Genetic use restriction technologies (GURTs)
Potential economic impacts at national and international levels

D.J.F. Eaton
Dr. F.W. van Tongeren

Project code 62554

March 2002

Report 6.02.01

Agricultural Economics Research Institute (LEI), The Hague

The Agricultural Economics Research Institute (LEI) is active in a wide array of research which can be classified into various domains. This report reflects research within the following domain:

- ☐ Statutory and service tasks
- ☐ Business development and competitive position
- ☐ Natural resources and the environment
- ☐ Land and economics
- ☐ Chains
- ☑ Policy
- ☐ Institutions, people and perceptions
- ☐ Models and data

Potential economic impacts of GURT technologies at national and international levels
Eaton, D.J.F. and F.W. van Tongeren
The Hague, Agricultural Economics Research Institute (LEI), 2002
Report 6.02.01; ISBN 90-5242-711-9; Price € 12,25 (including 6% VAT)
48 p., fig., tab.

This report examines the possible economic impacts from the development and commercial application of genetic use restriction technologies (GURTs). The economic rationale for GURTs is reviewed and the various benefits and costs are identified. The report argues that GURTs offer the potential to attract increased private sector investment in a number of major crops that have not been successfully hybridised. Increased segmentation of genepools in the breeding sector and the possibilities for a heightened productivity lag are discussed as possible risks. The possible contribution of GURTs to the trends in the seed and agrochemical sector towards vertical integration and horizontal concentration is discussed. The report then examines a number of regulatory issues facing governments in the areas of intellectual property rights, anti-trust and competition laws, and biosecurity, as well as other potentially possible means for restricting GURT application. The report concludes that weighing up the various potential costs and benefits associated with GURT development poses a challenging task for governments, as much of the necessary information is at best only partially available.

Orders:
Phone: 31.70.3358330
Fax: 31.70.3615624
E-mail: publicatie@lei.wag-ur.nl

Information:
Phone: 31.70.3358330
Fax: 31.70.3615624
E-mail: informatie@lei.wag-ur.nl

Contents

		Page
Preface		7
Summary		9
1.	**Introduction**	11
2.	**Technical aspects of GURTs**	13
3.	**Economic rationale for GURTs**	15
4.	**Potential impacts on R&D and productivity**	18
5.	**Industry Structure**	27
6.	**Regulatory issues**	36
7.	**Conclusions**	42
References		45

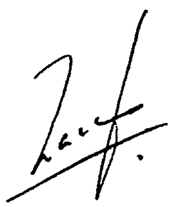
Preface

Methods involving specific genetic switch mechanisms that aim to restrict the use of genetic material for agricultural purposes (domesticated crops and animals) have been described in a number of recent patent applications. These methods have been referred to as 'Genetic Use Restriction Technologies' (GURTs). The genetic switch can be used to restrict either autonomous use of the germplasm itself or the expression of traits associated with that germplasm, or the unwanted release of genes from that germplasm into the environment.

The development and application of GURTs is primarily an attempt by private sector agricultural breeders to increase the extent of protection on their innovations. In countries where the use of seed varieties for commercial research or their replanting is already restricted through intellectual property rights systems, GURTs provide a strategy for increasing the enforcement of these rights through technological means. But in other situations, where for example plant variety protection is intentionally less comprehensive, GURTs become a strategy for extending this legislated protection beyond its intended limits using technological means. GURTs therefore demand that governments consider carefully their positions on these issues.

This study examines the possible economic impacts that could arise from the development and commercial application of GURT constructs. A shorter but broader study, also taking into account the expected technical developments as well as biosecurity considerations and the likely impacts on farming systems, was conducted by the Wageningen University and Research Centre at the request of the Food and Agriculture Organisation (FAO) in 2001. The current report expands on the economic impacts covered in that study, with financial support from the Dutch Ministry of Agriculture, Nature Management and Fisheries under its North-South research programme.

The managing director,



Prof. Dr. L.C. Zachariasse

Summary

Genetic Use Restriction Technologies (GURTs) fulfil one of two roles as technological innovations for their developers: product improvements in terms of transgenic containment, and appropriation of benefits from breeding improvements. The latter has the most relevance for sectoral, national and international policy, raising issues for regulatory policy, in particular intellectual property rights and competition issues.

There are two general applications of GURTs that can provide a means to restricting the use of breeding improvements by farmers or other breeders. First Variety-level GURTs (V-GURTs) could be used to produce seed that ensures that farmers cannot re-use saved seed and that breeders cannot use seeds in their own breeding programmes. Second, Trait-specific GURTs (T-GURTs) can ensure that value-added traits of seeds (such as induced flowering) can only be used by farmers that have purchased the necessary inducers from the breeding company, or its agrochemical affiliate.

GURTs are essentially an appropriation mechanism for the breeding sector, providing the opportunity to increase profits by protecting the efforts needed to develop new varieties. The key question is how much the increased appropriation offered by GURTs will lead to increased investment by the private sector and associated productivity improvements.

Hybridisation offers an example of how a technological means to increase appropriation has been associated with increased private sector investments in agricultural R&D. Evidence supports the hypothesis that hybridisation of major crops has attracted more private investment into plant breeding.

It is most likely that GURTs will only be applied in new breeds and varieties that offer considerable productivity improvements to farmers, given the considerable costs of GURT development and application. The specific crops and markets that would benefit from increased private investment will be among those for which hybridisation has not yet been fully successful. For example, wheat and cotton, are likely candidates. T-GURTs, in particular, may provide the protection necessary for breeders to provide differentiated products for the needs of different farmers and maybe also consumers.

The existence of net productivity improvements from GURTs as a result of increased private investment depends on whether the increased investment from GURTs is additional in the sense of expanding the overall portfolio of research activity as opposed to displacing publicly-financed activities. Freed public R&D resources for breeding could be directed to more marginal or orphan crops, which could be particularly important in developing countries. Realising these benefits for the agricultural sector depends on continued support for publicly-financed agricultural R&D.

While GURTs may lead to an increase in investment for some crops, the nature of the technology may have a negative effect on the productivity of these breeding efforts over the longer term by resulting in more separated pools of genetic diversity.

The most important effect that can be expected from the introduction of GURTs (especially V-GURTs as an appropriation mechanism) is an increase in the seed replacement rate by farmers, with a transfer of benefits from farmers to seed suppliers. There is also the potential to generate longer-term lock-in of farmers.

GURTs provide possibly a further rationale for a strengthening of the trend towards vertical integration in the seed breeding and agrochemical sector. Whether it provides further concern for the development of monopoly power in the biotechnology and seed sector depends in part on the extent to which incumbent firms or new entrants can develop their own GURT or non-GURT technologies.

The potential for GURTs to contribute to the increasing horizontal concentration is also clear. But it remains to be established which type of competitive (or anti-competitive) behaviour is actually emerging.

A number of possible rationales for regulation of GURT technology have been identified.

(1) IPR: Governments may need to respond proactively by deciding whether or not they agree to any possible circumvention of their IPR legislation, particularly with respect to farmer's privilege, as a result of the introduction of GURTs. Measures such as compulsory licensing in patent laws might by a possible means to preventing genepool separation for R&D purposes.

(2) Competition policy: Effective regulatory frameworks are necessary for examining potential problems, such as excessive pricing, vertical foreclosure, bundling and exclusive dealing, that could arise with GURTs. The development of such frameworks is a particularly urgent challenge for many developing countries.

(3) Biosecurity: Governments can probably make use of the legislative framework governing the use of pesticides and veterinary medicines for biosecurity risks arising from contamination through outcrossing of GURT constructs or components or effects of inducer compounds. However, it is not clear how governments can assess the risks of contamination.

On the other hand, very few viable options are available for restricting or prohibiting the use of GURTs. Using biosafety laws to ban GURTs from the market would be liable to complaints in the WTO. Variety release procedures may offer some possibilities through performance testing.

In summary, sufficient information is not yet available to provide governments with a clear answer to whether prohibition, restriction or promotion of GURTs is desirable on economic welfare grounds. A cautious interpretation of the arguments presented here indicates that the potential benefits offered by GURTs in comparison to their costs and risks are worth examining in more detail.

1. Introduction

Methods involving specific genetic switch mechanisms that aim to restrict the use of genetic material for agricultural purposes (domesticated crops and animals) have been described in a number of recent patent applications. These methods have been referred to as 'Genetic Use Restriction Technologies' (GURTs) [1]. The genetic switch can be used to restrict either autonomous use of the germplasm itself or the expression of traits associated with that germplasm, or the unwanted release of genes from that germplasm into the environment.

The development and application of GURTs is primarily an attempt by private sector agricultural breeders to increase the extent of industrial protection on their agricultural innovations. In countries where the use of seed varieties for commercial research or their replanting is already restricted through intellectual property rights systems, GURTs provide a strategy for increasing the enforcement of these rights through technological means. But in other situations, where for example plant variety protection is intentionally less comprehensive, GURTs then become a strategy for extending this legislated protection beyond its intended limits using technological means. GURTs therefore demand that governments consider carefully their positions on these issues.

In considering this fundamental judicial issue, it is important to examine the various impacts that GURTs may have on agriculture, the environment and food security in rural areas in developing countries. Positive impacts include increased investments by the private sector in crop and animal breeding as a result of the increased ability to appropriate the benefits arising from seed development. New varieties resulting from this investment could contribute to higher agricultural productivity, as well as better consumer products. Another positive aspect could be the prevention of unwanted geneflow, particularly from genetically-modified crops, into neighbouring crop stands and animal and fish populations and/or their wild relatives.

Potential negative impacts have been identified as well. These may require further discussion and close attention by regulatory authorities. One consequence of GURT application could be reduced exchange and flows of germplasm, particularly between private and public sector in developing countries. This could further accentuate the lag in productivity growth experienced by the large numbers of farmers who are outside of the 'formal' seed system. Secondly, the increased scale of private rights over agricultural genetic resources could provide corporations in the agrochemical and biotechnology sector with the ability to exercise and abuse to the detriment of competitors, farmers and possibly also consumers. Such problems demand an active role for public policy, both in terms of regulatory measures but also in terms of decisions concerning public agricultural research investments.

[1] The technology has also been given the label, 'Terminator technology', by those particularly concerned about its possible negative effects.

This report reviews the economic impacts of GURT-technologies at national and international levels. The discussion is, in general, of a qualitative nature. The next section summarises the technical aspects of GURTs (section 2). This is then followed by a review of the economic rationale for GURTs and an overview of the associated costs and benefits (section 3). The report continues with a discussion of the potential impacts of GURTs on investment in agricultural R&D and productivity (section 4). Particular attention is focussed on the examples and insights provided by hybrids, and specific considerations for developing countries. Further sections delve into regulatory issues. It is often suggested that GURTs will promote further horizontal concentration and vertical integration in the breeding sector. Potential developments are therefore reviewed (section 5). This is then followed by a review of the regulatory support and reactions possible for government (section 6). The most important policy areas are those relating to IPR and to anti-trust and competition systems.

