

Genetically Modified Organisms in Agriculture: Social and Economic Implications

by

Ben Davies¹, Caspian Richards¹, Clive L. Spash^{1,2} and Claudia
Carter¹

¹ Socio-Economic Research Programme (SERP), The Macaulay Institute, Aberdeen.

² Department of Geography and Environment, University of Aberdeen

**Aberdeen Discussion Paper Series: People,
Environment and Development.**

Editor: Ayele Gelan

Series Coordinator: Clive Spash

2004

ISSN 1743-9965

The Macaulay Institute, Craigiebuckler, Aberdeen AB15 8QH, Scotland

ABSTRACT

This paper shows how the debate over GM technology has been framed and reflects the broader tensions within society. Broadly political factors are discussed, followed by economic considerations to show how socio-economic factors influence and are influenced by novel technologies. Welfare impacts and issues relating to less industrially developed economies are also considered. The paper argues that whether genetic modification of crops is seen as radically different or simply a further step of 'traditional' breeding techniques affects the perception of the associated benefits and risks of their commercialisation and the wider context scrutinised to assess potential consequences. Current risk regulation and GM legislation is shown to be narrowly defined, and largely concerned with scientific evidence of harm to human health and the environment. This contrasts with the public disquiet and a greater concern for overarching issues such as institutional and power structures (and the way political decisions are made), the role of science in society and the social and economic impacts of new technologies in the UK and abroad.

INTRODUCTION

The scientific techniques termed 'genetic modification', and in particular the new food products that have resulted from their use, have been widely interpreted in public debate as representing a radically new direction for global food production systems, and even for society as a whole. Whether this is seen as beneficial or threatening depends in part upon the extent to which something being genetically modified (GM) is seen as a departure from the past. Such techniques can be debated in terms of their own scientific reference base (genetic manipulation vs. traditional breeding techniques) or within a broader frame of technological development in modern society (economic growth vs. the environment) with corollaries to other recent innovations, for example, in computing and telecommunications. While the scientific debates may be important in their own right, they are often far removed from the drivers of public concern. Public disquiet over the impacts of technological innovation is intrinsic to the type of modern economy in which we live, and similar concerns are expressed across a range of problems facing society from biodiversity loss and global climate change to nuclear power. The overarching issues include the institutional framework for appraising and managing risk and uncertainty, the role of both science and markets within society, understanding of human-environment interactions, and the distribution of power and wealth. Thus, new technologies can bring into focus fundamental conflicts in our society relating to the institutional and economic framework which regulates the development and marketing of new technologies. The tensions that emerge through public debates on genetically modified organisms (GMOs) concern the relationships between the wider public and scientists who develop new technologies, corporations that bring them to market, and regulators expected to place controls on their development and commercialisation.

A common critique of public debates concerning GMOs is the failure to address and understand the scientific detail. General survey questions testing public knowledge find that the vast majority of people know little or nothing about the techniques in question (e.g., Morris and Adley, 2001: 46). This is particularly noted by scientists working on GMOs, and is used as an argument for the invalidity of public opinion. Hence McHughen (2000: 1) regards the survey finding that only 40% of respondents in the UK correctly recognise that ordinary non-GM tomatoes contain genes as

evidence that “there is virtually no discussion of the relevant issues”. Others see the debate as having transcended the technical minutiae of the world in which the scientists operate in order to engage with issues of fundamental social importance. Across Europe the institutional context within which GMOs have been developed, evaluated and promoted is a consistent public concern (Marris et al., 2001: 47). Thus, Toke (2002: 74) claims there is no point in “...industrialists appealing to ‘science’ when the whole nub of the argument is about what sort of science is to be pursued in the first place”.

The following sections reveal how the debate over GM techniques has been framed and reflects some of the broader tensions within society. The process of regulating new technologies is shown to select certain issues as relevant and define the treatment of uncertainty over future events. From a discussion of broadly political factors the paper moves to economic considerations such as how markets operate with respect to new technologies. The aim of this latter section is to place GM food within a broader market context and show how socio-economic factors influence and are influenced by technologies.¹ Some inherent economic characteristics of GM technology are highlighted including crowding out effects with respect to alternative research and technologies, co-evolution of economic and environmental systems, and socio-economic costs of product segregation. The final section considers some of the welfare impacts covering changes in the food supply chain and issues relating to less industrially developed economies.

RADICALLY NEW OR MERELY NOVEL?

Genetic modification has been portrayed at different times and by different people as both ‘radically new’ and ‘merely novel’, and a number of the conflicts to be discussed in later sections hinge on which of these conceptions prevails.

¹ A comprehensive review of the introduction of transgenic biotechnology into current food supply systems would need to consider, *inter alia*, marketing channel co-ordination and integration, intellectual property rights, farmland tenure and ownership control, international trade agreements, domestic agricultural policy including farmer and commodity price support, regulatory procedures, food licensing requirements, and consumer awareness. Such a review is beyond the scope of this paper and we limit the discussion here to some key concerns.

As Graham (1999: 21) discusses in the context of the Internet, the issue is whether or not such a technology will transform “the character of personal and social life across a wide range”. Predictions regarding such transformative effects of a technology are hard to make and even for the Internet Graham decides more proof is required.

Regulators initially appear to have treated GM crops as ‘merely novel’. The first application to the European Union for the commercial production of GM crops was acknowledged in February 1994 (Carr and Levidow, 2000: 30). In the USA, UK and many other countries they were initially regulated in the same way as new crops that had been bred without using recombinant DNA. That is, licences were to be granted where research had produced no evidence that the products had adverse effects on human health (AEBC, 2001: 9). A few years later, environmental pressure groups in the UK began presenting the opposing view that these technologies represented a radical departure from previous techniques, and that a moratorium on their commercial use should be declared pending proper evaluation (FOE, 1997). The mass media have generally followed the pressure groups’ line, basing their coverage of GM foods on the premise that they represent a potentially dangerous new departure (Toke, 2002: 70). Studies of public opinion have also tended to find that genetic modification is generally perceived as ‘radically new’. Indeed, the opposition between this perception and the approach initially taken by regulators and retailers underlies debates regarding how risks and uncertainty are conceptualised and managed. Opponents of GM crops ground their objections in the ‘radically new’ character of the techniques, and on the issues of safety, ignorance, uncertainty and morality arising from this perception.

The proponents of genetic modification seem less consistent in that their expressed views cover both ‘radically new’ and ‘merely novel’ arguments. Biotechnology companies, in particular, show an ambivalence in public presentations which reflects on the one hand a concern with promoting new products in a manner which excites their clients, and therefore emphasises GMOs as innovative and revolutionary developments, and on the other hand as based on techniques and expertise which are tried and tested, and which therefore present no new risks to society. Even in the absence of such commercial pressures, independent scientists working on these

techniques are also capable of experiencing the same ambivalence. McHughen (2000: 7-8), for example, reveals his excitement when he announces that “For the first time [...] we humans now have the ability to modify life in its most fundamental form”; while at the same time giving qualified support to the view that, “If we believe the ‘suits’ from the multinational corporations, molecular genetic technology is simply an extension of past, acceptable technologies and we have no reason to fear it”.

The distinctions here make a fundamental difference to the public debate because they make quite different assumptions about the inherent risks and ability to control technologies. New products founded upon tried and tested methods tend to be regarded as of little risk relative to those which depart radically from existing techniques. In addition, decisions about a ‘radically new’ direction seem likely to be perceived as more significant than those about ‘novel’ directions. Spash (1995: 289) has described various economic, behavioural and institutional forms of ‘lock-in’, where once the path of technological development is chosen, reversing the process (i.e. choosing another technology) can become extremely difficult. If GM techniques are portrayed as a ‘merely novel’ refinement of a technology society has already chosen, the perceived cost to society of rejecting them is considerably greater than if they are ‘radically new’ and the initial decision of adoption is being taken now.

