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Economic Perspective for Agricultural Biotechnology Research Planning

Agnes C. Rola

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Economic Perspective For Agricultural Biotechnology Research Planning

A.C. Rola

There is no other agricultural technology that has been subjected to a lot of controversies than agricultural biotechnology. More than ever, intelligent decisions about this technology would be based on scientific data and objective analyses. As we meet the challenges of food security in a sustainable way, and given the very limited land and energy resources; available alternatives are few.

Because of its unique features, the economic study in biotechnology deviates from the standard economic impact of technological changes, such as mechanization. It is more closely related to measuring the impact of pesticides, though the issue of Intellectual Property Rights (IPR) has not been raised in the chemical technology. In addition, just like pesticides, some biotechnology products have externality effects. Thus the economic framework for its analysis will be consistent with the issues about the economics of sustainability, which has long-term benefits/costs and considered to be very knowledge intensive for both farmers and other handlers.

Some of the features that could impinge on the economic issues of agricultural biotechnology are the private-public sector partnership in research, development, and technology transfer; the role of the IPRs in both technology development and transfer; the regulations about biosafety and other licensing requirements for ultimate commercialization; and the management of the technology once in the market and in the farmers' fields. These could affect the cost and the output price structure. The ex ante economic analysis could guide us in the measurement of potential effectiveness and efficiency of biotechnology, and in general, in the research prioritization.

Economic Perspective for Agricultural Biotechnology Research Planning[1]

A.C. Rola[2]

I. Introduction

There is no other agricultural technology that has been subjected to a lot of controversies than agricultural biotechnology. More than ever, intelligent decisions about this technology would be based on scientific data and objective analyses. As we meet the challenges of food security in a sustainable way, and given the very limited land and energy resources; available alternatives are few.

Proponents of biotechnology claim that "biotechnology applications- integrated into traditional systems-probably hold the most promise in augmenting conventional agricultural production and productivity, particularly given the need to increase production sustainably, while protecting the environment and biodiversity and conserving natural resources for future generations " (Krattinger, 1997). The opposite view argues that there must be continued support to ecologically based agricultural research, "as all the biological problems that biotechnogy (*mainly referring to transgenics*) aims at can be solved using agroecological approaches" (Altiere, 1997). The dramatic effects of rotations and intercropping on crop health and productivity, and the use of biological control agents on pest regulations have also been confirmed by scientific research (Altiere, 1994; NRC 1996 as cited in Altiere, 1997).

As a science of resource allocation, economics plays a pivotal role in supporting public policy towards our aim of sustainable agriculture for food security. The purpose of this paper is to determine through literature review, current knowledge about the unique features of agricultural biotechnology for a deeper understanding of its economic perspectives.

Because of its unique features, the economic study in biotechnology deviates from the standard economic impact of technological changes, such as mechanization. It is more closely related to measuring the impact of pesticides, though the issue of Intellectual Property Rights (IPR) has not been raised in the chemical technology. This is because private sector in the industrialized world has single handedly developed the chemical technology, first as a proprietary product before it becomes a commodity. In addition, just like pesticides, some biotechnology products have externality effects. Thus the economic framework for its analysis will be consistent with the issues about the economics of sustainability, which has long-term benefits/costs and considered to be very knowledge intensive for both farmers and other handlers.

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[1] Final report for the Philippine Institute for Development Studies (PIDS), Makati, Oct. 1999.

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In the case of transgenics, some complex factors like the developing countries' ownership of the genes, the product development in the industrialized countries and the technology transfer back to the developing world are certainly worth a debate.

Some of the features that could impinge on the economic issues of agricultural biotechnology are the private-public sector partnership in research, development, and technology transfer; the role of the IPRs in both technology development and transfer; the regulations about biosafety and other licensing requirements for ultimate commercialization; and the management of the technology once in the market and in the farmers' fields. These could affect the cost and the output price structure. The ex ante economic analysis could guide us in the measurement of potential effectiveness and efficiency of biotechnology, and in general, in the research prioritization.

II. Agricultural Biotechnology: Status and Performance

A. What is biotechnology?

In general terms, biotechnology is a tool or technique using living organisms or parts of such, to develop or modify a product to improve plants or animals, or to develop microorganisms for specific uses. Biotechnology started with the simplest techniques of biological nitrogen fixation, collection, selection and production of appropriate strains of bacteria, plant tissue or cell culture and embryo transfer. Biotechnology applications in tissue culture make the propagation of planting materials easier. Through embryo transfer in animals, herd is upgraded by transplanting embryo from superior animal to another less desirable genetic traits. Biotechnology is also useful in developing drugs and vaccines, food additives and waste water treatment.

In the 1970s, genetic engineering emerged as new mode of biotechnology. Also referred to as the recombinant DNA (rDNA), it refers to a set of technologies that artificially move functional genes across species boundaries to produce new organisms.This more recent advance in biotechnology allowed for the manipulation of genes to produce plants with built-in resistance to pests and diseases.

Genetically modified agriculture has been recognized as a strategy to curtail food security problems in view of the increasing population with limited land resources. There have been projections that a ten year delay in biotechnology research will bear effects on production, area, yield, trade and prices of major crops (Evenson, 1998). Delay also has regional consequences with developing countries experiencing more negative impact on yields rather than developed countries. Estimate on the degree of welfare impact of the delay has also been calculated.

B. Agricultural Biotechnology: Status and Performance

The country can count a significant breakthrough in biotechnology products especially in agriculture (Table 1). These products include biofertilizers, growth hormones, biocides, tissue cultured plants, and diagnostic kits. Biofertilizers include biological microbial fertilizers and organic fertilizers useful in enhancing soil nitrogen fertility. Growth hormones are extensively used in tissue culture of vegetables and ornamentals. Biocontrol and biocides are useful alternatives to crop protection measures. Plant biotechnology has been developed in tissue culture for coconut, banana, pineapple, white and sweet potato, falcata, bamboo and orchids. Plant diagnostic kits are used in diagnosing specific plant viruses in papaya, citrus and banana.

Around 10% of R and D on biotechnology focused on biofertilizers. And over 15% of biotech R and D focused on biocontrol. Plant biotechnology covers almost 26% of biotechnology R and D. The following definitions are presented in De Guzman, et al (1999).

Biofertilizers

Biofertilizers include materials derived from living organisms and those derived from microbial sources. Biofertilizers can be classified into two groups: microbial fertilizers and organic fertilizers. Microbial fertilizers are further subdivided into two groups: biological nitrogen fixers and mycorrhiza.