2. Technical aspects of GURTs

Two types of genetic use restrictions have been distinguished to-date: restriction of the use of an entire variety in which the GURT [1] is embodied by inhibiting reproduction (V-GURT); and restriction of the use of a certain trait by regulating its expression (T-GURT).

At least three general V-GURT strategies have been identified. In the first strategy, a plant is provided with a disrupter gene that can inhibit embryo formation (described in the application by Delta & PineLand/USDA). This disrupter remains dormant until the seed is treated with a specific chemical, resulting in the expression of the disrupter gene in the second generation seed produced by the treated seed. In other words, the plant resulting from the seed produces seed which is not fertile (but can be consumed). In the second strategy, the situation is reversed. The disrupter gene is not dormant but can be suppressed through the application of a chemical (Zeneca application). The third strategy applies exclusively to vegetatively-propagated species (e.g. root and tuber crops, ornamentals). In this case, the variety is provided with a gene that inhibits growth. A second gene, which can be made active through the application of a chemical, can restore this growth. With T-GURTs, the expression of a specific trait by a transgene is regulated with the use of inducible promoters.

None of the GURT strategies has yet been fully developed into practical applications, although work appears to be progressing. The Delta & PineLand/USDA strategy still lacks efficient control of the disrupter geners. The Zeneca concept has gone further and is now been incorporated into transgenic tobacco plants, although not yet in a commercially-viable way. The concept has also been developed to control the vegetative reproduction of potatoes, resulting in the suppression of sprouting for two years, although it is not yet clear whether sprouting can be restored. Research on the T-GURT concept appears to have concentrated primarily on a strategy for removing antibiotic-resistance genes introduced as molecular markers and is coming close to the application stage. Technically, this is not a T-GURT because the intent is not use restriction but this does provide some indication on the potential feasibility of the technique.

Aside from the development of the GURT concepts themselves, other obstacles to practical or commercial application remain. One of these is the identification of effective inducible promoters, which switch the disrupter genes on or off. This is compounded by the fact that, in order to achieve the use restriction, such promoters should be unique and not available in the private domain. Another obstacle is difficulty involved in transgenic modification of many crop varieties, in particular those that would be of interest for GURT application, such as cotton and wheat. In general, it is expected that the full development of

[1] This section is based on a companion report to this one, prepared by Ingrid van der Meer and Jules Beekwilder of Plant Research International, and forming chapter one of the study prepared by Wageningen University and Research Centre for the FAO on GURTs, entitled, *Potential impacts of Genetic Use Restriction Technologies (GURTs) on Agrobiodiversity and Agricultural Production Systems* of which this study is also a part. The interpretation though remains the responsibility of the present authors.

the first GURT concepts may require another 10 years, and then only for those crops with short generation times. Others will take longer.

Research on the development of GURT concepts for farm animals and aquaculture has not advanced as far as it has for plants. The technological obstacles are greater and research is complicated by more ethical issues than is the case with plants. The lag in technology development for animals and fish has been estimated at about five years.

3. Economic rationale for GURTs

Genetic Use Restriction Technologies (GURTs) fulfil one of two roles as technological innovations for their developers: product improvements in terms of transgenic containment, and appropriation of benefits from breeding improvements. The potential benefits of GURTs, as a means of containing transgenes, is relevant primarily for biosecurity policy. It is the application of GURTs as a benefit appropriation mechanism that has the most relevance for sectoral, national and international policy, raising issues for regulatory policy, in particular intellectual property rights and competition issues. The analysis in this report concentrates therefore primarily on GURTs as an appropriation mechanism.

There are two general applications of GURTs that can provide a means to restricting the use of breeding improvements by farmers or other breeders. First, Variety-level GURTs (V-GURTs) could be used to produce seed that ensures that farmers cannot re-use saved seed and that breeders cannot use seeds in their own breeding programmes. Second, Trait-specific GURTs (T-GURTs) can ensure that value-added traits of seeds (such as induced flowering) can only be used by farmers that have purchased the necessary inducers from the breeding company, or its agrochemical affiliate.

Economic growth in the agricultural sector has been based on a number of factors, of which technology development, in the form of improved varieties/breeds of cultivated plants and domesticated animals and fish, has played an important and documented role. Given the self-reproducible nature of these innovations, it is expected that the private sector, in particular breeding companies, would underinvest in R&D in innovations in the area of breeding. For this reason, intellectual property protection, for example in the form of patents or plant varietal protection (PVP) is granted in most countries and has been included under the WTO TRIPS-Agreement (Article 27.3b).

Plant varietal protection (PVP) is the most common form of intellectual property right available to plant breeders. This form of protection offers breeders exclusive rights over the production and sale of the protected variety. Important allowances have been made in the PVP legislation of many countries to allow other breeders to use a protected variety in their breeding research (breeders' exemption) and/or to allow farmers who plant a protected variety to re-use or possibly sell the seed they then produce themselves (farmers' privilege). Standard requirements for PVP legislation have been agreed upon internationally in the form of the UPOV (Union for the Protection of New Varieties of Plants) treaties of 1978 and 1991, with the latter allowing further restrictions to the breeders' exemption and the farmers' privilege.

These forms of protection are intended to balance the interests of different groups (consumers, breeders, farmers). But the policy environment has been changing as there has been a trend towards wider rights being available to plant breeders, as reflected by these differences between the 1991 and 1978 UPOV Acts. In recent years, a number of countries have also allowed for patenting of plants as well as biological processes that may be inherent parts of modern agricultural varietal production.

In many situations, PVP systems operate with only partial enforcement due to the large transaction costs involved. The development of GURTs has thus been partly motivated by a desire by some breeding enterprises to capture a greater proportion of the research benefits where enforcement of intellectual property systems is ineffective or too expensive. But GURTs can also be an attempt to extend the scope of benefits appropriated beyond that granted in IPR legislation, partly with respect to further limiting the farmer's privilege. GURTs can thus be seen as another move in a history of developments leading to greater appropriability of research benefits in the agricultural sector.

The various economic benefits and costs from the development and introduction of GURTs are summarised in figure 3.1 in qualitative terms. [1] As a tool for increased appropriation, it is expected that GURTs will lead to increased investments by private sector breeders, leading to productivity improvements for farmers from the availability of new technologies in the form of varieties and breeds. These benefits for farmers, which are really only relevant in situations where breeding research is inadequately funded from private or public sources, would be partially offset by increased input costs from increased seed purchases (in the case of crops). For breeders, there may be some increased costs related to negotiating access to genepools of others, where desired. The net effects of this increased private R&D investment would presumably result in benefits for consumers in the form of lower food prices, as well as possibly more choice in terms of differentiated products. For governments there is the benefit in terms of a possible reduction of agricultural R&D in areas in which the private sector could now play a stronger role in favour of other neglected areas.

	Benefits	Costs
Farmers	Increased productivity from improved inputs due to increased R&D investment	Increased input costs from seed purchase (incl. transaction costs)
Breeders (especially private sector)	Increased appropriation of research benefits from new products	Increased cost for access to gene pools of other breeders
	Increased market segmentation & price discrimination	
Consumers	Lower food costs	
Governments	Reduced investment requirements in breeding	Other regulatory support required for GURTS
	Fewer enforcement costs for PVP	

Figure 3.1 Summary of Economic Benefits and Costs from GURTS

[1] The formal tools of cost-benefit analysis are not an appropriate tool of analysis for assessing the broad nature of the potential impacts of GURTs but the concept of benefits versus costs provides a useful framework for presenting these impacts across various groups.

Governments need to assess the benefits and costs associated with GURT introduction in order to develop the policy response most appropriate for their circumstances. It can be expected that these will vary, particularly between industrialised and developing countries but also between individual situations. The benefits and costs in figure 3.1 are intended to provide a framework to assist policymakers in making their respective assessments. It should be emphasised though that many of the identified benefits and costs should be subjected to further analysis to be better able to provide a well-reasoned basis for decision-making. This report aims to offer some initial qualitative expectations based on a cursory review of existing knowledge related to this technological development, but attempts to maintain a balanced perspective on the benefits and costs associated with GURTs.

4. Potential impacts on R&D and productivity

GURTs are essentially an appropriation mechanism for the breeding sector, providing the opportunity to increase profits by protecting the efforts needed to develop new varieties. The key question is how much the increased appropriation offered by GURTs will lead to increased investment by the private sector and associated productivity improvements. Breeders currently have two principal means to appropriate benefits: legal, through IPR legislation and biological, through hybridisation. IPR legislation, in the form of plant varietal protection or patents, is a relatively recent development in most countries. Systems of IPR-protection for agricultural crops have been established in industrialised countries during the course of the 20th century and the WTO, through the TRIPS agreement, is resulting in the establishment of PVP systems in its developing-country members. Hybridisation was also developed in the 20th century and is not yet technically possible for all major crops, including notably wheat, soybean and cotton. Both possibilities offer examples of how increased appropriability affects investment and productivity.

Plant varietal protection

PVP systems have been subjected to some study for their economic impacts, particularly in the UK and to some extent in the UK. Economic studies have been somewhat divided but there appears to be a moderate consensus that plant breeders rights do not provide incentive for adequate investment by the private sector in breeding activities (Eaton, 2001). This area is still open to debate as conclusive proof is difficult to demonstrate, particularly if one is interested not only in investment but also in increased productivity of the resulting innovations. Studies have been able to find possible evidence of a positive effect of PVP on investment expenditures (Butler, 1996, Perrin, Hunnings and Ihnen, 1983, Lesser, 1997). [1] Making a corresponding link with increased productivity has been more difficult, with mixed results (see for example, Perrin, Hunnings and Ihnen 1983 on US soybeans and Alston and Venner, 1998 on US wheat) as well as mixed interpretations of these results.

The inadequate incentives provided by PVP can be attributed to two aspects: the scope of the protection and the effectiveness of enforcement. The scope of protection varies from country to country. This variation will be further maintained through the lack of specific requirements on the scope of protection in Article 27.3b of the TRIPS Agreement. Key aspects of the scope receiving attention from research have been the farmer's privilege and the breeder's exemption (Lesser, 2000). Industrialised countries in particular have found it worthwhile to re-examine the balance struck in PBR and there has been a trend, as seen in the successive revisions of the UPOV convention, towards extending the scope of

[1] It is quite plausible that increased investment in breeding need not accompany increased productivity, as such investments might be oriented towards activities, such as brand marketing, or replacement of seed varieties in the market with marginally improved ones, that are largely intended to profit from the 'monopoly' powers conferred on the right holder.

protection under PBR, in particular by restricting the farmer's privilege, which may be seen as the greatest appropriation gap. In addition, the granting of patents on agricultural plants in a few countries can also be seen as a step in this direction i.e. a means to increase the scope of available protection.

