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Limiting Biotechnology? Information Problems and Policy Reponses

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The Issue

The revolution in biotechnology poses pervasive, although not entirely unprecedented, asymmetric information problems. Especially in Europe, but even in North America, there is mounting evidence that consumers do not treat genetically modified foods (GMFs) and their non-modified counterparts as perfect substitutes. If other things such as prices are equal, many consumers would prefer to consume non-GMFs; they perceive GMFs as lower-quality products. While farm-level producers are fully informed on the genetic qualities of their product, final consumers will often be unable to distinguish between the two types of products. Thus, the information structure will only sustain a *pooling equilibrium,* in which both GMFs and non-GMFs are sold together, or pooled, in a single market. Such hidden-type or adverse-selection problems tend to generate markets that are dominated by an inefficient proportion of low-quality products or "lemons" (Akerlof, 1970).

The asymmetric information problem potentially could be addressed by an identity preservation system (IPS) that involves product certification and labelling. A fully effective IPS would lead to a *separating equilibrium,* or separate markets for GMFs and non-GMFs. This paper provides a systematic investigation of the asymmetric information problem posed by biotechnological innovations and then assesses possible IPSs.

Implications and Conclusions

In the presence of asymmetric information, biotech innovation will be harmful to society whenever the adverse effect on quality outweighs the beneficial effect on price. Further, identity preservation systems do not necessarily help. On the one hand, innovation with a vol-

untary IPS for the non-GMF will be harmful to society if the costs of the IPS exceed the benefits of having low-cost GMFs present. A mandatory IPS for the corresponding GMF, on the other hand, may not be beneficial if enforcement costs are high. In many cases, environmental and ethical concerns will give rise to an additional negative public-good aspect to GMFs. When, and whether, to proceed with a particular GMF is essentially a difficult, but not intractable, empirical question. In certain cases, GMF production should proceed, while in others cases, more extensive testing and more prolonged field trials, or even outright bans, may be indicated.

Background

While biotechnology has applications in many areas, such as medicine, we focus on applications in agriculture. Biotechnology encompasses both within-species modifications and transgenic or interspecies modifications. In both cases, the extent of genetic modification may vary, so the issue of GMFs versus non-GMFs is not a simple black and white issue. On the one hand, within-species modification is relatively uncontroversial since it merely speeds up and makes more systematic what could be accomplished by "natural" breeding techniques. On the other hand, transgenics has become extremely contentious in spite of the fact that current scientific evidence typically points to the *substantive equivalence* between GMFs and their corresponding non-GMFs. Consumer objections to transgenic GMFs can usually be categorized as (i) long-term human health concerns, (ii) long-term animal welfare and environmental concerns, or (iii) ethical concerns. We accept the legitimacy of consumer preferences and avoid the alternative of paternalism (Hadfield and Thomson, 1998; Hobbs and Plunkett, 1999; Plunkett, 2000). For simplicity, we assume that these preferences are not open to manipulation although it is clear that advocacy groups on both sides of the biotechnology issue are attempting to affect the preferences of individuals.

Many GMFs will ultimately be designed with characteristics, such as health benefits, that are desirable for consumers. Such genetic modifications will pose few informational issues since they will either be directly verifiable to consumers or be credibly revealed to them by producers. To date, however, most GMFs in production and under development have input-reducing features, such as pesticide tolerance, that focus on producers. In this paper we focus on such producer-oriented genetic modifications, where consumers may perceive the non-GMF to be of higher quality than the corresponding GMF due to ethical concerns or fears of detrimental long-term health effects.

Over the supply chain as a whole, information is asymmetric in these producer-oriented cases. Farm-level producers, as well as the producers of biotech inputs themselves, have full information on whether particular crops are or are not genetically modified. In practice, there is typically a high degree of vertical coordination through contracts between producers of GM inputs and the farms that use them. In the absence of an effective IPS, however, the co-min-

