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by

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Clem Tisdell[2]

October 2008

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Economics, Ecology and the Development and Use of GMOs: General Considerations and Biosafety Issues

ABSTRACT

This article outlines both ecological and socioeconomic issues involved in the development and use of GMOs. It's argued that while initially new GMOs add to the global stock of biodiversity, in the long-term they result in a decline in biodiversity. Various mechanisms that bring about this decline in genetic diversity are identified. It is suggested that due to evolutionary forces, the desirable genetic properties of some GMO may be eroded in the long-term. They are unlikely to be sustained in their ecological effectiveness forever. The economics of developing and marketing of GMOs is given particular attention. When their development is left to private enterprise, it is found that the economics of developing and marketing GMOs favours large enterprises as primary suppliers. In marketing, there are also preferences for sales of GMOs to larger-sized commercial farms rather than smaller-sized ones. GMOs that are favoured for development are in demand for use in large agricultural markets, many of which are located in higher income countries. Aspects of the patenting of GMOs, co-evolution, various social conflicts in the use of GMOs and legal liability for damages caused by the development and use of GMOs are discussed both from a socioeconomic and biosafety point of view.

Economics, Ecology and the Development and Use of GMOs: General Considerations and Biosafety Issues

1. Introduction

The development of genetically modified organisms has generated both high expectations about their ability to increase economic production and help reduce economic scarcity as well as dire predictions about how they might reduce biodiversity and health risks and in the long-term threaten economic sustainability. However, assessment of the economic costs and benefits of the development and use of GMOs is complex as is the evaluation of their ecological consequences. Some of the issues that have been raised or discussed in Tisdell (2000) and further aspects are covered in Tisdell (2002).

It should not be assumed that the use of all GMOs will reduce economic scarcity. Individual cases need to be assessed. Some may and others may not reduce economic scarcity. Furthermore, in the case of those GMOs which reduce scarcity, their scarcity-reducing benefits may diminish with the increased frequency of uses.

The use of GMOs inevitably results in ecological changes. It is argued in this paper that the use of GMOs is likely to in a decline in biodiversity in the long run. Furthermore, some of the desired attributes of particular GMOs may be eroded in due course by the operation of evolutionary forces. The economics of developing and marketing GMOs is also analysed in this article. It is argued that when this is left to the private sector, the development of GMOs is heavily influenced by the nature and the economics of property rights in them. Economic factors favour the development and marketing of GMOs by large enterprises. Furthermore, economic considerations favour the development of GMOs to satisfy the requirements of large-scale commercial farms and those farms are the prime markets for GMOs. Several other socioeconomic and biosafety issues are important when considering the development and use of GMOs. These include the building of patent walls, lack of co-evolution and related safety issues, and social conflicts about the use of GMOs. Legal liability is also important. These are all discussed in this article.

2. Ecological Issues

Initially, the introduction of a GMO adds to the extent of global biodiversity. However, it is not an equilibrium situation. The continuing use of the GMO is likely to change the ecological balance with the passage of time and eventually reduce the extent of genetic diversity. The reduction in biodiversity may come about as a result of a variety of processes.

Processes of long-term biodiversity loss

Cross breeding with a GMO may eliminate naturally some other varieties or strains of living organisms**.** Cross breeds may become established as dominant types and eliminate some existing varieties of species. Furthermore, GMOs may escape into the wild and in some instances, may outcompete and eliminate some competitive organisms**.** However, this could be a rare event because many GMOs may only be able to survive under artificially managed environmental conditions, such as are common in modern agriculture.

An important indirect route by which GMOs can lead to a loss in genetic diversity is if they provide an economic incentive for the extension or intensification of agriculture, aquaculture or silviculture. Extensions of these land uses are likely to reduce the size and variety of habitats available to other species and reduce biodiversity in the wild. Intensification can also reduce the availability of diverse micro-habitats and reduce the presence of species inhabiting these. The greater the commercial economic success of a GMO, the more likely are these impacts, particularly if the demand for the produce of the GMO is fairly elastic.

Apart from this, a commercially successful GMO may displace similar traditional varieties of organisms in agriculture, aquaculture or silviculture due to economic or commercial selection (Tisdell, 2003 a). The consequence is a loss of human modified or developed genetic stock. Thus in the long-term, the sustained use of GMOs can reduce both biodiversity in the wild as well as the available stock of human modified or genetic material. Figure 1 summarises these consequences.