Biological nitrogen fixers (BNF). These are organisms which can directly obtain nitrogen from the atmosphere (N_2 gas) and convert this N_2 gas into organic forms which can be utilized by plants. BNF can be classified into four groups:

a. *Rhizobium* is a bacterium symbiotically associated with legumes which forms root or stem nodules. Nitrogen fixation occurs within the nodules where the bacterium resides. A commercial product known as Nitro Plus produced by BIOTECH is already in the market. Nitro Plus contains effective rhizobia specific for such legumes as peanut, mungbean, cowpea, pole sitao, and soybean (dela Cruz 1993).

b. *Azospirilium* is a nitrogen-fixing bacterium associated with the roots of plants belonging to the grass family. The inoculant under the trade name Bio-N is now being commercialized by BIOTECH which is specifically used for rice and corn. This biofertilizer enhances growth and development of plants and provides 30-50 percent of their nitrogen requirement (Sison 1999).

c. *Azolla* is an aquatic fern which lives in symbiotic association with the N-fixing blue-green algae *Anabaena azollae*. The biomass of azolla is a good source of organic fertilizer after decomposition. Azolla can also be used as feed supplement for poultry, duck, and swine, and weed control in rice paddies.

d. *Blue-green alga (BGA).* As a biofertilizer, BGA enhances soil nitrogen fertility by excreting nitrogenous compounds into the soil while alive and the release of N-fixed compounds when it decomposes. BGA was estimated to provide up to 80 percent of its nitrogen content by mineralization and up to 13 percent of the total amount through exudation or excretion (Martinez 1989, cited in dela Cruz 1993). BGA also improves soil texture.

Table 1. Technologies developed at BIOTECH for the past 20 years

A. Commercialized technologies

1. Cell and protoplasts culture and orchids
2. Lysine production
3. Inocula for bio-organic fertilizer
4. Biological nitrogen fixers for legumes (Nitro Plus)
5. Biological nitrogen fixers for rice and corn (Bio-N)
6. Mycorrhiza inoculants (Mykovam)
7. Pasteurella vaccines
8. Diagnostic kits for detection of papaya, citrus, and banana viruses
9. *Bacillus thuringiensis* insecticide (Pelmictrol)
10. Mushrooms

B. Biotechnologies for large scale verification

Crop production

1. Azotobacter for increased N-content of compost materials (Bio-fix)
2. Decomposers of organic materials (Bio-quick)
3. Growth hormones from coconut water (Cocogroe)
4. Direct seedling block containing VAM
5. Biopesticide (LEP 20)
6. Bio-organic fertilizers for field verification trials

Food and feeds

1. Diagnostic kits for aflatoxin
2. Microbial processing of carbohydrate-rich agricultural crop residues
3. Protein enrichment of industrial by-products for animal feeds
4. Baker's yeast for baking industry
5. Bioconversion of copra meal for agriculture and industrial uses
6. Tylosin as feed additives

Industry

1. Distillery yeast for alcohol production
2. Enzymes (pectinase, cellulase, proteases)

Source: Sison (1999)

Mycorrhiza. Mycorrhiza is a symbiotic association between plant roots and fungi. It promotes increased absorption of nutrients and water, biocontrol against harmful pests and diseases, improve soil structure, and increase activity of other microorganisms such as nitrogen fixing organisms. Mycorrhiza in crop plants belong to the vesicular-arbuscular (VAM) type.

VAM inoculants produced by BIOTECH which are now being commercialized come in two forms: Mykovam-1 in powdered form and Mykovam-2 in granulated form. These soil-based biofertilizers assist in the absorption of nutrients and water from the soil and have been proven to be effective for many agricultural crops and fruit trees.

Organic fertilizers (BOF)

Trichoderma technology. Production of organic fertilizer through composting is hastened with the use of an activator containing pure culture of *Trichoderma harzianum*. Application in rice resulted in 15-20 percent in yield compared to rice plants receiving full inorganic fertilizer rates (Cuevas 1991, cited in dela Cruz 1993).

Trichoderma-azotobacter technology. This involves the biodegradation of compost materials with *Trichoderma sp.* and inoculation of the composted material with strains of nitrogen-fixing bacteria *Azotobacter sp*. BOF produced with the technology contains an average N-P-K of 3-13-4 (Espiritu 1991, cited in dela Cruz 1993).

Growth hormones

Plant growth hormones derived from waste coconut water have been extensively used in tissue culture of vegetables and ornamentals. The technology is introduced under the trade name Cocogroe but still being field tested for formulations, dosages, and combinations for various agricultural crops.

Biocontrol and Biocides

Biocontrol or biological control refers to the use of organisms to control unwanted organisms. Biocides are substance produced or released by the microbial biocontrol agents that can kill or control pests. It has been a good alternative to pesticides in crop protection, thus, averting the high level of risks associated with the use of conventional pesticides.

Several species of bacterial, fungal and viral biocon agents against a wide range of insect pests are commercially available (Sison 1999). These include the following:

a. *Bactrolep*. The product contains *Bt* strain that can kill vegetable pests such as corn borer and diamond back moth in crucifers. It is compatible with parasites and predators and is environmentally safe.

b. *Pelmictrol*. This biocide contains endotoxins from *Bt* strain. It kills mosquito larvae but safe for humans and other life forms.

c. *Bio-act*. A fungal product (*Paecilomyces anisopliae*) that can control nematodes developed by the National Crop Protection Center (NCPC). The product is now commercialized by a private company in Australia.

d. *Metarhizium*. A fungus-based (*Metarhizium anisopliae*) biocide for the control of wide array of insects by penetrating and secreting toxins in the insect's body cavity. It was developed by NCPC.

e. *Nuclear polyhydros virus*. This beneficial virus can control specific insects. It was developed by NCPC.

f. *Beauveria*. A fungus (*Beauveria bassiana*) that can control many insects by penetrating the body wall and producing toxins in the body cavity.

Major activities in biocontrol R&D in the past several years were on field collection, screening, and characterization of isolates; laboratory and field evaluation of virulence to target pests; laboratory and field evaluation for host specificity; study on the mode of action; research on mass production protocols; research on formulation and use; research on enhancing effective use through genetic engineering; and research on product development for commercialization.

Velasco *et al*. (1997) estimated that the Philippines is about 10-15 years behind biocontrol R&D. While other countries are already into commercialization, limited efforts in the country have been unsystematic and have been largely concentrated on field collection and screening of microbial biocon agents.

Plant biotechnology

Advances in tissue culture technology provided with ease the mass propagation of economically-important plants from a single cell or tissue obtained from various parts of the plant. The technology is now well-developed for plants such as coconut, banana, pineapple, white and sweet potato, falcata, bamboo, and orchids. Whole plants can now be regenerated from protoplast isolated from callus cultures. This technology is specifically successful in orchids.

Recently, transgenic plants have been the subject of much research in plant biotechnology. Transgenic plants contain transient genes from other sources for specific purposes. For example, transgenic rice and corn that contain *Bt* endotoxin gene are essentially intended to control the attack of major pests such as leaf roller and borer.

