production functions. Placing plant breeding within a search-theoretic framework, Evenson proposes that the expected value, or productivity improvement, *z*, obtained from a draw, or search, among a population of *n* varieties, or genebank accessions, can be approximated as $E(z) = a + b \cdot \ln(n)$. (Kortum (1997) has shown that this also holds for most commonly used distributions except those that are "fat-tailed".) Costs can be viewed as being proportional to *n*, the size of the search population. This production function thus corresponds to a cost function such as the exponential function, in which marginal costs are increasing at an increasing rate in the quality or trait being sought. For simplicity, we use a quadratic cost function, which has constantly increasing marginal costs. For our purposes, this is a conservative approach as a steeper function can be expected to reinforce the strength of the results.

Whereas Motta (1993) used identical cost functions for both firms, we now introduce an extra parameter to account for effects of restricting or phasing in the breeders exemption. This leads to asymmetric costs with firm 2 experiencing higher costs as a result of restricted or delayed access to the new variety of firm 1. Firm 1's costs are given by $\lambda u_1^2 / 2$ and firm 2's costs, by $\alpha\lambda u_2^2 / 2$. Notice that this contrasts to other innovation models where the follower may have a cost advantage relative to the leader, since the follower may be able to benefit from the leader's investments in research (spillover). In conventional plant breeding, it can be argued that competing firms operate on an equal basis in this respect. The breeders' exemption allows them to benefit from each other's investments, roughly in equal amounts. The point here is that if a *policy* change may reduce this possibility. In a leader-follower setup, the ability of the follower to benefit from the research of the leader is thus constrained. In our formulation, this is represented as an increase in costs. (An alternative approach, that we are currently exploring, is to represent the breeders' exemption as a spillover the size of which may be constrained by IPR policy.)

In addition to α (> 1) for the breeders' exemption, λ is a variable that allows us to examine the effects of proportionally increasing the cost functions of both firms. The motivation for this is the exhaustion of the genetic pool issue mentioned above; as breeders exhaust the existing genetic pool in which they are searching, either recharge will become necessary, through costly germplasm acquisition and evaluation, or genetic material may be sought in other species, including wild relatives.

In the first stage of the game, firms now choose their quality levels, u_1 and u_2 respectively to maximize their full profit functions:

$$\begin{aligned} \pi_1(u_1, u_2) &= 4(u_1 - u_2)\left[v_{\max} u_1 / (4u_1 - u_2)\right]^2 - \lambda u_1^2 / 2 \\ \pi_2(u_1, u_2) &= u_1 u_2 (u_1 - u_2)\left[v_{\max} / (4u_1 - u_2)\right]^2 - \alpha \lambda u_2^2 / 2 \end{aligned} \tag{5}$$

The first order conditions are,

$$\begin{aligned} \partial\pi_1 / \partial u_1 &= 4u_1 v_{\max}^2 \left(4u_1^2 - 3u_1 u_2 + 2u_2^2\right) / (4u_1 - u_2)^3 - \lambda u_1 = 0 \\ \partial\pi_2 / \partial u_2 &= v_{\max}^2 u_1^2 (4u_1 - 7u_2) / (4u_1 - u_2)^3 - \alpha \lambda u_2 = 0 \end{aligned} \tag{6}$$

Substituting for v_{max} and rearranging,

$$4u_1^3 - (7 + 16\alpha)u_1^2 u_2 + 12\alpha u_1 u_2^2 - 8\alpha u_2^3 = 0 \tag{7}$$