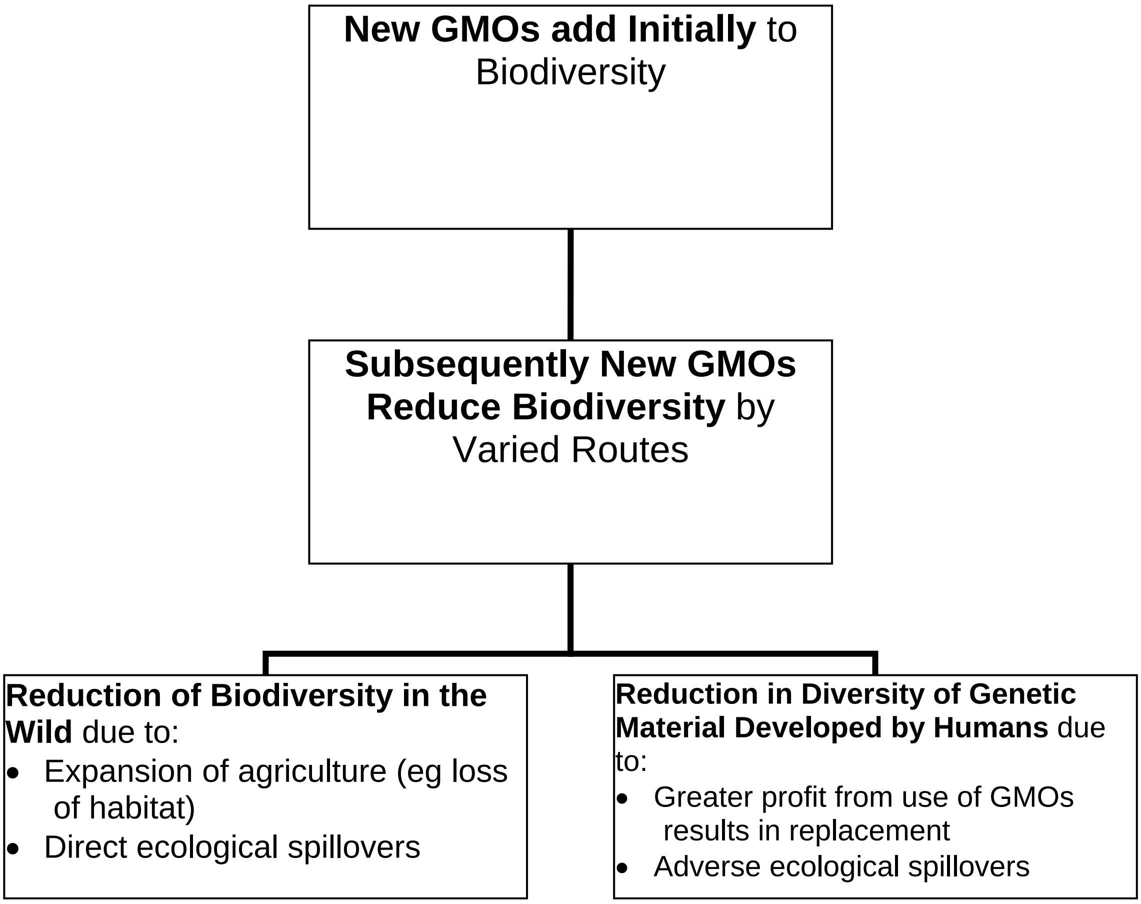

Figure 1: A chart indicating how the use of GMOs can reduce genetic diversity in the long run.

Genetic erosion

The quality of some desired attributes of GMOs may be diminished in the long run by evolutionary processes. For example, it is conceivable that in the long run, an insect pest (as a result of natural selection) could develop increased resistance to Bt modified crops. Another possibility is that pests not affected to any great extent by Bt may eventually increase their populations and affect to some extent the benefits otherwise obtained from Bt modification. Ecological evolution and change may occur in natural organisms to take advantage of new niches opened up the presence of genetically modified organisms.

Genetic modification can involve trade-off between attributes

In genetically modifying an organism in order to increase its fitness for a particular purpose, there is a risk that other relevant traits will be weakened and negative characteristics may occur. These are not always anticipated by scientists. For example, Dr. Liu (2008) has reported that exudates from Bt cotton roots in China increase its susceptibility to cotton blast, a fungal disease. The incidence of this disease has increased and is causing a substantial decline in cotton yields in China. This trait of Bt cotton was not predicted by scientists.