Plant diagnostic kits

Monoclonal antibodies-based kits can diagnose specific plant viruses such as papaya ringspot, citrus tristeza, and banana bunchy top. Diagnostic kits are useful tool on the early detection of major diseases in plants.

C. Biotechnology commercialization

The Philippine Case

Commercializing biotechnology products produced in the Philippines does not seem to be an easy matter (Dela Cruz and Ebora, 1999). Constraints are both technical and economic. Problems arise during the production in large quantities of the product, i.e. scaling up. The private sector seems to experience difficulty in the large scale commercialization because problems in the interpolation of the requirements have not been studied. The economic environment also affects commercialization. Most of the technology takers are classified as small and medium scale enterprises which do not have the financial capabilities to produce products on a sustained basis (De la Cruz and Ebora, 1999). The interest rates and the prices of the final biotech product in relation to substitute technologies hamper successful commercialization.

The other concern of biotech researchers in the Philippines is the conflict in the mandate of the government R and D institution (Dela Cruz and Ebora, 1999). As a matter of policy, BIOTECH is mandated to do research and development and not commercialization. It is also cited that our patenting mechanism will have to be strengthened to provide incentives to inventors. At the moment, most products have a shelf-life in the market only as long as the inventor is active in producing his own products in the lab. For the economic part, the necessity of ex ante analysis is very much evident, when one talks about the future scenarios (time period) wherein the technology will be in the market. The researcher has to understand the price structure of competing products, especially those produced in other countries.

Table 2.1 lists the near commerciable biotech products. They range from plant diagnostics to some enzymes. On the other hand, Table 2.2 lists the biotech products now in the market. These are mostly organisms for the production of biofertilizers, s well as some vaccines. The cost of the product is also indicated. In another paper, it was noted that commercialization of the biofertilizers have attained modest success (Rola, 1999). In most instances, the sales are in the downtrend. This could also be due to the reasons as cited in Dela Cruz and Ebora, (1999)

At least six types of biofertilizers have been commercialized in the Philippines. The process of commercialization varies in each type. While private investors have picked up some of the technologies, the public sector had also significant investments in the commercialization process. The other form of commercialization is through farmer cooperatives and with close support of the academic/research institute that produced the technology.

Table 2.1 Biotechnology products near commercialization (Dela Cruz and Ebora, 1999)

Product	Description
a) Plant Diagnostic Kits	Monoclonal antibody-based kits which can accurately diagnose specific plant diseases caused by viruses e.g., papaya ringspot, citrus tristeza and banana bunchy top. The kits are used to detect specific viruses in plants so that they can be removed and disposed of before they infect other plants. These are also useful in screening disease free planting materials.
b) Tylosin	Antibiotic used as animal feed additives, which acts as a therapeutic agent and growth promoter. The product was developed by Dr. Asuncion K. Raymundo and her research team.
c) High-protein animal feeds from agro-Industrial wastes	Biotechnological process converted agro-industrial wastes into high protein animal feed ingredients using solid state fermentation.
d) Vaccines against Fowl cholera and Swine plague	Vaccines formulated from the immunogenic fractions *of P. multocida* Group A and effective against fowl cholera and swine plague.
e) Rennet	Locally produced microbial rennet, the enzyme for the production of local cheese developed by Dr. Susana M. Mercado and her research team. Rennet is the enzyme preparation used to coagulate milk in cheese manufacturing. BIOTECH Rennet is produced by liquid fermentation using locally isolated fungus, *Rhizopus chinensis* and wheat bran as substrate.
f) Specialty fats Produced from Coconut oil and other non-lauric oils	Specialty fats and oils were prepared from coconut oil and non-lauric oils such as pili nut, cashew nut and soybean oil using non-specific lipases nd by interesterification. Modification of the triglyecerides of these oils using biotechnological techniques produced oils of high value for the food, pharmaceutical and cosmetic industries.
g) Hydrolysis of Copra Meal	The technology converts copra meal into high value animal feed. This is done treating copra meal with the enzyme mannanase.
h) Lysine	Locally produced amino acid used as nutritional food additive that can promote growth and improved metabolism. As feed ingredient, it improves the palatability of feeds.
i) Protease	Microbial protease enzyme for the food industry
j) Pectinase	Enzyme used to increase the efficiency of fruit juice extraction and fermentation into wine.
k) Lipase	Enzyme used for the enzymatic transformation of lipids.
l) Amylases	Microbial enzyme used for liquefaction and saccharification of starchy materials and desizing of textiles.

Table 2.2 Biotech Products in the market (Dela Cruz and Ebora, 1999)

Product	Description	
a) Mycogroe	Soil based biofertilizer which promotes survival and growth of reforestation species such as Eucalyptus, pines, and agoho. Growth (height) can be increased by 50-100% while biomass can be increased by as much as 200%. Each tablet contains spores of mycorrhizal fungi.	P1 per tablet
b) Mykovam	Another mycorrhiza product in powdered from effective for many agricultural crops (rice, corn, mungbean, pineapple, melons, eggplant, etc.), fruit trees (guava, citrus, atis, papaya, mango, etc.), and reforestation species (Gmelina, narra, falcata, acacias, etc.). MYKOVAM also contains mycorrhizal fungus which can promote survival and growth of plants in the same manner as MYCOGROE.	P25 per kilo
c) Bio-organic Fertilizers (Bio-Green, Cocorich, etc.)	An organic fertilizer produced from decomposition of agricultural residues. Biodegradable wastes such as bagasse, corn stover, rice straw, manure, etc. are first decomposed by a fungus, *Trichoderma sp*. After full decomposition, a nitrogen fixing bacterium (*Azotobacter sp*.) is added to increase the nitrogen content of the final product.	Varies with the kg bag
d) Bio-N	A biofertilizer effective for rice and corn. The product contains the bacterium Azospirillum sp. Which can fix nitrogen from the air. The fixed nitrogen is later transferred to the plant. Thus BIO-N can provide at least 30-50% of the nitrogen requirements of the plant.	P25 per packet hectare
e) Nitro-plus	A biofertilizer which contains the bacterium *Rhizobium* effective for legumes such soybean, peanut, pole sitao, cowpea, and mungbean. The inoculant is usually coated on the seeds before they are sown.	
f) Batrolep	The product contains *Bacillus thuringiensis* than can kill specific lepidopteran pests such as corn borer and diamond backmoth. If does not affect parasites and predators of the target pests above and is environmentally safe. The product is also safe to human beings.	P25 per packet hectare
g) Pelmictrol	A microbial insecticide containing the *bacterium Bacillus thuringiensis* which produces endotoxins. It kills mosquito larvae but does not harm humans and other life forms.	
h) Cocogro	This mixture of plant growth hormones (auxins, giberellins and cytokinins) and other plant regultors is derivd from waste coconut water. It can be used in tissue culture and ornamental, vegetable and orchid production.	P250/liter, P12
i) Pasteurella vaccine	This vaccine increases resistance of animals (cattle and carabao) to pasteurellosis (hemorrhagic septicemia), a deadly livestock disease. Protection is attained through yearly vaccination.	P10/dose