While the scope of protection increases, this provides an operational means of increased appropriation only if the enforcement of the property rights granted is effective. This is limited by the costs of checking and pursuing potential violators. Where farmer's privilege has been limited, such costs may be exceptionally high, involving field checks and possible laboratory analysis, followed by legal proceedings. Such enforcement also requires a certain level of institutional development not yet present in many countries.

Hybridisation

The limited scope of protection in some cases and the difficulty associated with effective enforcement in cases where the scope of protection is broader provide an incentive for breeders to seek other means of appropriating benefits. Hybridisation has offered one means to do this for a growing number of crops, including maize, sorghum and rice. Hybridisation offers an example of how a technological means to increase appropriation has been associated with increased private sector investments in agricultural R&D. While the parallel is not exact, the case of hybridisation, also a form of biological appropriation, is the closest real-world example of a technological development that comes close to GURTs.

It can be expected that GURTs, by increasing the appropriability of research benefits by breeders, will provide an incentive for them to increase investments in R&D. Limited evidence from the US supports the hypothesis that hybridisation of major crops has, by increasing the appropriability of research investments, attracted more private investment into plant breeding (Srinivasan and Thirtle, 2000). Using the ratio of breeding investments to seed sales as an indicator of investment, table 4.1 shows that for the hybrid crops, maize and sorghum, private plant breeding has accounted for more than 10% of seed sales in the US while the ratios for three non-hybrid crops are 5% or lower (Fuglie et al., 1996).

It would be helpful though to know the differences in public investment between these crops. Appropriability is seen from the higher percentage of seed purchased for the hybrid versus the non-hybrid crops. Differences in the growth in seed prices show more variation among the non-hybrid crops, wheat, soybean and cotton, but are on average lower than for the hybrid crops. This difference also supports the increased appropriability argument. As if to reinforce this, there is no marked difference in the annual growth in crop yields between hybrids and non-hybrids. This can be interpreted as an indication that the private investment is as equally productive as public investments, although the higher variation among the productivity increases for non-hybrid crops may indicate that other crop-specific factors are equally, or more, important.

Table 4.1 Seed Sales, Private Plant Breeding and Trends in Seed Prices and Yields of Major Field Crops in the US (1975-1992)

Crop	Seed sales USD million (1989)	Private plant breeding USD million (1989)	Ratio private breeding to sales %	Seed cost USD/acre	Share of seed purchased %	Growth in seed price %/yr	Annual growth in crop yields %/yr
Hybrid seeds							
- Maize	1,031	112.9	11	21.09	95	4.75	1.33
- Sorghum	90	12.6	14	5.13	95	5.08	1.54
Non-hybrid seed							
- Wheat	256	13.5	5	8.92	40	0.97	1.13
- Soybean	610	24.9	4	12.03	73	1.92	1.23
- Cotton	108	4.6	2	14.93	74	4.46	2.23

Source: Reproduced from Fuglie et al. (1996); Ratios of private breeding to sales are authors' own calculations.

Potential productivity improvements and public R&D

It is most likely that GURTs will only be applied in new breeds and varieties that offer considerable productivity improvements to farmers. This is not least because the costs of GURT development and application appear to be considerable, taking into account the need to back-cross from original to elite lines as well as the research necessary for the selection of inducers and compounds. Such productivity improvements may be in the offing. Some of the latest improvements witnessed in GMO crops give reason to expect that the rapid advances being made in this area will lead to yet further agronomic improvements that go beyond the rate of increase seen in conventional breeding efforts. For example, productivity increases of 10 to 25% in crops such as wheat and rice have been proposed as realistic expectations with the application of biotechnology (James and Krattiger, 1999). From a simple marketing perspective, farmers are more likely to increase their expenditures on seeds, the purpose of increased appropriation, if these offer simultaneously better performance.

T-GURTs, in particular, may provide the protection necessary for breeders to provide differentiated products for the needs of different farmers and maybe also consumers. A given variety could be specifically adapted to different growing conditions, for example, managed by the use of a trigger, for example, a chemical inducer, as in the case of triggering flowering or pathogen resistance. If the inducer is a proprietary product, then the technology has a built-in genetic use restriction. It is important to emphasise that the trait-specific benefit would probably be achievable without the use restriction, but the latter might provide sufficient incentive for the development and commercialisation off the innovation. Triggered control of trait-specific innovations could then be a component of more productive precision farming or the production of differentiated products, meeting the needs of either farmers or consumers.

Despite this likely bundling of GURTs with improved varieties, the existence of net productivity improvements from GURTs as a result of increased private investment depends though on the nature of current investment, both public and private, in those crops concerned. GURTs are by themselves an appropriation tool. By enabling increased appropriation of benefits, GURTs may lead to productivity benefits for crops in which current investment in breeding is insufficient. This is more likely the case in developing countries than in industrialised countries, as the latter generally have public breeding programmes with relatively better resources. Such greater investment should be welcomed for its effects on agricultural productivity with benefits for farmers and consumers alike.

Whether the increased investment from GURTs is additional in the sense of generating new productivity improvements depends thus on the extent to which this investment expands the portfolio of research activity as opposed to displacing publicly-financed activities. If such displacement does take place, then the effect on productivity depends on decisions taken concerning the reallocation of public breeding investments. In this case, the productivity benefits might be indirect, being found in the impacts of another crop that consequently receives higher public breeding investment.

Indirect productivity benefits could also be particularly important in developing countries. Freed public R&D resources for breeding could be directed to more marginal or orphan crops, which are generally of greater importance to poorer farmers, or to developing varieties to more marginal growing conditions, which tend to be inhabited by poorer farmers. Public agricultural R&D resources could also be redirected to other agricultural topics, such as irrigation water management, for example. Thus, if support for publicly-financed agricultural R&D is maintained, then GURTs could allow this total portfolio of investment to be expanded with associated productivity gains in other sectors. But it is important to emphasise that realising these benefits for the agricultural sector depends on continued support for publicly-financed agricultural R&D. This concern is particularly for developing countries in which a modernising agricultural sector needs to take advantage of new productivity improvements but an informal sector is even more dependent on productivity improvements developed with public funds.

In industrialised countries, the benefits from GURTs would be even more likely to be of an indirect nature. There is currently a long-term trend of decreasing public agricultural R&D in most OECD countries, or at least decreasing growth in public spending in this area (Alston et al., 1997). GURTs could be expected to reinforce this trend, providing further reasons for the public sector to reduce its investment budget while the private sector increases its own. Thus there may not be any overall effect on productivity but public resources will be freed for other purposes.

Of equal importance would be the even stronger need for developing countries, and also the international agricultural research centres, to find new mechanisms for accessing the benefits of research in industrialised countries (Goeschl and Swanson, 2000). In general, one of the impacts of GURTs, as with hybridisation, would be to bring agricultural R&D further into the private realm. To ensure that publicly-funded R&D is able to continue to address market segments or issues that are not commercially viable, access to private research results will be necessary. Possible solutions will probably have to involve public-private partnerships, in which companies can be given incentives (including altruistic ones or fiscal benefits) for making material and technologies available to public research institutions for markets that could be considered as unattractive for commercial interests. Such initiatives would require innovative forms of licensing or technology transfer agreements, with incentives and brokering provided by government agencies in industrialised countries.

Opportunities for commercial application

The specific crops and markets that would benefit from increased private investment are difficult to predict although major crops for which hybridisation has not yet been fully successful, such as wheat and cotton, are likely candidates. Other considerations that breeders will probably take into account include:

- market size and growth possibilities;
- current productivity gaps;
- current rates of farm-saved seed;
- development of marketing channels;
- GMO environment: consumer acceptance, segregation and regulatory support possibilities.

The first two of these relate to general investment opportunities for breeders. Market size tends to be greater in many industrialised countries whereas growth possibilities and productivity gaps point towards more opportunities in developing country markets. How these factors interact with the potential for increasing the appropriation of benefits from farmers, in terms of current rates of farm-saved seed, would probably influence investment and marketing decisions of breeders. In general, the use of farm-saved seed is highest in developing countries, but also fairly common in industrialised countries (see table 4.2). A more serious consideration, at least in the short term, probably relates to consumer acceptance of GMOs and (costly) measures to ensure segregation of GMO and non-GMO products in the food chain, which is discussed further below.

Table 4.2 Farm-saved seed in the EU

Country	Farm-saved seed as % of total seed demand
Germany	50
France	50
Italy	70
Netherlands	20-25
Denmark	5
Ireland	20
UK	30
Greece	90
Spain	90
Belgium	35

Source: Rabobank (1996).

Specific predictions about crop and market combinations to be targeted first for increased investment would require more detailed study. The factors above provide reasons to support a focus on some industrialised country markets. Others point to possibilities to address crops in certain more developed markets of the developing world, such as in Asia, that have not benefited from hybridisation.

Specific considerations in developing countries

To the extent that GURTs do lead to greater investment in agricultural R&D and therefore greater productivity, there will be benefits not only for farmers and breeders but also for consumers. In general, GURT-enabled productivity improvements could be expected to exert downwards pressure on prices for the respective products. Such benefits are potentially quite large, particularly in developing countries, and could be examined further with specific likely crop-market combinations. It should be emphasised that such benefits are relatively more important for the urban poor.

While GURTs may lead to an increase in investment for some crops, the nature of the technology may have a negative effect on the productivity of these breeding efforts over the longer term by resulting in more separated pools of genetic diversity. At present, breeders are relatively free to use the products of other breeders in their own research activities (breeder's exemption under PVP), although a cost is increasingly becoming possible with the possibility to patent plant varieties in some countries. V-GURTs could increase the effect of patenting in making access to germplasm more costly for other breeders, whether they compete in the same market or not. In the short term, this may be seen as yet a further strengthening of appropriation and a cost for breeders (figure 3.1). But in the longer term, the risk is that varieties of agricultural plants or animals will be based on different pools of restricted genetic diversity with little exchange between them. This could translate into lower potential productivity in the future than would otherwise be possible with open use of genepools. Quantification of such a loss is quite difficult and will certainly take place over a longer time horizon. Potential regulatory issues and responses are discussed below in section 4.

Concern over an increased productivity lag is most relevant for developing countries. Many breeding enterprises in developing countries, especially those in the public sector, regularly use the elite lines developed elsewhere or by multinational firms for the development of varieties for the local market. This is also true of the international agricultural research centres (IARCs), who more often then not also provide improved lines for national enterprises. With V-GURTs, but also T-GURTs use of these lines would become more difficult or costly, leading to a further productivity lag for developing country farmers. Sombilla and Evenson (1999) have demonstrated how reduced flow of improved genetic material to developing countries as a whole would decrease production relative to current growth forecasts, leading to an increase in net food imports, as well as an increase in the number of malnourished children.