POLICY, POLITICS AND THE PUBLIC

How the criteria and methods used to evaluate a new technological development are decided is central to understanding the framework for public debate. When biotechnology companies, seed producers and some farmers first expressed an interest in growing GM crops on a commercial basis in 1996, the UK government was supportive, and believed that well-organised management of these crops would be an adequate regulatory mechanism (Toke, 2002: 68). Public attitude measures at the time generally reported low levels of interest, low perceptions of risk, and widespread acceptance of GM crops (Morris and Adley, 2001: 44). Increased public concern, which most analysts attribute to negative media coverage, apparently came later. A cited turning point is the summer of 1997 when certain environmental groups started to campaign for a moratorium, on the commercial growing of GM crops in the UK, on the grounds that the effects of these new technologies on biodiversity were unknown (Carr, 2000: 3; Toke, 2002: 68). This argument was adopted by

environmental organisations closer to government, in particular English Nature, and in 1998 the UK government announced that field-trials, termed 'Farm-Scale Evaluations' would be carried out to investigate the effects of individual GM crops on biodiversity, before licenses would be granted for commercial use (Gilland, 2000: 60-62; Toke, 2002: 69). Environmental groups had in effect managed to influence the evaluation criteria by adding biodiversity impacts to the agenda.

Arguments over GM were brought into the public arena, particularly when environmental pressure groups without direct governmental influence first identified the issue, and the attention of the mass media was engaged. The UK tabloid newspapers began to refer to GM crops as 'Frankenstein foods' and the term was also popular with Friends of the Earth (e.g., FOE, 1998). Newspaper reports broadened concerns beyond those of the environmental pressure groups, frequently portraying GMOs as 'radically new' products with unknown and untested public health implications. Previous perceived failures of regulatory mechanisms to safeguard public health were raised (McHughen, 2000: 8), and GMOs were associated with a list of food chain health problems including BSE and salmonella (Toke, 2002: 70). The risk to public health, according to some surveys, raised considerably more concern than effects on the environment, despite the fact that the regulatory framework already claimed to safeguard the former, but had at the time made no provision for the latter. A UK survey in early 2000 reported that 29% of respondents considered GM food a risk to public health, while "only 13% thought that spread of genes or breeding with other plants was a risk" (Toke, 2002: 70). A survey conducted in Ireland in 1999 found that 82% of respondents reported a concern with the health safety of GM foods (Morris and Adley, 2001: 46). Such public concern has commonly been regarded as a lack of trust in regulatory institutions and scientists, although it could also be explained as a failure by regulators to demonstrate to how safeguards operate. Attempts to account for this lack of trust focus upon the public's attitude to risk, and lack of involvement in decision-making.

Risk, Uncertainty and Indeterminacy

Differences have been highlighted between the ways that 'risk' and 'uncertainty' are understood by scientists and regulators on the one hand, and members of the public on the other. Scientists and engineers have a framing of the world derived from

dealing with structured mechanical problems where processes are well-defined and deterministic. In such a world scientific experimentation is seen to lead to objectively identifiable outcomes with associated statistically defined probabilities of occurrence. This approach has been extended to non-mechanistic environmental systems and taken from the laboratory to the global scale. However, some writers have claimed that such an approach is poorly adapted to dealing with problems that are complex, large-scale, and involve substantial commitment from economic and social systems (e.g. see Funtowicz and Ravetz, 1992; Wynne, 1992). Unlike technological artefacts, widespread systems cannot be designed, manipulated and reduced to fit within the boundaries of existing analytical knowledge. Pragmatic factors, such as finding artefacts that can be measured in the desired way, therefore dominate the resulting findings. Thus Carr and Levidow (2000: 31) argue that "...because of the uncertainties, risk assessment depends as much on professional judgements about the relevance, plausibility, and acceptability of effects as it does on scientific evidence". Hence Spash (2002) argues for a division of lack of knowledge between weak uncertainty, covering standard risk assessment, and strong uncertainty, where outcomes are unknown or unknowable. In the latter case, socially created indeterminacy can be more important than a lack of scientific understanding.

Beck (1992) claims that such contrasting approaches to risk and uncertainty are inevitable in modern industrial society, where risks are seen to have their origins in the decision-making procedures of organizations and political groups rather than in external factors, such as fate, the Gods or Nature. The management of such risk is then fundamentally a political process: "For with the origin of industrial risks in decision-making the problem of social accountability and responsibility irrevocably arises, even in those areas where the prevailing rules of science and law permit accountability only in exceptional cases. People, firms, state agencies and politicians are responsible for industrial risks" (Beck, 1992: 98). At the same time, the nature of the risks we now face has reached the point where "there is no institution, neither concrete nor probably even conceivable, that would be prepared for [...] the 'worst imaginable accident', and there is no social order that could guarantee its social and political constitution in this worst possible case" (Beck, 1992: 101). The scale of such 'worst imaginable accidents', and the 'politically charged' character of risk have led political institutions, he argues, to specialise "...in the only remaining possibility:

denying the dangers. For after-care, which guarantees security even against hazards, is replaced by the dogma of technological infallibility, which will be refuted by the next accident” (Beck, 1992: 101).

Beck’s analysis has obvious relevance to the widespread concern that GMOs pose risks to public health despite the presence of a regulatory framework supposed to protect it. In the UK, BSE gave members of the British public ample opportunity to practise imagining disaster scenarios with respect to food supplies. At the same time, the ‘dogma of technological infallibility’ had apparently already repeatedly been publicly ‘refuted’ by a whole series of food scares, making the predictable government and industry assurances that GMOs posed no threat to human health unconvincing to the majority, as evidenced by opinion polls. Participants in focus groups across Europe frequently referred to earlier food scares to explain their lack of trust in the institutions regulating the commercialisation of GMOs, and considered these events to be indications of inherent flaws in the regulatory institutions and the way they operate (Marris et al., 2001: 84).

Viewed in this light, the widespread concern that GMOs may present a serious hazard appears as a symptom of an underlying tension in modern society, concerning the management of industrial risk and uncertainty. Those responsible for ‘taking decisions’ are held accountable for the risks associated with their choices, and tend to respond by ‘denying the dangers’ (the only way Beck believes is possible within such a framework). Relations between members of the public and political and regulatory institutions then inevitably deteriorate, as evidence emerges that certain dangers refuse to be denied. For some writers, the solution to this dilemma is for regulatory institutions to explicitly acknowledge the uncertainty inherent in decision-making procedures, rather than persisting in ‘denying the dangers’. Stirling and Mayer (2001: 552), for example, claim that decision-makers need to be more open about the way decisions are reached, “to show precisely how different considerations and perspectives have been involved in an evaluative process and what were the implications”. Only thus can suspicions of hidden influence, aroused by evidence of links between groups with a vested interest and decision-makers, be allayed – as McHughen sums up some of the concerns of private collusion with regard to the regulation of GMOs: “Public confidence in political leadership is rarely enhanced by

cabinet ministers owning major stakes in biotechnology companies, like Lord Sainsbury in the UK..." (2000: 8).

Partial Ignorance, Power and Public Debate

When dealing with any problem or information set there is a need to bound knowledge. That is, all problems require simplification in order to aid understanding. However, how that process of bounding occurs becomes crucial to the way in which the world is understood. This emphasises the need for taking multiple perspectives into account and allowing for the revisions of decisions and avoidance of significant irreversibilities. In studying and modelling economic systems Loasby (1976) has termed the process of narrowing down knowledge as the creation of partial ignorance. In the current context, when analysing how economic systems interact with the environment different information is emphasised by different interest groups and all can be viewed as having only a partial view. Informed social decision processes face the challenge of bringing different perspectives together while avoiding manipulation by powerful interest groups.

Beck (1992: 119) argues the solution lies in reconfiguring the relations between 'decision-making' institutions and the wider public through the "creation of a public sphere":

"Only a strong, competent public debate, 'armed' with scientific arguments is capable of separating the scientific wheat from the chaff and allowing the institutions for directing technology – politics and law – to reconquer the power of their own judgement".

This accords closely with the political programme of Habermas (1992), and indeed borrows the term 'public sphere' from him. The nub of the argument is that where responsibility is assigned to institutions this leads them to attempt to curtail the discussion of risk and 'deny the dangers'. Beck's proposed solution appears instead to assign responsibility to society as a whole, on the basis of a collective involvement in assessments of the nature and acceptability of risks.