As $u_1 \geq u_2$ (by assumption), let $u_1 = \mu \cdot u_2$, with $\mu \geq 1$. The auxiliary variable μ thus represents the relationship between the quality levels of the two firms but it is introduced primarily to facilitate the solution of (7), by substituting for u_1 and then factoring out $\cdot u_2$ to give

$$4\mu^3 - (7 + 16\alpha)\mu^2 + 12\alpha\mu - 8\alpha = 0 \tag{8}$$

For given values of α, equation (8), a third-order polynomial in μ, can then be solved using numerical methods. Given μ, we can find all the parameters in the model, expressed as a function of v_{max}:

$$u_2 = \frac{\mu^2(4\mu - 7)}{\alpha\lambda(4\mu - 1)} v_{max}^2 \qquad u_1 = \mu u_2 \tag{9}$$

$$v_{12} = \frac{(2\mu - 1)}{(4\mu - 1)} v_{max} \qquad v_{02} = \frac{(\mu - 1)}{(4\mu - 1)} v_{max} \tag{10}$$

Equilibrium prices are given in equation (3), and quantities by,

$$q_1 = 2\mu v_{max} / (4\mu - 1) \qquad q_2 = \mu v_{max} / (4\mu - 1) \tag{11}$$

Profits of firm 1 and 2 are given above in (5). Farm profits are measured with a simple formula, as is typically done with consumer surplus (see Motta, 1993):

$$\pi_{Farms} = \int_{v_{02}}^{v_{12}} (v u_2 - p_2) dv + \int_{v_{12}}^{v_{max}} (v u_1 - p_1) dv \tag{12}$$

The proof that solution (8) represents a Nash equilibrium follows the proof of Motta (1993) and depends on the numerical solutions for μ. Our use of the additional parameters, α and λ, only reinforces the logic of the proof. The following section examines how the solution varies for different values of α and λ.

4. Simulations

Numerical simulations are conducted for various values of α and λ. We begin with the benchmark solution where $\alpha = 1$ and $\lambda = 1$ i.e. with no asymmetry in costs, as also calculated by Motta (1993). These are summarised in Table 1 as coefficients on v_{max}. The equilibrium quality levels are $u_1 = 0.2533 \cdot v^2_{max}$ and $u_2 = 0.0482 \cdot v^2_{max}$ which are related by the factor $\mu = 5.2512$. This reflects the findings of Shaked and Sutton (1982) that even in a symmetric situation, firms will ease price competition by choosing different quality levels.

Given the stylistic nature of the model, equilibrium parameter values were calculated for a range of $\alpha = \{1.0, 1.1,.., 10.0\}$, with higher α increasing the proportionally the cost function of firm 2. This leads to a seemingly linear increase in μ, as seen in Figure 1 from 5.2512 for $\alpha = 1$ to 41.031 for $\alpha = 10$. Given a seemingly linear relationship between α and μ, it may be possibe to devise an analytical solution that eases further analysis.

What happens to the qualities offered by both firms as it becomes more difficult for firm 2 to conduct its R&D? Figure 2 shows that firm 2 decreases its quality as a result of the higher costs. Recall that we interpret these higher breeding costs for firm 2 as resulting from a phased-in, or even eliminated, breeders' exemption. A doubling of firm 2's costs relative to that of firm 1 results in a quality decline for the former of roughly a half. As α increases to 5, firm 2's quality approaches zero (recall that there is a minimum quality required by the model). How does firm 1 react to the reduced threat posed by firm 2? Although perhaps difficult to see in Figure 2, firm 1's quality also declines but only marginally, remaining roughly constant as α increases. Firm 1 does not therefore have any incentive in this setting to increase its R&D investment as a result of increased scope of IPR's and to develop a higher quality seed variety. Firm 1 can increase its price and while moderately decreasing quality, thus tending towards monopolistic behaviour (Figures 3 and 4).