Varying rates of diffusion of GURT-embodied productivity gains at an international level could also lead to shifts in international markets, including the emergence of new 'growth clubs' among developing countries (Goeschl and Swanson, 2000). A lag did occur with the development and diffusion of high-yielding hybrid crops to developing countries, particularly maize and sorghum, providing insight into the possible effects of GURTs. A simulation study conducted by Goeschl and Swanson (2000) for six widely-cultivated crops (barley, cotton, millet, rice, soybeans and wheat) at the national level indicates mixed effects for yield gaps arising from GURTs depending on how far a country lags behind the genetically potential yields. Developing countries with a better infrastructure for promoting diffusion of innovations can also be expected, as a whole, to reap the benefits of increased productivity accompanying V-GURT protection. In other words, despite their lag behind the technology frontier, the diffusion of new productivity gains would be sufficient to result in overall productivity gains beyond the current trends. But for countries that have profited less from hybrid development in the past, the balance could tip the other way. Without access to a widely-adopted V-GURT technology, such countries could be expected to lag even further behind current trends in productivity increases, given that V-GURTs imply fewer technical possibilities for outcrossing of elite varieties to local varieties via informal breeding systems. It must remembered though that this type of analysis masks stark differences experienced between adopters and non-adopters of new varieties, especially since the diffuse flow of genetic benefits to varieties used by the latter group will be further restrained under GURTs than was the case with hybrids.

This diffusion lag works quite slowly. In their analysis, Goeschl and Swanson (2000) found that significant differences in most developing countries, in terms of positive or negative deviations from current productivity growth trends, would not emerge on a significant scale until after a period of about ten years. The only exception is unfortunately the slowest laggers, or again the poorest of the developing countries, which would probably see divergences from the trend almost immediately after the introduction of GURTs. While there is still an overall positive trend in productivity growth, the sharpened differences between countries will probably also have effects in global markets, as addressed in the following section.

The negative productivity impact of a diffusion lag could be increased if developing country governments chose to restrict availability of GURT technologies. This would have the effect of further restricting access to the related genetic material. This assumes that this material is not otherwise available and that measures are not taken to negotiate access to it by countries not targeted for reasons such as those listed in the previous section (e.g. market buying power, institutional support, etc.).

Input markets

The most important effect that can be expected from the introduction of GURTs (especially V-GURTs as an appropriation mechanism) is an increase in the seed replacement rate by farmers. This implies the potential to increase the amount of seed purchased i.e. an effective increase in demand, with a transfer of benefits from farmers to seed suppliers. The size of this transfer would depend on the existing seed replacement rates, and the relative prices of seed and crop products, and the rate at which yields deteriorate in replanted seed [1].

[1] See Heisey and Brennan (1991) for a model of farmers' demand for replacement seed.

These types of predictions must however be seen as, at the very best, speculative or even just illustrative. The reason for this is the difficulty in predicting the exact nature and extent of adjustments in the seed markets to the introduction of GURTs. On the demand side, farmers cannot be expected to simply increase their purchases of seed by a factor of two or more, without some extraordinary productivity increase. Farmers in almost all parts of the world simply do not have the necessary profit margins to accommodate such an increase. The possibility is, as discussed above, that GURTs, as an appropriation mechanism, will provide the incentive for the private sector to develop such improvements.

If seed suppliers attempt to appropriate more revenue from farmers, then this will likely have to be through an incremental process that over time allows for adjustments in other markets, including those for farm products. In fact there is evidence in some places to suggest that a form of indirect appropriation currently takes place in which seed breeders demand somewhat higher prices for their seeds (Hansen and Knudsen, 1996). They are of course aware of the practice of farmer seed re-use. To the extent that this takes place, there is a rationale for GURTs, aside from bundled productivity increase, to exert a downward pressure on supplier prices.

From a demand side, GURTs might also have the potential to exert a downward pressure on farmers' demand. If farmers' factor demand for seed inputs is such that total expenditures are largely constrained around current levels, then given new restrictions on the usefulness of purchased seed, it is quite possible that farmer's demand for such seed will decrease. That is, farmers will only be willing to pay much less for a bag of seed than previously. Much of this depends on the other options available to the farmer in terms of other varieties, or in terms of other crops or activities. In the short term, the farmer faces greater costs in shifting to avoid the purchase of GURT seed. In the long term, these costs reduce.

Seed suppliers would have to take all these issues into account in their marketing and pricing strategies for GURT products. It is unrealistic to expect that they will be able, from one year to the next, to 'extract' massively greater revenues from farmers, in either developing or industrialised countries. There are enough alternatives and the downstream markets for food products are so competitive that such an expectation would not be realistic.

This is not to argue that the effects of GURT introduction, by limiting farmers' options, would not have serious consequences for some farmers at some places (see accompanying report on impacts on farming systems). But by examining the sector as a whole, it becomes more apparent that widespread change is less likely.

GURTs are thus more likely to form part of a longer term strategy of breeders that allows them to slowly increase the appropriation of benefits from farmers. There is also the potential to generate longer-term lock-in of farmers. By effectively making use of their genepool more expensive for competitors with the use of GURTs, seed suppliers may be in a position to reduce the range of choices available to farmers. This could be in the form of both reduced seed varieties of similar quality and increased costs in making such a shift. Whether such lock-in has efficiency considerations could be an area for future investigations.

Price Discrimination

Both V-GURTs and T-GURTs may open up possibilities for market segmentation by breeders and seed suppliers. Such a practice, consisting of essentially the same variety being sold in different market segments at different prices, could yield efficiency gains and result in the diffusion of new varieties to segments of the market that previously could not afford the newest seed technology. One prerequisite for the application of price discrimination schemes is the existence of barriers to arbitrage trade across different market segments. The cheaper versions of the seed must be prevented to be re-sold on the high-end markets at higher prices. [1] Price discrimination with agricultural seeds is already reasonably possible at international level given the relatively low level of trade in agricultural seed (Rabobank, 1996). Again specific opportunities for such benefits would need to be identified and assessed. At this point, this motivation does not seem to be a pressing concern for breeders, thus implying that it should not yet be an important policy consideration for governments. [2]

[1] GURTs promise some technical opportunities to prevent resale from developing countries to richer markets. For example, T-GURT could be induced by conditions related to specific geographical conditions (e.g. day length).

[2] See chapter 1, for a review of current technological developments.

5. Industry Structure

Vertical integration

Vertical integration and horizontal concentration in the seed breeding and agrochemical sector has been the subject of much recent attention. GURTs provide possibly a further rationale for a strengthening of this trend. Whether it provides further concern for the development of monopoly power in the biotechnology and seed sector depends in part on the extent to which incumbent firms or new entrants can develop their own GURT or non-GURT technologies.

Integration to assure supply by reducing risks is a common explanation for past integration in the seed and agrochemical industries, particularly as these become more commercialised with market development (Morris, 1998 en King, 2001). Another source of high transaction costs in biotechnology arises from extensive co-ordination, where development processes at different stages are closely interrelated. Strategies of tying and bundling have been advanced to understand the behaviour of firms in the glyophosphate and Roundup-ready soybean markets (Hennessy and Hayes, 2000).

Recent vertical integration in the seed industry can be separated into two waves. First, multinational companies, mainly active in agricultural chemicals and pharmaceuticals, acquired smaller biotechnology start-ups. These acquisitions were mainly driven by the perceived commonalties in research technology required to develop new products (Bijman, 1999). By combining pharmaceutical and agricultural biotechnology research, these companies perceived they could enjoy economies of scale (*The Economist*, Nov. 16th, 2000). The mergers and acquisitions involving seed and pharmaceutical and chemical companies are presented in figure 5.1.

Parent Company	Chemicals	Biotech	Seed	Food/Feed
Monsanto/ Pharmacia (merged in 2000)		Agracetus (US, 1995) Calgene (US, 1996) Ecogen (US, 13%) Millenium Pharmaceuticals (joint venture)	DeKalb (US, 1996) Asgrow (US, 1997) Holdens (US, 1997) Cargill International (US, 1998) Plant Breeding Institute (UK) Stoneville (US) Delta & Pine Land (strategic alliance)	Cargill International (joint venture for feed and food)
AgrEvo/ Aventis (Aventis thinking about divesting Aventis Crop Science)	AgrEvo= Hoechst and Schering (GER) Aventis: Rhone-Poulenc (FR) and Hoechst (GER)	Plant Genetic Systems (BE, 1997) Plant Tec	Nunhems, Sunseeds, Vanderhave, Pioneer vegetable genetics, Cargill US seeds (US, 1998) Limagrain (FR, alliance) KWS (20%, GER)	
Syngenta (merger of Novartis agribusiness and Astra-Zeneca, 2000)	Novartis= Ciba-Geigy and Sandoz (SWZ, 1996) AstraZeneca= Zeneca (UK) and Astra (UK) (1999)	Mogen International (NL, 1997) Japan Tobacco (1999, alliance for rice)	Northrup King, S&G Seeds, Ciba seeds, Roger seeds co., Benoist (FR), Maisadour (FR), Advanta (merger of Zeneca seed and Cosum, 1995)	Gerber Foods
Dow Chemicals	Eli Lilly (US, 1997)	Mycogen (US, 1996) Ribozyme Pharmaceuticals Inc.	Agrigenetics (1992), United Agriseeds (1996)	
DuPont		Alliance with Human Genome Science (1996) Curagen (1997)	Pioneer Hi-Bred (20% of shares, bought remaining shares in 1999) Hybrinova (UK)	Quality grain (joint venture with Pioneer) Cereal Innovation Center (UK)
Empresas la Moderna/ Seminis		DNA Plant Technology (1996)	Asgrow (1994, except for corn and soybean, sold to Monsanto in 1997) Petoseed (1994), Royal Sluis Seminis (62%)	Bionova

Figure 5.1 Overview of Mergers and Acquisitions in the Agro-Biotechnology Industry
Source: Brennan et al. (2000) and information from companies' websites.

The second wave involved the acquisition of seed companies by the diversified multinational firms with significant capabilities in discovery and product development (Kalaitzandonakes and Hayenga, 2000). They realised that revenue generation would be difficult if based only on technology licenses to seed companies (Falcon, 2000). By vertically integrating, these firms were able to finance their research activities and to deliver their products to the market (Kalaitzandonakes and Hayenga, 2000). This integration is relevant not only for industrialised countries: with few exceptions, each of the major companies has a significant presence in the developing world (Byerlee and Fischer, 2000) as illustrated in figure 5.2.