A Chinese scientist (Lu Menzhu, 2008) has also reported that China has genetically modified some species of poplar trees to reduce their lignin content. Their lowered lignin content reduces the cost of processing them for paper production. But the lower lignin content makes the trees more prone to damage by wind and may increase their susceptibility to some species of pests. Furthermore, it has been found the development of Bt poplars to control attacks by one species of beetle has made them more vulnerable to attack by another species of beetle (Lu, 2008).

Some of the trade-offs as a result of genetic modification appear to be predictable but others are uncertain. When such a trade-off is unavoidable, there is an associated economic problem in the case of organisms that are used commercially, namely to ensure that the genetic combination engineered gives the greatest net economic benefit in relation to the attainable set of genetic combinations.

Reduction in interspecies competition as a negative consequence of GMOs

Two mechanisms have been mentioned that can result in the fitness of GMOs being undermined. These are genetic erosion and the need to trade-off traits. Another factor that can reduce the economic suitability of GMOs is that their presence may improve the competitiveness of competing species some of which may be regarded as pests. The case of Bt poplars has already been mentioned. Another case involves herbicide-resistant GM rice. This has been developed experimentally in China. It has been found that it is prone to cross-fertilise with wild rice which is regarded as a weed in rice crops (Lu, Baorong, 2008). Because there is less rural labor available for weeding by hand in China due to the rural to urban migration drift, the increased resistance of GM wild rice to herbicide could become a serious economic problem if herbicide-resistant GM rice becomes available for commercial use.

Selective breeding less risky

Note the above ecological changes can also occur when a new variety of organism is introduced by selective breeding, that is the natural ecological disturbances mentioned can occur plus those induced by economic change (Tisdell, 2003a). However, it is usually believed that such changes will be smaller and slower when selective breeding is adopted for genetic development than is potentially possible when new GMOs are introduced. Hence, the ecological risks and uncertainties associated with the introduction of GMOs are usually considered much higher than in the use of selective breeding. The introduction of hybrids poses even less ecological risk when they are unable to reproduce themselves. However, their introduction can vial economic exterior and intensification lead to an indirect reduction in biodiversity.

3. Economics of Developing and Marketing GMOs

General influences of economic factors on the nature of development and marketing of GMOs

High costs and considerable business risks are involved in developing GMOs. Therefore, when their development is left to private enterprise, only large firms usually engage in this activity. Furthermore, if businesses are to have an economic incentive to develop new GMOs, then they must be assured of intellectual property rights. Patents are used in many countries for this purpose.

However, it is important to note that patent laws and regulations covering the granting of patents in relation to GMOs are not the same in all countries. For example, in China, patents are granted on the techniques for producing specific GMOs but not on the products produced as a result of the availability of those techniques (Greenpeace China and Third World Network, 2008). For example, a patent would be granted in China on techniques to produce a Bt modified plant but not in seed which transmits this genetic trait. However, in the United States both techniques for producing genetically modified organisms and the products produced as a result of applying these techniques are protected by patent law. The economic analysis of GMOs that follows is based on the assumption of strong and extensive patent laws of the type adopted in the United States.

Patents grant a monopoly to the patentee to use the patented invention for a specific number of years. During this period, the inventor has a monopoly in the use of the invention, in this case a new GMO. A business that has a patent for a GMO may, therefore, engage in monopoly–pricing of its use. This is not socially ideal. (Tisdell and Hartley, 2008, pp. 36-37, Ch. 8). However, it is necessary for the inventor to be sufficiently rewarded for his/her inventiveness. Otherwise, there is no private economic incentive to engage in R& D effort. This is particularly important bearing in mind that not all research efforts are successful in developing an economically viable new product. Furthermore, the patent is only for a limited period of time and there is no guarantee that some other firm will not develop a commercially superior competitive GMO within this period. This will limit the profit possibilities available to the original patentee.

In addition, the level of the monopoly price of say GM seed will be influenced by the price of competitive traditional seed and by farmers' net profits when using this seed (Tisdell, 2006, p.221). This constrains the price which the owner of GM seed will find it profitable to charge. In some instances, however, the GMO-monopolist may deliberately charge a low price initially for the use of its GMO to encourage its adoption and eliminate the use of competing traditional organisms. This predatory behaviour can eliminate competing traditional varieties of a crop and can be a prelude to higher monopoly prices for the GMO (Tisdell, 2006, p.222).