As described in Rola (1999), the following is the status of the efforts to commercialize biotech products:

1. Bioorganic fertilizer, also known as BIOGREEN is derived from agricultural and agroindustrial wastes composted with fungal inocula and enriched with free living N-fixing bacteria. The technology was developed in 1991 and commercialized since 1993. There are several brand names: Full of Grace in Nueva Ecija, Bionomics in Tuy, Batangas, Cocorich in Bauan, Batangas, Buhay Lupa in General Santos City and Lakas Ani in Cabuyao, Laguna. Biofertilizer bought at BIOTECH is produced in Bauan, Batangas, with brand name Cocorich. The price of the product is P160 per 40kg. bag.

2. *Mycorrhiza inoculants* (Mycovam)- promotes symbiotic association between plant roots and fungi; and used in agricultural crops (such as upland rice, corn, sugarcane, peanuts, mungbean, soybean, sweet potato, potato) fruit trees and reforestation species. This was developed in 1988 and commercialized since 1991. This is produced and distributed by BIOTECH only. The transfer of technology (in terms of production and marketing) to Los Banos Biotechnology Corporation is under negotiation. There are other private enterprises that are also interested but no negotiation has taken place as of the moment.

   For this inoculant, the total production is 3820 kg in 1997 and 3500 in 1998. The price is P25/kg. Total sales is P83,000 in 1997 and P74,900 in 1998.

3. Biological nitrogen fixers for rice and corn (BIO-N). This is a microbial based fertilizer which provides 30-50% nitrogen requirements of plants. This was developed in 1989 and commercialized since 1990. Like the Mycovam, this is also produced and distributed by BIOTECH only. It is claimed that this is used all over the country. A memorandum of agreement (MOA) with the TLRC is under negotiation. In this set-up, the TLRC extends loans to the farmer cooperators who will produce the BIO-N. The farmer cooperators will represent various areas in the country.

   This technology is sold at P20/250gm pack. Sales in 1998 is P55,385; while for Jan.-May, 1999, this is P 35,275.

4. Biological nitrogen fixers for legumes (Nitroplus). This was developed in 1976 and commercialized since 1982. It is produced only at BIOTECH but is used all over the country. The price is P20/150 gm packet. Total production in 1998 is 750 packets, while total sales in the same year is P 15,000.

5. Mycogroe is a tablet inoculant which acts as a supplement/replacement of chemical fertilizer; promotes growth and survival of the tree species. The production of this is handled by the Los Banos Biotechnology Corporation since 1990. MYCOGROE is protected by a Philippine patent and is registered with the Philippines' Fertilizer and Pesticide Authority (FPA) as a biological fertilizer. One table costs about P1.00 and one tablet per plant is needed to inoculate seedlings at planting time. Consumers of

this technology are mostly institutional users such as the Paper Industries Corporation of the Philippines (PICOP). Large reforestation programs in the countries like Thailand, Indonesia, and Kenya also subscribe to the technology.

Other users /buyers are nursery men, foresters, and golf course developers coming from different parts of the Philippines. The production of Mycogroe stopped since 1996; with a current stock of about 2million tablets. The 1998 sales is only P30,000.

6. The *trichoderma harzianum* or compost fungus activator (CFA) which has a potential as low-cost and environment friendly technology was not attractive to a private marketing firm because it was difficult to extend. While MYCOGROE was to be used by institutional users, the CFA was to be used by the small scale rice farmers. The Philippine national government launched a program in May 1990 to promote the CFA on a wider scale, with the end of full commercialization in view. CFA shortened the decomposition of base materials from five months to three weeks, thus the term rapid compost was used to describe its product which can be used as organic fertilizer.

CFA was introduced as a component of the package in the Rice Production Enhancement Program (RPEP) of the DA with a corresponding recommendation of 50% use of compost and 50% inorganic fertilizers. CFA was mass produced initially by the local offices of the Department of Science and Technology (DOST) and the Department of Agriculture (DA) with government subsidy. This strategy did not work because the government officials involved could not sustain the business operation, which was over and above their other official functions. There also was the problem of the unavailability of raw materials for production (Rola et al., 1995; Rola et al. 1997).

CFA is just one ingredient to the manufacture of compost. The other raw materials needed are the rice straw, ipil-ipil leaves, kakawate leaves and manure from pigs, chickens, carabaos and cows, and sawdust. The nutrient content of the compost depends on the proporation of the mix or raw materials used. Water is constantly needed to maintain the moisture of the compost heap. Because of this, technology was introduced initially in irrigated areas.

Several problems arose with respect to the farmers' production of the compost with the CFA. Foremost of these is the fact that the operation is very labor-intensive. It needs about 30 man-hours to produce a compost during the turn-around time. Sometimes, the raw materials are not available, including water. When the CFA dissemination by the government was not working, the DOST encouraged farmer cooperatives and the private sector to mass produce CFA and the compost as well.

The national program that backstopped the commercialization was terminated in 1996. At present (1999), there are 34 private enterprises that are still engaged in the production of the compost. Some DA/DOST offices and private enterprises produce

the activator. DA/DOST also monitor the performance and give technical assistance upon request.

The 1998 sales figures are not available but the price of the activator is P15/ .5 kg; and price of compost is P135-150/ 50kg bag. In 1997, estimated total sales of compost was P7.569 M, down from P77.919 M in 1994, the height of the commercialization program of the government. In the case of the CFA, estimated total sales in 1997 was P .266M, down from P3.144 M in 1994.

Transgenics

Transgenic engineering is relatively new in the country; the issue on transgenic or genetically modified organisms (GMOs) are inherently controversial. For instance, there are concerns that biotechnology will destroy agricultural biodiversity primarily because of the introduction of GMOs in the environment and the non-utilization of traditional plant varieties by farmers in favor of the new varieties and/ or the transgenics. Very recently, there was a decision to field test the Bt corn in several selected areas in the country.

This decision was handed down by the National Committee on Biosafety of the Philippines (NCBP), as it is required that all research pertaining GMOs should have a biosafety permit. It is interesting to note that despite the very low activity levels about GMOs in the country, we are one of the first few countries to adopt a national biosafety mechanism with guidelines considered by some as among the most stringent in the world. Thus, in the Philippines, all experiments involving genetic engineering will have to generate biosafety data to evaluate risks and benefits of the technology.