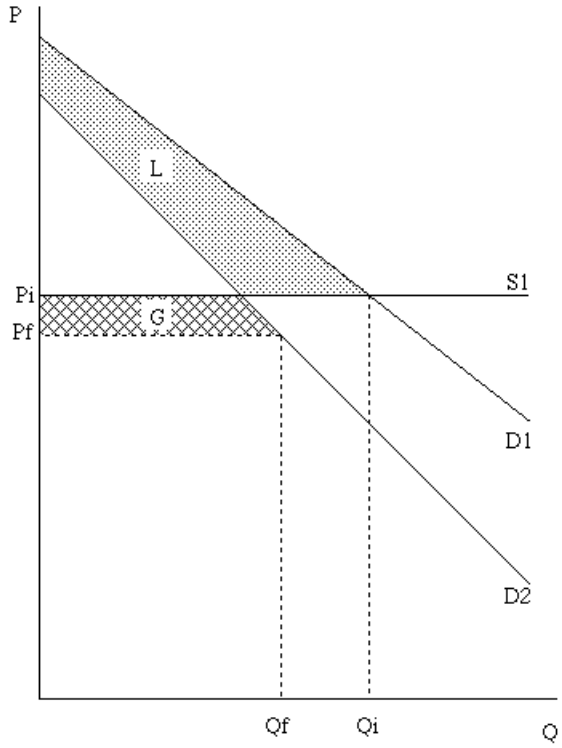
gling of product causes information to become progressively more incomplete as it moves downstream through the supply chain from farms to processors and on to distributors and retailers. Thus, consumers are unable to determine whether a particular batch of a final product contains genetically modified material or not. Further, the GMF and corresponding non-GMF will typically remain indistinguishable even after consumption. Since the genetic modification is not even detectable with experience, it can be referred to as a *credence* characteristic (Nelson, 1974).

Aggregate GMF production will have an additional adverse public-good effect for consumers with long-term animal welfare and environmental fears. Similarly, aggregate GMF consumption may have a further adverse public-good effect on consumers who have ethical concerns. Without wishing to downplay the importance of these adverse public-good features, we abstract from them so as to focus on informational issues.

Conceptual Framework

We assume a highly stylized supply chain in which farm-level producers sell directly to final consumers. There is free entry into non-GMF production, such that the initial supply by competitive producers is perfectly elastic at a price of Pi. In figure 1, the supply curve for non-GMF producers is S1. Given that the supply function for non-GMF product is perfectly elastic, we will see that it is unlikely that a non-GMF fringe will persist after GMFs are introduced unless an IPS is in place.

Figure 1 A Pooling Equilibrium with Hidden Quality



Biotechnology firms are involved in a two-stage game that is broadly similar to monopolistic competition. Stage one is the innovation or entry stage where biotechnology firms may elect to engage in costly research and development leading to a single, firm-specific genetically modified variety of the product. Stage two is a Cournot oligopoly subgame between however many biotechnology firms have entered at stage one. We assume that after innovation each biotech firm uses contracts to effectively integrate forward and control the farm-level production that uses its GM input. Although this is undoubtedly an exaggeration, detailed contracts between biotechnology firms and users of their products are common. We also assume, for simplicity, that the stage-two production costs and stage-one R&D costs are all symmetric across all biotech firms. While each biotech firm makes its own particular genetic modification, we stipulate that the resulting low-quality GMFs are all viewed as perfect substitutes for each other in the eyes of consumers. Nonetheless, with Cournot quantity-setting behaviour, price remains above marginal cost as in the conventional monopolistic competition model. Further, stage-one entry dissipates overall profit, completing the parallel with monopolistic competition.

There is a perceived quality difference between GMFs and non-GMFs even though GMFs are treated as perfect substitutes for each other. While the marginal benefit of the non-GMF always exceeds that of the GMF, the marginal benefit of consuming the GMF can still be positive. In figure 1, the demand curve D1 shows what consumers are willing to pay in the initial situation when only the non-GMF is on the market. By contrast, the demand curve D2 shows how much less consumers will be willing to pay when only GMFs are being supplied.

Analysis of the Hidden-Quality Problem

In the absence of a credible IPS, consumers face a hidden-quality problem because they can distinguish neither between GMFs and non-GMFs, nor among the various types of GMFs. There is a single market with a *pooling equilibrium* where consumers expect the actual weighted average blend of quality. For example, the probability or proportion of GMFs may be inferred on the basis of acreage planted. Since the market typically becomes dominated entirely by GMFs in equilibrium, consumers become fully aware of this fact.