The legal costs of protecting patented GMOs against infringements of rights can be high. Once again, this tends to favour large firms as developers of GMOs.

The establishment of legal property rights in new GMOs is only part of the economics of developing and marketing them. The transaction costs of marketing GMOs (for example GM seed) are high because considerable effort is required to ensure that the buyers do not re-use or sell any GM seed they produce without permission. This adds to the cost of drawing up contracts with clients, there are costs incurred by sellers in monitoring the use of GMOs by buyers to ensure compliance with agreements, and there may be considerable legal costs if breach of contract occurs. Similar costs do not arise in the case of hybrids.

These transaction costs favour the marketing of GMOs by large companies. They also favour their sale to larger-sized agricultural and related enterprises because market transaction costs per unit of the GMO sold tends to decline with the value of sales to an individual production unit.

Taking into account potential economic gains and transaction costs, there is an economic incentive to develop GMOs that are likely to be adopted by large-scale commercial enterprises, particularly in higher income countries. Furthermore, organisms (for example, crops) for which there is a large volume of demand are likely to the favoured, other things equal. Private businesses have little incentive to develop GMOs to suit farming involving small-scale units or semi-subsistence. Therefore, crops which are important in LDCs (but not in higher income countries) are unlikely to be targeted by private enterprises for the development of GMOs unless they are plantation crops, possibly involving foreign investment. Figure 2 provides an overview of predicted patterns of development of GMOs by private enterprises when economic considerations are taken into account.

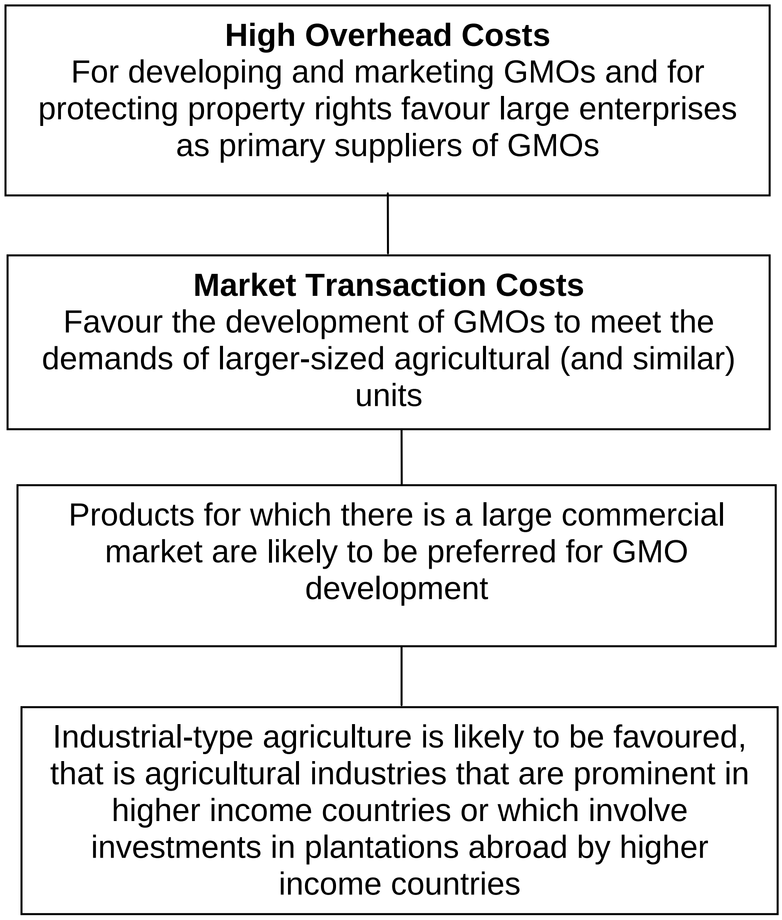

Figure 2: A chart showing predicted patterns of development of GMOs by private enterprises due to economic considerations.

Support from economic theory for the above propositions

Support for several of the above propositions about likely patterns of development and use of GMOs can be provided by the application of basic economic theory. In order to show this, assume that the GM product is GM seed and consider the proposition that, other things being equal, the economic incentive to develop such seed is greater the larger is the expected size of the market for it. For simplicity, assume that the successful development of the GM seed will establish a monopoly for it.