Much of the debate in this field have been tempered by emotions and passion; passion for the preservation of the status quo and the infringement of the rights of other entities (i.e. plant breeders). As is also perceived by most, the reason why there is not enough intelligent discussions about risk and benefits of the technology is because we do not have enough persuasive information to debate upon.

Ideally, field trials of the GMOs should consider both the economic and the environmental risk variables. These treatments will also be compared with the current practices of farmers, and with other potential alternatives.

The Global Scenario

Genetic engineering of plants became technically feasible in the 1970s, but it was not until the 1990s that commercial agriculture products became available. By 1999, there are about 40M hectares planted to transgenics, 72% of which is in the USA (Table 3). Eighty-two percent of the global area of transgenic crops are in industrialized countries (Table 4).

The seven transgenic crops grown in 1999 were soybeans, corn/maize, cotton, canola/rapeseed, potato, and squash and papaya (Table 5). The relative ranking of the principal transgenic traits showed that herbicide tolerance garnered 71% of the total area; while areas for insect resistant crops decreased (Table 6). Table 7 also shows that herbicide tolerant soybeans occupy 54% of total transgenic areas.

It is claimed that the spread of biotechnology products in crops is possibly a historically high adoption rate for a new technology (James, 1999, NE-165, 1999). However, it is also observed that the sequence and the effects remain largely undocumented (NE-165, 1999) and that some other profound effects are taking place. These include the shift of agricultural research funding from the public to the private sector, the privatization of agricultural innovations through the use of intellectual property rights (IPR), and the broad based concern about food safety of what is termed as the "Frankenstein" foods, or the genetically engineered foods, including ecological risks.

Table 3. Global Area of Transgenic Crops in 1996, 1997, 1998 and 1999.

	Hectares (million)	**Acres (million)**
1996	1.7	4.3
1997	11.0	27.5
1998	27.8	69.5
1999	39.9	98.6

Increase of 44%, 12.1 million hectares or 29.1 million acres between 1998 and 1999.

Source: Clive James, 1999.

Table 4. Global Area of Transgenic Crops in 1998 and 1999: Industrial & Developing Countries (millions of hectares)

	1998	**%**	**1999**	**%**	**Increase (Ratio)**	
Industrial Countries	23.4	84	32.8	82	9.4	(0.4)
Developing Countries	4.4	16	7.1	18	2.7	(0.6)
Total	**27.8**	**100**	**39.9**	**100**	**12.1**	**(0.4)**

Source: Clive James, 1999.

Table 5. Global Area of Transgenic Crops in 1998 and 1999: By Crop (millions of hectares)

Crop	1998	%	1999	%	Increase (Ratio)	
Soybean	14.5	52	21.6	54	7.1	(0.5)
Corn	8.3	30	11.1	28	2.8	(0.3)
Cotton	2.5	9	3.7	9	1.2	(0.5)
Canola	2.4	9	3.4	9	1.0	(0.4)
Potato	<0.1	<1	<0.1	<1	<0.1	(--)
Squash	0.0	0	<0.1	<1	(--)	(--)
Papaya	0.0	0	<0.1	<1	(--)	(--)
Total	**27.8**	**100**	**39.9**	**100**	**12.1**	**(0.4)**

Source: Clive James, 1999.

Table 6. Global Area of Transgenic Crops in 1998 and 1999: By Trait (millions of hectares)

Trait	1998	%	1999	%	Increase (Ratio)	
Herbicide tolerance	19.8	71	28.1	71	8.3	(0.4)
Insect resistance (Bt)	7.7	28	8.9	22	1.2	(0.2)
Bt/Herbicide Tolerance	0.3	1	2.9	7	2.6	(8.7)
Virus resistance/Other	<0.1	<1	<0.1	<1	<0.1	(--)
Global Totals	**27.8**	**100**	**39.9**	**100**	**12.1**	**(0.4)**

Source: Clive James, 1999.

Table 7. Dominant Transgenic Crops 1999

Crop	Million Hectares	% Transgenic
Herbicide tolerant Soybean	21.6	54
Bt Maize	7.5	19
Herbicide tolerant Canola	3.5	9
Herbicide tolerant Corn	2.1	5
Herbicide tolerant Cotton	1.6	4
Herbicide tolerant Corn	1.5	4
Bt Cotton	1.3	3
Bt/Herbicide tolerant Cotton	0.8	2
Total	**39.9**	**100**

Source: Clive James, 1999.

III. Issues in Agricultural Biotechnology Development and Commercialization

A. Public –private sector roles

Available information show that the private sector has substantial investments in biotechnology R and D; but that the public sector investment is also increasing. The figures at the global level revealed that slightly more than 60% of the investments were by the private sector (James, 1997). The data of 1985 showed that of the R and D investments, two-thirds was spent on seeds, and the balance on microbiology applications. However, it is estimated that of the total biotechnology sales in the US in 1996, only 3 % was in agriculture (Ernst and Young, 1996, as cited in James, 1997). It is also recognized that there are many applications of biotechnology in developing countries, but for commercial reasons, many of these will not be pursued by the private sector. This would be for the "orphan" crops that are usually the main staples of poor people. It is this reason that the public sector like the CGIAR would want to invest in biotechnology research and development (James, 1997).

Because the industry has the comparative advantage in the basic biotechnology knowledge, it is deemed that a private-public partnership in technology development and transfer will be more cost effective. Thus, governments can design policies to foster the public –private sector collaboration. And a major challenge is for both the private sector and the public sector to find ways to collaborate in sharing and transferring appropriate new technologies, which are often proprietary, from the private sector in the developed countries to the public sector in the developing world (James, 1997).

This means that biotechnology research prioritization in national agricultural research systems would have to take into consideration available technologies for the taking from the private sector as well as from the international research centers; and determine the economics of this. Actually, many centers have formed partnerships with the national agricultural research centers to undertake joint or contractual biotech research, receiving access to proprietary materials through partnership agreements (ISNAR, 1998b). But this has bearing on intellectual property rights (IPR) especially if the national system has the needed inputs and the private sector has the knowledge about the process. Especially because of IPR issues, the calculation of the returns to research becomes complicated.

But issues are raised as to incentives to be provided the private sector for undertaking research targeted at the production problems of poor farmers (ISNAR 1998b)? In the US and Canada, the gradual shift over the past 20 years from public to private funding of plant related-agricultural research has raised questions about the role of the public sector. Canada, with its successful canola program is perhaps the most advanced in the transition to largely private funding and hence provides a limited return on investment. Studies of the effects of the consolidation of IPR holdings are less advanced but, provisionally show that the financial benefits to the universities from biotech patents are limited, while raising broad public policy issues (NE-165, 1999).

B. Intellectual Property Rights (IPR) and Biotechnology Development

What is IPR?