Despite interest from both members of the public and existing institutions there are many hurdles to be overcome before achieving the kind of social change Beck advocates. In terms of the debate on GM crops, the criteria considered admissible in decisions on commercialisation exclude many areas of public concern, such as: "Why

do we need GMOs? What are the benefits? Who decided that they should be developed and how? Have potential long-term consequences been assessed? How? Who will be responsible in case of unforeseen harm?" (Marris et al., 2001: 86). The Agriculture and Environment Biotechnology Commission (AEBC), set up by the UK Government, sums up European Union legislation on granting licenses for commercialisation as follows:

"The legislation does not allow the European Commission or any other Member State to turn down an application on grounds other than those specified in the Directive. Consent could not, for example, be refused on the grounds of public concern about the technology in principle" (AEBC, 2001: 9).

Environmental pressure groups bringing GMOs into the public eye did succeed in getting their arguments accepted in the UK to the extent that effects on biodiversity were also declared an admissible criterion. This has been regarded as a radical step – Gilland (2000) who disagrees with such a policy, observes that "Never before has an agricultural development been put on hold to examine its effects on wildlife". Nevertheless, an experimental approach was then adopted which saw effects on biodiversity, like effects on human health, as a matter to be resolved by scientific experts, thereby excluding wider public involvement

Thus, while many of those involved in taking decisions have agreed that public debate is necessary if concerns are to be addressed, they often find this difficult to reconcile with the regulatory framework in which they work. For example, Ross Finnie, Scotland's Minister for the Environment and Rural Affairs, has stated that while "I've always said there was a need to improve public consultation", "...the basis of any objection has to be science-based, so squaring that with your average public meeting is a very difficult process" (BBC News, 2001). Others reject the notion that 'science', regulatory systems and 'public meetings' are necessarily difficult to reconcile (e.g. Marris *et al.*, 2001: 78-79). However, such a divide may underlie public concern. As Levidow and Marris (2001: 356-357) also argue: "science and technology have become a special problem because they are routinely cited as an objective basis for policy. [...] Official expert advice is implicitly equated with 'science', in turn invoked as if scientific knowledge were a value-neutral, even omniscient basis for regulatory decisions".

The AEBC (2001: 9-10) have concluded: "Public concerns which go beyond the criteria prescribed for the regulatory arrangements have no expression in this process". This means individuals with objections considered to be 'unscientific' are unable to voice them within the context of the regulatory framework. Even where objections might be construed as 'scientific', they can only relate to the issues of public health and effects on biodiversity.

"The narrowly-based risk assessment approach to decision-making seems to us to be at the root of much of the public concern. The public is not necessarily expressing a lack of trust in science or scientists, but simply pointing out that judgements are being made, both within and beyond the science, which demand wider public involvement" (AEBC, 2001: 42).

The scope for influencing decisions regarding the regulation of GM crops through 'official' routes is therefore currently constrained by existing national and European legislation, which restricts this input to particular groups of people (e.g. 'scientists'), and to specific topics (e.g. human health and biodiversity), irrespective of public concerns and preferences. A slightly more open approach to public engagement is taken in the Aarhus Convention; and hence it is maybe surprising that the recently revised European legislation on the release of GMOs (European Directive EC/2001/18) continues to restrict nation states to reject GM crops only on the basis of scientific evidence of adverse health or environmental impacts. Thus, even where public consultation or deliberation takes place, whether and how outcomes will influence decisions or policy outcomes is at the discretion of existing national and international decision-makers/politicians and how they position their case under current legislation. Briefly looking at the approaches, outcomes and criticisms of attempts to scale up public participation in the UK's official GM consultation exercise is worth reflecting upon in this light.

Approaches, Outcomes and Criticism of the UK's National GM Debate

A process called the 'GM Nation? The Public Debate' which officially took place over a six-week period between 4th June and 18th July 2003. The overall aim was to find out what people across the UK thought about the possible commercial production of GM crops in the UK and the options for possibly proceeding with this, and also to communicate a 'balanced' set of arguments for and against GM to the public.

In 2002 nine 3-hour long 'Foundation Discussion Workshops' were held to allow a representative cross-section of the lay public to frame the debate.² These were successful in establishing a wide range of concerns, and helped formulate the questionnaire/feedback form (supplied in paper and internet versions). Participants also identified the need for material to inform the wider public and stimulate the debate. Consequently a 17-minute video, booklet and CD-Rom (replicating the content of the booklet) were produced as a 'toolkit' to support a series of public events.

The public events were organised at three levels. Tier 1 consisted of six centrally organised national/regional events in which participants held round-table discussions using the toolkit material to stimulate the debate. Tier 2 events (about 40) were also large-scale events but this time organised in partnership with county councils and other public bodies. These either used a similar format to Tier 1, or invited experts to answer questions, or debated a motion. Tier 3 consisted of several hundred 'bottom-up' local events which as they saw fit could draw on material supplied by the 'toolkit'. Through these various events and the interactive internet site, several thousand members of the public participated and 36,557 questionnaires were returned and analysed. No significant differences could be detected between responses of those actively participating in physical meetings from other respondents, and Table 1 summarises the general picture that emerged from the national debate.

While the national debate was widely welcomed in principle, the process has received considerable criticism (see e.g. Select Committee on Environment, Food and Rural Affairs 2003a, b, c, d; Mayer 2003). The main criticism was levied against the Government who from the outset imposed considerable time and budget constraints. The initial deadline for reporting the outcomes of the debate was June 2003 – later extended to September 2003, and this resulted in the public debate being limited to 6 weeks; whereas national good practice guidelines recommend a minimum of 3 months for public consultation exercises. To make matters worse, results from socio-economic and scientific studies (including outcomes of the field

²Eight of the discussion groups involved members of the general public (two socio-economic groups and different age groups covered) and one for those "actively involved" in GM (half supporters, half opponents).

trials) only became public at the end or *after* the formal public debate. The original budget allocated was only £250,000 – later doubled to £500,000 – which restricted spending on publicity, production of support material to stimulate debate, and the possible formats of debate (e.g. no use of television broadcasts). Similar undertakings in New Zealand and the Netherlands in comparison received about £2 million, with populations of only about 1/16 and 1/4 respectively of that in the UK (Select Committee on Environment, Food and Rural Affairs, 2003e).

Table 1: Outcomes of the UK National Debate on GMO in Agriculture (Summer 2003)

Key Messages

People are generally uneasy about GM

The more people engage in GM issues, the harder their attitudes and more intense their concerns

There is little support for early commercialisation of GM crops in the UK

There is widespread mistrust of government and multi-national companies

There is a broad desire to know more and for more research to be done

Developing countries have special interests

The debate was welcomed and valued

Source: AEBC, 2003.

The failure to attract the wider public (most meetings were attended by relatively well-informed and already politically engaged individuals) was also seen as a direct result of time and budget constraints. These constraints led to the use of the Central Office of Information to manage and facilitate the debate despite doubts, and later criticism, as to their ‘independence’ from Government. There were also doubts raised as to their experience and capacity to run such a large-scale event. Certainly, many participants and interest groups viewed the toolkit resources as unimaginative, uninformative and inadequate.

Finally, the Government has been vague as to how it will consider the outcomes of this public debate, with a formal response expected sometime in March 2004. How the different strands of government investigations – public debate, scientific research and socio-economic reports – will be ‘compared’ and considered also remains

unclear. The Government made little attempt to link the different strands during their conduct in 2002 to 2003 and the outputs now stand as separate and unintegrated.

ECONOMIC CONCERNS

A key driver in the adoption of new technologies is the economic return to entrepreneurs who take up such innovations. There is a perception within national governments and business communities that failure to adopt new technologies places a country at an economic disadvantage internationally. In the context of GMOs the case of brain drain to Australia from the UK has been cited by The Guardian (September 2003). In the article Michael Wilson, the chief executive of Horticulture Research International, warned that the exodus would have serious consequences for Britain's reputation for scientific research and he stated that "The way it is going, Britain is lining itself up to become an intellectual and technological backwater". This implies that market competition is a key determinant of which technologies will be adopted. Some, such as free market economists, might support this case by arguing that technologies themselves are inherently neutral.³ Clarification of the role markets play is therefore required and in this context three related questions can be used to help:

- I. What kind of choices can, and should, be made in markets? That is, what is the role of a market as a social organising device determining the types of technologies which are adopted?
- II. Are there inherent or 'embedded' characteristics of GM technology that predetermine the type of impacts it will have on social and economic systems?
- III. What are some of the likely economic effects of GM technology within the current socio-political and institutional context and how will they be distributed given current socio-economic systems?