In Figure 3, line BD_1 represents the demand for the GM seed if the market is small and the line D_2D_2 represents the demand for it if its market is larger. The average operating cost of supplying the GM seed once it has been developed is assumed to be a constant OA and therefore, line AC represents the average variable cost of its supply. The line AMR is the marginal revenue line corresponding to the demand relationship

BD_1. Hence, when demand is at level BD_1, the maximum operating profit of the producer of patented GM seed is equivalent to the area of quadrilateral $AFJP_1$. There is a mark-up on average operating costs for each unit of seed sold of AP_1. If this margin is retained when the demand for the seed is much higher at D_2D_2, operating profit increases substantially. It rises by an amount equal to the area of rectangle FGHJ, that is by an amount equivalent to $(X_2 - X_1). (P_1 - A)$. Therefore, the economic advantages of a larger-sized market are apparent.

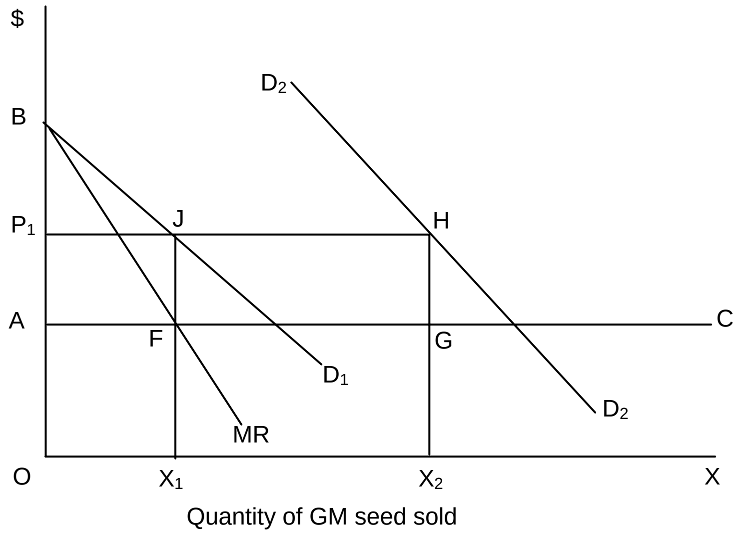

Figure 3 An illustration that the larger is the size of the expected market for a GMO, the greater is the profitability of developing it, other things held constant. In the case illustrated, the operating profit of patented GM seed in the larger-sized market is equal to the area of rectangle $AGHP_1$ but in a smaller-sized market it is only equal to the area of rectangle $AFJP_1$.

Observe also that if there are fixed overhead costs to be recovered (for example, the costs of the R&D invested in the creation of the GMO), this will also favour markets of larger size. When overhead costs are taken into account, the average total cost of supplying a new type of GM seed might be as indicated by the declining curve marked RST in Figure 4. Line BD_1 represents the demand for the GM seed if the market is relatively small and D_2D_2 represents demand if the market is larger. Because of the overhead costs involved, the development of GM seed for the smaller-sized market is unprofitable but it is profitable for the larger-sized market, other things being equal.

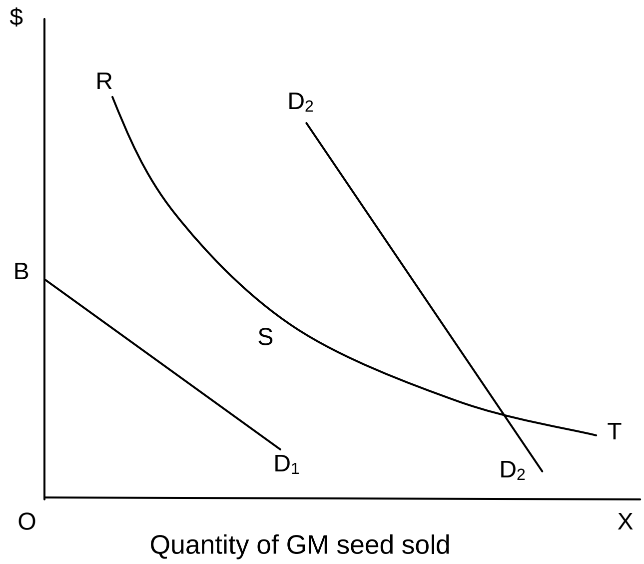

Figure 4: An illustration that when overhead costs are large (as they are likely to be for the development and marketing of GM seed) the development of a GMO smaller-sized markets is unlikely to be profitable. This is due to the declining nature of average total cost. In the case illustrated, development is unprofitable if market demand is as shown by BD_1 but is profitable in the larger-sized market where market demand is shown by D_2D_2.

