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A Role for Technology In 21st-Century Agriculture

Globalization—in the form of expanded trade, investment, and economic integration—could expand market opportunities for both developed and developing economies. Technological advances can be spread around the world, with the potential to enhance agricultural productivity, incomes, and the quality of life in all countries. However, some regions of the world have gained little from the discoveries and innovations made in agriculture and from global agricultural markets. This is partly because private research investment tends to be directed toward meeting the market demands of developed-country consumers rather than the needs of less developed countries.

At recent meetings attended by the leaders of the major industrial countries, a commitment was made to increase the possibilities for less developed countries to participate in the global economy. One way that the agricultural community and public sector could contribute to this effort is to strengthen the technological infrastructure in developing countries and facilitate the transfer of technologies appropriate to developing countries' needs.

R&D Increases Productivity In the Developed World

New technologies and innovative practices have been key factors in the economic development of high-income countries. Investment in agricultural research and development (R&D) by both the private and public sectors in the U.S. has resulted in a high level of productivity. Recent breakthroughs in information technology and life sciences have expanded opportunities to increase production efficiency and to provide consumers with the products they demand.

U.S. agricultural productivity, measured as the ratio of output to inputs, has increased two-and-one-half times since 1948. Canada and many European countries also have seen high rates of agricultural productivity growth over this period–averaging nearly 2 percent per year. The production of more agricultural goods using fewer inputs frees resources to be invested in other parts of a country's economy, thus increasing affluence. In the U.S., less than 10 percent of disposable income is spent on food, and this share includes the purchase of high-quality and convenience attributes that consumers now demand. In many developing economies, more than 50 percent of disposable income goes toward providing food.

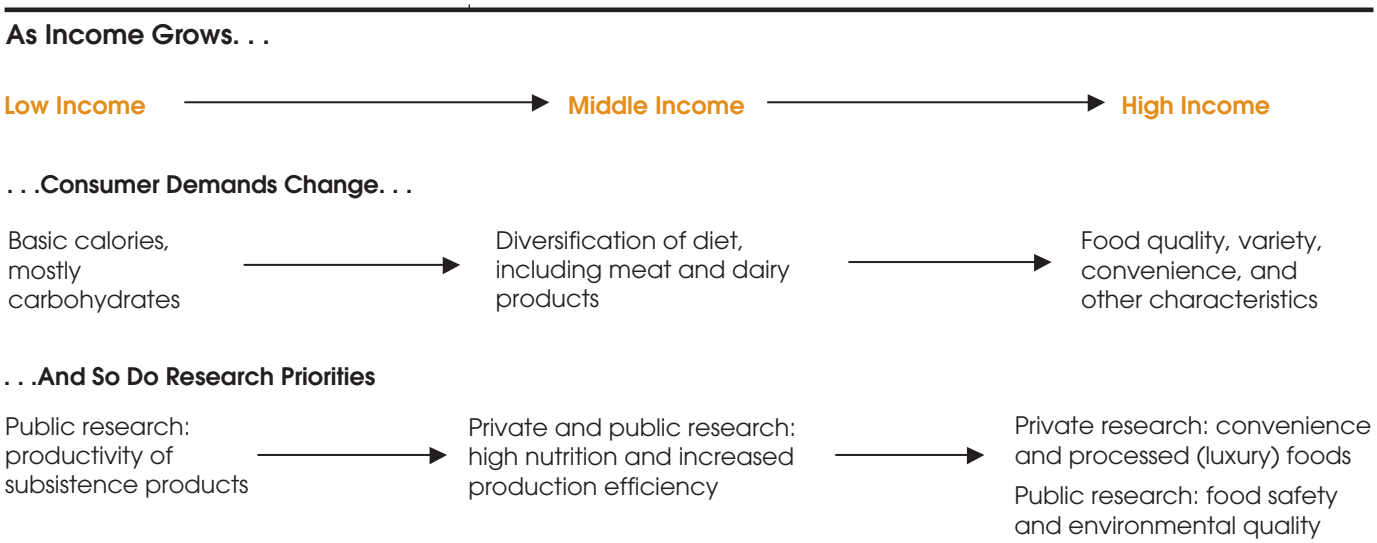
The development of new machines, chemicals, and biological improvements was the result of substantial investment in R&D. Both public and private investment in U.S. agricultural R&D has grown over the last four decades, contributing to productivity growth. Private investment, however, has grown faster and now surpasses the R&D expenditures of the public sector. The public and private sectors often have different investment objectives. In general, public research has supported the development of basic scientific knowledge and applications that are beneficial to the general public, while private R&D has tended to focus on marketable applications.

