BIOTECHNOLOGY: OPPORTUNITIES AND CHALLENGES FOR DEVELOPING COUNTRIES

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Q1 The developing world faces a triple challenge—poverty in the midst of plenty; environmental degradation caused by both plenty and poverty; and islands of security surrounded by conflict. All the three phenomena affect the food security and well being of nearly a billion people earning less than $1 a day. An overwhelming share of these people live in Africa and Asia, two continents that also bear a disproportionate share of the world's disease burden, particularly in terms of HIV-AIDS, malaria, and tuberculosis. Among the poor are some 125 million stunted and underweight children and over 10 million orphans.

Many of the world's poorest derive livelihoods from agriculture—broadly defined to include forestry, fisheries, and livestock—drawing on a natural resource base of limited productive value. The economies of the countries in which they reside depend on agricultural primary and commodity exports food imports. Recent events underscore the growing vulnerability of the poor in developing countries, especially in light of their continuing heavy dependence on agriculture.

Recent food shortages in Africa are being attributed to the rapid loss of agricultural labor, a direct result of a scourge of diseases. Export volumes have collapsed. Conflicts have decimated household seed supply for critical food crops in some countries; global climate change has adversely affected the low-lying countries among them. Under its best-case scenario, the Food and Agriculture Organization (FAO) predicts that 450 million people around the world will still be food-insecure in 2015.

Key Messages of this Paper

While by no means a panacea, biotechnology[1] offers tremendous potential to address a variety of these challenges. Early country-specific evidence shows favorable benefit—cost ratio of genetically modified (GM) crops from the perspective of small farmers, although some studies question this. Furthermore, although multinational corporations with GM technologies are concerned about weak intellectual property rights (IPR) protection and infringement in developing countries, these technologies are successfully being commercialized in developing countries.

This may explain the adoption of GM technologies by small farmers in developing countries although globally the share of GM crops planted by developing countries is less than 2% of the total cropped area. Moreover, wide experimentation with GM technologies is currently taking place within the public research systems of developing countries. The challenge for developing countries thus seems to be *how* to manage the risks associated with biotechnology, not *whether* to deploy it, particularly since biotechnological benefits would be mostly domestic—to their own producers and consumers. Yet due to the popular opinion against these technologies and the regulatory requirements prompted by these concerns, in the European Union and East Asia, the costs of environmental and other risk assessment are large—and they are mounting.

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[1] "Biotechnology" has been defined by the Office of the Technology Assessment (OTA) of the U.S. Congress as "any technique that uses living organisms or substances from those organisms, to make or modify a product to improve plants or animals, or to develop microorganisms for specific uses." It encompasses both "traditional biotechnology," which includes well-established technologies used in commercially useful operations such as biological control of pests, conventional breeding of plants, animal vaccine production, and cell and tissue culture techniques, as well as "modern biotechnology," which includes recently available tools for expediting selection and breeding ranging from the use of recombinant DNA, monoclonal antibodies, molecular markers, and transgenic techniques, to genetically engineered live organisms used to modify a variety of characteristics in host plants and animals such as productivity enhancement, growth cycles, and resistance to a variety of environmental or genetic stresses.

Fellows Panel.

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The limited, hesitant response of developing countries to the rapid promotion of biotechnology seems overwhelmingly determined by the considerations of trade policy, consumer preferences, and environmental risks articulated by the opponents of technology, primarily in OECD countries. From an ethical as well as developing country perspective, in an interconnected world, there is an urgent need for the global community to develop holistic, credible, independent, scientific standards and procedures for assessing the net socioeconomic and environmental impacts of biotechnologies, together with the necessary complementary global, regional, and national public policies, institutions, and investments. The Consultative Group on International Agricultural Research (CGIAR), with its large gene banks, 16 international centers spread around the world and track record of helping with food security of millions of the poor could possibly be positioned to perform some of the global functions.

Biotechnology is More Than GM Crops with Range of Applications

Tools based on the use of genomics, proteomics, combinatorial chemistry, and bioinformatics among others are making biological research processes far more efficient (Watson, p. 149). The new tools are already being applied in a variety of human and animal health-related issues—for example, to develop vaccines for AIDS and malaria, immunization for other commonly encountered diseases, and to improve diagnostic tools for tropical diseases, among others. The Bill and Melinda Gates Foundation, the World Bank, and bilateral donors have provided several million dollars for such research (Govindaraj and Sarna). Biotechnology is helping the developing countries and the CGIAR centers in germplasm enhancement including gene identification and characterization, marker assisted selection, DNA sequencing and finger printing, transformation for herbicide and drought resistance, enhancement of nutritional quality, and control of animal diseases (Lele et al., p. 44). Animal disease control in developing countries has far reaching global health implications. Foot and mouth disease alone causes losses estimated at $12 billion. An estimated 50% of organisms are naturally transmitted from livestock and wild species to humans. The recent rapid DNA sequencing of the SARS virus demonstrated the high return to the new biological tools. SARS caused damage of well over $30 billion to China and East Asian economies.

