Chapter 3

Rich and Poor Country Perspectives on Biotechnology

Per Pinstrup-Andersen and Marc J. Cohen

Introduction

The current debate about the potential utility of modern biotechnology for food and agriculture and the associated risks and opportunities often ignores the differences between conditions in rich and poor countries. Positions for or against the use of genetic engineering in food and agriculture in industrialized countries are frequently extrapolated directly to the developing world. But food and agriculture problems differ widely between poor and rich countries, and one would expect the most appropriate solutions to also differ. It is important that each country, and population groups within countries, be in a position to make their own decisions regarding modern biotechnology. Attempts by wealthy countries, population groups, and advocacy groups to decide for poor farmers and consumers are paternalistic and unethical. This chapter first discusses the different perspectives and the reasoning behind them. It then discusses in more detail the risks and benefits associated with the use of modern biotechnology in developing-country food and agriculture. It concludes with a look at issues requiring future action.

Why Should Perspectives Differ?

Rich and poor country perspectives on the use of modern biotechnology for food and agriculture differ for many reasons. Similarly, within any given country views

Table 3.1 Illustrative impact of a 33 percent reduction of food commodity prices on poor and rich consumers

	Poor consumers	Rich consumers
	(percent)	
Assumed budget share on food	80.00	10.00
Assumed commodity cost share	70.00	10.00
Impact on consumer purchasing power[a]	19.00	0.33

Source: Authors' calculations.

a. The budget and commodity shares used to estimate the impact of a 33 percent reduction in price are hypothetical, but deemed representative of typical poor and rich consumers. To illustrate the calculation, a poor person is assumed to spend 80 cents of every dollar of income on food, and 70 percent of that 80-cent expenditure entails the cost of commodities; thus, the commodity costs per dollar of expenditure are 56 cents. Reducing the price of those commodities by 33 percent is equivalent to a 19 percent (0.33 x 56) increase in the income of the poor. The same method, with different budget and commodity shares, was used to estimate the income effect of a food price reduction on the rich.

likely differ between poor people and the nonpoor. The factors deemed most important in determining these different perspectives are discussed below.

The Budget Share for Food

Application of modern biotechnology in food and agriculture may increase productivity and reduce unit costs in production and marketing. This may lead to higher incomes for innovative producers, reduced prices for consumers, or most likely a combination of the two. Consumers spending a large share of their budget on food are thus likely to be more interested in such productivity increases than consumers who spend a relatively small share of their budget on food.

Low-income people in developing countries often spend 50–80 percent of their total disposable income on food whereas Americans, Australians, and Europeans spend 10–15 percent on average. Furthermore, the cost of the food commodity occupies a much larger share of the consumer price among the poor. Costs of processing and marketing tend to dominate in foods consumed by the rich. Unit cost savings in the production of food commodities are therefore likely to result in a larger price reduction for poor consumers (see Table 3.1). For these reasons, one would expect poor people and poor countries to emphasize reduced unit costs and prices for food.

The Importance of Agriculture

Insofar as farmers can capture the benefits of increased productivity, reduced unit costs, and lower production risks, they would likely favor the use of modern biotechnology in production. More than 70 percent of the world's poor reside in rural areas, and it is not uncommon for 50–80 percent of a low-income country's population to depend directly or indirectly on agriculture. In contrast, 2–5 percent of the populations of most industrialized nations depend on agriculture for their livelihoods. Therefore, it is reasonable to expect that the application of modern biotechnology in food and agriculture would be far more favorably received by low-income countries than by high-income ones.

Another closely related aspect is the relative importance of the agricultural sector in generating broad-based economic growth in society as a whole. Agricultural growth is essential in promoting rapid overall growth in low-income countries, while it may be of limited importance in industrialized nations.

Market Power and Political Power

Insofar as farmers expect to gain from the introduction of modern biotechnology in food and agriculture, they will try to influence political decisionmaking in favor of such technology. Farmers in industrialized nations have used political power effectively to gain access to large farm subsidies supported by fiscal resources and artificially high consumer prices. At the same time, however, the market power of industrialized-world farmers has gradually deteriorated, as consumers gain a greater say. Thus, while European farmers continue to receive large subsidies by exercising their political power, they have been unable to exercise similar power in questions related to genetically modified (GM) food. On the other hand, farmers in low-income developing countries possess very limited political power and generally have been taxed rather than subsidized by their governments. Domestically, however, they continue to exercise a great deal of market power, as poor consumers seek low-cost foods instead of the more expensive products demanded by consumers in European domestic markets. Like European farmers, farmers in the United States have also managed to maintain large farm subsidies, but unlike their European colleagues, they have not met strong opposition by consumers or government to GM food in the marketplace—at least not yet.

Strong opposition to GM food in the European Union (E.U.) has resulted in severe restrictions on modern agricultural biotechnology, including limited approval for commercial use of new GM agricultural products. The opposition is driven in part by perceived lack of consumer benefits, uncertainty about possible negative health and environmental effects, widespread perception that a few large corporations will be the primary beneficiaries, and ethical concerns.

While European governments have tended to follow the desires expressed by advocacy groups, and most consumers are opposed to genetically engineered food, the U.S. government supports the farm sector and the private sector engaged in developing and distributing modern biotechnology for food and agriculture. One could argue that European consumers have gained a great deal of political power over agriculture in their capacity as consumers, while still agreeing to provide large subsidies to agriculture in their capacity as taxpayers. The possibility that the application of modern biotechnology in European agriculture could reduce the need for farm subsidies does not seem to enter into the European debate. To the extent that this potential contradiction has been considered by consumers and government, consumers seems to prefer to pay farmers not to produce GM food either through additional subsidies or through higher food prices. Such a contradiction is not prevalent in the United States.

The Power of Advocacy Groups

Another factor that has led to differing perspectives between rich and poor countries is the relative political power of civil society groups, including advocacy groups opposed to genetic engineering in food and agriculture. Such groups have successfully influenced the debate and consumer and government attitudes towards GM food in Europe. Advocacy groups opposed to genetic engineering in food and agriculture are also gaining power in developing countries such as the Philippines. The groups in developing countries often maintain close contact with European and international counterparts such as Greenpeace, Friends of the Earth, and the Soils Association.

Those responsible for food and agriculture in developing countries do not always welcome efforts by multinational advocacy groups based in high-income countries to groom opposition to modern biotechnology in their countries. In a recent op-ed in *The Washington Post,* Nigerian Minister of Agriculture Hassan Adamu states:

> We do not want to be denied this technology [agricultural biotechnology] because of a misguided notion that we do not understand the dangers or the future consequences. We understand. . . .We will proceed carefully and thoughtfully, but we want to have the opportunity to save the lives of millions of people and change the course of history in many nations. That is our right, and we should not be denied by those with a mistaken idea that they know best how everyone should live or that they have the right to impose their values on us. The harsh reality is that, without the help of agricultural biotechnology, many will not live (Adamu 2000, A23).

One might expect a similar statement from a European minister of health if Africans tried to spur opposition in Europe to the use of modern biotechnology to develop a cure for cancer.

Professor Thomson of the University of Cape Town, South Africa, puts it this way:

> Rich countries may engage in lengthy disputes about real or imagined risks. We suggest that is largely a luxury debate. From the perspectives of many developing and newly industrialized countries, agricultural biotechnology's benefits are very real and urgently needed today and indispensable tomorrow. The developing world cannot afford to let Europe's homemade problems negatively impact the future growth in our countries (Thomson 2000, 1).

The African Biotechnology Stakeholders Forum also expresses concern about "mounting attempts to curb the evolution and development of biotechnology in Africa" and states "that those in the industrialized countries continue to assume they know what is best for Kenya and the rest of Africa" (ABSF 1999, 3).

The president of the Federation of Farmers Associations in Andhra Pradesh, India, also expresses great concern about the failure of "certain well-known activist organizations in developed countries" to consider how modern agricultural technology could improve the well-being of the poor in Asia. He suggests that we should "leave the choice of selecting modern agricultural technologies to the wisdom of Indian farmers" (Reddy 2000).

However, while some advocacy groups fail to distinguish between rich and poor countries in their position on modern biotechnology for agriculture, many are beginning to recognize the opportunities this technology offers for improving food security and reducing poverty in developing countries. For example, in a recent position paper, Oxfam GB recommends donor support for "(1) public research into applications of GM technology of benefit to smaller farmers and low-income consumers in developing countries, and (2) regulatory and monitoring systems in developing countries" (Oxfam 1999, 3).

Paarlberg summarizes what appears to be the position of many in developing countries:

> It would be unfortunate if the same environmental activists in rich countries, who previously waged an inspired and courageous battle to prevent the dumping of toxic wastes in developing countries, should now use their reputation to deny those same countries access to modern agribiotechnology. This is a powerful tool of science, not a toxic waste. It is the toxic quality of the current industrial world debate regarding GM seeds that the developing countries should perhaps choose not to import (Paarlberg 2000b, 26).