³The FAO (2001) notes in its report on the ethics of GMOs: "[G]enetically modified organisms, like all new technologies, are instruments that can be used for good or for bad in the same way that they can be either democratically managed to the benefit of the most needy or skewed to the advantage of specific groups that hold the vital political, economic and technical power. In the case of GMOs, it must be noted, the main beneficiaries to date have been the private sector technology developers and large scale agricultural producers, mostly to be found in developed countries."

The second question separates what can be considered as more intrinsic elements of the technology, which can be usefully distinguished from the third, which concerns the likely means of implementation and associated distribution of economic advantages within society. The issue of what kind of decisions are made in markets can thus be separated from questions concerning the effects of technological innovation upon markets.

The 'inherent' characteristics of biotechnology are considered below while highlighting several ways in which institutions, economies and ecosystems are intertwined. The effect of GM in food supply chains and the agricultural systems of industrially developing countries are also briefly considered.

Markets, Freedom and Choice

The market, as a human institution is essentially a mechanism for resource allocation. The information which enables a market to fulfil this function is contained in the relative prices of goods, wages and services. Those prices themselves reflect both factors which determine prices within the system and those which set the boundaries of the system. In this way, every market price reflects an institutional package alongside a production package. Institutional packages include such things as product safety regulations, minimum wage legislation and environmental licences. Such institutional aspects cannot, by definition, be chosen within the market place because they would themselves then be commodities, or at least aspects of commodities, which can be traded. A key political tension within industrial economies concerns the choice of those aspects which can be treated as commodities to be traded in markets, and those which are determined outside the market and exist as market-defining institutions. Technical market efficiency in resource allocation is only a meaningful target if there is acceptance at the societal level of how this efficiency serves social purposes, and how it is best served by different kinds of institutional arrangements. The overall guiding principles are ethical.

The moral conditions underpinning economic systems are inherently of two kinds: (i) the rights and freedoms of individuals, and (ii) the welfare levels of individuals. These concepts are so closely intertwined that separating them completely is seldom meaningful but there are some key distinctions. Whereas individuals determine many aspects of their own welfare through markets, they cannot determine their

rights and freedoms in a similar way. The rights of individuals thus help pre-determine the extent of markets (defining the aspects of society that are considered appropriate for inclusion within markets). In contrast, welfare considerations are partially pre-defined by the extent of markets (through the range of choices people are able to make within those markets). Welfare without markets is therefore ill-defined but markets without rights are also ill-defined. The tension to be resolved here rests on the domain of choice where individuals can exercise their rights and enhance their welfare.

In this regard the technologies used to produce goods and services are always circumscribed by a wide range of socially accepted norms and values. The current debate over biotechnology is intense due to differences over these wider values in relation to gene manipulation. This is a political and social issue, as well as an economic one. The endorsement of controversial technologies cannot be determined by open choice within an economic market place because the issue directly concerns what is considered acceptable within that market. The issue presented by transgenic biotechnology is thus initially one of deciding on ethically acceptable parameters to production processes; only after this has been addressed is it appropriate to consider the institutional structures through which development can occur.

Inherent Characteristics of GM Technology

Three inherent socio-economic aspects of GM technology are identified in this section. First, the opportunity cost of any research agenda and its potential impact on alternative research. Second, the implications of the technology for the co-evolution of economic and environmental systems. Third, the impossibility of perfect supply segregation, and the resulting cost implications.

Opportunity Costs of Research

The costs of fundamental research within transgenic biotechnology (e.g. mapping, isolating and describing the function of gene sequences) are indisputably high. Indeed, one of the frequent criticisms of the current state of biotechnology development is that public research into many potentially useful products is very poorly funded, whilst privately funded companies have targeted innovation towards cost-saving technologies for wealthy Western markets. More public funding of

biotechnology is therefore urged to address development needs, but where budgets are limited the relative cost-effectiveness of alternative research programmes is also an important question, i.e. those development goals may be met more effectively at lower cost by other means.

Domestic agricultural research budgets have been falling in real terms. Total official development assistance for agriculture fell by 31 per cent over the 1990s in real terms, whilst international lending for agricultural development fell by 40 per cent (FAO, 2002). Against the current backdrop of falling agricultural research budgets, in both industrially developed and developing countries, increasing proportions of the decreasing overall budgets are now becoming directed to biotechnology research. There has been pressure on public research organisations to recoup costs through marketed applications of their research, which is also encouraged by the intellectual property regime surrounding biotechnology. Such financial pressure inevitably narrows research and extension capacity in other areas. Perhaps of most concern in this context is funding of sustainable, organic, and other systems-based agricultural research. Thus, for example, the University of Minnesota has tried to expand its biotechnology programme while reducing support for its well-known sustainable agriculture programmes (Benbrook, 2000).

The process of technological development should therefore be considered within the general context of alternatives, and the meaning of 'neutral' technology in this regard is debatable.⁴ Spending public money on 'alternative' technologies, if it occurs at all, is usually small because the political process tends to favour large projects offering simple solutions, and economies of scale are used to argue in favour of 'putting all the eggs in one basket'. While the case is sometimes made for public funding of

⁴The pursuit of nuclear power offers some significant parallels. The UK government developed a programme of funding for non-fossil fuel-derived electrical power generation, based on a tax on fossil fuels, in 1989. Although the resulting support ran to billions of pounds, more than 90 per cent of this funding went to supporting nuclear power generation (see Oosterhuis 1996). This was itself the result of two factors: the immense cost of nuclear power development, and a technological optimism that this would solve the power generation problem 'once and for all'. Regardless of whether the current outcome of the technology is seen as success or failure, a direct result was a virtual suppression of energy alternatives, both politically and economically. Critics of this particular example argue that had the nuclear budget been spent on a package of alternative, known technologies including energy efficiency measures, and innovative research into wave, solar, biomass and combined heat and power sources, power generation needs could have been substantially reduced.

'non-dominant' technologies to complement private venture capital, agricultural research budgets have seldom been very supportive of 'alternative agriculture'. Hence, whilst many researchers stress the potential compatibility of GMOs with sustainable systems, in reality the expansion of biotechnological research tends to reinforce the industrial model of agriculture, with an emphasis on products rather than systems knowledge and applications. Areas that concern 'management knowledge' rather than 'products' are inherently unpatentable.

Perhaps less well publicised is the fact that funding for innovation will almost inevitably outstrip funding for monitoring. Monitoring is regarded as revenue consuming (although it may save resources overall by identifying problems) whereas product development is regarded as revenue generating (although products may fail). More effort, *ceteris paribus*, is therefore targeted on demonstrating product benefits than on exploring possible costs and dangers. While extensive regulatory procedures may be put in place, the simple economic reality remains that research investigating potential problems will be much less well funded than the search for patentable products. Thus Wright (2000), in an economic review of GMOs for the New Zealand Royal Commission, notes that "[a] relatively small amount of research is being done on the impacts of GMOs in the environment (for example, horizontal gene transfer) compared with the amount of research being done on potential commercial GM products". This is seen as an outcome of "... science reforms [which] have pushed the [New Zealand] Crown Research Institutes in the direction of profit maximisation, or at least cost recovery". Since there is also a time lag between innovation and the effects of innovation, some scientists caution that the current claimed 'absence of evidence' of problems should not be taken simply as 'evidence of absence' of problems (Clark, 1999).⁵ This would be to confuse Type 1 and Type 2 statistical errors, i.e. the likelihood that a proposition is found false while in fact true compared to being found true while in fact false. Emphasising experimentation for crop development runs the risk of accepting the technology as benign by default.

⁵Experience with GM crops is currently limited to a few commercialised products and adoption in only a handful of countries. Predominantly there has been a rapid adoption of herbicide resistant soybeans and insect resistant cotton and corn in the USA, accounting for roughly 75 per cent of all plantings, with Argentina, Canada, and China the only other countries planting any significant acreage of GM crops (notably canola, soybeans, cotton and tobacco). All these 'first generation' GM crops have been developed with crop management characteristics in mind.

This has particular implications when uncertainty is high, potential problems poorly understood, and in addition when budgets are under pressure.