When the demand for using an organism is relatively inelastic, this can increase the profitability of developing a GMO, other things being held constant. The more inelastic is the demand for a resource, the higher is the monopoly price that can be secured by monopolist from it and the greater are the profits from its supply, other things being equal. This is illustrated in Figure 5. If demand for GM seed corresponds in this diagram to BD_1, then making the same assumptions as previously made for Figure 3, the patentee's monopoly price is P_1 and his/her profit is equal to the area of rectangle $AFJP_1$. Should, however, the demand curve for the GM seed be steeper, as for example indicated by the line D_2D_2, the profit-maximizing monopoly price will be higher. In the case illustrated it is P_2. Consequently, operating profit from selling the GMO rises by an amount equivalent to the area of rectangle P_1JKP_2. The steeper or more inelastic the demand curve, the greater is the monopoly profit. Hence, if the size of the market for GM seed is large and the demand for it is relatively inelastic, this provides a strong economic incentive for the development of GM seed.

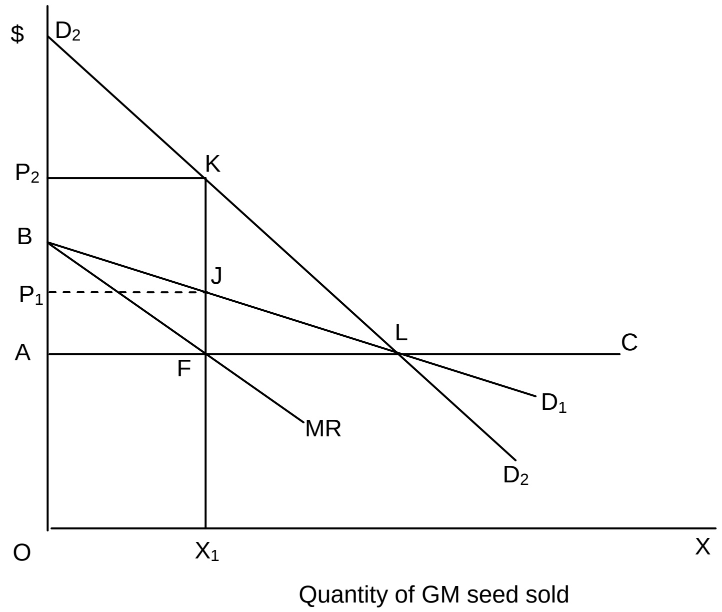

Figure 5: An illustration that other things held equal, the profitability of developing a new GMO is greater the more inelastic is the predicted demand for it. In the case illustrated demand relationship D_2D_2 is more inelastic than BD_1 and the profitability of supplying GM seed is higher in the former case.

It was argued above that sellers of GMOs are likely to find it more profitable to sell to large-scale farms than smaller ones. This is based on the view the average transaction costs involve in sales are likely to fall as the quantity sold to any production unit rises. This is illustrated by Figure 6. In Figure 6, line AFL represents the average production cost of the supplier of GM seed and curve HJK represents the average total cost of supplying GM seed to a farming unit. The difference between line AFC and curve HJK represents the level of average marketing transaction costs involved in selling GM seed to a farm. Suppose that the seller of GM seed sells it at P_1 per unit. Then it is unprofitable to sell GM seed to farms that wish to buy less than x_1 of it. For those farms wanting to buy more than x_1 of seed, the profit of the seller rises with the amount sold to a farm. Hence, the hypothesis stated above that developers of GMOs favour developing these for industries in which large commercial farms exist is supported.

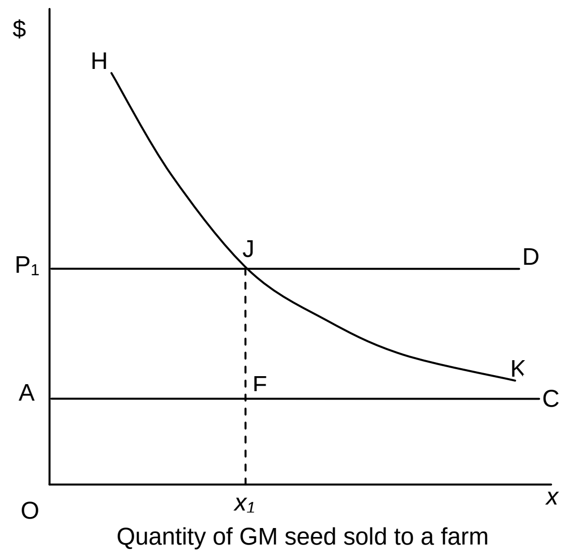

Figure 6: An illustration of the proposition that developers of GM seed are likely to find it more profitable to sell it to large commercial farms than small farms. In the case illustrated, it is unprofitable for the seller to sell to a farm which buys less than x_1 of seed.