Willingness to Take Risks

The willingness to take certain risks is expected to differ between the poor and the rich, primarily because the consequences of taking or not taking these risks differ between the two groups. This relates to the levels of food safety demanded by the poor and those demanded by the rich. One would expect that increasing levels of food safety would tend to increase food prices. Thus, consumers may be faced with a trade-off between the quantity and quality of food they can acquire. Poor people would tend to place a higher premium on quantity until basic nutritional requirements are met, even if it implies lower levels of food safety. On the other hand, American, Australian, and European households, spending 10–15 percent of their budget on food, are prepared to pay a premium for even small increases in food safety and reduced uncertainty.

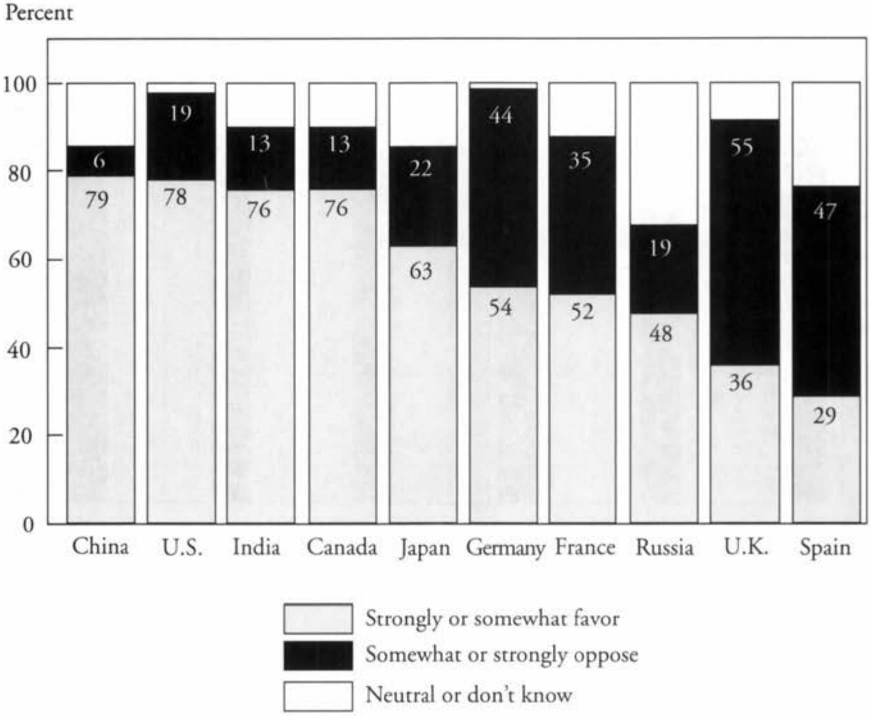
The relationship between a society's income level and its desired level of food safety is illustrated not only across countries but also over time in any given country. The food-safety level demanded by high-income countries today is quite different from that demanded by those same countries 50–100 years ago, when incomes were lower and food-budget shares higher. The implication for the introduction of modern biotechnology in food and agriculture is that higher-income people and higher-income countries would be less willing to take risks associated with genetically engineered food, even if those risks are very small or nonexistent. Globalization may impose the levels of food safety preferred by the rich on the poor at the expense of the latter's food security.

The rich are likely to accept biotechnology that improves food safety—even if it raises food prices—although this does not seem to be the case for GM seed that reduces the use of chemical pesticides such as *Bt* food crops. The possibility of reducing or eliminating pesticide residues in food through genetic engineering has not played a significant role in the European debate, even though European farmers rely heavily on synthetic pesticides. As shown in Figure 3.1, 75–80 percent of nationally representative samples in Canada, China, India, and the United States favored using modern biotechnology to develop pest resistance in crops and reduce the use of chemical pesticides. The percentage was considerably lower in Japan, and significantly lower in Europe.

Different Health Problems

While poor people in poor countries worry about their ability to acquire sufficient food to feed their families, rich households in rich countries are concerned about health problems such as obesity, cancer, diabetes, and heart disease. This explains at least in part why Europeans strongly support the use of modern science to develop pharmaceuticals to prevent or cure diseases of concern to them, while they oppose

Figure 3.1 Selected countries of 25 surveyed on the use of biotechnology to grow pest-resistant crops that require fewer farm chemicals



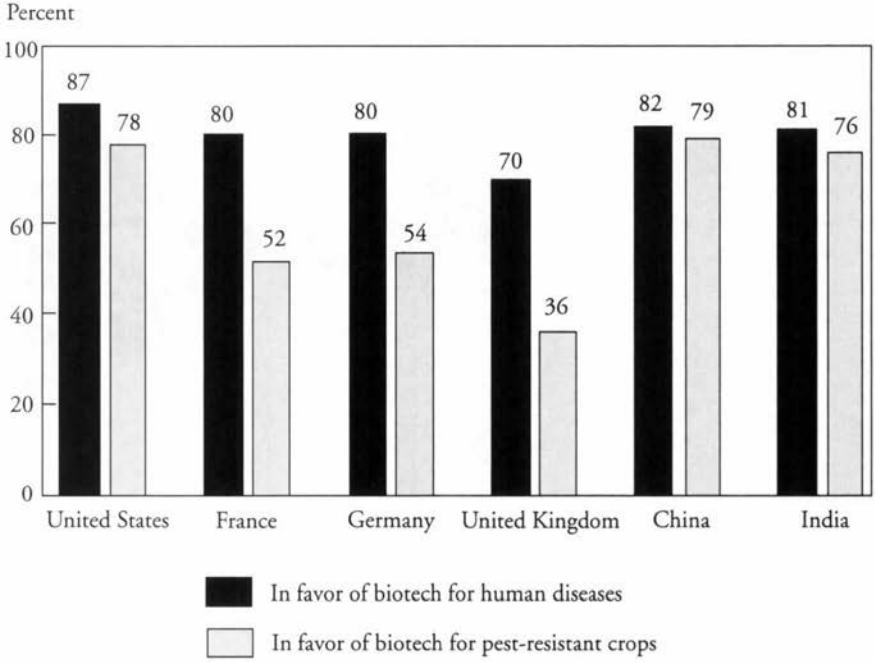
Source: Environics International, Ltd. (1998).

use of such science to improve food and agriculture. Few people seeking a cure for cancer are likely to reject a cure developed through genetic engineering, and GM insulin is widely accepted to control diabetes. West African farmers unable to grow or purchase enough food to feed their children are much more concerned about improvements in food and agriculture than about developing a cure for cancer.

One would then certainly expect the rich and poor to differ on the priorities of modern science. This is borne out by an assessment of public opinion in selected countries (Figure 3.2). While a large majority of people in China and India favor the use of modern biotechnology both for treating human diseases and for developing pest-resistant crops, European populations are much more in favor of using modern biotechnology to treat human diseases than for food and agriculture.

In addition to concern about obtaining enough food for the family, the low-income mother in a developing country also worries about other health

Figure 3.2 Public opinion on the use of modern biotechnology in selected countries



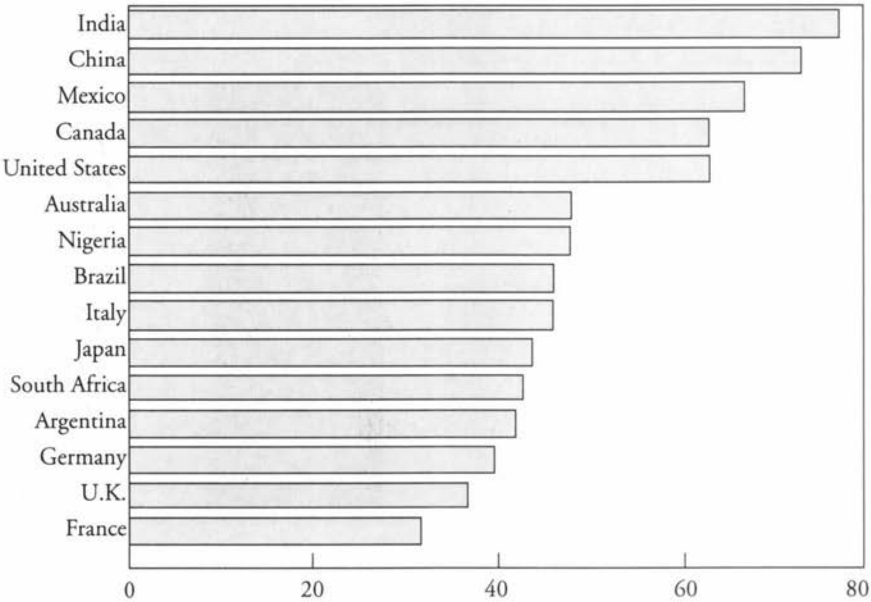
Source: Environics International, Ltd. (1998).

problems. These tend to be related to infectious diseases, many of which are associated with unclean water, poor hygiene, and extremely low food-safety standards. She is thus likely to favor the use of modern science to solve problems related to infectious diseases rather than those related to chronic diseases.