If transgenic innovations reduce stage-two marginal production costs to a sufficient degree, the Cournot equilibrium between biotech oligopolists will result in a perceptible price reduction. In figure 1 the price falls from Pi to Pf and, consequently, all non-GMF producers are driven from the market. The possibility of fringe non-GMF production rules out a final price that is higher than Pi. In the situation shown in figure 1, the marginal costs of the GMF oligopolists, however, will be below Pf. Since consumers will realize that the market is dominated entirely by GMFs, the demand curve will shift from D1 all the way to D2. On the one hand, area L is a loss of consumer surplus from the deterioration in quality. On the other hand, area G is a gain in consumer surplus from the decrease in price. Meanwhile, open entry into

both biotechnology and non-GMF production dissipates rents on the production side. Society, therefore, will either lose or gain from the biotech innovation depending on whether the adverse quality effect is of larger or smaller magnitude than the favourable price effect. Figure 1 shows a case where biotechnology is harmful overall.

In situations where the reduction in marginal cost is less dramatic, there may not be a beneficial price effect at all. For example, the Cournot equilibrium could involve the biotech oligopoly setting a preemptive price just below Pi, which precludes production of the non-GMF by the fringe. In such a case, the market would continue to be dominated entirely by GMFs, and the adverse quality effect would remain undiminished. Since the beneficial price effect would be insignificant, there would be an overall welfare loss.

A Cournot equilibrium among biotech firms that accommodates the persistence of any fringe is unlikely and could only arise in the limiting situation where biotech and non-biotech firms alike happen to make zero profits at a price of Pi. In such a situation, demand would be given by a weighted average of the D1 and D2 curves in figure 1 because consumers would correctly expect to consume a blend of GMFs and various non-GMFs. In this limiting case, the magnitude of the adverse quality effect would be reduced, but there would still be an overall reduction in welfare because of the continued absence of a beneficial price effect.

In a more general setting, society may benefit from positive overall profits earned by biotechnology firms in addition to the possible gain from lower prices for consumers. Since the number of biotechnology oligopolists is not continuously divisible, "small" positive profits will typically remain in equilibrium; entry will only proceed until an additional firm would drive profits negative. Further, if the R&D and/or production costs of the biotechnology firms are not symmetric, the overall profits of intramarginal firms will be positive even if the profit of the marginal firm is exactly equal to zero. Despite the possibility of producer benefits in the form of positive profits to innovating firms, the central point remains unchanged. If the adverse quality effect on the consumption side is large enough, biotech innovation will leave society worse off.

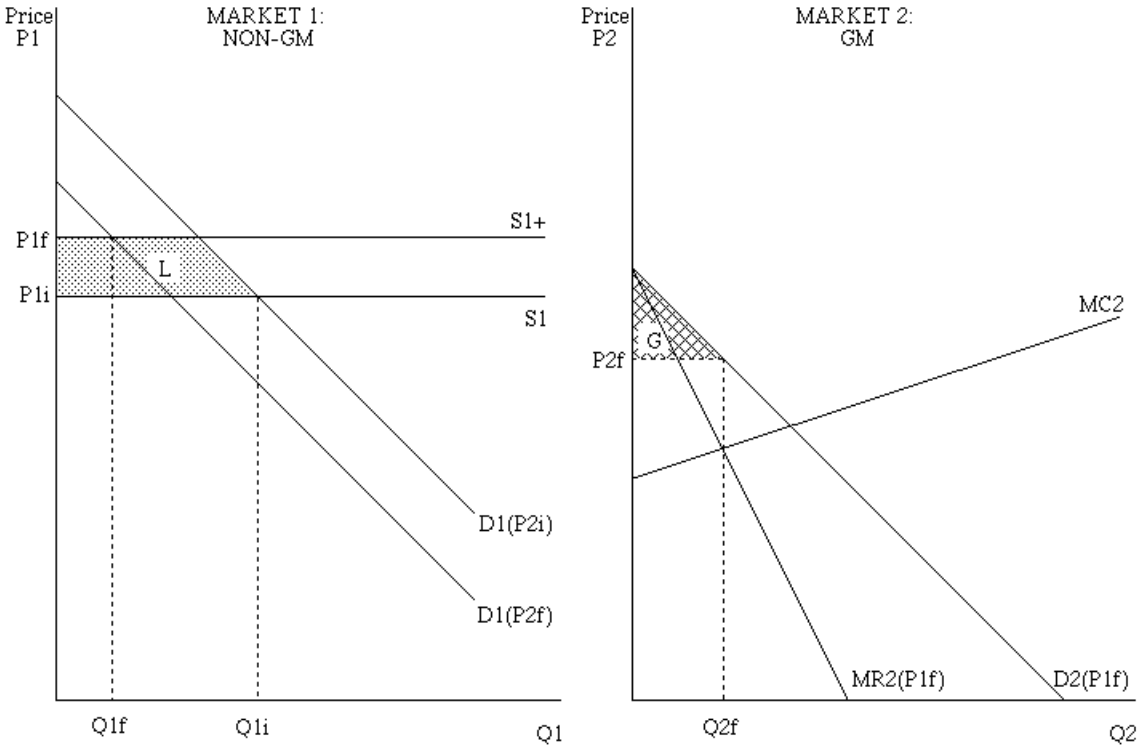
Analysis of Identity Preservation Systems