Table 1: Benchmark Results ($\alpha = 1$ and $\lambda = 1$)

	Firm 1	**Firm 2**	**Farms**
u	$0.2533 \cdot v^2_{max}$	$0.0482 \cdot v^2_{max}$	-
p	$0.1077 \cdot v^3_{max}$	$0.0103 \cdot v^3_{max}$	-
q	$0.5250 \cdot v_{max}$	$0.2625 \cdot v_{max}$	$0.7875 \cdot v_{max}$
π	$0.0244 \cdot v^4_{max}$	$0.0015 \cdot v^4_{max}$	$0.0432 \cdot v^4_{max}$
Total profits	$0.0692 \cdot v^4_{max}$		
v_{02}	$0.2125 \cdot v_{max}$		
v_{12}	$0.4750 \cdot v_{max}$		

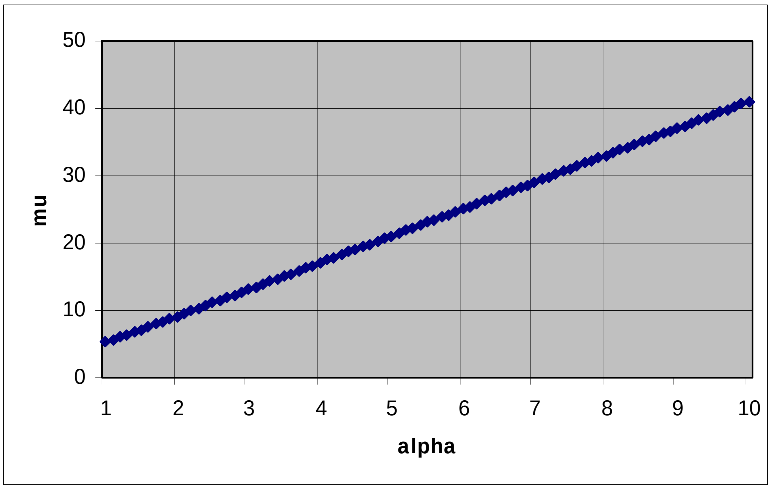

Figure 1: Mu for increasing alpha

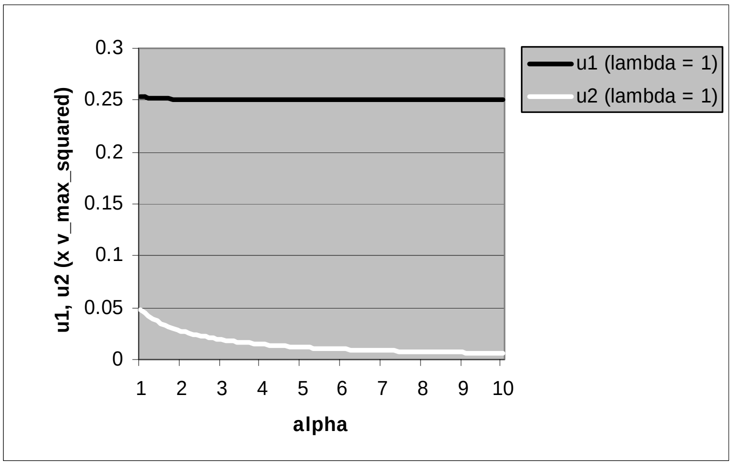

Figure 2: Equilibrium Qualities for Increasing alpha

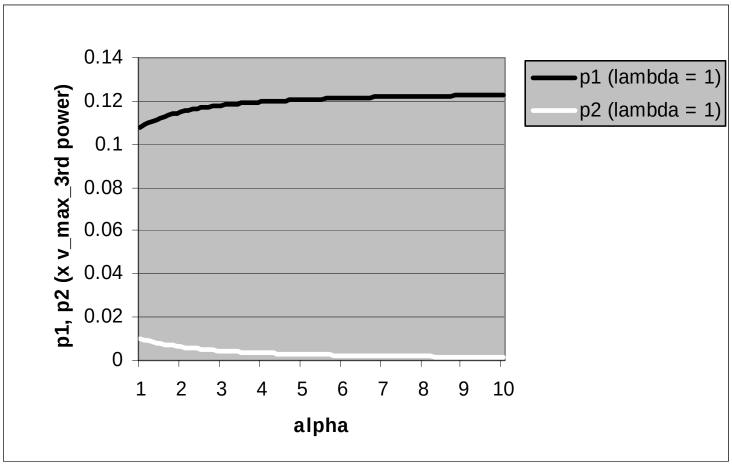

Figure 3: Equilibrium prices for increasing alpha

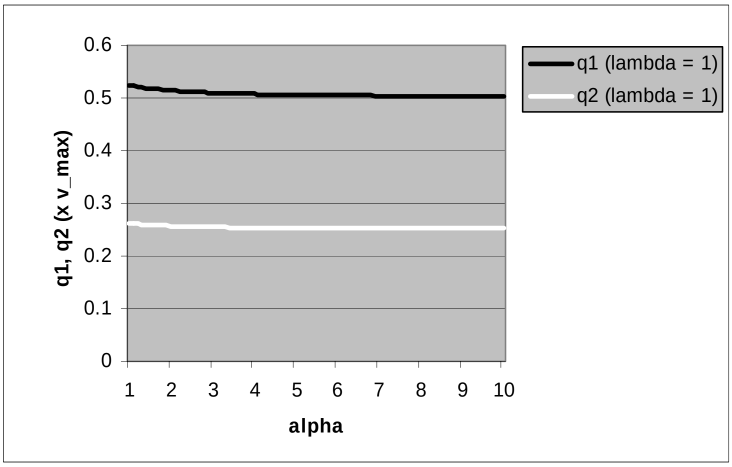

Figure 4: Equilibrium quantities for increasing alpha

The results supports the argument that increased scope of IPR protection will lead to market power for the leading seed breeder, at the expense of both competitors and client farms. This can be seen by examining the effects of α on profits as shown in Figure 5. Firm 1's profit increases as α increases. Firm 2's profits are of a much lower magnitude and decrease even further. The combined profits of the two seed breeders increase while those of the farming sector decrease. The decline in farm profits is greater than the increase in those of Firm 1, and total profits, a measure of economic surplus in this partial framework, decrease. Thus a phased-in breeders' exemption would be welfare-decreasing. The decrease in farm profits can be divided between two effects. First, firm 1, which is offering roughly the same quality, is able to increase its price. Second, farms in the lower end of the range of v suffer from the reduced quality of firm 2 which approaches the minimum possible quality level. In other words, many farms have effectively less choice for economically profitable seed varieties. In the modelling framework, this is seen by v_{02} (the farm, earning zero profits which is indifferent between variety 2 and not producing at all) increasing with α (not shown).