The Importance of Environmental Concerns

Finally, differing environmental concerns between rich and poor countries are likely to lead to different perspectives on the use of modern biotechnology. Modern biotechnology, which would increase productivity in staple food production but with a potentially negative environmental impact, is more likely to be accepted by the poor than by the rich, simply because of the pressing food problems facing the poor. High-income countries are less likely to approve of the application of modern biotechnology in agriculture if there is even a small or unknown environmental risk, because concerns about impact on biodiversity are much more prevalent there than concerns about hunger and malnutrition. The opposite is likely to be true in poor countries.

Figure 3.3 Percentage of adults who "agree" that benefits of using biotechnology in food crops are greater than the risks



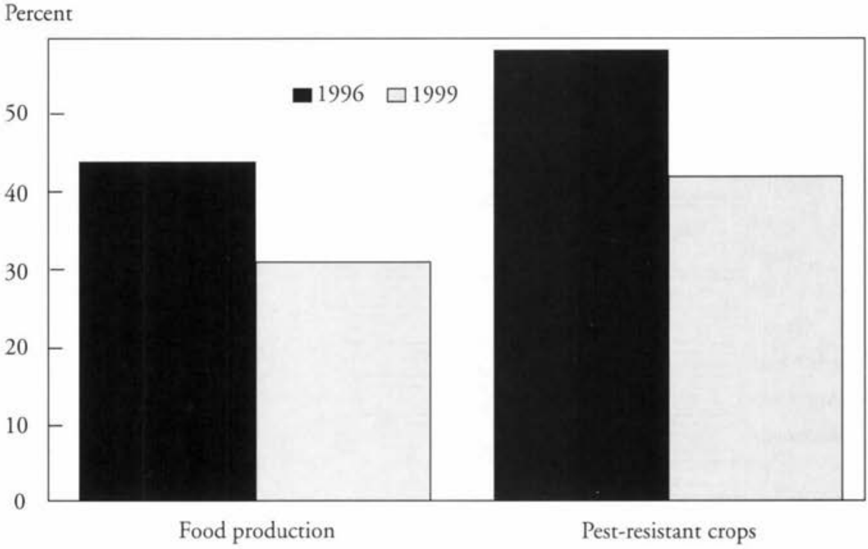
Source: Environics International, Ltd. (1998).

Do the Perspectives Differ as Expected?

The answer to the above question is generally "yes" but with some significant exceptions. For the most part, governments of low-income countries and individuals responsible for facilitating food security for people in those countries favor the use of modern biotechnology in food and agriculture. Public opinion surveys indicate that a larger share of the populations of some developing countries favor using biotechnology in food and agriculture than is the case for western European countries and Japan. However, in some high-income countries that rely heavily on agricultural exports for foreign exchange, such as Australia, Canada, and the United States, there is stronger support for the technology (Figure 3.3). Moreover, there is increasing opposition from various advocacy groups in a number of poorer countries, notably India and the Philippines.

While most developing-country governments seem to favor the use of modern biotechnology, including genetic engineering for food and agriculture, enthusiasm for the new technology differs significantly among countries. The Chinese government is eagerly promoting research based on molecular biology to develop GM food and other agricultural commodities, and it perhaps needs to strengthen its

Figure 3.4 European support for the application of biotechnology in the production of foods and development of crops with increased resistance to pests, 1996 and 1999

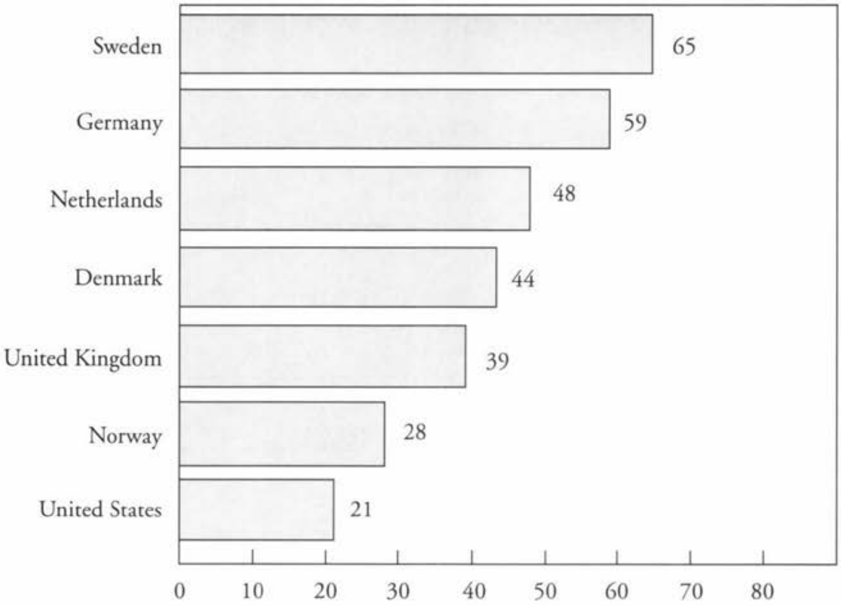


Source: European Commission (2000).

regulatory system. India has yet to approve its first GM seed for commercial planting, yet it has accepted food aid that is likely to be genetically modified. Large, middle-income developing countries such as Brazil, Egypt, India, and South Africa are promoting molecular biology-based agricultural research, but approval for commercial production is still very limited.

Views on using modern biotechnology for food and agriculture also differ among high-income countries. While most E.U. citizens oppose the production and consumption of GM food, such opposition is less prevalent in Australia, Canada, and the United States, perhaps because of the importance of export agriculture to their economies. A recent study by Gaskell et al. (1999) showed that about 40 percent of the E.U. population and 60 percent of the U.S. population support the use of biotechnology in food production. European support for applying modern biotechnology in food and agriculture deteriorated from 1996 to 1999 (Figure 3.4). The viewpoint expressed in Japan seems close to that of the Europeans, maybe because of Japan's substantial reliance on food and feed imports. A perceived health risk partly explains the opposition in Europe (Figure 3.5). However, the perceptions of risks and benefits are based on very limited knowledge of basic biology, as Figures 3.6 and 3.7 illustrate.

Figure 3.5 Percentage of sample population that perceives a serious health risk associated with consumption of GM foods, 1995



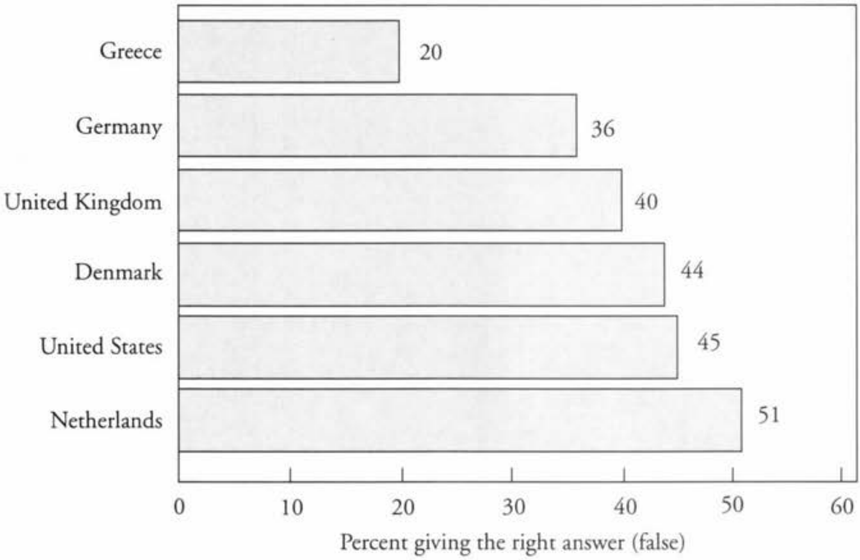
Source: Hoban (2000).

Why Does It Matter That Perspectives Differ?

Different perspectives leading to different policies and standards may conflict with current globalization trends. For globalization to continue in food and agriculture, certain policies and standards need to be synchronized. The biggest threat is that low-income countries will have to adopt policies and standards appropriate only for high-income country situations.

Opposition to the use of genetic engineering in food and agriculture by the rich countries may harm poor people in developing countries for at least three reasons. First, governments and high-income people in developing countries may follow the leads of the industrialized countries in accepting or rejecting the use of modern science for food and agriculture. A coalition is possible between those with decision-making power in developing countries, who are generally nonpoor, and governments and other decisionmakers in high-income countries. Such a coalition would behave much like a high-income country and might establish policies and standards that would harm the majority of the populations of developing countries, which are poor. This situation of course is not limited to the application of modern biotechnology. It can be argued that rich people in developing countries may have more in

Figure 3.6 Ordinary tomatoes do not contain genes, while genetically modified ones do: True or False?