Parent Company	India	China	S.E. Asia	South Africa	Brazil	Argentina
Monsanto/ Pharmacia	MAHYCO (joint-venture cotton, 26% of shares)	CASIG Xinjiang and Shaanxi Provincial Seed Cos. Hebei Provincial Seed Co. Cargill	Charoen Pakphand (joint venture with DeKalb) Cargill	Delta&PineLand (strategic alliance) Calgene Carnia (Cargill)	Agroceres Asgrow BrasKalb Monsoy Cargill	Asgrow DeKalb Cargill
AgrEvo/ Aventis	Proagro Sunseeds	Sunseeds (joint venture)	Sunseeds	Aventis	Aventis Granja 4 Irmaos S.A. (rice)	Aventis
Syngenta	Novartis ITC/Zeneca	Advanta	Novartis Advanta		Northrup King Advanta?	Northrup King Advanta?
Dow					Dinamilho Hibridos Colorados	Morgan SA
DuPont	Joint-venture with Southern Petrochemicals	Pioneer research subsidiary	Pioneer	Pioneer	Pioneer	Pioneer
Empresas la Moderna/ Seminis		Petoseeds (joint venture with CASIG)	Petoseeds		Petoseeds	

Figure 5.2 Overview of Mergers and Acquisitions in Developing Country Seed Industries related to Life Science Companies

Source: Byerlee and Fischer (2000).

This wave of vertical integration has thus been driven by the desire to reduce transaction costs in accessing and applying biotechnology in integrated product development. Biotechnology product development frequently involves specific assets, which are tailor made to one particular seed-chemicals combination. In this case, vertical integration is a reaction to a hold-up problem, which makes at least one of the transaction partners vulnerable to moral hazard behaviour of the other partner. High quality germplasm is an important complementary asset for commercialisation, hence vertical integration into the seed business and ownership of germplasm are primary strategies of the firms for profiting from their innovations (Kalaitzandonakes and Bjornson, 1997). The relatively high transaction costs of assuring access to germplasm and proprietary biotechnology supports the integration process (Kalaitzandonakes and Hayenga, 2000). Transaction costs in licensing and/or resolving patent disputes with respect to biotechnology's provide strong incentives for mergers and take-overs of companies holding rights to these assets (Lindner, 1999). Another way in which complementary assets can play an important role fostering integration and concentration is linked to the development of innovations requiring the use of proprietary chemical technologies, of particular relevance in the area of T-GURTs (Hayenga, 1998). This complementary integration is illustrated in table 5.1 showing seed and pesticide sales for 1999.

Table 5.1 Top companies in the seed and pesticide industries, 1999

Company (million USD)	Parent Company	Seed Sales (million USD)	Pesticide Sales
Pioneer Hi-Bred (USA)	DuPont	1,850	2,099
Monsanto (USA)	Pharmacia	1,700	3,214
Syngenta (SWZ/UK)	Novartis+ AstraZeneca	947	6,410
Limagrain (FR)		700	
Seminis (USA)	SAVIA/Grupo Pulsar	531	
Advanta (NL)	Cosun and AstraZeneca	416	
Sakata (JP)		396	
KWS Saat AG (GER)		355	
Dow AgroSciences (USA)	Dow Chemical	350	2,088
Delta&Pine Land (USA)		301	
Aventis CropScience (FR/GER)	Aventis	288	4,320
BASF (GER)		3,525	
Bayer (GER)		2,316	
Makhteshim-Agan (ISR)		720	

Source: Bijman (2001).

There has more recently been a trend in the industry for the multinational, diversified companies to divest their agricultural biotechnology holdings (Bijman, 2001; King, 2001). Combining pharmaceutical and agricultural research provides economies of scale for basic research, but these tend to evaporate when it comes to further development and marketing

(*The Economist*, Nov. 16th, 2000). [1] Furthermore problems with consumer acceptance of GMOs in food chains (for example, recent problems with StarLink™ corn) have contrasted with enthusiasm for applications of biotechnology in pharmaceutical products. Through divesting biotechnology research, the potential risks of negative public opinion are shifted from the diversified company to the biotechnology firms. This, compounded with the lower profit margins in the agricultural sector relative to the pharmaceutical sector, has contributed to the divestment trend (Bijman, 2001).

GURTs and vertical integration

From the discussion above, it appears that some of the past motives for vertical integration may be reinforced in the context of GURTs. In particular, the following aspects deserve attention:

- complementary and specialised assets
  This seems to be especially relevant in the case of T-GURTs, where specific chemicals (inducer compounds) function together with the seed per se;
- extensive co-ordination
  GURT technology is an 'add-on' to other innovations imbedded in the seed. V-GURTs protect the imbedded innovation, while T-GURTs enable or disable certain functions in the seed. Knowledge about this innovative feature is required to effectively utilise their potential. There is therefore the need for close co-operation between the biotechnology and the chemical (pesticides, fertilisers, trigger compounds) aspects of product development. Such co-ordination can perhaps more easily be achieved within one vertically integrated organisation;
- strategic entry deterrence
  Integration to strategically deter entry by increasing the costs of entry into the industry is also relevant in the case of GURTs. Since T-GURTs produced in an integrated chemical-seeds industry typically involve combinations of two products that must be used together. A single-product entrant in the seed industry will only be able to produce one of those complementary products. The incumbent firms can inhibit potential entrants by design of the technology, which makes the new entrant's product (the genetically modified seed) incompatible, or at least difficult to use, with the incumbents product (e.g. the inducer). Such strategic behaviour is well known from the information industry (see Shapiro and Varian, 1999). Whether or not this strategy might be successful, depends in part on the ability of newcomers to reverse-engineer existing products.

Economic theory does not provide a clear-cut general answer to the question whether vertical integration is desirable or not from a societal perspective. Vertical integration may be beneficial to consumers, for example if double marginalisation is avoided or if the vertically integrated industry provides an improved service, or an improved quality of the product. Service and quality improvements typically result from better co-ordination

[1] Novartis and AstraZeneca combined their agribusinesses into a single, independent entity in 2000 (Syngenta). Aventis announced in November 2000 its intention to sell its agricultural division, while Pharmacia (that recently bought Monsanto) is expected to sell the agribusiness within two years.

within the chain and from the elimination of free-rider behaviour. As outlined above, there may be strong reasons to expect that vertically co-ordinated structures are necessary to foster the development of GURTs.

Vertical integration may not be welfare improving if the integration process leads to cartelisation and restricted entry, and at the same time the negative effects of the cartel are not offset by benefits to buyers. It is an empirical matter requiring assessment on a case-by-case basis. In empirical cases, one has to establish the social benefits or costs of supplying a given seed product in an integrated structure, relative to the costs of supplying it via an uncoordinated set of market transactions. Here lies a potential difficulty for assessment of welfare effects: it is possible that the non-integrated development and supply of the GURT enabled seed may not be observed at all.

Horizontal concentration

Horizontal concentration (fewer suppliers of the same product) in breeding and agricultural input industries has also been taking place. This concentration can be explained by the increasing economies of scale associated with the application of biotechnology. Thus, biotechnology start-ups, if successful are increasingly acquired by larger consolidated companies to acquire access to new proprietary technologies (Kalaitzandonakes and Hayenga, 2000). The consequences of such consolidation have affected other related markets: the agricultural input industry is becoming increasingly concentrated (Brennan et al., 2000), and so are the innovation markets, as shown in table 5.2 (Hayenga, 1998). In the US, innovation is becoming concentrated among a small number of large firms, where both investments and research output are increasing, while new firm entry is declining (Brennan et al., 2000). Table 5.2 illustrates that during the late '80s and early '90s innovation output in the US plant biotech industry was highly concentrated among a few firms. Increasing merger activities are observed in the mid-'90s, a period that also witnessed a mild decline in concentration as the result of entry of new firms. Comparing the Herfindahl-Hirschman measure with its lower bound indicates that the new entrants were rather small. [1] It is clear that research in the US plant biotech industry has been characterised by a high degree of concentration, which is aggravated over time in spite of entry of some new firms. Brennan et al. (2000) conclude that the level of research activity of large firms tended to increase relative to that of small firms. In addition, they assert that the effectiveness of research has been negatively correlated with size: the larger the (merged) companies become, the smaller the number of deregulation's per field trial.

Research and development in the seed industry is also concentrating from the point of view of crops. A few crops are receiving the major share of investments in the industry (Rangnekar, 2000). Along the same lines, concentration of intellectual property rights is

[1] The four-firm concentration ratio is defined as the sum of market shares of the largest four firms. The Herfindahl-Hirschman Index is defined as the sum of squared market shares over all firms in the industry: $HHI = \sum_{i=1}^{n} (m_i)^2$. The maximum value of this index equals 1, and it is bounded from below by 1/n, if all firms have equal market shares. Note that the Brennan et al. (2000) figures used in table 5.2 are based on research output, as measured by the number of field trials, and not on market sales.

also a preoccupying issue, as a few companies have control over most patents (Brennan et al., 2000). Such situation tends to erect barriers to the entry of new firms (Lesser, 1998; Falcon, 2000; Rangnekar, 2000), which in turn reduces the possibilities to increase competition in the industry.

Table 5.2 Market Concentration in US plant biotech industry

Year	Four firm concentration ratio (pre-merger) a)	Herfindahl-Hirschman Index (pre-merger) a)	Herfindahl-Hirschman Index (post-merger) a)	Number of mergers	Number of firms	Lower bound Herfindahl-Hirschman index b)
1988	87	0.24	0.24	0	6	0.17
1989	85	0.28	0.28	1	8	0.13
1990	82	0.24	0.24	1	11	0.09
1991	63	0.12	0.12	0	19	0.05
1992	70	0.16	0.16	0	21	0.05
1993	64	0.16	0.16	0	32	0.03
1994	67	0.15	0.15	2	39	0.03
1995	63	0.11	0.13	3	36	0.03
1996	69	0.09	0.13	7	37	0.03
1997	71	0.13	0.19	5	35	0.03
1998	79	0.16	0.22	4	29	0.03

a) Concentration indices calculated on the basis of numbers of field trials (innovation output), rather than on the basis of sales; b) Author's calculation: lower bound HHI = 1/n, where n denotes the number of firms
Source: Brennan et al., 2000.

The high degree of concentration in research extends into concentrated seed input markets. Table 5.3 shows market shares and concentration ratios for the three major North American crops in 1998. With a four-firm concentration in excess of 87% the cotton seed market is most highly concentrated, followed by corn (67%) and Soybean seed (49%). The market is not only characterised by the presence of a few players, but also by a very skewed size distribution, with the largest two firms occupying by far the largest market share.