Intellectual Property Rights are a form of economic policy intended to advance the production and the use of new products and technologies. Intellectual properties are the product of the mind and hence, these are intangible. Unless they are expressed in tangible form, they remain protected and cannot be used by others. Traditionally, IPRs are covered by five forms of protection rights- patents, copyrights,trademarks, trade secrets, and plant breeders' rights (De Guzman et al., 1999).

Among these, the patent and the plant breeder's rights (PBR) are the more relevant in biotechnology development. A patent is an exclusive right of the inventor to exclude others from imitating, manufacturing, using or selling a specific invention for commercial use during a specified period of time. Patentable articles are those that are novel, inventive, and industrially applicable and useful. An invention that can be produced and used in any industry is considered industrially applicable and useful. A patent is not intended to protect new knowledge but rather the knowledge embodied in the new product or process. So for instance, a new pesticide product can have patents, and there is a price for the proprietary right of the company, for a number of years. Patent rights are granted over a fixed period of time i.e. from 15 to 20 years. At some number of years, however, or maybe after it is known that the investment to invent such has already been recouped, then, the pesticide product becomes a commodity, and product prices will be relatively low. This particular policy could also be applied to biotech products.

On the other hand, PBR is a specialized patent-like system for cultivated plants. It is an exclusive right granted to breeders to distribute and use a new plant variety. Protection is granted on the basis of distinction, uniformity and stability of the novel plant. This protection can be extended to a selected range of plant species. PBR protection may be limited to the reproductive material or all materials of the variety including harvested material. Protection is by means of a certificate for a term of 20 to 25 years. PBR is distinguished from patent by allowing the so-called " farmers' privilege" and "breeders' exemption". Farmers' privilege allows the farmer to save seeds of protected varieties and use the seed for planting the next season. On the other hand, breeders' exemption allows the use of protected variety in the breeding of new varieties (De Guzman, et al. 1999).

The key function of IPRs is to provide incentives for investment in the creative process and in particular the transformation of basic insights into marketable products. These incentives are most applicable to private entities but have been used increasingly by the public sector as a source for generating research funds.

In the biotechnology development, at least two issues have to be resolved in the assignment of property rights, especially to transgenic products. The first is the

ownership of the input, such as the gene; the second is the ownership of the knowledge on the use of the gene.

There is a need to raise the question about the IPR protection of genetic materials. Conceptually, IPR protection for cooperative technologies (Lesser, 1997)- or those produced by the communities in accordance with age old practices in the areas of genetic resources and landraces- fits smoothly within the historical development of IPR legislation. In the Philippines, we protect improved plant varieties, but not landraces. Patents are usable for other materials, but the costs of documenting and preparing an application make patents a prohibitive approach for the great bulk of materials of uncertain use and value.

When the application requirement is enlarged to include "non-traditional" forms of IPR, i.e farmers' rights and folklore, they are not fully developed in their present forms for the protection of cooperative technologies. Farmer's rights is a call for payment to traditional farmers for the development and preservation of landraces in particular, which provide the genetic base for many advances in variety development. But would this be effective? And according to Lesser (1997), it could be effective if the tax rate is not onerous (i.e about 5% in the case of India).

How much would research centers pay for the inputs in biotech research? Do we have a measure of the benefits of biodiversity? What is the economics of biodiversity conservation?

IPR systems have costs, royalty payments being the most obvious, but the costs of the absence of protection in terms of denied or delayed access must be determined on a case-by-case basis (Lesser, 1997).

But why are we concerned about this? Most technologies have royalties, but these are the technologies that are from the private sector. With public sector investment in research, is there a need for IPR? Some scientists say that this is not ethical, because we invent for the public good. But the public sector also must be efficient in its resource use, by calculating the ROI of the said investment in R and D. To apply the IPR would be :1. An incentive to scientists, and 2) would give a quantifiable return on public sector invention.

In general, Intellectual products have commercial value. It is the intellectual additions to those materials, the knowledge of use which has value distinct from the physical products themselves. The limited amount of intellectual property protection being sought by public research institutions can be attributed to many factors. These include lack of familiarity with the IPR issues, the fact that suitable IPR options are not yet developed and approved, and the traditional reliance on goods and services developed as international public goods (ISNAR 1998a). It was also mentioned that many bilateral donors and civil society organizations are opposed to applying IPR protection to products of public sector research, making it a highly controversial issue.

A review of studies also showed that all available information is consistent with the theoretical expectations that increased IPR protection does indeed lead to greater investment, esp. for copied products.

The Philippine IPR Code

In the Philippines, IPR is governed by the Philippine IPR Code. Republic Act 8293 is a consolidation and update of all existing laws on IPR, and governs the protection of intellectual creations in the country. The IPR Code brought the country's IPR laws in harmony with the minimum standards for IPR protection required under the World Trade Organization-Trade Related Aspects of the IPRs (WTO/TRIPs). Two modalities of IPR protection that exist in other countries are not covered in the Code- utility models nd the breeders' rights (De Guzman, et al. 1999).

The IPR Code in its present form contains some ambiguities in its application to biotechnology products. As indicated in the Code, patents can not be granted to plant varieties and animal breeds, or any biological processes for the production of plants and animals. One interpretation could be the exclusion of the naturally-occurring plant varieties and uncontrolled biological processes from patent protection. However, biological processes aided with non-trivial human intervention, as in genetic engineering, may not be considered essentially biological although they re partially biological. And so, GM plants may be subject to patent protection. Different interpretations of patentable lifeforms may soon find intense debate in local courts and may require working out fair principles as to the scope of patentable biotechnology (De Guzman, et al. 1999).

IPR and Technology Transfer

Technology transfer is the application of technologies in new geographic or product areas, generally involving adaptation to local needs and conditions (Lesser, 1997). Due to the diversity of product traits, biotechnology cannot be treated as a single entity, but as a composite of products with individual specific attributes and transfer processes. In the transfer of biotech products, there are two conceptual justifications for the IPRs: the personal property argument and the incentive mechanism. IPRs are intended primarily to foster private R and D. The available evidence generally supports that expectation (Lesser, 1997). Also , according to Lesser (1997), there is evidence to support that IPR is an important component of the incentive system.

A secondary function of the IPR according to Lesser (1997) is to encourage access to inventions produced elsewhere, that appropriate IPR facilitates access, which was the principal motivation for its adoption in several countries.

The situation in many developing countries, where 98% of the patents are granted to foreigners, is cited as evidence that patents do little more than to provide import monopolies for multinationals (Lesser, 1997). Products of biotechnology are based on

genetic resources. The recognition of IPRs respects only one group of rights in technology transfer, those of the owners of protected technologies. There are other players as well, including technology buyers and suppliers of non-protected, nontraditional technologies such as genetic resources and the knowledge surrounding those resources.