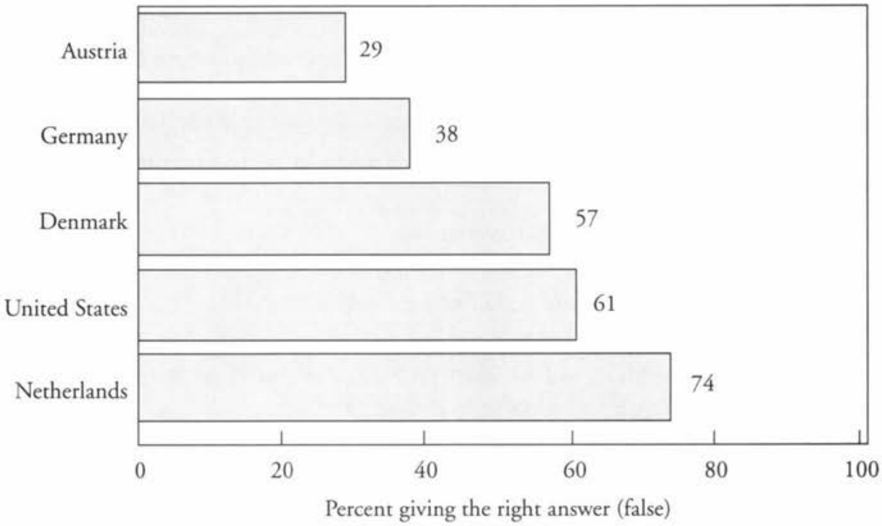
Source: Hoban (2000).

common with the populations of high-income countries than with poor people in their own countries.

Second, most developing countries will be unable to undertake agricultural research to develop the technology needed by their farmers and consumers without research collaboration and financial support from industrialized countries. If industrialized countries decide to limit their molecular biology-based research to solving the health problems of greatest concern to them, developing countries will not get the support they need to apply molecular biology-based research to food and agriculture. A few large developing countries including Brazil, China, India, and South Africa do have the capability to develop the necessary research capacity in food and agriculture; their efforts could provide some of the support needed by other developing countries.

Third, different standards among countries with respect to GM food are likely to hamper trade liberalization and agricultural exports from developing countries. This could be harmful to low-income people in developing nations because most of them depend on agricultural growth, which in turn, is likely to depend in part on expanded export earnings. Some developing countries that are considering the commercialization of GM crops have been warned by the E.U. that they may lose access to the European market not only for the commodities that have been genetically modified but possibly also for those that have not been modified.

Figure 3.7 By eating a genetically modified fruit, a person's genes can be changed: True or False?



Source: Hoban (2000).

Presumably, the reason for possibly not discriminating between GM commodities and others is that most countries would have great difficulty keeping the commodities separate. This was recently illustrated in the United States, where GM maize approved for animal feed but not for human consumption ended up in processed food sold for direct human consumption. The GM maize (Starlink®) was simply mixed with other maize either on the farm or in grain elevators. Even if developing countries agreed to label all GM food, the existence of GM food in a developing country could preclude that country from exporting labeled non-GM food to the E.U. This possibility has put pressure on governments of such countries as China and Thailand not to approve the use of GM seed for commercial production.

Developing countries that might wish to use genetic modification to improve agricultural productivity and the nutritional quality of their foods might be faced with a choice: either use genetic modification for the domestic market and lose export opportunities, or forego the potential benefits to domestic consumers while maintaining export opportunities.

The Importance of Productivity Increases in Developing-Country Agriculture

In low-income developing countries, agriculture is the driving force for broad-based economic growth and poverty alleviation. A healthy agricultural economy also offers farmers incentives to soundly manage natural resources. To facilitate agricultural and rural growth, accelerated public investment is needed in a number of areas:

- environmentally friendly, yield-increasing crop varieties, including pest-resistant and drought- and salt-tolerant varieties, and improved livestock;
- access to productive resources (such as land) and appropriate inputs and credit;
- extension services and technical assistance;
- improved rural infrastructure and effective markets;
- attention to the needs of women farmers, who grow much of the locally produced food in many developing countries; and
- primary education and health care, clean water, safe sanitation, and good nutrition for all.

These investments need to be supported by an enabling policy environment including good governance as well as trade, macroeconomic, and sectoral policies that do not discriminate against agriculture. Development efforts must engage small farmers and other low-income people as active participants, not passive recipients; unless the affected people have a sense of ownership, development schemes are not likely to succeed.

Public investment in agricultural research that can improve the productivity of small farmers in developing countries is especially important. The research should develop and draw upon the most appropriate technologies, including making better use of the insights to be gained from traditional indigenous knowledge. The private sector is unlikely to devote substantial resources to such work because it cannot expect sufficient returns to cover costs. Even minor increases in agricultural research aimed at the problems of small farmers in developing countries can significantly boost food supplies, while relatively small cuts can have serious negative effects. Benefits to society from such research generally exceed 20 percent per year, compared with long-run real interest rates of 3–5 percent for government borrowing. Yet these returns will not be obtained without public investment, and average annual growth rates of public agricultural research expenditures in the developing world have slowed since the 1970s (Alston et al. 2000; Alston, Pardey, and Smith 1999; Rosegrant, Agcaoili-Sombilla, and Perez 1995). Low-income developing countries invest less than 0.5 percent of the value of farm production in agricultural research, compared with 2 percent in higher-income countries (Pardey and Alston 1996).

Continued low productivity in agriculture contributes not only to gaps between food production and demand in poor countries, but also prevents the broad-based income growth and lower unit costs in food production needed to improve food security. Efforts to raise longer term productivity on small-scale farms, emphasizing staple food crops and high-value cash crops, must be accelerated.

Research and technology alone will not drive agricultural growth however. The full and beneficial effects of agricultural research and technological change will materialize only if government policies foster and support poverty alleviation and sustainable management of natural resources. Also, it is critical that small farmers are put in decisionmaking roles and that they are informed about their options for improving productivity, reducing risks, and increasing the well-being of the farm family.

The Role of Agricultural Biotechnology in Achieving Food Security

Although tissue culture and other biotechnological work is under way in several developing countries, very little transgenic seed material has been grown in the developing world. Only a few countries—Argentina, Brazil, China, Egypt, India, and South Africa—account for almost all the current developing-country research in agricultural biotechnology; therefore ex post assessment of its risks and benefits, and its relevance for the problems outlined above, is virtually impossible. Identifying similarities and differences between conventional breeding and modern biotechnology can help ex ante assessment of the latter's likely risks and benefits.

Comparing Conventional Breeding with Modern Biotechnology

Within-species versus transgenic breeding. Molecular biology-based research includes both within-species and between-species research. The former may include tissue culture and marker-assisted conventional breeding, while gene transfer between species is usually referred to as "genetic engineering" or "transgenic" work. Although the terms "modern biotechnology" and "genetic engineering" are often used interchangeably, the opposition, concerns, and uncertainties usually refer to the latter.

There are four major differences between conventional plant breeding and genetic engineering. First, the human-induced transfer of one or more genes between species and from microorganisms and animals to plants is relatively new. While all plant breeding arguably involves "genetic modification," conventional breeding crosses different varieties within a single species. Because of their recent origin, there is considerable debate about whether gene transfers across species boundaries entail significant risks to human health and the environment.

A shift to private-sector research. The public sector, with support from philanthropic institutions, has traditionally taken the lead in conventional crop research, especially in developing countries. As a direct consequence, improved seed was usually freely available for multiplication and distribution. In other instances, the improved material was subject to breeders' rights, which may permit a royalty charge. But even in these instances, intellectual property rights (IPR) often did not extend beyond the initial varietal release. Having acquired the seed, farmers could reuse it without further payment, although reuse of hybrid seed would drastically reduce the yield advantage. Such practices are in keeping with the principle of "farmers' rights" included in the International Undertaking on Plant Genetic Resources. Negotiations are currently under way to incorporate the Undertaking into the Convention on Biological Diversity.[1]

In contrast, private-sector firms undertake the bulk of modern agricultural biotechnology research. Consolidation has proceeded rapidly in the agricultural biotechnology industry, with more than 25 major acquisitions and alliances worth US$15 billion between 1996 and 1998 (Serageldin 1999). Transnational life science companies protect IPR through patents that extend beyond the first release of a variety that contains patented technologies. Thus, farmers cannot legally plant or sell for planting the crop produced with the patented seed without the permission of the patent holder. Patent holders are currently seeking to enforce IPR through legal agreements and technologies that will deactivate specific genes.