The industrially developing world is caught in a double bind in this regard. Resources for effective regulatory and monitoring systems are simply unavailable in many countries that will be faced with pressure to accept GM foods and seeds. Many of these countries also lie in the Vavilov centres of plant genetic diversity where particular caution is urged due to the areas' ecological significance. This combination of resource constraints, development pressure and ecological sensitivity raises a wide range of concerns over international equity, self-determination and public cooperation in science, which creates a great challenge for international agreements.

Co-evolving Economic and Environmental Systems

Insect resistant crops have been one of the most widely adopted transgenic biotechnologies to date, with an estimated 12 million hectares planted in 2001 (James, 2001). These crops rely on engineered plant production of varieties of the naturally occurring toxin, *Bacillus thuringiensis* (Bt). The properties of Bt as an insecticide have been well known for decades, with Bt compounds being the only permissible pesticides used in organic agriculture.

Whilst these technologies may reduce the need for some external applications of insecticides in industrial systems, they are subject to the same pest-resistant problems that affect all pest management products. When insect pests are subjected to selective environmental pressures, successive generations develop resistance to those pressures. Hence modern intensive cropping systems are locked-in to a continual product development struggle against natural pests which thrive in the monoculture environments, and which develop resistance to each new pesticide over several generations (Norgaard, 1994). The costs of crop management have hence risen accordingly and new crop varieties are required at regular intervals. Sustainable agro-ecological systems replace this 'temporal' rotation of crops and products in industrial agriculture with a 'spatial' rotation, which in combination with other techniques aims at prevention of the build-up of pests to economically significant levels.

Recognising the issue of pest resistance to Bt crops, management guidelines based on the refuge concept have been developed by the US Environmental Protection Agency (EPA) to attempt to reduce the risk of resistance developing in pests. The refuge is an area of non-Bt crop that harbours pests that are not subjected to selective pressure and which should interbreed with those within the Bt fields, helping to prevent 'pure breeding' of resistant pests and a concomitant accelerated rate of resistance development. Initially voluntary refuges of 5-10% of the cropped area were assumed adequate, but rapidly this was raised to 20% and made mandatory, and to 50% where Bt corn is grown next to Bt cotton.

Critics have pointed out the difficulties of ensuring adoption of such a 'refuge' approach in poorer nations where extension services are heavily overstretched and mismanagement of agricultural chemicals is widely acknowledged, and is itself a significant health problem. Whilst reduced external applications of chemicals will help reduce direct health problems for farm workers, the biotechnology 'solution' may present alternative problems and relief may only be short term. Even assuming continual innovation at a faster pace and with more sophisticated defence mechanisms than pests themselves, those farmers who remain outside the agro-industrial system, or who cannot pay for the ever rising expense of seed or crop protection products will become increasingly vulnerable. Alternative, and particularly organic agricultural, systems will suffer accumulative stress if GM crops accelerate pest resistance to Bt or other naturally occurring plant defence mechanisms. In fact, the prospect of being locked-in to a ceaseless (but patented) effort to produce new crop varieties at faster rates, against a backdrop of making alternatives unviable, is theoretically the economically ideal state for private biotechnology companies.

The aspects of strong uncertainty which arise here are identifiable in the following summary of the situation by Nelson *et al.* (1999: x-xi):

"Much attention is being paid to resistance in the target pests; less has been paid to the potential for development of resistance in secondary pests that pose a threat to other crops. The loss of effectiveness of Bt toxins would be particularly serious for the organic industry, which relies heavily on Bt-based bioinsecticides. In essence, US agriculture is conducting a large-scale 'experiment' to test resistance management strategies for Bt crops. Elements of this experiment include optimal sizes of refuges and viability of voluntary compliance approaches. The outcome could have serious consequences for agriculture as a whole, and for potential acceptability of other new

technologies. [...] More generally, we find that great uncertainty remains about the unintended effects, positive and negative, of GMOs currently in use and those that are under development. It is somewhat disconcerting, for example, that possible negative effects for the monarch butterfly were not evaluated before the Bt technology was widely disseminated. Clearly, more research is needed in this area.”

However, the extent to which more research can be expected to help is limited by the inherent characteristics of the technology in this respect and the need to address strong uncertainty.

The UK farm-scale evaluation (FSE) between 2000 and 2002 are the largest world-wide to compare the effects of GM herbicide-tolerant (GMHT) crop varieties on ‘weeds’ and invertebrates with their conventional counterparts and farming practices (i.e. no comparisons with bio-dynamique or organic production systems). Sugar beet, fodder beet, maize and spring-sown oilseed rape – the most likely varieties for commercial production in the UK – were grown in 273 trial fields (half had GMHT, the other half conventional crops) and monitored. The results for beets and oilseed rape showed reduced presence of invertebrates and weeds and hence suggest that commercial use of GMHT varieties would have adverse impacts on biodiversity in farmland landscapes. On the other hand, GMHT maize fields harboured more wildlife than adjacent plots growing non-GM maize. However, ‘conventional practice’ included the use of Atrazine (a herbicide highly toxic to insects and already banned in some European countries) whereas the GMHT plots were treated only once with glufosinate ammonium (resulting in vigorous weed growth that substantially reduced the final yield) rather than the commercially recommended weed killer which contains 32% atrazine. This was later criticised and the field trials for maize seen as flawed and worthless (e.g. Dube 2003). In addition to disagreements over these specific management practices used in the field trials, British statutory nature conservation agencies point to the uncertainties in predicting impacts on biodiversity:

“We cannot and will not predict the magnitude of adverse or beneficial effects on biodiversity of herbicide regimes associated with the crops tested. [...] as the FSE research team pointed out, such estimates rely on assumptions about uptake by farmers, distribution and areas of GMHT crops cultivated and policy influences such as the impact of CAP reforms on cropped areas. In addition any forward look would have to take into account the impacts of UK and European measures to encourage non-food uses of these crops. We argue that these factors are almost impossible to predict with any degree of

certainty.” (Countryside Council for Wales, English Nature, JNCC and Scottish Natural Heritage, 2003: 4.1)

Hence, while general *trends* in effects on biodiversity may be picked out from the trials, trying to estimate the *magnitude* of impacts over landscapes and crop rotations is seen as premature and potentially misleading (*ibid*: 5.1).

Socio-economic Costs of Product Segregation

The ability of GM plants to cross fertilise with non-GM plants, thereby creating progeny that are effectively GM, has been a major concern amongst environmentalists. Scenarios of cross fertilisation include both environmental and market impacts. The former cover possible production of ‘superweeds’ and the transfer of other traits into wild species which then continue to be widely replicated. The latter refer to the crops of organic or conventional producers being contaminated so they cannot be sold through (currently) premium non-GM market channels. The market impacts are addressed here.

Two critical factors determine GM and non-GM system compatibility: (i) the distances over which cross-fertilisation may occur, and (ii) the purity level below which crop contamination is considered negligible. The probability of contamination will depend on the fertilisation route, and declines with distance between crops. The appropriate separation distances required between crops remains uncertain and debated. In the UK use is made of the separation distances specified for seed production, which are typically between 50 and 400 meters depending on crop type. The UK organic movement argues that much greater distances of up to 6 kilometres should be designated.

The UK field trials found that bees were able to carry GM oil seed rape pollen for up to 16 miles (The Guardian, 14th October 2003). This makes isolating GM oil seed rape from conventional crops by physical separation virtually impossible. In addition, once GM oil seed rape has been grown in a field a conventional crop could not be grown for 16 years in the same field without fear of contamination of more than 0.9 per cent (the threshold for claiming that the crop is GM-free). Separate trials of GM forage maize and sweet corn failed to show similar travel. A study by a group of researchers from the University of Reading, the National Institute of Agricultural

Botany in Cambridge, and the Centre for Ecology and Hydrology in Dorset stated that GM oilseed rape is certain to breed with wild crops and produce hybrids. Their findings also stated that: "The presence of hybrids is not a hazard in itself and does not imply inevitable ecological change... an estimate of UK hybrid abundance represents only the first step toward a more quantitative assessment of risk at the national level". (Wilkinson *et al.*, 2003: 459). While the issue of pollen transfer is itself open to scientific enquiry, the other key consideration - the level of GM cross contamination considered acceptable - is more clearly a social, economic and ethical matter.