The paper by Lesser (1997) considers technology transfer as two interrelated components: a) effective technology transfer as fostered by the IPRs, and b) equitable technology transfer for other classes of technology, particularly that of local and indigenous peoples. Biotechnology is a methodology, not a class of products. This is important because the biotechnology process can lead to many and diverse products. These products potentially can protect biodiversity.

The economic incentive approach recognizes that the inventor assumes time and other costs associated with the creation process. According to Lesser (1997), the invention process can be divided into three components: discovery, development and commercialization. While the discovery process seems to function by luck, development and commercialization are lengthy and costly processes of turning an idea into a marketable product. Work on these stages is very responsive to incentives and can be considered as the real target of IPR systems.

Seeds are patentable subject matter in the USA and provisionally patentable elsewhere. What is really being protected is the human knowledge of how the organism is to be used. Equity is also an issue; but as was agreed in the Biodiversity Convention, this emphasizes the need for training developing country representatives in negotiating skills and related legal concepts.

C. Agricultural Biotechnology Commercialization

Decisions about the production and delivery of products to users must be considered early on. Joint ventures between the private, commercial sector and the public institutions is essential. In some cases, national or international intermediary organizations have facilitated technology transfer from public to private sector organizations. The strong relationships between the public and the private sectors in product development was emphasized, specifically in the areas of product price regulation, and registration; offering on-farm demonstrations, pilot production facilities, and procuring and distributing planting materials. (ISNAR, 1998b).

IPR, and patents per se, are a driving force in the evolution of agbiotechnology. Commercialization permission for component materials accessed from the private sector is limiting the ability of public sector researchers to release completed products, but any remedy will be extra-market. Universities, it is recommended, can more effectively market their research capabilities s a disciplinary unit, as opposed to a grant-by-grant process (NE-165, 1999).

Issues on trade and development have to be considered as well. Regulatory certainty is one reason proposed for the leading role of US firms in agbiotech research. However, in developing countries, there may be insufficient means, and incentive, to enforce trade rights, including those for intellectual property rights (NE-165).

D. Food Safety and Environmental Risks

Altiere (1997) claims that there are already signals that the commercial scale use of some transgenic crops poses serious ecological risks (Table 8). There is a recognition that transgenic crops can produce environmental traits that move through the food chain and may also end up in the soil and the water; affecting invertebrates and "maybe" ecological processes such as nutrient cycling.

These effects are important to understand in the economic sense. This suggests that the economic evaluation should be strengthened along the environmental impact of the technology. Currently, many results have emerged from the environmenatl performance of released transgenic crops. This suggests that in the development of "resistant crops", not only is there a need to test direct effects on the target insect or weed, but that the indirect effects on plants (such as growth, nutrient content, or metabolic changes), soil, and non-target organisms must also be evaluated (Altiere, 1997).

Krattinger (1997) also reported that biotechnology applications do not represent a silver bullet but needs to be integrated into production systems. Proponents suggest that "no one will become too complacent and entirely rely on the new transgenics," but one has to monitor its performance from season to season. For the developing countries like he Philippines, this needs a stronger regulatory body, more informed extension bureaucracy, and intelligent farm decision makers.

Table 8. Field performance of some recently released transgenic crops.

Transgenic crop	Performance	Reference
1. Bt transgenic cotton 1996;	Additional insecticide sprays needed due to Bt cotton failing to control bollworms in 20,000 acres in eastern Texas	The Gene Exchange, Kaiser 1996
2. Cotton inserted with roundup Ready TW gene	Boils deformed and falling off 4,000-5,000 acres in Mississippi Delta	Lappe and Bailey 1997; Myerson 1997
3. Bt corn	27 percent yield reduction and lower Cu foliar levels in Beltsville trial	Hornick 1997
4. Herbicide-resistant oilseed rape	Pollen escaped and fertilized botanically related plants 2.5 km. Away in Scotland	Scottish Crop Research Institute 1996
5. Virus-resistant squash	Vertical resistance to tow viruses and not to others transmitted by aphid	Rissler, J. (personal communication)
6. Early FLAVR-SAVR tomato varieties	Did not exhibit acceptable yields and disease-resistance performance	Biotech Reporter 1996
7. Roundup Ready Canola	Pulled off the market due to contamination with a gene that does not have regulatory approval	Rance 1997
8. Bt potatoes	Aphids sequestered the Bt toxin apparently affecting coccinellid predators in negative ways	Birch and others 1997
9. Herbicide-tolerant crops	Development of resistance by annual ryegrass to Roundup	Gil 1995

Source: Altiere, 1997

IV. Economic Perspective for Agricultural Biotechnology

A. Ex ante Economic Analysis

In our search for agricultural technologies to increase future agricultural productivity, research investments are needed. But the main goal of agricultural research is enhanced economic efficiency (Alston et al. 1995). Along this line, contributions of research to economic efficiency and the distribution of benefits can be measured as the net present value of research induced changes in economic surplus. The size of economic gains depends on the size of the research induced shift in the product supply curve, the nature of the shift, elasticities of supply and demand, the pattern of trade in the commodity and the market distortions. Especially in the case of biotechnology, distortions maybe both market (IPR) and nonmarket (environmental risks) in nature.

There is also a need to understand whether the technology presents a biased or a neutral technological change. For most biotech products, (i.e. organic fertilizers), technical change maybe labor using. For GMOs, this could be a neutral change, but the output quality may differ; and other environmental risks are involved.

For any technology for that matter, the major determinants of net research benefits are the value of production, probability of research success that may be manifested by successful commercialization and high adoption of the technology, size as well as timing of per unit cost reductions or yield increases if the research is successful, the discount rate and the cost of research (Alston et al. 1995).

The reason for some unsuccessful commercialization and low adoption of a biotech product is the technology's non-competitiveness in the market, mainly shown by its failure to shift the marginal cost curve or the supply curve. This means that production cost is high and if information were available before hand, one may know the economic environment that such a technology could thrive in. Thus, ex ante analysis should also concern a lot of sensitivity analysis for scenarios including alternative credit policies and exchange rate regimes (for open economies).

An example of an ex ante evaluation of the economic impact of agricultural biotechnology is the case of porcine somatropin, a growth hormone (Lemieux and Wohlgenant, 1989). It was projected that introduction of the new growth hormone, will have significant impact on the pork industry. Ex ante effects were estimated using standard elasticity model. The model accounts for interrelationships between domestic and international markets for hogs and pork, different adoption rates and lengths of run for supply and consumer demand shifts from leaner pork. Methodological contribution of this study was the use of experimental data to quantify production function and supply shifts.