4. Other Socioeconomic Issues and Some Further Biosafety Matters

Patent walls

Use of the patent system by creators of new GMOs can be used in special cases to create patent walls. This involves the use of a range of unilateral patents which make it difficult for others to make progress in developing new GMOs without infringing on the rights of existing patents. This creates barriers to the development of potential competitors to existing supplies of GMOs and reduces market competition.

Some LDCs believe that such a situation is likely to be unfair to them since they are likely to be restricted in their future options of developing GMOs by the existence of patented GMOs, many of which are based on the modification of genetic material originally obtained from them e.g. soya beans (Xue et al., 2004). A further bone of contention is that in many cases, no compensation is paid to our LDC for use of the original genetic material used the presence of which was essential for the creation of the GMO. The issue of whether compensation should be paid for the use of such material is, however, complex from an economic point of view. From a global development and economic welfare point of view it can be argued that payment for the use of extant genetic material of this type is only justified in special circumstances (Tisdell, forthcoming a). The matter is complicated for example, by the fact that some LDC make extensive use of genetic material derived from other LDCs (for instance, tomatoes and potatoes) and they also use genetic material that has come from countries that are now higher income countries, for example some types of maize from the United States.

Lack of co-evolution

GMOs are usually developed in experimental conditions divorced from local conditions. Whereas most other methods of genetic change involve slow and gradual changes in genetic material, creation of GMOs can result in rapid and large shifts in the composition of genetic material. Therefore, the creation of GMOs is considered to be relatively hazardous. Change may not be gradualistic, scope for learning by trial-and-error may be reduced and the potential for irreversible consequences are seen as heightening the risk of releasing GMOs. Hence, there are considerable concerns about biosafety risks associated with the introduction of GMOs.

A further potential problem is the lack of social and ecological co-evolution which can arise when new GMOs are released. Some writers, such as Norgaard (1994) regard lack of co-evolution to be undesirable. In the past, the social practices of many local communities evolved in step with changes in their agricultural and other productive practices, thus balance and social harmony existed between local communities and changes in production methods. In modern times, however, this harmony is destroyed by rapid changes in production methods and in types of production (Tisdell, 2003b, Ch. 19). The result in increasing stress for individuals and social dislocation. The introduction of GMOs potentially adds to this lack of co-evolution. Lack of co-evolution seems to be symptomatic of modern economic systems.

Social changes and variations in productive forces are interdependent, as observed by Marx (1930). The social desirability of such changes is always difficult to evaluate. For example, are the social changes that occur desirable or undesirable? If they are undesirable, does the increase in the availability of economic commodities as a result of the introduction of new techniques, e.g. GMOs, more than compensate for the undesirability of the social changes that are generated? Scientific answers to such questions based on positivism are not available but consideration of these questions should not be avoided even though they are beyond the scope of economics when it is defined narrowly.

Social conflicts about the use of GMOs

The use of GMOs frequently creates social conflict. For example, some social groups are fearful of their possible biological consequences, including their possible long-term impacts or health. Some buyers of produce wish to avoid products, particularly food products, that contain GMOs. This can result in some GM products selling at a reduced price compared to similar non-GMO products. This contributes in part to the occurrence of conflicts between growers of non-GMO crops and those cultivating GM crops.

Two problems can occur:

(1) cross pollination may occur between some GM and non-CM crops and

(2) if it is unclear to buyers what produce is based on GMOs and which is not, they may become suspicious of crops for which both GM and non-CM varieties exist and reduce their demand for these crops.

There is a problem of asymmetric information between sellers and buyers in this case (Akerlof, 1970; Varian, 2006, Ch. 37). In this case, sellers know the nature of the product but buyers are unable to determine this just from inspection of the product. Consequently, there is scope for fraud by sellers. In extreme cases, this leads to the collapse of the whole market and in many cases results in reduced demand for some types of the marketed product. For example, in the case being considered here, it could result in the demand for produce which is claimed to be GM-free declining. Certification schemes can, however, help to reduce the problem and laws may be strengthened to require accurate disclosure of the nature of the goods being traded, that is whether they are GM-free or not.