Country Specific Evidence of Agricultural Biotechnology Benefits and Costs to Developing Countries

The benefits from agricultural biotechnology accrue to the scientists from the precision, and reduced costs of research as well as to society from the production, productivity, improved quality of life, improved incomes, reduced consumer prices and related benefits of a wide variety of biotechnology products (Watson). Credible empirical evidence is emerging from the studies of the early trials and/or adoption of Bt cotton in China (Pray et al., pp. 423–430), India (Quim and Zilberman, pp. 900–902), Mexico (Traxler et al.) and Bt maize in South Africa (Ismael, Bennet, and Morse) that suggests more stable and/or higher yields in selected locales compared to conventional varieties under comparable circumstances. The new GM technology (in the form of seed and related inputs) is highly divisible and per unit of output farm production costs are reported to be low due to the reduced use of pesticides and labor. Using these studies Traxler estimated positive incremental profits per hectare in Bt cotton production relative to conventional varieties across countries although with substantial variation in the level of profits among countries. Less visible but important benefits reported by Pray et al. in China include improved human health and well being as a result of the reduced application of chemical inputs and less use of labor. They report well over 4 million farmers had planted GM cotton in the Yellow River Delta by 2001 with substantial increase in cotton production.

Although some dispute the claims of some studies (e.g., *GENET*'s Sahai 2002) regarding benefits of Bt cotton in India, incremental profits may explain small farmer interest in adopting the new technology. Area under transgenic crops is growing more rapidly in developing than developed countries, albeit from a smaller base (James, p. 8). Six developing countries had over 25% of the global share of 150 odd million hectares of transgenic crops in 2002. China leads, but India, with the largest acreage of cotton, and Mexico, the cradle of biodiversity in maize, are following in the case of cotton, along with Indonesia, South

Africa, and Kenya in other crops. From their Next Harvest Study of public GM crops, Luijben and Cohen report 52 crops under transformation and field testing events in 16 transition and developing economies, more than twice the number of the crops covered by the CGIAR (Luijben and Cohen). Crops entering international trade—soybeans, maize, cotton, and canola—dominate, but "orphan crops" grown by the poor are beginning to attract attention.

Favorable Economics of Transfer of GM Crop Varieties May Explain Their Spread to Developing Countries

A rare early comparative study of biotechnology in an entire system of genetic improvement chain from technology development to adoption and bringing in developed and developing countries' perspective, draws on the studies of Pray and others in China, Mexico, and the United States (Traxler). It suggests farmer share in total benefits as high as 88% and 86% from GM crops in developing countries like China and Mexico, respectively, compared to the farmer share of 45% in the U.S. cotton industry. Traxler argues that although the high cost of basic research on biotechnology is confined to a handful of multinational companies, the process of plant breeding using the particular genes is relatively low cost and can be afforded by most developing countries (Traxler). Technology transfer takes place through licensing. Absence of enforcement of IPRs benefits farmers and maximizes the production of GM crops, Giannakas argues that zero enforcement is an optimal strategy for developing country governments wishing to maximize adoption and maintain competitiveness of their producers *vis-à-vis* producers in competing countries. Multinational private companies, nevertheless, are conducting most of the trials in developing countries. Excluding China during the 1991–99 period, as many as 630 trials were undertaken by multinational companies compared to 87 by the developing country private sector and 97 by the developing country public sector (Traxler). But this proportion may be changing rapidly. The number of commercial seed companies in developing countries, virtually absent around the time of the green revolution in the 1970s is growing. Furthermore, many multinational corporations have acquired seed companies in developing countries.

Perhaps the best indicator of farmer profitability may be the reported incidences of "reverse biopiracy," for example in Argentina, Southern Brazil, China, and India. This means developing-country farmers are acquiring GM seeds illegally, much as the developed countries are alleged to acquire plant genetic material from developing countries illegally. Farmers are reported to either plant or cross breed the GM material with their local varieties for planting.

Control of Intellectual Property and Private Sector Role

Pardey and Beintema reported global private sector agricultural research investments in the developed countries of $10.8 billion in 1995 compared to $0.7 billion in developing countries. Well over 70% of developed country private sector research was on genomics with 80% of the intellectual property emanating from it. Although multinational acquisitions of private sector companies in developing countries has increased considerably, private sector *research* by multinationals in developing countries has perhaps not increased to the same extent, most of the investments being for the "Development" aspect of the Research and Development (R&D) chain.