B. Farm Level Impacts

Data to describe farm level effects of agricultural biotechnology are very scanty worldwide and quite nil in the Philippines. In the US setting, with three years of field data for soybeans, corn, cotton and canola, showed that on the average, producers benefited financially, and that there were environmental benefits in the form of reduced chemical use and less erosion when herbicide tolerant crops made no-till cultivation more feasible. Within the averages, however, there is significant variation among crops and among years, suggesting the products to be more of an insurance than production expense. Unlike most recent technological innovations, the available agbiotechnologies tend to reduce rather than increase management requirements (NE-165, 1999).

While the above talked about actual impacts, previous research on the farm level economics of the technology used an ex ante analysis. One farm level study dealt with an economic comparison of the current technology and the transgenic virus resistance potato technology in Mexico (Qaim, 1998). The with-technology budgets took into account the technological features and potentials. Results showed that the technology has

the greatest potential to increase household incomes from potato production for small scale farmers, followed by medium- scale and large scale farmers. The reason for this pattern is that the small scale farmers suffer the most from yield losses due to the viruses. But however, it is difficult to project the adoption rates of the new seeds, as most small farmers do not change their seed purchase behaviour. Initial subsidies maybe necessary.

Several assumptions were made in the calculations of potential benefits of the technology: 1) the with technology enterprise budgets assume that farmers are using the transgenic potatoes. It is abstracted from the institutional bottlenecks that might restrict farmers' access to the technology; the enterprise budgets also build on the assumption that the potato farm gate prices will not change due to technology use. While this might be realistic for some early adoptors, a more widespread technical change will lower potato prices, as producers face a downward sloping demand curve.

In an ex post evaluation of the organic fertilizer technology, results revealed that N decreased but only for farmers who knew the nature of the organic fertilizer (Rola, et al. 1997).

C. Industry Level Impacts

The study by Qaim (1998) also assumed different scenarios, in the quantification of aggregate benefits and costs. The assumptions were made at three different levels.

1) Level of R and D- this states the condition that there are contractual arrangements between the private sector and the public sector research funding;

2) Level of factor markets- another assumption is that to accelerate distribution and adoption, a distribution mechanism could be in place. And hence, the analysis could be with and without the distribution mechanism.

3) Level of Potato Market- This analyzes the impact of the increased international potato trade on the technology-induced change in economic surplus. Today, Mexico is a closed potato economy, but this could change within the NAFTA area after Year 2004. So, a trade and a no-trade case was considered. In the no trade case, only the national demand curve is relevant. In the trade case, it is assumed that a there exists a totally elastic demand curve at the average cif import price of fresh potatoes at the Mexican border.

The results showed that the over-all technology induced changes in the economic surplus measures are significantly positive for all scenarios. The author however stressed that his calculations are built on the assumption that farmers will use the technology without paying a higher price for the potato seeds as compared to their traditional sources of seed materials, that is that farmers do not carry the cost of the technology. If seed prices increase, per unit cost reductions and technology adoption rates would decrease, but particularly, for small and medium scale farmers, and with a concomitant fall in the economic surplus.

On the other hand, the cost of the technology consist of the costs of the different organizations involved in the financing and implementing the technology project. In the Mexican case, it included the cost of technology transfer by the Rockefeller Foundation, the material contributions of the public sector research agency, the opportunity cost of the private sector management personnel, and other transactions costs. But the cost of the basic research by the multinational firm is not considered.

The computed Internal rates of Returns (IRR) are in a reasonable dimension for the long term technology projects (Qaim, 1998). Results were also subjected to sensitivity analysis because there are a lot of parameters involved that are subject to uncertainty due to unavailability of precise data or because they refer to future events. The alternative scenarios used in the sensitivity analysis included reduction of unit cost for the individual farm types, the variations in the adoption rates, and the price responsiveness of consumers and producers. In general, the sensitivity analysis reveals the robustness of the results over a wide range of parameters. However, it was also stressed that it is of paramount importance for institutional adjustments to eliminate the bottlenecks that prevent the small-holder participation in the technology benefits (Qaim, 1998).

D. Environmental Economic Impact and the Economics of Managing Biotechnology

Because of the inherent risks of the agricultural biotechnology products, it is important to always consider the external effects. In most instances, these are with respect to biodiversity, soils and the ecology, in general. Similar to the pesticide technology, biotechnology products are also subject to evaluation including efficacy, environmental safety and human toxicity. This need a risk assessment framework that would determine whether risks of the technology is below some threshold level. For regulators, risks have to be compared with the relative benefits of the technology. Hence, its expected price effects, and maybe its nutritional effects, would likewise be important factors.

The challenge is really for more reliable estimates of the environmental damage that may be due to the technology. Economists need to look at this, in addition to the pure price effects of the technology.

Managing biotechnology products also need an economic analysis. In some countries, biotechnology products in the market are already segregated and labelled as such. This will give consumers the information about the quality of food that they buy. In the process of our ex ante assessment, the potential demand for the biotechnology product may have to be established. The cost of segregating products in the marketplace will be substantial, at least until the volume increases, and the system adjusts from its present commodity focus. But potentially more significant, significant threats are posed to the world grain and oil products trading system, whether they come from expansive biosafety regulations, as was proposed under the Biodiversity Convention, or through refusal of Europeans to consume GM foods. The latter raises troubling issues of scientific

proof of health effects under WTO rules (NE-165, 1999). The study of economics of the health effects is a natural consequence.

V. Research Program Planning for the Economic Perspectives on Biotechnology

To describe the framework for economic analysis, Qaim (1998) enumerated the following points:

1. Agricultural biotechnology holds great economic potentials for food producers and consumers in the developing countries. The private biotechnology sector of the industrial countries can play an important role in making certain basic technologies available.
2. The actual impacts of a biotechnology innovation are not only a function of the technological characteristics but also are very dependent on social and institutional support mechanisms. Timely socioeconomic information is sorely needed to identify and eliminate institutional bottlenecks.
3. The donation of proprietary technologies can pave the way for future commercial businesses of private enterprises.

The most relevant socioeconomic research topics on biotechnology were seen to be impact assessment and priority setting (ISNAR, 1998b). Economic research on biotechnology should include solid arguments on biotechnology's potential (through some ex ante evaluation) and guidelines for adequate investment. Economic research could also assist in determining market niches for biotechnology products.

Furthermore, the economics of biotechnology will not be the standard economics of technological change issue. Aside from the shifts in the supply and demand and the determination of the economic surplus, there should be a clear understanding of the sources and sizes of the distortions. These could be caused by the costs due to IPRs (cost of the genetic material and cost of the knowledge in the use of the material or the process involved) in technology development and/or in (international) technology transfer. There is also additional transactions costs to meet requirements of biosafety regulations. The environmental impact and the food safety attributes will also have to be considered in economic terms. Finally, the knowledge intensiveness of the technology (KIT) also requires a deeper understanding of the economics of KIT, in technology transfer.

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