The focus of technology development in agriculture in the last half of the 20th century was to increase production efficiency on the farm. These changes were driven by innovations in machinery, pesticides, fertilizers, information technologies, and plant breeding. While this was a supply-driven focus, consumers also benefited from increased production of basic commodities at low prices.

Increased efficiency altered the structure of U.S. agriculture. As agricultural productivity increased by a factor of two-and-one-half, the total number of U.S. farms decreased by nearly two-thirds since the 1940s. Fewer farms are now involved in agriculture, but the total amount of land being farmed has changed little since the 1940s, and the average farm size has grown from under 200 acres to almost 500 acres.

The Promise of New Technologies

Developments in the biological sciences have always been major contributors to agricultural productivity. Innovations in plant breeding after World War II produced the "Green Revolution" in many parts of the world. At the end of the 20th century, breakthroughs in molecular biology led to the development of crops that are disease- and pest-resistant or herbicide-tolerant. Current farm-level biotechnology research is focused on developing crops that will tolerate a wider range of drought, acidity, salinity, heat,



and flooding. These crop characteristics could contribute to productivity increases in resource-poor countries.

In addition, biotechnology research is responding to consumer demand for more nutritious food with improved post-harvest quality. Transgenic plants and animals are being developed as sources of edible vaccines, medicines, and vitamins. Biotechnology techniques are also being used to develop sources of biomass to substitute for fossil fuels; biopolymers and enzymes for industrial uses; and bioremediation to remove toxic substances from the environment.

At the end of the 20th century, innovations in many nonagricultural fields contributed to new technologies in agriculture. For example, satellite technology, computers, and robotics allow a farmer to manage the use of pesticides, fertilizers, and water more efficiently by tailoring input amounts to the specific characteristics of the site. The use of these precision farming technologies may reduce both input costs to the farmer and chemical runoff to the environment.

Many have described the beginning of the 21st century as the "information age." Precision farming and biotechnology resulted from the increased ability to analyze information. Innovations in computing capabilities and low-cost access to computers have dramatically enhanced the ability to store and analyze data. In addition, today's communication networks have facilitated the rapid exchange of information. Firms can assess consumer demands throughout the world, farmers can produce value-added crops for specific markets, and scientists can collaborate with researchers around the world in data gathering and analysis.

A World of Difference In Trade Opportunities

In May 2001, Neal Lane, former director of the National Science Foundation and former director of the White House Office of Science and Technology Policy, expressed optimism about the value of new biological and information technologies. "The swift globalization of knowledge," he noted, "has created a web with the potential to draw nations and cultures together and to share benefits in a more equitable manner." Global trade, Lane said, has the potential to benefit all nations (making the pie bigger), but he cautioned that not all countries had the capacity to take advantage of these promising developments.

With continued technology-induced productivity growth will come opportunities to develop new markets for agricultural products throughout the world. Export revenues accounted for 20-30 percent of U.S. farm income over the last 30 years. But expanding demand for agricultural products will depend on the income and agricultural productivity of the importing countries. Despite optimistic predictions about the benefits of globalization, there are still major differences in incomes and opportunities between countries.

In developed economies, where incomes are relatively high, consumers demand high-quality and varied agricultural products. They demand value-added processed products that offer convenience, enhanced nutritional characteristics, and assurances of food safety. Further, they increasingly are concerned with the potential environmental impacts of agricultural production systems.