This raises a number of issues for developing countries. First, despite a handful of multinationals controlling intellectual property, fragmented ownership of intellectual property is a huge problem. The example of 40 to 70 IPRs needing negotiations in the case of golden rice is often cited (Lele et al.; Nottenberg, Pardey, and Wright). There are the related issues of asymmetric information on patents, the high transaction costs of negotiations, the highly variable and confused regulatory environment for IPRs among countries, the reduced freedom to operate and generally higher than necessary costs of conversion of research into commercial products (Pardey and Wright, Q3 Cohen and Paarlberg, Graff and Zilberman). These interrelated phenomena are leading some analysts of the evolving IPR situation to describe the growing phenomenon of IPRs as the "global anti-commons" (Commission on International Property Rights). It is also leading to the emergence of new innovative approaches to establish clearing houses and information networks.

From a more dynamic perspective, however, there are also the questions as to what extent multinational companies would carry out

the necessary research in the developing countries to address the inevitable emerging issues of resistance to local insects and pests to the current GM varieties. This will depend in part on the protection of IPRs. Concurrently, investment in biotechnology by the public sectors of large developing countries such as China, India, and Brazil is growing. However, information on these public sector investments and the nature of their interaction with the private sector is still incomplete. Moreover, even large developing countries cannot match the resources of multinational companies. And all acknowledge that small and/or low income developing countries, especially in Africa, do not have the capacity to invest in biotechnology research and particularly to support research on crops with limited market prospects (and therefore of limited interest to multinational corporations) but of substantial interest to poor farmers with low risk tolerance. Hence the importance of public sector investment at the global level through such entities as the CGIAR, as well as of South–South cooperation, both issues are discussed in the recently conducted meta evaluation of the CGIAR in the World Bank's Operations Evaluation Department (Lele et al.).

Environmental, Ethical, and Moral Debates

The huge debates prompted by biotechnology fall into three categories. First, those related to human health from such things as allergens and toxins; second, environmental impacts from gene escape and altering the balance in living organisms; and third, ethical questions related to where boundaries begin and end in such things as stem cell research, cloning, or the insertion of genes from one form of living organisms to another. Only some of these issues are resolvable through increased research, testing, and assessment. Although costly, particularly from the perspective of resource-strapped developing countries, such research and the labeling of biotechnology products will have to grow in response to the EU requirements and guidelines for labeling. Other concerns emanate from value systems and have no solutions in research and information. Only the researchable issues are discussed here.

Ecosystem changes prompted by the new technologies could be a researchable issue although they too are grounded in value systems. Land use changes prompted even from traditional plant breeding have tended to be complex and highly controversial depending on the precise nature of technical change and factor endowments. For instance, at the ecosystem level, the green revolution in the land short labor surplus India saved millions of hectares of land and diversified land use but at the farming system level increased mono cropping of wheat and rice. In contrast, improved soybean production in Brazil's land surplus labor-short Amazon region resulted in increased land clearing for soybean production (Angelsen and Kaimowitz, pp. 73–78). Proponents argue that genetic engineering permits a more diversified cropping patterns. Yet it does pose the risk of gene escape.

Hence in 1998, at considerable economic sacrifice, which the country can ill afford, the Government of Mexico, the center of mega maize biodiversity, declared a moratorium on planting transgenic maize anywhere in the country. This was notwithstanding active maize trade under NAFTA with the United States, a producer of transgenic corn. But the controversy surrounding the alleged discovery of transgenic DNA in traditional varieties of maize grown in the remote highlands of Oaxaca region in Mexico has already involved prestigious scientific establishments such as the University of California, Berkley scientists, the Nature magazine, multinational corporations involved in GM crops, and NGOs (Mann, 1617–18). The controversy goes to show the high stakes, the high costs, as well as the fundamental importance of urgently putting in place credible, *independent* scientific assessments and broadly accepted procedures. The need for such international standards and procedures is particularly high, although costly in terms of time, resources, and expertise, from the perspective of developing countries because the claims also touched CGIAR's Centro International de Mejorameinto de Maiz y Trigo (CIMMYT) but turned out to be without foundation. These claims potentially jeopardize food security not simply of the poor in Mexico but of those other developing countries that rely on the CGIAR maize germplasm to increase maize productivity in their countries.