In order to reduce the problem of possible cross pollination of GM crops and non-GM crops, they may be located in areas that are spatially well separated. For some crops which depend on drifts of pollen in the wind for pollination, border hedges may be required to lower the likelihood of pollen-drift.

Some of the types of social conflicts between persons who want to grow GM crops and those who are opposed to this can be modelled by using game theory (Tisdell, forthcoming b). This will, however, not be discussed here.

Legal liability for the use of GMOs is an issue. For example, to what extent should developers of GMOs be liable for any environmental damages caused by their use? To what extent should farmers who use GMOs be responsible for any environmental damages caused by their use?

The socially appropriate extent of legal liability is difficult to determine. Strict liability for damages caused by a GMO will reduce economic incentives to develop and use them. The consequence could be loss of substantial economic benefits. Questions such as how wide ranging should legal liability for damages be, should it be capped, should a developer be absolved from legal liability if the government approves a GMO for use and to what extent should liability be reduced by the fact that its developer acts with care, all need to be considered (see Tisdell, 1993, Ch.5). It seems that as the level of income in countries rises that their preferences tend to shift from limited legal liability for possible damages caused by new products towards strict liability.

The conferral of legal rights is one thing and enforcing them is another. Similarly, this is so for legal liability. Costs and other difficulties are involved in enforcing laws or taking advantage of the law. The costs sometimes exceed the expected benefits of legal action and actions are frequently uncertain.

The question of the adequacy of proof and the burden of proof on parties affects the economics of pursuing legal action. If for example, a non-GMO crop is "contaminated" by a GM crop, it may be difficult to prove which farm(s) using GMs is (are) responsible. In Germany, this has resulted in laws being passed which make all growers of related GM crops in the locality legally responsible to contribute collectively to compensation. This means that the plaintiff does not have to identify the particular farm(s) that was (were) the sources of the "contamination".

The stage at which it is socially optimal to release a GMO after the development and testing of it is difficult to determine. This is because even after considerable testing, some environmental impacts may be uncertain. Further delay may reduce those uncertainties but if the economic benefits from using the GMO seem to be substantial, delay involves considerable opportunity costs. It is usually too costly to wait for the release of a new economically promising GMO until virtually no doubts remain about its environmental impacts. Community standards and expectations have to be taken into account in deciding on the appropriate time at which to release a new GMO.

5. Concluding Comments

The ecology and economics of the development and use of GMOs is complex, particularly compared, for example to that for non-reproducing hybrids. The latter do not pose direct genetic risks and it is easier for developers of hybrids (which do not self-reproduce) than developers of GMOs to enforce their property rights. Consequently, in the case of hybrids, biosafety problems are of lower importance and economic problems of maintaining property rights are less acute.

On the basis of the evidence presented, one would expect GMOs to be developed and marketed by larger enterprises rather than smaller ones. Furthermore, there is an economic incentive to develop GMOs that are likely to be used by large commercial farms rather than small or medium-sized farms. Market conditions are also liable to bias the development of GMOs in favour of large agricultural industries in higher income countries or plantation agriculture in developing countries, particularly those industries where large-sized commercial agricultural units predominate.

It was also pointed out that the development and use of GMOs involves several other socioeconomic issues. For example, concerns have been raised about the possibility that patent walls might be used to block out potential new developers of GMOs including developers in less developed countries. Attention was also brought to the nature of conflicts between users and non-users of GMOs and matters involving the protection of buyers of products that may or may not be GM-free. Considerable attention was given to questions involving legal liability of the developers and users of GMO for any damages which they might cause. Many questions remain about the nature and type of legal liability that should be placed on developers and users of

GMOs taking into account such matters as the biosafety risks involved, for example, should liability be limited and if so, in what way? Who should take action if damages occur, for example, should it be the injured party, the state or both? What is to be the standard of proof and on whom should the onus of proof fall? Who will pay the costs of legal action? Decisions about such matters affect economic incentives to develop and use GMOs and the biosafety risks to which societies are exposed.

It is evident that institutional arrangements for the development, introduction and use of GMOs are extremely important. The affect biosafety outcomes, incentives for the development of GMOs, the level of economic benefits obtained from their use and the distribution of these benefits. In this regard, the nature of patent systems and legal procedures for the enforcement of intellectual property rights in GMOs are particularly important (Then, 2008).

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