GURTs and horizontal concentration

There is therefore the concern that increasing horizontal concentration, which could be further be enhanced by the application of GURTs. The application of V-GURTs establishes a monopoly position over the new seed varieties. This monopoly fosters the appropriability of benefits from innovations, and thus tends to boost R&D activities, which eventually benefit farmers and consumers. In a similar vein, but possibly less pronounced, the development of T-GURTs also leads to monopoly positions. In this case, it is the novel features embedded in the seed that create at least a temporary monopoly in a niche market.

The potential benefits from increased R&D, fostered by imperfect competition, must be balanced against potential costs to society. Increasing horizontal concentration may lead to excessive pricing of inputs for farmers, through tacit or overt collusion among suppliers. Such an abuse of market power would lead to a redistribution of economic benefits from consumers to suppliers, who will be able to raise their profits. The ability to actually exercise market power is limited by a number of factors.

Table 5.3 North American seed market shares, 1998

Company	Corn	Soybean	Cotton
Pioneer	39	17	-
Monsanto	15	24	87
- Delta & Pine Land	-	-	71
- Stoneville	-	-	16
DeKalb	11	8	-
Asgrow	4	16	-
Novartis	9	5	-
Dow Agrosciences/Mycogen	4	3	-
Golden Harvest	3	-	-
AgrEvo/Cargill	4	-	-
Hoechst/Schering/Advanta	3	-	-
Syine	-	4	-
Others private and (public)	20	39 (10)	13
Four firm concentration ratio	67%	49%	>87%

Source: Based on Kalaitzandonakes and Hayenga (2000).

First, and most obvious, GURT varieties will also have to compete against non-GURT varieties. The substitution characteristics of demand between more traditional varieties and GURT varieties determine the extent to which suppliers of GURT-enabled varieties are able to raise prices.

Second, a small number of players alone does not necessarily imply an abuse of market power. Tacit or overt collusion is not an easy game to play. A cartel is prone to the incentive to cheat by individual members, and as a consequence, cartels are seldom stable over time. In some oligopolistic markets that are characterised by relatively homogeneous products, the oligopolists may engage in fierce competition, which leads to the same welfare outcome as the perfectly competitive benchmark [1]. In addition, even if there are only a small number of players, there may be a disciplining threat of potential competition by new entrants to the market. Here, the concept of the market has to be interpreted broadly. The relevant market is not confined to GURT varieties, but the entire seed market has to be taken into account. Only if incumbents are able to follow effective entry-deterring strate-

[1] In fact, it needs only two players that compete on price (a Bertrand duopoly) to arrive at this result.

gies will the threat of potential competition be avoided. Entry deterrence typically involves raising a newcomer's cost to such levels that entry is not profitable.

Large sunk investments in GURTs R&D, combined with effective knowledge protection may be such entry-deterring strategies in the GURTs market, but more empirical research is certainly required before anything firm can be said. [1]

An additional entry barrier probably arises from the lock-in of farmers, as outlined above in the section on input markets. If the acceptance of GURTS leads to an increase of switching cost to farmers, this can have implications for market structure in the seed industry. High switching cost tie buyers to the existing suppliers and make entry by newcomers more difficult (Klemperer, 1987). Another possibility are limit pricing strategies, which an incumbent with scale advantages might play to set prices at such low levels which make entry for a newcomer unprofitable who has not yet developed scale economies.

Although the welfare effects of various forms of behaviour in concentrated markets are rather well understood, it remains to be established which type of competitive (or anti-competitive) behaviour is actually emerging. Indications of increasing concentrations of market share (see table 5.2) are themselves not an indication of misuse of monopoly power. Detailed research is necessary to examine whether excessive pricing is occurring.

Previous research on this issue in seed markets has not yielded any strong evidence of monopoly pricing. Lesser (1994) examined the prices of soybeans in New York and found little evidence of monopoly rents attributable to the exclusive privileges associated with plant breeders rights. As Morris (1998) points out, despite increasing concentration and integration in maize seed markets in industrialised countries, there has been no strong evidence to-date of market power translating into higher seed prices. One potential explanation is that diversified input suppliers use seed as a 'loss leader' to secure sales of other more profitable chemical products.

The potential for GURTs to contribute to this increasing concentration is clear. The introduction of GURTs would provide further reasons for a strengthening of institutions to monitor the abuse of market power. Next to monitoring, and possibly regulation, there is another role for public policy to play, namely public R&D in the seed industry that functions as a (potential) competitor to private R&D. Scale economies in biotechnology R&D (and marketing) appear to be the overwhelming reason for both vertical and horizontal concentration. This type of entry barrier makes it very difficult for small private companies to enter the market. Public R&D that would not be required to recover average cost is one way to assure some level of competition.

[1] The basic principle is that the incumbent has made huge investments in the past, which the newcomer still has to incur if he wants to enter. The outlays are sunk from the incumbent's perspective, while the newcomer can still avoid them, and thus faces different choices than the incumbent who is committed to continue operations in this industry. The combination of economies of scale with irreversible capital commitments may constitute a barrier to entry (von Weizsäcker, 1980, Kessides, 1990). Another way to prevent entry is to invest in overcapacity which will only be used if entry occurs. Again, the combination of sunk investments and economies of scale can be used to deter entry (Spence, 1977, Dixit, 1980).

6. Regulatory issues

In this paper, it has been argued that GURTs offer the potential to increase private sector investment in agricultural R&D with significant productivity gains. There is a rationale for promoting the development and application of GURTs, based on the limited review undertaken here, although more in-depth analysis of these potential productivity gains would better inform such a perspective. This benefit needs to be weighed against the possible risks associated with GURTs. Based on such an analysis, governments need to decide if and how they wish to promote the benefits of GURT technology while minimising the costs associated with the risks. Other chapters and this one have identified a number of possible rationales for regulation of GURT technology, including:

- consistency with IPR systems including maintaining farmer's privilege under PVP;
- competition policy;
- preventing genepool separation and maintaining availability of genepool for R&D purposes;
- biosecurity risks arising from contamination through outcrossing of GURT constructs or components or effects of inducer compounds.

These issues are discussed below. Those arising primarily from other chapters are dealt with somewhat more briefly while issues relating to IPR, R&D and competition policy receive more attention. In each case, the availability to governments of appropriate regulatory tools is addressed. A more fundamental rationale than those listed above for regulating the use of GURTs arises from their possible character as GMOs. Some governments have adopted a policy of prohibiting the cultivation of GMO crops. The basis for such a rationale, which can involve other arguments, such as ethical concerns, in addition to biosecurity issues, has not been addressed in this study. If governments have adopted such a policy, then by logical extension, there is a rationale for also prohibiting the use GURTs, and presumably no need to compare potential benefits with risks or costs. To prohibit all commercial applications of GURTs, governments can make use of the existing legislation prohibiting GMOs.

IPR Systems

As has been seen, GURTs offer greater scope for appropriating benefits, through technological means, than current forms of intellectual property protection, including plant breeders' rights and patents. GURTs increase the appropriability of benefits in comparison to plant breeders' rights by extending the scope of protection. The scope of protection currently offered under plant breeder's rights systems, such as under the UPOV treaties (1978 and 1991), is the result of considerations by policy-makers of the tradeoffs involved in granting this particular form of IPR for a product and sector of special importance to national (food security) as well as individual (income and livelihood) interests.

Governments should proactively respond by deciding whether or not they agree to an effective circumvention of their IPR legislation as a result of the introduction of GURTs. The main issue here is that of farmer's privilege. If a government has worked to ensure the maintenance of this privilege through its approach to PVP and patent legislation, then it may wish to restrict or even prohibit the use of GURTs as a broader appropriation mechanism. Such a perspective may be particularly relevant for a number of developing countries that are seeking to do just this in their actions to meet their TRIPS obligations. At the very least, this new technological development requires a consideration of the various benefits and costs associated with it.

In developing countries, a major consideration in such an argument may be the relative inability of GURTs, as compared to legal means, to discriminate between different types of permitted uses of protected material. Such flexibility allows developing countries, which have diverse farming systems to moderate the privileges of other breeders and farmers, as can be seen with the farmers privileges. This flexibility does come at the expense of higher transaction costs and difficulties in enforcement. On the other hand, T-GURTs may also provide the possibility to distinguish between different types of farmers, such as between poor farmers in remote areas and industrial farmers supported by a well-developed market infrastructure.

GURTs should thus provide governments reason to reassess their policies and regulations with respect to agricultural IPR systems. On the one hand, governments may decide then to adapt existing PVP systems to increase the scope of protection offered to match GURTs. In addition to extending the scope of protection, it could also be possible to adapt patent legislation to allow for the use of compulsory licensing as a regulatory means to ensure that governments have the legal means to ensure transfer of genetic material to public institutions (as discussed above) or as a potential means to counter concentration of market power (discussed in the following section)

Anti-trust and competition laws

This chapter has identified the concentration of market power through vertical integration or horizontal concentration as one potential impact of GURTs. This provides a rationale for regulatory measures that would be designed to prevent the misuse of such market power. About 80 WTO member countries, including 50 developing countries and countries in transition have adopted some form of anti-trust laws. These laws provide the legal basis to remedy potentially harmful effects of anti-competitive practices, such as price-fixing, cartelisation, abuse of dominant market positions, mergers that limit competition, entry deterring strategies, and vertical arrangements that limit entry by potential competitors. There are considerable differences between the national anti-trust laws, but certain elements are common. Typically, anti-trust laws do not declare monopolies illegal per se, but are designed to correct for inefficiencies that may be the result of monopolisation and cartelisation. Anti-trust laws do, however, typically provide for measures to prevent the acquisition of monopoly power, for example through mergers. Most anti-trust cases are concerned with the question whether a firm has market power, that is, the ability to set prices profitably above competitive levels, and further whether the firm abuses its market power. In practice, it is often difficult to ascertain whether a firm has indeed market power, and usually market share is used as an indirect indicator of market power. In order to make sense, the measurement of market shares must properly define the 'relevant' market. The relevant market may be limited to seed of only one crop, or extended to numerous crops if the latter comprises the choices facing farmers. The market may also include agrochemical inputs in addition to seeds where the choice of a given seed implies also a given chemical choice, given product tying due to technical requirements or simply due to distribution and marketing arrangements. Once a relevant market has been defined, a number of indicators based on market shares can be constructed, such as in tables 5.2 and 5.3.

It is evident that the institutionalisation of policies towards the regulation of anti-competitive behaviour is an important step towards the promotion of an efficient functioning of markets. Such regulatory frameworks can be applied to address potential problems, such as excessive pricing, vertical foreclosure, bundling and exclusive dealing, that could arise with GURTs. However, consumers and farmers in countries with weaker institutions and little resources to develop such institutions are more prone to such potentially harmful effects from GURTs in the seed industry. An important question is whether international agencies and international agreements can step in to fill this gap.