Organic farmers in the UK have insisted that their consumers require very high levels of purity regarding non-GM produce. The past UK Environment Minister, Michael Meacher, suggested a tolerance of 1.0 per cent GM contamination might be thought too high by the public and asked the AEBC to consider the possibility of a 0.1 per cent threshold (AEBC 2001). However, based on simulation models of the extent of crop contamination expected under different levels of GM adoption, a report to the European Commission regarded a 0.1 per cent contamination threshold to be close to unattainable (Bock *et al.*, 2002). This level is then beyond determination within the market-place since it determines which products can reach the market-place. Consumer preferences for uncontaminated products simply cannot be delivered by producers. This either/or choice between a GM or GM-free production environment has been a source of considerable debate at the national level in New Zealand, where island status offers a particular advantage in maintaining both the image and reality of product purity. In July 2003 the European Parliament voted to lift the moratorium on GM foods being sold in Europe if they were labelled: "This product is produced from GMOs". Calls for thresholds for labelling to be set at 0.5 percent failed and parliament backed 0.9 per cent as the threshold.

The costs of maintaining separate commodity supply chains for GM and non-GM crops will vary depending on several characteristics but one estimate based on segregation practices for speciality crops is an additional 6-17 per cent of farm gate prices (Directorate-General for Agriculture, 2000). The principal factors affecting segregation costs will be the tolerance level for cross-contamination, the genetic predisposition for cross pollination and for volunteer plants causing contamination

within crops, the economies of scale associated with the size of different marketing chains, and seasonal aspects of produce which incur additional storage costs. In addition, if only certain downstream processed products can utilise identity preservation for marketing, these 'differentiated' products will have to bear the full costs of supply segregation.

Product segregation has another aspect which relates to who gains from innovation. Product identity preservation is normally assumed to benefit innovative producers looking to extract premiums in the market place by ensuring the supply of valued product characteristics (such as taste, quality, region of origin or 'animal friendly' designations). The GMOs situation runs counter to this conventional economic logic if GM is considered a 'negative' by consumers, since the additional segregation costs are incurred by competing conventional or organic producers. That is, GM crops create a horizontal market differentiation by introducing a new source of value, namely 'GM free'.⁶ The ability to utilise this as a product differentiating strategy will depend on the response of demand to increased product prices to meet the added costs of identity preservation. Innovators usually pay such costs but if the GM attribute is considered negative, non-GM consumers face the costs of separation to be assured of GM-free food. In the GM case, the innovator generates additional costs for non-consumers of their products, thereby creating 'pecuniary externalities' which add to the costs for competitors. Consumers face a price rise for an unchanged conventional product, whilst the innovation bearing undesired characteristics becomes cheaper by default. If a majority of consumers consider GM a negative attribute, then net social welfare will fall with the introduction of GM crops. Who pays and who benefits in these circumstances is a matter of property rights and their enforcement. Prior property rights would suggest costs should fall on GM food producers to separate their products within the supply chain, to avoid imposing costs onto the existing non-GM consumers; but the opposite has in fact been the case. Indeed contamination at field level forces costs on non-GM producers who would then need to bring legal action to claim damages.

⁶That is, rather than increasing currently recognised sources of value via vertical product differentiation (e.g. juicier apples) a new value arises with the appearance of the product.

Indeed a farmer in Canada, Mr Schmeiser, has been in litigation with Monsanto since 1998, when it accused him of planting the company's GM canola (oilseed rape) on his land without permission, and demanded that he pay as if growing GM crops under contract. He claims to have followed his usual practice of collecting seeds from his own crop to plant for the following year and was very concerned, because of the contamination of the pure seed developed for half a century. Rather than finding Monsanto liable for contamination the judge in the original case ruled that it did not matter how the seed came to be in Mr Schmeiser's field, he was deemed to have infringed the company's patent rights simply by growing and harvesting it without permission. The judge was unconcerned that the farmer did not spray the crop with Monsanto's Roundup weedkiller and therefore gained nothing from the altered genetic structure of the plant. The case is proceeding to the Canadian Supreme Court but in the meantime the Canadian National Farmers Union believes any farmer suffering contamination will fail to report it. (Hirsch 2003)

Social Welfare and Distribution

Assessing whether the introduction of GM crops will enhance net social welfare requires comparison of the status quo position (i.e. no GM products) with the world after GM crop introduction. This means the additional cost of a new GM variety is weighed against the improved pest or weed control gained as a result. For example, Bt crop generation is claimed to increase social welfare by preventing damage due to the European corn borer, which was previously often uneconomic to control because the spraying costs were unjustified by the small crop losses. In general, welfare gains arise from either enhancing output or by reducing input costs, *ceteris paribus*. Besides the disputes over how GM might be introduced, and the effectiveness of any safeguards and regulations, there is uncertainty over the consequences both for food suppliers and the wider community. That is, the social costs and benefits of GM crop introduction are required to calculate the economic impacts but these are unknown. The aim here is then to outline some of the general characteristics of likely social welfare impacts.

The Supply Chain

Over time the introduction of a technology which increases output without raising costs, or reduces input costs without reducing output, is to reduce farm-gate prices

for crops because either total supply expands, or costs of production fall. The benefits of such technology favour early adopters who increase output or reduce costs before prices fall. Late adopters are essentially 'forced' to adopt the technology to remain competitive, or else to exit the industry. This picture is only altered if demand also changes as a result of the new technology. The demand for particular food products may rise or fall depending upon consumer preferences, and this will in turn affect the returns to producers.

A key distributional issue is which stage of the supply chain bears additional separation costs from the introduction of GM crops. This will determine many of the impacts on agricultural systems. There are three basic factors that will influence this distribution of costs: (i) demand elasticities, i.e. how much demand varies with changes in the prices of final foods; (ii) market power, e.g. bargaining power due to size or specialisation; and (iii) government policy, e.g. quotas or price support mechanisms that alter the incentives faced by producers (Buckwell *et al.*, 1998).

Where demand for food products is price inelastic, changes in price create little relative change in the quantity demanded. Responsiveness to food price changes is an empirical matter and can vary by food type and social context. Basic food stuffs can be unresponsive to price (e.g. bread, potatoes, rice) while brands of those same food stuffs are highly responsive due to the supply of close substitutes. Hence the desire of producers is to create brand loyalty and product differentiation through positive attribute enhancement.

Market power is a key concern for economists because the idealised free market is one where power is evenly distributed amongst numerous small producers while many actual markets tend to be dominated by a small number of large companies. One area of concern arising over the rapid commercialisation of biotechnology products in recent years has been the concentration of such products in the hands of a small number of multinational companies. Following a period of rapid acquisitions and mergers amongst biotechnology, seed and input manufacturing companies during the 1990s, there are now only a handful of significant multinational biotechnology players, including AstraZeneca, Aventis and Monsanto. Biotechnologists in both public and private sectors tend to regard this institutional context as an issue that is unrelated to biotechnology itself. For example

McCloughlin (1999), Director of the biotechnology research programme at University California Davis, states that “Western-style capitalism and market institutions ... [are] hardly relevant to the issue of biotechnology.” However, market power will be a key determinant of the size and use of research and development, particularly because product copyright acts as a traditional barrier to competition. The impact of the technology is therefore inseparable from the conditions under which it is being introduced and by whom it is being developed. Multinationals are able to muster political support more easily than dispersed small-scale producers. Thus, the US government is lobbying the World Trade Organisation on their behalf by claiming first the European moratorium, and then labelling are unfair trade practices. That the concern of European citizens over GM contamination of food supplies and the environment found voice shows how political institutions in Europe allow citizens to challenge those with concentrated economic power, although the consumer is far from the idealised sovereign in the market place.

Market power in the UK food supply system is exercised at the earlier and later stages of the supply chain. The chain is characterised by a highly concentrated input sector, a highly disaggregated farming sector, a moderately concentrated processing sector and a highly concentrated retail sector. Thus, individual farmers are in a relatively weak position and will be unlikely to pass additional production costs down the supply chain. Whether the bulk of costs fall on GM or non-GM growers will also be partially determined by government regulation and public interest in that regulation. Thus, for example, the rapid adoption rate of Bt crops in the USA has taken place against a backdrop of considerable price support for farmers (Directorate-General for Agriculture, 2000). This encourages farmers to look for supply cost savings and yield enhancing or maintaining technologies since these bring guaranteed advantages under price support, *ceteris paribus*. Changes in farm support payments and any moves away from production subsidies will also have impacts on the incentives to adopt new technologies.