Use of legal instruments is widespread for industrialized country agriculture, but it does not presently appear viable for poor developing countries. Monitoring and enforcing contracts that prohibit large numbers of small farmers from using the crops they produce as seed would be expensive and difficult.

Genetic use-restriction technology (the "terminator" gene) is the first patented component of the technological approach to intellectual property (IP) protection. Seeds containing this gene produce plants with sterile seed. This technology is inappropriate for small farmers in developing countries, however, because existing infrastructure and production processes cannot keep fertile and infertile seeds apart. Small farmers could face dire consequences if they inadvertently planted infertile seeds. The Consultative Group on International Agricultural Research (CGIAR), which supports 16 Future Harvest international agricultural research centers, has officially rejected use of "any genetic system designed to prevent seed germination" (CGIAR 1998, 52) as a means of protecting IPR. In its October 1998 statement the CGIAR cited concerns about the spread of the trait through pollen, the possibility of the sale or exchange of nonviable seed for planting, the importance for poor farmers of saving seed, potential negative impacts on genetic diversity, and the importance of selection and breeding by farmers for sustainable agriculture.

Rise of proprietary research processes and technologies. A third and related distinction between conventional crop breeding and modern biotechnology relates to the patenting of processes as well as products. Most conventional breeding technology lies in the public domain and is frequently employed by public institutions. The processes used in modern agricultural biotechnology are increasingly subject to IP protection, along with the resulting products.

As the global agricultural research environment becomes increasingly proprietary, will public agencies be able to maintain free access to the fruits of their research for poor farmers in developing countries? Basic but proprietary knowledge and processes may be needed in research, for example, on the so-called "orphaned crops," such as cassava and millet. These are critical staples in the diets of many poor people, but they do not offer promising economic returns to private-sector research and development efforts. So the public sector will need to develop disease-resistant cassava or drought-tolerant millet, whether through genetic modification or conventional breeding.

So far, international agricultural research centers have acquired access to proprietary technologies through commercial licenses, formal agreements providing limited-use rights for specific research, and informal arrangements. Sometimes, technology owners have permitted research but not distribution of the resulting products.

Patent applications are country-specific, and most existing patents related to agricultural research are held in the industrialized countries (Nottenburg, Pardey, and Wright this volume). Thus, if a patent is not obtained in a particular developing country, that country's national agricultural research system (NARS) is free to use the research processes and traits in further research, adaptation, and commercialization. An international agricultural research center located in the country would have the same freedom to operate locally. Farmers in the country are free to use commercialized improved seed even though it may be patented in other countries. The country, however, may not be able to export commodities produced by such seeds to countries where patents are in effect. Private-sector corporations are likely to take out patents only in countries where they expect a sufficiently large commercial demand for the patented product. Similarly, since patenting is costly, holders of patents on specific aspects of a research process may limit their patent applications to a few countries where they can obtain significant economic gains by providing access to the patented processes.

Thus, while all members of the World Trade Organization (WTO) must develop acceptable IPR regimes, many of the poorest and smallest developing countries may not be greatly affected by the rapid increase in patenting of agricultural research processes and outputs simply because the patent holders will not take out patents in those countries. Furthermore, countries need not permit patenting of living organisms, other than microorganisms, to comply with WTO requirements. Less restrictive property rights regimes suffice. An implicit market segmentation is thus developing where research processes and traits patented elsewhere may be freely available in countries and for agricultural commodities of little interest to the private sector.

Where required, agreements should be reached between developing-country NARSs and the major private-sector patent holders. These would explicitly segment markets and make available the output of modern biotechnology for further research and adaptation to benefit poor farmers and consumers in developing countries. Appropriate technology would become public goods in the poor and unprofitable markets while remaining private goods in profitable markets. Future Harvest centers could help facilitate such agreements while continuing to collaborate with NARSs.

Some firms have agreed to transfer proprietary technologies without charging royalties to developing countries where there are few potential commercial prospects. Monsanto, for example, has agreed to place its map of the rice genome in the public domain. The company has also agreed to transfer virus resistance technology to public research institutes in Mexico and Kenya working on potatoes and sweet potatoes, respectively. But so far such arrangements are few and generally involve the philanthropic arms of the private firms (Serageldin 1999; Qaim 1999).

Adaptation versus direct transfer. A final difference involves the adaptation of developed-country agricultural research to developing-country conditions. Conventional breeding efforts that focused on solving specific problems in developing countries (such as low rice yields) adapted developed-country technology to local conditions. Most current applications of modern biotechnology focus on developed-country agriculture.

In 2000, 76 percent of the land planted to GM crops was in developed countries, with the United States alone accounting for 68 percent of global GM crop area. Australia, with 150,000 hectares of commercial GM crops, accounted for 0.3 percent of 2000's total area. Among developing countries, the bulk of the hectares planted to GM crops were in Argentina and China, although Mexico, South Africa, and Uruguay also had commercial plantings. The GM crop area in the developing world increased by more than 50 percent over 1999 levels. Developing countries other than China with commercial GM plantings have a substantial number of large-scale, capital-intensive farms and produce primarily for industrialized-country markets. Herbicide-tolerant cotton, maize, and soybeans and insect-resistant cotton and maize account for 94 percent of global GM plantings. Both the area planted to GM crops and the value of the harvests grew dramatically between 1995 and 2000, from under a million hectares to more than 44 million. The global market for transgenic seed grew from US$1 million to US$3 billion between 1995 and 1999 (James 2000a and 2000b).

To date, little private-sector agricultural biotechnology research has focused on developing-country food crops other than maize. Moreover, little adaptation of the research to developing-country crops and conditions has occurred through the not-for-profit, public-goods-oriented channels prominent in conventional breeding efforts in the developing countries. Except for limited work on rice, maize, and cassava, mostly done by Future Harvest centers, little biotechnology research focuses on the productivity and nutrition of poor people. The Rockefeller Foundation's agriculture program is one of the few examples. In 1998, it provided about US$7.4 million for biotechnology research relevant to developing countries, mainly through international agricultural research centers and developing-country NARSs, with a major emphasis on rice. This sum pales in comparison with the multibillion-dollar research and development budgets of the life sciences companies (Rockefeller Foundation 1999; Monsanto Company 1999).

As with conventional breeding, the challenge is to move from the scientific foundation established by research efforts oriented toward developed countries to research focused on the needs of poor farmers and consumers in developing countries. Direct transfer of much of the current crop of agricultural biotechnologies to the developing world is inappropriate. For example, poor farmers in developing countries may not be able to afford herbicides. More appropriate research for the developing world might focus on biotechnology and conventional breeding to develop alternative forms of weed resistance. The West African Rice Development Association (WARDA), a Future Harvest center based in Côte d'Ivoire, used a combination of conventional breeding and tissue culture to cross African and Asian rice varieties. This resulted in a hardy, leafy rice that denies weeds sunlight. In addition to improving yields, this reduces the time women must spend weeding, allowing them to devote more attention to the childcare practices that are essential for good nutrition (WARDA 1999).

Insect-resistant crops could have great potential value for poor farmers. So far, however, the development of crops containing genes from the *Bacillus thuringiensis* (*Bt*) bacterium, which produces a natural insecticide, has focused on the crops and cropping environments of North America and on production for developed-country markets. *Bt* crops currently available require knowledge-intensive cultivation[2] and have proved transferable to larger-scale operations in developing countries such as Argentina and Uruguay. Nonetheless, debate abounds about the risks associated with gene-derived pest resistance, such as harm to beneficial species and cross-pollination of wild and weedy relatives, but evidence is so far inconclusive.

Research on crops and problems of relevance to small farmers in developing countries, including biotechnology research, will require expanded adaptive research engaging public and philanthropic institutions, including international agricultural research centers. Additional public resources must be allocated to such efforts. Moreover, the public sector can encourage private-sector research for poor people by converting some of the social benefits to private gains. For example, the state could offer to buy exclusive rights to a newly developed technology and make it available either free or at a nominal charge to small farmers. As in developing technology for the market, the private research agency would bear the risks of failing to develop the technology or having some other research agency do it first. This arrangement is similar to that recently proposed by Harvard University economist Jeffrey Sachs for developing a malaria vaccine for use in Africa (*The Economist* 1999). There is no reason to believe that the social rates of return to agricultural biotechnology research would be less than those for conventional research.

Without investment in biotechnology research oriented to developing-country agriculture, continued expansion of GM crop production in the developed countries may well harm small farmers in the developing world, as imported GM grain and feed crops undercut local production. Some developing-country consumers would benefit, but those consumers who also farm (a very high percentage of consumers in the poorest countries) could experience net losses. Also, the development of GM substitutes for developing-country export crops, such as high-protein rapeseed oil as a substitute for palm oil, could have a devastating impact on the livelihoods of developing-country farmers.