Typically national anti-trust laws and regulations are concerned with effects on national markets. [1] Consequently, the authority of anti-trust agencies ends at the border. Interest in interaction between trade and competition policy is only recently developing. At one level, more openness to international trade implies more competition on domestic markets, and will consequently limit domestic firm's ability to exercise market power. However, this argument may need to be reconsidered as more supply chains are multinational enterprises, which serve a multitude of national markets. A multinational will not compete with itself, and in so far as the concentration in the seed industry is a global phenomenon, the 'relevant market' may be global rather than national.

At the Singapore Ministerial in 1996, the WTO set up a working group on Trade and Competition Policy (WGTCP). This work has concentrated on stocktaking of existing instruments and defining the scope of an international co-operation in this area [2]. The Doha Ministerial Declaration in November 2001 announced the further institutionalisation of work on the interaction between trade and competition policies.

Biosecurity

Biosecurity concerns were discussed in chapter 2. There is a rationale for regulating the use of T-GURT or V-GURT constructs or their components to minimise the risks due to contamination of other crops or wild relatives. Furthermore, there is a rationale for regulating the introduction of inducer compounds to minimise risks on people and the

[1] The European Union's competition laws are perhaps an exception (Articles 85 and 86 of the Treaty of Rome and the European Commission Merger Regulation). Here, anti-competitive behaviour is subject to scrutiny of Brussels if such behaviour has a communitarian effect i.e. the market here is seen to go beyond the national boundaries and extends to the European Common market. Similar attempts are being made in the MERCOSUR custom's union of South America.

[2] There is currently one known case in the feed industry, where a cartelisation issue in the lysine (a protein used in animal feed) market was brought to attention under the WTO safeguard process and subsequently lead to prosecution in the USA under USA anti-trust laws (OECD, 2001).

environment. Based on information available at this point, it is not possible to say that these concerns imply a justification for prohibiting the commercial applications of GURTs. It seems more likely that there is a rationale for ensuring that steps are taken to minimise these risks, although this judgement depends on the size of the potential risks involved, about which little is known.

In the case of inducer compounds, governments can probably make use of the legislative framework governing the use of pesticides and veterinary medicines as a basic tool of regulation although legislation would require modification. In the case of regulating the use of GURTs to minimise risks to the environment, governments are likely to be faced with a lack of available legislative tools. The main precedent might be existing legislation on the use of GMO varieties. More importantly, it is not clear how governments can assess the risks of contamination nor what forms of appropriate measures would be desired. This is an area requiring urgent work so that governments wishing to promote the use of GURTs for their benefits have well-founded regulation systems for minimising biosecurity risks.

Maintaining availability of genepools

The potential risk of genepool separation has been discussed in chapters 2, 3 and 4. It has been argued that there is a risk that GURT-protected varieties could enhance the trend of separation based on the increased application of patent laws in the breeding sector. The rationale for regulation concerns maintaining the availability of new material primarily for national and international public agricultural research programmes in developing countries. The likely risk in industrialised countries would probably be less given the possibility that companies in the private sector have the option of negotiating licenses among each other to access material whereas public sector organisations in developing countries would be financially more constrained. But it is here also difficult to assess the potential size of this risk.

On the other hand, the tools for dealing with this issue could be provided by the legislative framework of the patent laws. It seems very likely that patent protection will be sought for GURT applications, given that the economic rationale for GURT development is as an appropriation mechanism. Current applications for patents for GURT technologies seem to confirm such a hypothesis. Compulsory licensing provisions could be incorporated into patent legislation to provide governments with the means to ensure the public availability of GURT-free variants of GURT protected varieties. To not remove the incentives for the private sector in GURT development, such provisions would have to incorporate considerations such as an appropriate embargo or waiting period, as well as provisions concerning the use of such material. This possibility requires that countries have functioning patent systems for plants or biotechnological products. It also implies that countries need to maintain public research programmes for such purposes.

Other Regulatory and Policy Measures

If a government decides that it is willing to permit the increased scope of protection under GURTs and to support their implementation, then a number of other regulatory/policy issues are important. These include in the first instance, whether other forms of accompanying regulatory support are potentially warranted.

Information provision to farmers is an accompanying policy issue of particular importance for developing countries. In areas where information flow in rural areas is not very efficient and where farmers have few options for verifying information received concerning products in the market, there is a great risk of misinformation concerning available varieties, particularly of agricultural seed. Farmers may, on the one hand, suspect all available modern varieties as containing GURTs. On the other hand, farmers may unknowingly purchase GURT-enabled varieties, or may simply not have any means for verifying the authenticity of claims made by local traders. The potential impacts on livelihoods of such misunderstandings are quite large. Governments would have to look for ways to further reinforce the market infrastructure so as to improve the availability of information for farmers. Unfortunately, the potential for errors and their consequences are greatest in remoter areas where the challenges of providing such market infrastructure are greatest.

Complementary public investment is another possible accompanying measure to GURT introduction, and has already been alluded to above. In developing countries, this could be useful for addressing the needs of farmers not addressed by the new technology. The tools to do so, public agricultural research programmes, exist although they have been neglected recently in some countries due, for example, to fiscal pressures. As argued in section 2, GURTs could actually allow a refocusing of public agricultural R&D funds, by increasing the amount of private sector investment. Another possibility is to use public sector R&D to maintain some sort of competition for GURT based lines, perhaps only at pre-breeding stages. This could provide farmers with a non-GURT choice among elite lines, and thus ensure a certain amount of competition.

Yet another supportive measure concerns regulations that restrict those other than the right holder from selling a variety is compulsory removal from certified variety lists. In most countries, apart from PVP, legislation also exists requiring commercialised varieties to be approved and certified for sale, primarily from the perspective of quality control and consumer (in this case, farmers) protection. Such legislative frameworks can be designed in such a way that varieties must be removed from the list, after a certain time period, or at the request of the breeder. This further extends any patent protection offered on a GURT technology itself. Whether this is desirable from a policy perspective depends again, as with IPR in general, on the balance sought between innovation incentives and monopoly powers.

Measures to prohibit or restrict GURTs

On the other hand, very few viable options are available for restricting or prohibiting the use of GURTs if governments wish to deny this increased appropriability. Biosafety legislation's cannot be easily used to prohibit the introduction of GURTs, because most GURTs themselves do not pose a specific threat to food or environmental safety. Using biosafety laws to ban GURTs from the market would be liable to complaints in the WTO.

IPR systems are based on either novelty, non-obviousness and industrial application (patents) or distinctness, uniformity and stability (PBR). New GURT based varieties are likely to be eligible for protection in those countries that offer patents and/or plant breeder's rights. There are no existing grounds for disapproval of GURT as a technology or a variety containing GURT. Such grounds would have to be added to the IPR legislation, possibly by appeal to the 'ordre publique' clause of TRIPS, but this would probably be the subject of a dispute under TRIPS.

Some types of seed legislation may, however, offer an opportunity. Variety release procedures are often liable to registration procedures and performance testing. Since requirements for registration are strongly linked with those for breeder's rights, there are no reasons to disapprove a GURT based variety. Where variety release also includes compulsory performance testing, it is possible to disapprove V-GURT varieties, on the basis of not producing a viable second generation. Prohibiting T-GURTs will not likely be possible through seed legislation because conventional hybrids lose part of their value when multiplied. This option requires having a system of compulsory performance testing as part of a restrictive variety release system. Many countries have however dispensed with this type of seed legislation or maintained it only for certain crops.

Yet another option might be the use of trade restrictions to prevent the import of GURT-enabled products, although this could possibly become the subject of a trade dispute founded on technical barriers to trade. Trade restrictions also do not prevent a producer from setting up production facilities within a country.

Summary

As stated at the outset of this section, sufficient information is not yet available to provide governments with a clear answer to whether prohibition, restriction or promotion of GURTs is desirable on economic welfare grounds. A cautious interpretation of the arguments presented here and in other chapters indicates that the potential benefits offered by GURTs in comparison to their costs and risks are probably worth examining in more detail. Outright prohibition does not seem to be overwhelmingly justified at this stage and is probably quite difficult from a legal point of view, although the possibilities might only be known through a process of WTO dispute resolution. On the other hand, there is scope for further examining the possibilities of promoting the benefits of GURTs while developing appropriate regulatory measures to minimise the costs and risks. Such an examination, by revealing new information, should support more detailed assessments of the economic impacts of GURTs.

7. Conclusions

GURTs provide an interesting example of the various policy issues presented by transgenic agricultural biotechnology. The technology may lead to productivity benefits and greater consumer choice by attracting increased private investment to particular crops. But its primary purpose is to increase the ability of such breeders to appropriate the benefits of their research investments. The benefits to the agricultural sector are expected only as a possible result from achieving this primary purpose. With GURTs, biotechnology could thus potentially strengthen the extent and effectiveness of IPR systems without any legislative component.

One obvious victim of such development could be seed and farming systems in developing countries that rely on largely public breeding programs and the exchange and reuse of seed, among both breeders and farmers. GURTs could restrict the flow of elite material to these sectors, a flow that has contributed to the more meagre achievements in productivity growth for more marginalised countries and farming systems. More seriously, GURTs could go even further and provide the means for corporations to abuse their resulting market power. The agrochemical and seed sector is becoming increasingly consolidated both horizontally and vertically. More effective technological restrictions on the use of genetic material could possibly reduce competitive forces, implying a need for regulatory scrutiny.

As a transgenic technology, GURTs are susceptible to the same consumer acceptance problems as other genetically modified crops. Ironically, GURTs may also provide part of a solution to biosecurity concerns relating to genetic contamination, which is one aspect of consumer reluctance to accept transgenic technology in foodstuffs. But, at the same time, there are fears that genetic leaks could pose serious threats to the food security of farming systems relying on informal seed systems that then become contaminated with GURT sterility.

For all these reasons, GURTs pose a number of important policy issues. This report has reviewed these issues from an economic perspective, while recognising that ethical and biosecurity issues also need to play a major role in an integrated assessment of the potential impacts of GURTs.

Weighing up the various potential costs and benefits associated with GURT development poses a challenging task for governments. As this review has pointed out, much of the necessary information is not available. Furthermore, the balance between costs and benefits may differ from crop to crop, favouring a flexible approach to policy making.

The most important policy decision facing governments, particularly with respect to V-GURTs, is whether any inherent extension by technological means of existing IPR regimes is now desirable. In other words, would governments also be willing to revise their plant varietal protection (PVP) legislation to offer the same degree of protection? Presumably such a desire implies an evaluation of the existing legislation with the conclusion that the scope of protection should be broadened. An important factor in such a decision must be the evaluation of the effect of PVP on investment incentives with the conclusion that even more productive investment in certain breeding activities is desirable and can be achieved through more stringent protection measures.