Industrially Developing Country Perspectives

Considering potential biotechnology impacts on industrially developing countries requires both inter-country and intra-country distinctions. Even for the purposes of simple comparisons, several sectors should be differentiated: there are larger

farmers, producing both food for national consumption and for export, and cash crops; smaller subsistence farmers; landless rural labourers; and the urban poor. These groups exist in different proportions in different countries, and the impact of changing agricultural technology varies as a result. A detailed review of potential impacts on developing countries must address these complexities and is beyond the scope of this paper; instead we raise a few key points in the on-going debate.

A repeated argument offered in support of biotechnology is that, although fundamental research costs are very high, the final products, in the form of seeds, are themselves not 'high tech' and can be easily used by and benefit industrially developing country producers. However, the products being commercialised have a range of impacts and have been designed mainly for biotechnology company profit rather than any ulterior motives. Three examples of how this commercial goal can conflict with the interests of those in industrially developing economies serve to illustrate the type of problems arising.

Case one is where GM is delivering alternative ways of producing industrially developing country commodities, such as palm oil substitutes from rapeseed grown in Northern climates. The comparative advantage of industrially developing countries in producing such crops are thereby being eroded. Advances in such biotechnologies will cause increased hardship amongst farmers who lose their markets and contribute to greater poverty in countries where export markets falter. The beneficiaries will be consumers in industrialised economies who receive cheaper products, and the companies copyrighting these products.

The second case is where research has been directed towards labour saving. For example, Integrated Coffee Systems Incorporated is designing a variety of coffee in which maturation can be controlled artificially (ACTIONAID 2001). This will facilitate mechanical harvesting. Currently coffee is one of the few commercial cash crops reliant on numerous small-scale farmers, and a large number of labourers for harvesting due partially to the uneven ripening of coffee berries. Coffee supports over 7 million farm families mostly in Africa and Latin America. Biotechnology is economically inefficient when applied to saving labour where there is no scarcity. The unintended social consequences in terms of reducing the livelihoods of these farmers and labourers is then neglected because the technology is being developed

for modern industrialised agriculture in Western economies where labour is relatively scarce.

Case three is where the costs of the technology is passed on with the purchase of seed. This increases costs to farmers at the start of the growing season when incomes are generally at their lowest. Financial pressure to borrow is thereby increased and if harvest returns are lower than anticipated credit problems will arise, leading to loss of small farm livelihoods. In low-income countries there is seldom sufficient alternative employment to accommodate these displaced workers, adding to the numbers of urban and rural poor who cannot exercise their demand for food. Demand for small-scale local services also then declines.

Whether GMOs could benefit industrially developing economies is highly uncertain but clearly the products actually being developed are being designed for other purposes. The twin issues of direct market competition (lowering export prices), and labour reduction (lowering employment opportunities), are possible short-term outcomes of commercialised biotechnology targeting the most profitable markets. Some potentially more positive impacts could also occur. Thus, for example, increased productivity from reduced labour in staple food production may lead, *ceteris paribus*, to lower food prices, a benefit to the urban poor in particular. Any increase in biological productivity could also generate opportunities for more employment in downstream processing, increasing incomes and the effective demand for food from employed workers. However, there may also be better ways of achieving such secondary benefits more directly.

The same is true of the claim that GM crops will 'feed the world'. The type of argument put forward is typified by a speech of President Bush (BBC News, 2003):

"Acting on unfounded, unscientific fears, many European governments have blocked the import of all new biotech crops, because of these artificial obstacles, many African nations avoid investing in biotechnology, worried that their products will be shut out of important European markets. For the sake of a continent threatened by famine, I urge the European governments to end their opposition to biotechnology. We should encourage the spread of safe, effective biotechnology to win the fight against global hunger." He added that the US biotechnology industry was the strongest in the world, and the US needed to keep it that way.

These kinds of statements tend to be very generalised and fail to delineated the problems faced into preventing periodic famines, chronic malnutrition and general food scarcity. Amartya Sen, Nobel Laureate in Economics, has written over many years on the subject of famine and squarely places the cause at the door of undemocratic regimes and lack of purchasing power (for example see Sen, 1986). A lack of purchasing power is clearly a distributional issue and different from a general lack of food to supply adequate nutrition. In 1997, a European scientist's comment that: "those who want GMOs banned are undermining the position of starving people" provoked the following statement from Tewelde Berhan Gebre Egziabher of the Institute for Sustainable Development in Addis Ababa, Ethiopia: "There are still hungry people ... but they are hungry because they have no money, not because there is no food to buy..." (FAO, 2001). The FAO (2002) shows that projected demand growth for food can be met with current technology, but this will fail to help the poor. They recommend pro-poor international trade agreements, sufficient sustained investment, institutional capacity building, and changing political will.

Numerous factors have been identified in the literature on poverty as contributing to under nourishment, but lack of advanced technology is largely absent. There is a need to consider the specific patterns of employment, numbers and opportunities of the food insecure, security of land tenure, distribution of land ownership, credit access, existing technology and international trade barriers. By way of summary, Kydd *et al.* (2000) suggest that the optimists and sceptics regarding biotechnology and its potential role in assisting developing countries can mostly be defined by their views of the Green Revolution itself. Those who see the Green Revolution as a tremendous success point to per capita food increases and suggest GM will replicate this. Sceptics on the other hand see the Green Revolution as a missed opportunity, citing the increasing environmental problems now being faced and the fact that inequality of access to food has gone hand in hand with increasing productivity. They emphasise the needs of the food insecure and smaller scale subsistence and traditional farmers, using simple management practices, building on indigenous knowledge and working with ecological systems rather than emphasising the benefits of individual products. Whilst some applications of biotechnology may be possible to implement in combination with these alternative agricultural approaches, others are in direct competition with the goals that they seek to achieve.

CONCLUSIONS

Whether GMOs are perceived as 'radically new' or 'merely novel' is important in public debates on these new techniques and products. The mass media and biotechnology corporations have recognised this, seeking respectively to inflame public interest by playing up radical aspects, or to ease concerns by emphasising continuity with existing practices. From studies of public opinion on GMOs, the former perception clearly holds the upper hand in Europe at present. The 'political' concerns which have arisen in the context of public debate on GMOs can therefore be seen as stemming from fundamental social tensions which erupt whenever technologies seen as 'radically new' appear on the scene, providing a context for renewed debate about their management. That technologies lock society into set development paths and create co-evolving economy-environment interactions increases the significance of potential decision points, due to the opportunity costs of subsequently reversing the decisions.

Some writers have suggested that the only way to deal with social tensions is through wider public debate, where such debate is linked to decision processes and their outcomes. However, wider public involvement in decisions regarding the regulation of GM crops is constrained by existing legislation, which only accepts 'scientific evidence' on human health and biodiversity to oppose GMO commercialisation. While bounding any problem is essential to its understanding, the way these particular boundaries have been drawn excludes the possibility of public involvement and the issues they wish to have expressed. This creates a specific type of partial ignorance surrounding the debate and is one reason why technical arguments miss the concerns of the general public. In the UK the public consultation exercise was quite novel but beyond airing existing positions and providing lessons for future large-scale deliberation/participation exercises appears to have been of limited value. In-depth deliberation requires a willingness of interested parties and ordinary citizens to engage, calling experts as witnesses, and evaluating evidence. A common misconception seems to be that GMOs were on trial for acceptance or rejection but in fact each new crop variety will be judged on its own via the existing risk assessment procedures.

The variety of potential impacts of GM development on agricultural and other systems raises a broad range of economic issues. At a fundamental level, political debates recognise that the economic market place is itself only one forum for social choice, and one which is defined by a set of associated social and legal institutions. If social disagreement exists on the acceptability of biotechnology as a process, this fundamental tension should logically be addressed before market commercialisation, which would then proceed only on the basis of a shared social position over the kind of products appropriate for the market. In practice, ethical concerns are conflated with economic and political factors.