If reliable information were made available, the hidden-quality problem might be mitigated (Hadfield and Thomson, 1998). To provide useful product-quality information, it is necessary to have an effective identity preservation system (IPS) where the supply chains for the GMF and non-GMF products are separated. The costs of such IPSs are likely to be significant. By contrast, low-cost labels such as "may contain products of biotechnology" provide little useful information to consumers.

If consumers are willing to pay a sufficiently large premium, there will be a market incentive for non-GMF producers to attempt to identify their product. Figure 2 shows a case where a GMF, good 2, is introduced, but non-GMF or good-1 producers respond with an IPS. The

additional costs of the IPS shift the supply curve from S1 to S1+ in the left panel, which shows the market for the non-GMF. For simplicity, we assume constant IPS costs per unit of the non-GMF. The availability of the substitute GMF at a final price of P2f shifts the demand curve for the non-GMF inward from D1(P2i) to D1(P2f). Since the GMF is not initially available, its initial price, P1i, is infinite.

Figure 2 A Non-GMF Identity Preservation System



The introduction of the GMF product and the non-GMF IPS raises the price of the non-GMF product from P1i to P1f. Since we choose to consider the price increase on the market for the non-GMF, the relevant demand curve remains D1(P2i). Consequently, consumer surplus falls by the shaded loss area, L, on the non-GMF market. For clarity, we show the situation where only one biotech firm innovates and enters into production of the GMF. The resulting GMF monopoly shown in the right panel is an equilibrium situation if the overall profit of the biotech firm, including stage-one sunk costs, is equal to zero. The introduction of the GMF, however, does give rise to new consumer surplus, represented by area G. If it happens that area L exceeds area G, then the social costs of the IPS exceed the benefits of having the new, cheaper GMF variety, and society is worse off overall. Welfare declines as a result of the biotech innovation in the presence of the IPS.

While an IPS for non-GMFs might be largely voluntary, a GMF IPS would have to be mandatory. This is because there is little incentive to report low quality. If we blithely assume

full compliance under such a mandatory GMF regime, our only positive result is obtained. Since the price of the non-GMF would remain unchanged, there is no impact on consumers in the market for the non-GMF. Whenever innovation proceeds under such a costly non-GMF IPS, however, new consumer surplus would be generated on the GMF market. Consequently, there is an overall gain to society.

It should be emphasized that our results do not imply a complete ranking of the various alternatives. An identity preservation system need not be an improvement over the hidden-quality situation and, further, a mandatory GMF IPS may or may not be superior to a voluntary non-GMF IPS. Further, compliance is an issue in reality. Society would have to bear additional monitoring and enforcement costs for either type of IPS to prevent the GMF producers from misrepresenting their products so as to sell at the higher non-GMF price. Since enforcement activities are public goods, provision by the government would generally be warranted. Including such enforcement costs introduces the possibility that even when biotech innovation is combined with a mandatory non-GMF IPS, the overall impact on society could be negative. The only way to avoid this ambiguous result would be to use taxes on the GMF to finance the enforcement costs.

Our analysis shows that biotechnology presents some very serious policy problems that require careful empirical analysis on a case-by-case basis. Along with other recent work (Kerr, 1999a & 1999b), this article also suggests the need to thoroughly rethink international trade rules concerning biotechnology. In the European Union, for example, quality concerns with biotech products seem especially deeply rooted. When considering the alternatives of unrestricted imports of GMFs versus an outright import embargo, Gaisford and Lau (2000) show that the latter may sometimes be the lesser of two evils. In such cases, however, mandatory labelling of GMF imports will typically lead to an improvement over an embargo but not necessarily an overall welfare improvement relative to the pre-GMF state.

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