Lessons from conventional breeding. Experience with conventional crop research offers some guideposts for assessing the likely risks and benefits of agricultural biotechnology for developing countries. Risks and benefits may be inherent in a given technology, or they may transcend the technology. The policy environment into which a technology is introduced is critical. For example, International Food Policy Research Institute (IFPRI) research found that in Tamil Nadu, India, adoption of high-yielding grain varieties meant not only increased yields and cheaper, and more abundant food for consumers, but also income gains for small and larger-scale farmers alike, as well as for nonfarm poor rural households. Increased rural incomes contributed to nutrition gains (Hazell and Ramasamy 1991). The benefits were widely shared because the Tamil Nadu state government has pursued active poverty alleviation strategies, including extensive social safety net programs and investment in agriculture, rural development, nutrition, and education, along with a fair measure of equity in access to resources such as land and credit. Where increased inequality followed the adoption of modern crop varieties, this was not because of factors inherent in the technology, but rather a result of policies that did not promote equitable access to resources and development of human capital. Even in these areas, landless rural laborers usually found new job opportunities as a result of increased agricultural productivity, particularly where appropriate physical infrastructure and markets developed.

On the other hand, successful adoption of modern crop varieties depended on access to water, fertilizer, and pesticides. Thus, inequality between well-endowed and resource-poor areas increased because of the properties of the technology itself. Likewise, excessive or improper use of chemical inputs led to adverse environmental impacts in some instances. To some extent, this problem was offset by other characteristics inherent in the technology; by allowing yield gains without expanding cultivated area, the technology kept cultivators from clearing forests and marginal lands.

Applications of agricultural biotechnology in developing countries could address some of these very issues if research focuses on how to reduce the need for inputs and increase the efficiency of input use. This could lead to the development of crops that utilize water more efficiently, fix nitrogen from the air, extract phosphate from the soil more effectively, and resist pests without the use of synthetic pesticides. Such efforts, if successful, would reduce dependence on pesticides, fertilizers, and other inputs, making the technology more readily available to poor farmers.

Introducing agricultural biotechnology into developing countries could help increase productivity, lower unit costs and prices for food, preserve forests and fragile land, reduce poverty, and improve nutrition. Whether it will do so depends on whether the research is relevant to poor people, on the economic and social policy environment, and on the nature of the IPR arrangements governing the technology.

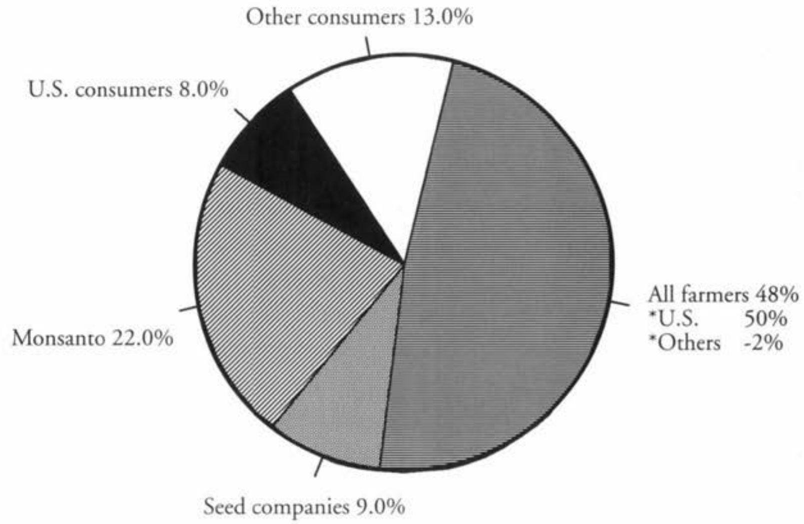
Weighing Risks and Benefits of Biotechnology in Developing Countries

The experience of the industrialized countries. In the industrialized countries, it is generally assumed that the economic benefits of GM crops accrue primarily to the life science companies that develop the new varieties and hold the patents, along with the seed companies that distribute them (increasingly, these firms are integrated as a consequence of mergers and acquisitions). While farmers stand to gain from reduced pest management costs and, in the case of herbicide-tolerant crops, greater efficiency of pesticide use, the potential yield gains may mean reduced prices. Consumers gain through lower prices. There are social and environmental benefits to reduced pesticide use, though these could be offset by potential environmental and health problems.[3]

As GM crops have been commercially available for only about six growing seasons, information is limited on their economic benefits and distribution. Some

Figure 3.8 Distribution of economic surplus generated by the use of Roundup Ready® soybean seed in the United States, 1997

(Total net economic surplus, US$360 million)



Source: Falck-Zepeda, Traxler, and Nelson (1999)

recent studies in the United States suggest that the reality may be more complex than conventional wisdom indicates. Falck-Zepeda, Traxler, and Nelson (2000) found that in 1996 U.S. farmers gained the largest share of the benefits from that year's *Bt* cotton crop (59 percent); while the gene developer, Monsanto, received 21 percent; consumers 13 percent; and the germplasm supplier, Delta and Pine Land Company, 5 percent. Falck-Zepeda, Traxler, and Nelson (1999) report that 1997 gains from herbicide-tolerant soybeans favored consumers even more (21 percent), while farmers gained fully half. Agribusiness's share was only 22 percent (Figure 3.8). Another soybean study confirms the global consumer gains and those of agribusiness, but suggests that the price-depressing effects of the yield gains may wipe out any benefits farmers could hope to achieve (Moschini, Lapan, and Sobolevsky 1999). A study of *Bt* maize found that the price premium placed on *Bt* seed was so high that the gains from efficiency and reduced pesticide use may not justify the costs unless farmers face a relatively high probability of European corn borer infestation and their yields are higher than average (Hyde et al. 1999). This literature suggests that, even under monopoly or oligopoly ownership of the technology, farmers and consumers may gain from the technologies and the benefits to consumers may be larger than assumed.

The potential benefits in developing countries. There are many potential benefits for poor people in developing countries. Biotechnology may help achieve the productivity gains needed to feed a growing global population, confer resistance to pests and diseases without costly purchased inputs, heighten the tolerance of crops to adverse weather and soil conditions, improve the nutritional value of some foods, and enhance the durability of products during harvesting or shipping. Bioengineered products may reduce reliance on pesticides, thereby reducing farmers' crop-protection costs and benefiting both the environment and public health. Biotechnology research could aid the development of drought-tolerant maize and insect-resistant cassava, helping small farmers and poor consumers. The development of cereal plants capable of capturing nitrogen from the air could contribute to plant nutrition, could also help small farmers, who often cannot afford fertilizers. Biotechnology may offer cost-effective solutions to the scourge of micronutrient malnutrition, which affects hundreds of millions of poor people in developing countries, through the development of vitamin A and iron-rich crops. For example, *Golden*Rice™, which is rich in beta carotene, a precursor of vitamin A, has been engineered in the laboratory but is not yet grown in farmers' fields. By raising productivity in food production, agricultural biotechnology could help to further reduce the need to cultivate new lands and to conserve biodiversity and protect fragile ecosystems.

Policies must expand and guide research and technology development to solve problems of importance to poor people. Research must focus on crops relevant to small farmers and poor consumers in developing countries, such as bananas, cassava, yams, sweet potatoes, rice, maize, wheat, and millet, along with livestock.

Food safety and biosafety. GM foods are not intrinsically good or bad for human health. Their health effect depends on their specific content. GM foods with higher iron content are likely to benefit iron-deficient consumers. But the transfer of genes from one species to another may also transfer characteristics that cause allergic reactions. Thus, GM foods need to be tested for allergen transfers before they are commercialized. Such testing prevented the commercialization of an allergenic soybean variety containing a Brazil nut gene. GM foods with possible allergy risks must be labeled. Testing for toxicity, digestivity, and the presence of known carcinogens is likewise needed.

Labeling may also be needed to identify content for cultural and religious reasons or simply because consumers want to know the contents of their food and the processes used to produce it so they can make informed choices. While the public sector must design and enforce standards, as well as labeling required to protect public health, other labeling might best be left to the private sector in accordance with consumer demands for information.

Failure to remove antibiotic-resistant marker genes used in research before a GM food is commercialized presents a potential although unproven health risk. Recent legislation in the E.U. requires that these genes be removed before a GM food is deemed safe (Levidow, Carr, and Wield 1999).

Risks and opportunities associated with GM foods should be integrated into the general food-safety regulations of a country. In addition, effective national biosafety regulations should be in place before modern biotechnology is introduced. Aid donors need to help developing countries build the capacity to monitor compliance and enforce these kinds of regulations. In 2000, with the successful negotiation of the Biosafety Protocol to the Convention on Biological Diversity, the international community took some modest steps toward supporting capacity-strengthening in developing countries. Minimal, globally accepted standards need to be put in place with respect to biosafety regimes. The development of a public global regulatory capacity has lagged far behind the pace of economic globalization (Juma and Gupta 1999; Cohen 2000).