In terms of the impacts on social welfare the food supply chain must be considered. The relative power of different suppliers and consumers in the market place will determine how costs are distributed and who gains. Clearly the strong position of an oligopoly of multinational companies is an important factor in evaluating the economic implications. Similarly, USA and European trade politics have a strong bearing on how GMOs are regulated.

Whatever the commercial future of GM products, there are some inherent characteristics of the technology which suggest how development will proceed. Whilst the technology is heralded by some as revolutionary, the rationale behind the features of the first generation of GM agricultural products remains in many senses very conventional. This can be viewed as a continuation of the industrial approach to agriculture as seen under pesticides. The direct effects of these crops on conventional farm economics will determine their immediate commercial viability, but the indirect effects of cross-contamination on the economics of alternative systems is a new area of controversy, and one in which production regulations will have a critical relationship with market prices. By contrast in the industrially developing world, arguments about the economic importance of GM technology have centred on the twin imperatives of poverty alleviation and agricultural development. The impacts of GM in these contexts are complex but clearly some of the claimed secondary benefits such as preventing famine are beyond a single technological innovation and require more fundamental understanding and change of the political and economic systems which prevent their eradication.

This paper has argued that biotechnologies are both nested within institutional frameworks and carry inherent economic and biological features. These influence not only production methods but also research priorities, economic interactions, and ecosystem functions. At the same time, technology is a development from within a set of social and institutional structures and cannot then be divorced from those structures.

REFERENCES

- AEBC, 2001. Crops on Trial. Available on-line at <http://www.aebc.gov.uk/aebc/crops.pdf>.
- BBC News, 2001. Finnie welcomes GM crops report. Available on-line at http://news.bbc.co.uk/1/hi/english/uk/scotland/newsid_1535000/1535176.stm.
- BBC News, 2003. US in new global GM push. Available on-line at <http://news.bbc.co.uk/1/hi/sci/tech/3013394.stm>.
- Beck, U., 1992. From Industrial Society to the Risk Society: Questions of Survival, Social Structure and Ecological Enlightenment. *Theory, Culture & Society* 19, 97-123.
- Benbrook, C., 2000. Who controls and who will benefit from plant genomics? Presented at paper presented at 'The 2000 Genome Seminar: Genomic revolution in the fields: Facing the needs of the new millenium', AAAS Annual Meeting, Washington, DC.
- Bock, A., K. Lheureuz, M. Libeau-Dulos, H. Nilsagard and E. Rodriguez-Cerezo, 2002. Scenarios for co-existence of genetically modified, conventional and organic crops in European agriculture. Institute for Prospective Technological Studies (IPTS), Joint Research Centre (JRC), European Commission, Brussels.
- Buckwell, A., G. Brookes and D. Bradley, 1998. Economics of Identity Preservation for Genetically Modified Crops. CEAS Report 1745/GJB. CEAS Consultants (Wye) Ltd, Wye, England.
- Carr, S., 2000. EU safety regulation of genetically-modified crops. The Open University.
- Carr, S. and L. Levidow, 2000. Exploring the links between science, risk, uncertainty, and ethics in regulatory controversies about genetically modified crops. *Journal of Agricultural and Environmental Ethics* 12, 29-39.
- Clark, E. A., 1999. Genetic engineering in field crops: Ethics and academic. Presented at Paper presented to Annual Meeting of Saskatchewan Institute of Agrologists, April. Available on-line at: <http://www.plant.uoguelph.ca/research/homepages/eclark/ethics.htm>.
- Directorate-General for Agriculture, 2000. Economic Impacts of Genetically Modified Crops on the Agri-Food Sector: A First Review. Working Document Revision 2, Directorate-General for Agriculture, Commission of the European Communities.

- FAO, 2001. Genetically Modified Organisms, Consumers, Food Safety and the Environment, FAO Ethics Series No. 2. Food and Agriculture Organisation of the United Nations, Rome.
- FAO, 2002. Anti-Hunger Programme: Reducing hunger through agricultural and rural development and wider access to food, First Draft. Food and Agriculture Organisation of the United Nations, Rome.
- FOE, 1997. Shoppers Say 'No!' to Genetically Modified Food. Published on-line at <http://www.foe.org.uk/pubsinfo/infoteam/pressrel/1997/19970425112530.html>.
- FOE, 1998. Supermarket Shoppers Say No to Frankenstein Food. Published on-line <http://www.foe.org.uk/pubsinfo/infoteam/pressrel/1998/19981020114147.html>.
- Funtowicz, S. O. and J. R. Ravetz, 1992. Risk management as a post-normal science. *Risk Analysis* 12 (1), 95-97.
- Gilland, T., 2000. Precaution, GM crops and farmland birds. In, *Rethinking Risk and the Precautionary Principle*, ed. Julian Morris. Oxford: Butterworth Heinemann.
- Graham, G., 1999. *The Internet: a philosophical inquiry*. Routledge, London.
- Habermas, J., 1992. *The Structural Transformation of the Public Sphere*, translated by Thomas Burger & Patrick Lawrence. Polity Press, Cambridge.
- James, C., 2001. *Global Review of Commercialized Transgenic Crops: 2001*. International Service for the Acquisition of Agri-Biotech Applications (ISAAA), Brief No 24: Preview, Ithica, New York.
- Kydd, J., J. Haddock, J. Mansfield, C. Ainsworth and A. Buckwell, 2000. Genetically modified organisms: Issues for DFID's research programme, updated version of paper for UK Department of International Development (DFID), Crop Post Harvest Research Programme. Presented at Presented at Agricultural Economics Society Annual Conference, Manchester, April 15th.
- Levidow, L. and C. Marris, 2001. Science and governance in Europe: lessons from the case of agricultural biotechnology. *Science and Public Policy* 28 (5), 345-360.
- Loasby, B. J., 1976. *Choice, Complexity and Ignorance: An Inquiry into Economic Theory and the Practice of Decision-Making*. Cambridge University Press, Cambridge.
- Marris, C., B. Wynne, P. Simmons and S. Weldon, 2001. *Public Perceptions of Agricultural Biotechnologies in Europe: Final Report of the PABE research project*, published on-line at <http://www.pabe.net>.
- McCloughlin, M., 1999. Ten reasons why biotechnology will be important to the developing world. *AgBioForum* 2 (2-3), 1163-1174.
- McHughen, A., 2000. *A Consumer's Guide to Genetically Modified Food*. OUP, Oxford.
- Morris, S. H. and C. C. Adley, 2001. Irish public perceptions and attitudes to modern biotechnology: an overview with a focus on GM foods. *Trends in Biotechnology* 19 (2), 43-48.
- Nelson, G., A. De Pinto, D. Bullock, E. Nitsi, M. Rosegrant, T. Josling, J. Babinard, C. Cunningham, L. Unnevehr and L. Hill, 1999. *The Economics and Politics of*

- Genetically Modified Organisms in Agriculture: Implications for WTO 2000. Bulletin 809. University of Illinois at Urbana-Champaign (UIUC).
- Norgaard, R. B., 1994. *Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future*. Routledge, London.
- Sen, A., 1986. *Poverty and Famines: An Essay on Entitlement and Deprivation*. Clarendon Press, Oxford, England.
- Spash, C. L., 1995. The political economy of nature. *Review of Political Economy* 7 (3), 279-293.
- Spash, C. L., 2002. *Greenhouse Economics: Value and Ethics*. Routledge, London.
- Toke, D., 2002. UK GM Crop Policy: Relative Calm before the Storm? *The Political Quarterly* 73 (1), 67-75.
- Wilkinson, M. J., L. J. Elliot, J. Allainguillaume, M. W. Shaw, C. Norris, R. Welters, M. Alexander, J. Sweet and D. C. Mason, 2003. Hybridization between *Brassica napus* and *B. rapa* on a national scale in the United Kingdom. *Science* 302, 457-459.
- Wright, J., 2000. 'The Economics of Genetic Modification', Background Paper on Economics for New Zealand Royal Commission on Genetic Modification. Christchurch, New Zealand. Available on-line at http://www.gmcommission.govt.nz/publications/Economic_Issues_Jan_Wright.pdf.
- Wynne, B., 1992. Uncertainty and environmental learning: Reconceiving science and policy in the preventive paradigm. *Global Environmental Change* (June), 111-127.