Some governments have made such a decision already by offering patent protection to agricultural crops, or their components. Others may need to examine the past impacts of their PVP systems in order to assess this decision. Still others, in particular many developing countries, are only currently implementing PVP, as part of their obligations under the TRIPS agreement. Some of these countries, in designing relatively weak sui generis systems, would presumably be against GURTs. Others, that may for example have opted for adhesion to the UPOV Convention, may presumably have a more nuanced view.

As this report has pointed out, there may actually be very limited means for prohibiting or restricting the development and application of GURTs. The most appropriate manner appears to be through seed certification legislation, as opposed to through biosecurity/biosafety legislation. If governments decide to allow, or perhaps even support, GURT development and application, a number of other policy issues still deserve attention, stemming from the review of the various impacts. Leaving aside biosafety/biosecurity which has not been the subject of this report, the first of these issues concerns the priorities for public agricultural research. Governments should re-examine these, based on knowledge as to where GURT investment is concentrating. In some cases, it may be possible for public funds to be shifted towards other priorities that are neglected by commercial breeding activities, such as poorer farmers' crops in the case of developing countries. By maintaining and shifting public research funds, it is possible to gain the additional investment benefit from GURTs. On the other hand, it may be desirable in some circumstances to adjust public research so that it continues to provide or support a source of competition in given sectors targeted by GURTs. Making such decisions requires a good understanding of the importance of germplasm flows in the breeding sector between various actors in the public and private sector.

Anti-trust and competition policy is another issue that will deserve attention with GURT development. Governments will want to ensure that they have sufficient legislative frameworks and regulatory capacity to ensure that any abuses of market power resulting from GURT application can be investigated with the threat of effective penalties. For developing countries, capacity in this area is a particular concern. Given the multinational character of many agrochemical and seed corporations, the need for international competition frameworks would also become stronger, probably with the context of the WTO.

References

Alston, J.M., P.G. Pardey and V.H. Smith, *Financing Agricultural R&D in Rich Countries: What's Happening and Why*. IFPRI Environment and Production Technology Division Discussion Paper No. 29, September, Washington, 1997.

Alston, J.M. and R.J. Venner, *The Effects of US Plant Variety Protection Act on Wheat Genetic Improvement*. Paper presented at the symposium on 'Intellectual Property Rights and Agricultural Research Impact' sponsored by NC 208 and CIMMYT Economics Program, El Batan, Mexico, March 5-7, 1998.

Bijman, J., 'Life Science Companies: Can they combine seeds, agrochemicals and pharmaceuticals?'. In: *Biotechnology and Development Monitor* 40 (1999) 14-19.

Bijman, J., 'Restructuring the Life Science Companies'. In: *Biotechnology and Development Monitor* 44/45 (2001) 26-31.

Brennan, M.F., C.E. Pray and A. Courtmanche, 'Impact of Industry concentration on innovation in the US plant biotech industry'. In: Lesser, W. (Ed.) *Transitions in Agbiotech: Economics of strategy and policy*. Proceedings of NE-165 Conference June 24-25, 1999, Washington, D.C. http://agecon.lib.umn.edu/cgi-bin/pubview.pl?pubid=24, 2000.

Butler, L.J. 1996. 'Plant Breeders' Rights in the U.S.: Update of a 1983 Study'. In: Van Wijk, J., Walter Jaffe (eds.) *Proceedings of a Seminar on the Impact of Plant Breeders' Rights in Developing Countries held at Santa Fe Bogota*, Colombia, March 7-8; University of Amsterdam; Amsterdam, pp. 17-33, 1996.

Byerlee, D. and K. Fischer, *Accessing Modern Science: Policy and Institutional Options for Agricultural Biotechnology in Developing Countries*. Paper presented at the XXIV International Conference of Agricultural Economists, Berlin, 13-18 August 2000.

Dixit, A., 'The role of investment in entry-deterrence'. In: *Economic Journal* 90 (1980) 95-106.

Eaton, D., *TRIPS and Plant Varietal Protection: Economic Analysis and Policy Choices*. LEI-report 7.02.01. Agricultural Economic Research Institute, The Hague, The Netherlands, 2001.

Falcon, W.P., *Globalizing Germplasm: Barriers, Benefits and Boundaries*. Paper presented at the XXIV International Conference of Agricultural Economists, Berlin, 13-18 August 2000.

Fuglie, K., N. Ballenger, K. Day et al., *Agricultural Research and Development: Public and Private Investments Under Alternative Markets and Institutions*. AER-735. Economic Research Service, United States Department of Agriculture, 1999.

Goeschl, T. and T. Swanson, *The Impact of Genetic Use Restriction Technologies on Developing Countries: A Forecast*. Paper presented at the 4th International Conference on the 'Economics of Agricultural Biotechnology' organised by the International Consortium on Agricultural Biotechnology Research (ICABR), Ravello, Italy, 24-28 August, 2000.

Hansen, L. and M. Knudson, 'Property right protection of reproducible genetic material'. In: *Review of Agricultural Economics* 18 (1996) 403-414.

Hayenga, M.L., 'Structural Change in the Biotech Seed and Chemical Industrial Complex'. In: *AgBioForum* 1 (1998) 2 pp. 43-55 www.agbioforum.org

Heisey, P.W. and J.P. Brennan, 'An Analytical Model of Farmers' Demand for Replacement Seed'. In: *American Journal of Agricultural Economics* 73 (1991) 1044-1052.

Hennessy, D.A. and D.J. Hayes, 'Competition and tying in the agrochemical and seeds markets'. In: *Review of Agricultural Economics* vol. 22 (2000) 2 389-406.

Hindmarsh, R., 'Consolidating Control: Plant Variety Rights, Genes and Seeds'. In: *Journal of Australian Political Economy*, no. 44, 60-76. www.biotech-info.net

James, C. and A. Krattiger, *Biotechnology for Developing-Country Agriculture: Problems and Opportunities. The Role of the Private Sector*. IFPRI Focus 2, Brief 4 of 10. October, 1999.

Kalaitzandonakes, N. and B. Bjornson, 'Vertical and Horizontal Co-ordination in the Agro-Biotechnology Industry: Evidence and Implications'. In: *Journal of Applied and Agricultural Economics* 29 (July 1997) 1, pp. 129-139.

Kalaitzandonakes, N. and M. Hayenga, 'Structural change in the biotechnology and seed industrial complex: theory and evidence'. In :Lesser, W. (Ed.) *Transitions in Agbiotech: Economics of strategy and policy*. Proceedings of NE-165 Conference June 24-25, 1999, Washington, D.C. http://agecon.lib.umn.edu/cgi-bin/pubview.pl?pubid=24, 2000.

Kessides, I.N, 'Towards a testable model of entry: a study of US manufacturing industries'. In: *Economica* 57 (1990) 219-238.

Klemperer, P.D., 'Entry deterrence in markets with consumer switching cost'. In: *Economic Journal* 97 (1987) 99- 117.

King, J.L., *Concentration and Technology in Agricultural Input Industries*. Electronic report from the Economic Research Service, Agriculture Information Bulletin number 763. www.ers.usda.gov, 2001.

Lesser, W., 'Valuation of Plant Variety Protection Certificates'. In: *Review of Agricultural Economics* 16 (May, 1994) 231-238.

Lesser, W., 'Assessing the Implications of Intellectual Property Rights on Plant and Animal Agriculture'. In: *American Journal of Agricultural Economics* 79 (1997) 5: 1584-1591.

Lesser, W., 'Intellectual Property Rights and Concentration in Agricultural Biotechnology'. In: *AgBioForum* 1 (1998) 2, 56-61 www.agbioforum.org.

Lesser, W., 'An economic approach to identifying an 'effective sui generis system' for plant variety protection under TRIPS'. In: Santaniello, V., R.E. Evenson, D. Zilberman and G.A. Carlson (Editors), *Agriculture and Intellectual Property Rights: Economic, Institutional and Implementation Issues in Biotechnology*. CABI International, Wallingford, U.K., 2000.

Lindner, B., 'Prospects for Public breeding in a Small Country'. In: Lesser (Ed*): Transitions in Agbiotech: Economics of Strategy and Policy*. Proceeding of NE-165 Conference, June 24-25, 1999, Washington, D.C. http://agecon.lib.umn.edu/cgi-bin/pubview.pl?pubid=24

Morris, M.L., 'Future Directions for National Maize Seed Industries'. In: Morris, M.L. (Ed.) *Maize Seed Industries in Developing Countries*. Lynne Rienner, Boulder, Colorado and CIMMYT, Mexico City, 1998.

OECD, *The OECD Agricultural Outlook*. OECD, Paris, 2001.

Perrin, R.K., K.A. Hunnings and L.A. Ihnen, *Some effects of the US plant variety protection act of 1970*. Economics Research Report No. 46. Dept. of Economics and Business, N.C. State University, Raleigh, 1983.

Rabobank, *The World Seed Market: Developments and Strategies*. Netherlands, 1996.

Rangnekar, D., *Intellectual property rights and agriculture: an analysis of the economic impact of plant breeders' rights*. ActionAid, UK, 2000.

Shapiro, C. and H.R. Varian, *Information Rules: A Strategic Guide to the Network Economy*. Harvard Business School Press, Cambridge, Mass, 1998.

Sombilla, M.A. and Evenson, R.E., *Economic Implication of Alternative Roles of Diffusion of Biotechnology Methods to Developing Countries*. Paper prepared for the 3rd International Conference on the 'The Shape of the Coming Agricultural Biotechnology Transformation: Strategic Investment and Policy Approaches from an Economic Perspective' organised by the International Consortium on Agricultural Biotechnology Research (ICABR), Rome 17-19 June 1999.

Spence, A.M., 'Entry, capacity investment and oligopolistic pricing'. In: *Bell Journal of Economics* vol.8 (1977) 2, 534-544.

Srinivasan, C.S. and C. Thirtle, *Impact of Terminator Technologies in Developing Countries: A Framework for Economic Analysis*. Paper presented at the 4th International Conference on the 'Economics of Agricultural Biotechnology' organised by the International Consortium on Agricultural Biotechnology Research (ICABR), Ravello, Italy, 24-28 August, 2000.

The Economist, 'Biotechnology: Dry Season'. Nov. 2nd, 2000.

The Economist, 'Terminator genes: Fertility Rights'. October 7th, 1999.

The Economist, 'Biotechnology: Big is beautiful'. March 25th, 1999.

The Economist, 'Life Sciences: Green and Dying'. Nov. 16th, 2000.

Weizsäcker, C.C. Von, 'A welfare analysis of barriers to entry'. In: *Bell Journal of Economics* vol. 11 (1980) no. 2, 399-420.