The ecological risks that policymakers need to assess include the spread of traits such as herbicide resistance from genetically modified plants to unmodified plants (including weeds), the buildup of resistance in insect populations, unintended harm to nontarget species, and the potential threat to biodiversity posed by widespread monoculture of bioengineered crops. These risks are particularly significant in the centers of origin and diversity of major food crops, which are mainly in developing countries. Applications of technology that can switch specific genetic characteristics off and on offer great promise for the development of seed that will prevent the spread of new traits through cross-pollination. The seed would contain the desired traits, such as pest resistance or drought tolerance, but these would be activated through chemical treatment. Otherwise, the seed would maintain its normal characteristics. Thus, if a farmer planted improved seed, the offspring would not be sterile; rather it would revert to normal seed, without the improved traits. The farmer would have the choice of planting the seed and doing no more, or activating the improved traits by applying the chemical.

Both food-safety and biosafety regulations should reflect international agreements and a given society's acceptable risk levels, including the risks associated with not using biotechnology to achieve desired goals. Poor people should directly participate in debate and decisionmaking about technological change, the risks of that change, and the consequences of inaction or alternative actions.

Thorough testing is necessary to ensure the safety of new crop varieties developed through biotechnology. Questions about environmental safety and health risks must be addressed head-on. Testing of GM crops needs to increase in developing countries; at present, about 90 percent of the testing occurs in developed countries.

Anti-GM activists' destruction of test plots should also cease. Open debate is essential, but physical attacks on research and testing efforts contribute little to the free exchange of ideas or the formulation of policies that will advance food security. Moreover, without testing there can be no clear evidence concerning the safety of GM crops.

Socioeconomic risks. Unless developing countries have policies in place to ensure small farmers access to extension services, productive resources (such as land, water, and credit), markets, and infrastructure, there is considerable risk that agricultural biotechnology could lead to increased inequality of income and wealth, because larger farmers may capture most of the benefits through adoption of the technology, expanded production, and reduced unit costs (Leisinger 1999).

An ex ante assessment of Monsanto's transfer to Mexico of transgenic virus-resistance technology for potatoes examined some of the issues relating to social and economic benefits (Qaim 1999). It found that all classes of potato growers would likely benefit. Because small farmers have higher yield losses from viruses than larger producers, their yield gains and per-unit cost reductions are likely to exceed those of large farmers. This assessment thus found the technology to be biased toward small, rather than large farmers. This bias is reinforced by Monsanto's unwillingness to license the potato leaf roll virus-resistance technology for use with the potato variety that accounts for 69 percent of large farmers' plantings, because this variety is also grown in industrialized countries. Mexican seed distributors would be unlikely to charge a premium for the transgenic seed, which Monsanto transferred without charging royalties, given the competitive nature of the industry in Mexico. The study also found that a targeted government intervention to make transgenic red potatoes available to small and medium-sized farmers, comparable to the government seed distribution program for maize and bean seeds (*Alianza para el Campo*), would enable small farmers to capture 45 percent of the economic benefits from the cultivation of transgenic potatoes. Consumers would benefit from lower prices as a result of higher production. However, as Mexico reduces potato import barriers, the consumer gains are likely to decline (Qaim 1999).

Growing concentration among companies engaged in agricultural biotechnology research may lead to reduced competition, monopoly or oligopoly profits, exploitation of small farmers and consumers, and extraction of special favors from governments. Effective antitrust legislation and enforcement institutions are needed, particularly in small developing countries where one or only a few seed companies operate. As with biosafety, there is an urgent need for global standards regarding industrial concentration.

Finally, developing countries will need to enact and enforce IPR legislation in order to benefit from biotechnology. This legislation must harmonize protection of farmers' rights to access to germplasm and plant breeders' rights to benefit from their innovations.

Trade-related risks. The outcome of the new global agricultural trade negotiations, launched in Geneva in March 2000, could also affect developing countries' social and economic risks related to biotechnology. If the E.U.'s "precautionary principle" is accepted as the basis for new agreements on sanitary and phytosanitary standards and technical barriers to trade, then the E.U. could discriminate against any potential exporters of GM food or feed without scientific evidence of harm. At present, because it is private consumers and retailers who reject GM foods in Europe, the discrimination is not government trade policy and does not violate WTO rules. The Biosafety Protocol permits heightened scrutiny of GM imports, including labeling and segregation of GM and non-GM imports, but not outright bans.

Low-income developing countries that wish to use an agricultural export-led growth strategy will be forced to choose between adopting modern biotechnology in agriculture or maintaining the possibility of GM-free food export to the E.U. They could choose to differentiate and label GM foods and non-GM foods, and if they can manage such a system, they might be able to capture the benefits of modern agricultural biotechnology for domestic consumption while maintaining an export market for GM-free foods. Developing countries may also decide to label GM foods and GM-free foods in their domestic market to enable domestic consumers to choose. Because more productive agriculture is important for both urban and rural poor in low-income developing countries, it is hard to believe they would not utilize appropriate modern biotechnology in agriculture if biosafety regulations can be enacted and enforced.

A large share of the food imported by developing countries originates in the United States. These importing countries must therefore take a position not only on biosafety and food safety, but also on whether they wish to insist on product differentiation and labeling for imported food. Europe and Japan's rejection of GM crops may make such crops cheaper for Asian importers that are willing to purchase them (Anderson, this volume).

For Asian agricultural exporters, trade-related dilemmas are not hypothetical: The E.U. has warned Thailand that it will reject imports of Thai rice containing GM organisms (Petsiri 1999). This could undermine Thailand's rice biotechnology research, which is seeking to develop disease-resistant varieties among other things. In addition, Saudi Arabia has banned imports of Thai tuna because it is usually packed in soy oil, which may be made from GM beans from the United States. Fearing bans in other Middle Eastern countries, Europe, and Japan, Thai canneries have switched to sunflower oil (Paarlberg 2000a; Tanticharoen 2000; Petsiri 1999; Anonymous 2000).

Ethical issues. A major ethical concern is that genetic engineering and "life patents" accelerate the reduction of plants, animals, and microorganisms to mere commercial commodities, bereft of any sacred character, and that humans should not tinker with nature. This is far from a trivial consideration. However, all agricultural activities constitute human intervention in natural systems and processes. Continued human survival depends on precisely such interventions and is likewise a critical ethical concern. Condemning biotechnology for its potential risks without considering the alternative risks of prolonging the human misery caused by hunger, malnutrition, and child death is as unwise and unethical as blindly pursuing this technology without the necessary biosafety.

Modern biotechnology is not a silver bullet for achieving food security. But used in conjunction with traditional knowledge and conventional agricultural research methods, it may be a powerful tool in the fight against poverty. As such, it should be made available to poor farmers and consumers. It has the potential to enhance agricultural productivity in developing countries so as to reduce poverty, improve food security and nutrition, and promote sustainable use of natural resources. Solutions to the problems facing small farmers in developing countries will benefit both farmers and consumers.

The biggest risk of modern biotechnology for developing countries is that technological developments will bypass poor people. A form of what Ismail Serageldin, former chairperson of the CGIAR, calls "scientific apartheid" may well develop in which cutting-edge science is oriented exclusively toward industrialized countries and large-scale farming (Serageldin 1999, 387–89).

Issues for Future Action

To accommodate the different perspectives on modern biotechnology without excluding developing countries from making choices that they consider most appropriate, policy action is required on a number of fronts:

- Expand public investment in agricultural research, including molecular biology-based research where appropriate, aimed at achieving sustainable food security in developing countries.

- Build collaboration, support, and partnerships among NARSs in developing countries and between such national research systems and public- and private-sector research institutions in industrialized nations. The CGIAR could play a key role in facilitating such collaboration, support, and partnership while helping to undertake research of an international public goods nature.

- Strengthen national capabilities for testing GM foods and other agricultural commodities for health and environmental effects and for establishing effective biosafety and regulatory mechanisms.

- Develop IPR regimes in each developing country compatible with international agreements and national circumstances including the maintenance of farmers' rights to replant their own seed.

- Facilitate trade with developing countries irrespective of whether the countries choose to commercialize GM foods and nonfoods in their domestic production and consumption.

Additional efforts are needed to further inform the debate at all levels and in all countries. Such efforts should span the spectrum: from the generation and dissemination of results to the testing of new products and analyses of where modern biotechnology might help solve food, agriculture, and environmental problems and where alternatives are preferable. Education in basic biology with emphasis on improving understanding of the biological aspects related to genetic engineering is also urgently needed.

All parties, including private corporations and advocacy groups, should exercise responsible behavior. Scare campaigns and pressure on decisionmakers to shortcut testing of new products should be replaced by sound testing and evidence-based arguments, debates, and decisions.