Internationally, these controversies have resulted in the adoption of four ethical pillars—(*a*) do good, (*b*) do no harm, (*c*) offer the right to choose, and (*d*) respect the ethical values of others. But these concepts are by no means easy or cheap to implement in practice. The World Bank's safeguard policies now cover environmental assessment, natural habitats,

pest management, indigenous people, forestry, dam safety, cultural property, involuntary resettlement, international waters, and disputed areas. The "do no harm" safeguards, among other reasons—result in risk avoidance behavior among World Bank staff and managers, leading to fewer World Bank investments in water, forests, marginal areas, pesticides, and research. Overall agricultural lending to developing countries has declined precipitously since the early 1990s and currently only $50 million of the Bank's agricultural loans go to biotechnology (Lele et al.).

GM Crops, Food Aid, and Trade

Developed countries dominate global markets. Asia and Africa are already substantial food importers and their imports are projected to increase. Whereas overall international trade has become more open, agricultural trade is highly managed. Overall OECD agricultural trade policies, costing well over $350 billion annually, lower world market prices, and cause lower agricultural exports, higher food imports, higher poverty rates and increased debt for developing countries (Nogues; Gardner).The subsidies are also regressive in terms of income distribution both within and across countries. In the case of cotton, the mainstay of several poor countries in West Africa, 25,000 large U.S. cotton producers received $3.6 billion of agricultural subsidies in 2001, with price declines in Benin alone leading 250,000 cotton-dependent people to fall below the poverty line (Watkins, pp. 10–12). Tariffs imposed by industrial countries on processed agricultural commodities from developing countries are several times higher than tariffs on nonprocessed commodities. Thus the future import dependence of developing countries depends not only on how well they manage their domestic policies and natural resources and embrace technical change to remain internationally competitive but on the agricultural policies of OECD countries.

Yet adding to their troubles, precautionary country by country biosafety standards of OECD countries with regard to GM crops are complicating their decisions on the adoption of biotechnology and market access (Cohen and Paarlberg). The GM debate, for example, has opened up a huge non-GMO market for Brazilian soybeans in Europe and Japan, but without a price premium for non-GMO soybeans. The GM debate has also reduced incentives for food-deficit Zambia to import food aid supplied GM maize, because Zambia fears it could close access to the European markets when maize surpluses do emerge in Zambia. This is even though the FAO world food summit in 2002 endorsed the promotion of GM crops and WHO declared no evidence of health hazards from GM maize.

Biotechnology, the CGIAR and International Public Goods in Agricultural Research

It is clear from the preceding discussion that how OECD countries address their consumer preferences, perceive environmental risks, put in place national environmental assessments which are domestically credible to their populations as well as meeting WTO standards and procedures with regard to biosafety, will profoundly affect market access of developing countries through environmental and food safety standards. It will also determine the investment climate for agricultural research and development in developing countries.

From this perspective the CGIAR's annual expenditures of $365 million in 2002 dwarf before the OECD annual subsidies of $362 billion. CGIAR funding has declined in real terms over the 1994–2002 period and the share of restricted funding has increased from 36% earlier to 57% in 2002. The CGIAR's productivity enhancing germplasm enhancement research, which fueled the green revolution and lifted millions out of poverty and hunger, has declined at 6.5% annually during this same period due to unpopularity of even the conventional germ plasm improvement research in the constituencies of some OECD donor countries. The CGIAR spends only $25 million annually on biotechnology compared to well over $10 billion by the private sector. Its center by center approach to research is fragmented and lacks a critical minimum mass of scientists or equipment. It also lacks a *system level* policy, strategy, or capacity for biotechnology and IPRs or public–private partnerships. And CGIAR's environmental research is not sufficiently focused on its plant science research at a time when environmental consequences of biotechnology research are attracting worldwide attention.

Biotechnology is Running Ahead of Capacity and Institutional Development

The increased scrutiny of biotechnology requires routine, objective, credible, long term

independent international assessment system in place regarding the potential environmental and socioeconomic impacts of new technologies and their adherence to biosafety and trade rules. Developing countries need the capacity to deal with the environmental concerns, strategies to deal with the rapid growth of the private sector and intellectual property, an ability to mobilize the best practices in these areas, to address the rising and complex trade issues and to deal with the vocal NGOs and the civil society. Currently there is a huge gap between the R&D capacity in developed and developing countries, with nearly 10 times as many scientists per capita in industrial countries as in developing countries. Global collective action is needed to take advantage of the communications and information technologies, exploit economies of scale in the organization of institutional solutions, reduce search and transaction costs for developing countries, harmonize standards of bio and food safety, bridge the scientific, human, and informational gap, and establish the confidence of the consumers and civil society through clearly defined international standards and norms.

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Queries

Q1 Author: The article does not require a heading at the beginning as per style. Please check.

Q2 Author: Sahai (2002) is not included in the reference list. Please check.

Q3 Author: Pardey and Wright is not included in the reference list. Please check.

Q4 Author: Sahai (2003) is not cited in the text. Please check.