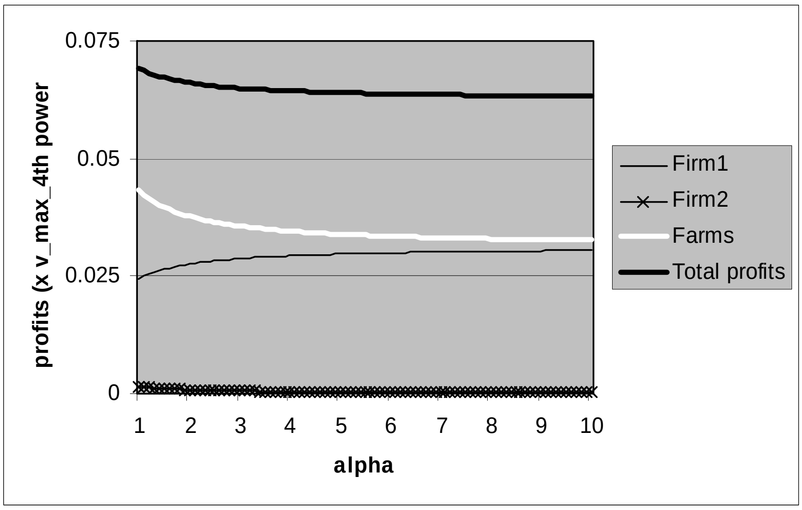

Figure 5: Firm and Farm Profits

The equilibrium solutions of the model were also found for various values of λ between 1 and 10. Recall that λ allows for equal increases in costs of quality development for both firms, representing a general narrowing of the germplasm pool and an increase in the costs of achieving a given quality increase. With $\lambda > 1$, qualities decrease for both firms as do profits, but the effect of increasing α alpha follows a similar pattern with results that are relatively comparable with those discussed above. This follows from the fact that λ factored out of equation (8) above, meaning that values of μ do not change with $\lambda > 1$. There may however be better ways to capture increasing costs for the breeding sector as a whole in such a model. Quality is represented here in as a one-off choice, while the increasing costs refers to those necessary to achieve the subsequent, incremental quality improvement. In the next and final section, we discuss other limitations to the model and possible future directions for research.

5. Conclusions

In this paper we have developed a model that illustrates the potential negative effects of increasing the scope of PBR protection on plant varieties, as proposed with either a phased-in breeders' exemption or patents. Such a policy could increase the costs for varietal development for breeding companies, in particular if their access to varieties of the market leader is constrained. We have represented this scenario as an asymmetrical increase in the costs of varietal development. This feature is incorporated into a simple extension to Motta's (1993) and Shaked and Sutton's (1982) model of endogenous quality choice under price competition a simple model of a duopoly. This stylized model shows how the leading breeder is able to exercise market power while not increasing its own R&D investments or seed quality. The profits of the market leader increase but this is more than offset by decreases to farm profits, who also lose from decrease in quality levels offered. In addition to being detrimental for innovation incentives and welfare, we also argue that a phased-in breeders' exemption might also reduce the use of germplasm resources with negative diversity consequences.

Our results provide one possible explanation for the fact that an expansion of the breadth of PBR protection has been proposed by the industry leader and met with much resistance from smaller players in the market. Such a proposal may simply reflect strategic behaviour on the part of the industry leaders in which they lobby policy makers for a legislative change on the grounds of broader social benefts (genetic diversity), but where the principal motivation may lie in raising costs for competitors.

Numerous issues could be studied further. Our stylistic model suffers from the usual deficiencies. One of these derives from the nature of the incentive to offer vertically differentiated products; in our model, the two firms choose to offer different qualities in order to relax price competition. With the imposed cost asymmetry, the incentive for the leader does not become any stronger. Nonetheless we feel that there are some interesting possibilities for pursuing a vertical differentiation approach. In particular, it seems important to further develop approaches for examining how restricting access among firms to the genetic pool will affect their ability to breed new varieties, particularly for firms in the competitive fringe or operating as followers. Our analysis points to the possibility of examining the implications for their breeding costs as an important line of empirical research. While the issues at stake are quite important, and include the use and maintenance of genetic diversity, empirical research would be difficult given the secrecy with which breeders guard information concerning the germplasm they are using. Pioneer has argued that this carving up of the genetic pool would be mitigated by cross-licensing of germplasm (Donnenwirth et al., 2004). It could therefore also be useful to apply lessons and modelling approaches from the extensive literature on licensing of patent-protected innovations.

Other extensions to the analysis includes addressing multiproduct firms in oligopoly, as well as other market structures such as more than two firms, or some other forms of monopolistic competition. The results from the model of vertical differentiation used here could be contrasted with models based on other preference structures as well as those that yield symmetric outcomes(e.g. Motta 1992, Sutton, 1998). Secondly, it may be helpful to represent breeders' use of each others' varieties as a spillover in product innovation and drawing on some of the recent work in this area (Symeonidis, 2003). Thirdly, different distributions of farm heterogeneity may be more realistic for some circumstances (e.g. developing versus industrialized country agriculture) and yield different results (Anderson et al., 1997 analyse the implications of non-uniform distributions in this class of vertical differentiation models). Another issue is whether there is some added value to a more direct representation of the breeding production function developed by Evenson (1998), including the consequences of the application of modern biotechnology. At issue here is whether the scale economies involved provide the basis for natural oligopoly in the plant breeding sector. Addressing this last issue may require a shift to a dynamic framework.

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