Decisionmaking should be left to countries and individuals who are most likely to be affected by the decisions. Self-appointment of spokespersons and representatives of the poor and poor countries should cease, and low-income people and countries should be empowered to make their own choices on the basis of informed debate and their own estimates of risks and benefits.

Notes

1. The Undertaking was approved by the FAO Conference in 1983. The notion of farmers' rights includes the right to save, use, reuse, exchange, share, and market seeds. For more detail see Wright (1997) and various documents available at <http://www.fao.org>.

2. For example, licenses to use *Bt* maize in the United States require farmers to plant a "refuge" of non-*Bt* maize to slow the development of resistance to *Bt* in the targeted pests.

3. For some recent examples see Anonymous 1999; Knutson 1999; and Verzola 1999.

References

ABSF (African Biotechnology Stakeholders Forum). 1999. Re: Biotechnology and Kenya's socio-economic survival. ABSF, Nairobi, Kenya, September, 3. Occasional paper.

Adamu, H. 2000. We'll feed our people as we see fit. *The Washington Post* (September 11): A23.

Alston, J. M., C. Chan-Kang, M. C. Marra, P. G. Pardey, and TJ Wyatt. 2000. *A Meta-analysis of rates of return to agricultural R&D: Ex pede Herculem?* Research Report No. 113. Washington, D.C.: International Food Policy Research Institute.

Alston, J. M., P. G. Pardey, and V. H. Smith, eds. 1999. *Paying for agricultural productivity.* Baltimore: Johns Hopkins University Press.

Anonymous. 1999. Separate place for transgenic products in shop. *Dutch Agrarian Journal* (September 8). Posted to biotech_activists@iatp.org listserver.

———. 2000. Modified oil cited in tuna ban. *Bangkok Post* (March 25).

CGIAR (Consultative Group on International Agricultural Research). 1998. *Shaping the CGIAR's future: Summary of proceedings and decisions.* CGIAR International Centers Week, Washington, D.C., October 26-30, 1998. Washington, D.C.: CGIAR Secretariat.

Cohen, J. I. 2000. Harnessing biotechnology for the poor: Challenges ahead regarding biosafety and capacity building. Background paper prepared for the United Nations Development Programme (UNDP) *Human Development Report 2001*, October.

Environics International, Ltd. 1998. *The Environmental Monitor: 1998 International Report.* Toronto.

European Commission (EC). 2000. The Europeans and biotechnology. *Eurobarometer* 52 (1).

Falck-Zepeda, J. B., G. Traxler, and R. G. Nelson. 1999. Rent creation and distribution from biotechnology innovations: The case of *Bt* cotton and herbicide-tolerant soybeans. Paper presented at the NE-165 conference Transitions in Agbiotech: Economics of Strategy and Policy, Washington, D.C., June 24–25.

———. 2000. Surplus distribution from the introduction of a biotechnology innovation. *American Journal of Agricultural Economics* 82 (2): 360–370.

FAO (Food and Agriculture Organization of the United Nations). 1996. *Investment in agriculture: Evolution and prospects.* World Food Summit Technical Background Document No. 10. Rome.

———. 1998–2000. *State of Food and Agriculture 1998, 1999, and 2000.* Rome.

Gaskell, G., M. W. Bauer, J. Durant, and N. C. Allum. 1999. Worlds apart? The reception of genetically modified foods in Europe and the U.S. *Science* 285 (5426): 384–87.

Hazell, P., and C. Ramasamy, eds. 1991. *The Green Revolution reconsidered.* Baltimore: Johns Hopkins University Press.

Hoban, T. J. 2000. Public perceptions of transgenic plants. In *The handbook of transgenic plants.* New York: Marcel Dekker.

Hyde, J. M., A. Martin, P. V. Preckel, and C. R. Edwards. 1999. The economics of Bt corn: Valuing protection from the European corn borer. *Review of Agricultural Economics* 21 (2): 442–54.

James, C. 2000a. *The global status of commercialized transgenic crops: 1999.* International Service for the Acquisition of Agri-biorechnology Applications Brief 17. Irhaca, N.Y., U.S.A.

———. 2000b. *Preview—Global review of commercialized transgenic crops: 2000.* International Service for the Acquisition of Agri-biotech Applications Brief 21. Ithaca, N.Y., U.S.A.

Juma, C., and A. Gupta. 1999. *Safe use of biotechnology: Biotechnology for developing countries—problems and opportunities.* 2020 Vision Focus 2, Brief 6 of 10. Washington, D.C.: International Food Policy Research Institute.

Knutson, R. 1999. Look at *Bt* benefits with an open mind. *Des Moines Register*, September 14.

Leisinger, K. M. 1999. *Disentangling risk issues.* 2020 Vision Focus 2, Brief 5 of 10. Washington, D.C.: International Food Policy Research Institute.

Levidow, L., S. Carr, and D. Wield. 1999. *Safety of transgenic crops completing the internal market? A study of the implementation of EU Directive 90/220—EU level report.* Prepared under contract no. BI04CT97-2215, 1997-99, by the Centre for Technology Strategy, The Open University, Milton Keynes, U.K. (November).

Michel, J. H. 1999. *Development co-operation, 1998.* Paris: Organisation for Economic Co-operation and Development.

Monsanto Company. 1999. *Annual report 1998.* <http://www.monsanto.com/monsanto/investor/report/98/financialsection/income.html>. Accessed October 19, 1999.

Moschini, G., H. Lapan, and A. Sobolevsky. 1999. *Roundup Ready® soybeans and welfare effects in the soybean complex.* Department of Economics Staff Paper 324. Ames: Iowa State University (September).

Oxfam. 1999. Genetically modified crops, world trade, and food security. Oxfam GB Position Paper, November, 12–14. Oxford.

Paarlberg, R. L. 2000a. *Governing the GM crop revolution: Policy choices for developing countries.* 2020 Vision for Food, Agriculture, and the Environment Discussion Paper 33. Washington, D.C.: International Food Policy Research Institute.

———. 2000b. Genetically modified crops in developing countries: Promise or peril? *Environment* 42 (1): 19–27.

Pardey, P. G., and J. M. Alston. 1996. Revamping agricultural R&D. 2020 Brief 24. Washington, D.C.: International Food Policy Research Institute.

Petsiri, E. 1999. EU warns Thailand over gene-altered rice exports. *Reuters Business Briefings* (October 12).

Pinstrup-Andersen, P., and M. J. Cohen. 1998. Aid to developing-country agriculture: Investing in poverty reduction and new export opportunities. 2020 Vision Brief 56. Washington, D.C.: International Food Policy Research Institute.

Pinstrup-Andersen, P., M. Lundberg, and J. L. Garrett. 1995. Foreign assistance to agriculture: A win-win proposition. 2020 Vision Food Policy Report. Washington, D.C.: International Food Policy Research Institute.

Pinstrup-Andersen, P., and E. Schiøler. 2001. *Seeds of contention: World hunger and the global controversy over GM crops.* Baltimore: Johns Hopkins University Press.

Qaim, M. 1999. Potential benefits of agricultural biotechnology: An example from the Mexican potato sector. *Review of Agricultural Economics* 21 (2): 390–408.

Reddy, P. C. 2000. When western activism is midguided. Personal communication to Klaus von Grebmer, communications director, International Food Policy Research Institute (October 31). Washington, D.C.

Rockefeller Foundation. 1999. *Annual report 1998*. <http://www.rockfound.org>. Accessed October 19, 1999.

Rosegrant, M. W., M. Agcaoili-Sombilla, and N. D. Perez. 1995. Global food projections to 2020: Implications for investment. 2020 Vision for Food, Agriculture, and the Environment Discussion Paper 5. Washington, D.C.: International Food Policy Research Institute.

Serageldin, I. 1999. Biotechnology and food security in the 21st century. *Science* 285 (16 July): 387–89.

Tanticharoen, M. 2000. Thailand: Biotechnology for farm products and agro-industries. In G. J. Persley and M. M. Lantin eds. *Agricultural biotechnology and the poor*. Washington, D.C.: CGIAR.

The Economist. 1999. Sachs on development: Helping the world's poorest. August 14: 17–20.

Thomson, J. A. 2000. Developing countries can't wait and see. Available at <http://www.cid.harvard.edu/cidbiotech/comments/comments69.htm>. Accessed July 28, 2000.

Verzola, R. S. 1999. The genetic engineering debate. Posted to biotech_activists@iatp.org listserver (November 14).

WARDA (West African Rice Development Association). 1999. *The Spark that lit a flame: Participatory varietal selection*. Bouaké, Côte D'Ivoire.

Wright, B. D. 1997. Crop genetic resource policy: The role of *ex situ* genebanks. *Australian Journal of Agricultural and Resource Economics* 41 (1): 81–115.