In middle-income countries (e.g., Poland, Mexico, and South Africa), the basic calorie needs have been met for the majority of the population. Consumers demand a wider range of agricultural commodities and sources of protein, but import demands are primarily for basic agricultural commodities and meats rather than for value-added processed products.

Developing countries offer the largest potential for expanding global markets, but major obstacles remain before incomes in these areas are sufficient to increase participation in international trade. Many of these countries have neither the income nor the productive capacity to consistently meet the basic nutritional needs of the population. Agricultural output makes up a large share of the national economy in many less developed countries. Per capita income is quite low in some of these regions, and there are wide gaps in income between and within

Expenditures for Research and Development Differ Among Regions

* Negligible
Source: World Bank.
Economic Research Service, USDA

regions. These countries currently offer little opportunity for profitable trade.

Meeting Consumer Demand: The Role of Technology

Consumer demands depend in part on income level, and public and private research priorities change to meet those demands. To supply the products demanded in high-income countries, the private sector invests in research to develop value-added products that can be profitably traded. Public-sector agricultural research can develop technologies and practices used to ensure food safety and to lessen potential environmental impacts of production. If consumer demand is strong for products that meet food safety or environmental quality criteria, the private sector can provide these products profitably as well.

To meet demands in middle-income countries, both public and private agricultural research programs focus on providing increased quantities of affordable sources of nutrition. There is less demand for value-added and processed products than in high-income countries.

In less-developed countries, demand for imported products is low. R&D efforts within many of these countries are not sufficient to substantially increase agricultural productivity, and opportunities for profitable private research investment are limited. The success of public research depends on financial resources and educational levels (human capital), as well as natural resource endowments, adequate infrastructure, and political stability among many factors. Due to constraints on many of these factors, less developed countries often do not have the strong public research capacity needed to develop technologies suited for their needs.

The need for increased productivity growth is great in many developing countries. Population growth rates in lower income countries are generally higher than in developed regions. If current trends continue, the world's population is expected to increase by 737 million persons by 2011, and most of the growth will be in developing countries. Unfortunately, crop yields are often substantially lower in these developing regions. Even though world food production has been increasing faster than population growth (*AO* June-July 2002), many people are undernourished in less developed regions. In Sub-Saharan Africa, 43 percent of the population is chronically undernourished, consuming less than the minimum recommended nutritional requirements. However, the greatest numbers of undernourished people live in Asia.

With high population and low productivity levels, many low-income countries are not able to produce enough food domestically to meet basic nutrition needs. Nor do they have adequate income to import enough to eliminate these food gaps. Agricultural productivity in developing countries must grow more rapidly than it has in the past decade, both to increase domestic food production and to raise incomes—which, in turn, will lead to increased agricultural trade. Development and adoption of new technologies will be necessary to improve both food availability and access to food. The projected yield growth that would be needed to achieve food security is highest in Sub-Saharan Africa.

Most low-income countries do not have large financial resources to invest in the training of scientists, maintenance of research facilities, or many other components of a strong agricultural R&D program. Asian countries have been able to invest more than most countries in Africa, but the average level of expenditure in Asia is still below the world average. Since internal investment may not be adequate, there is a need to transfer technologies from developed to less developed countries to increase agricultural productivity and income. But technology transfer entails more than just shipping machines, seeds, or blueprints. Often, existing innovations developed for one region are not suitable to the unique circumstances that exist elsewhere.

Removing Barriers to Technology Transfer

Problems can arise in transferring agricultural technologies, methods, and ideas between developed and less developed countries. While each situation is different, three barriers often have been encountered within developing countries:

- lack of investment incentives;
- weak or nonexistent intellectual property rights; and

• insufficient research capacity.

Within a developing country, financial resources and incentives for private research investment may be lacking. In order for a company to develop improved agricultural inputs or enhanced outputs, there must be a large and growing demand for its products. To ensure strong demand, farmers must have access to financial resources to purchase inputs, and the country's infrastructure must support the deliveries of inputs and crops in a timely fashion. Increases in on-farm efficiencies have little benefit if the product cannot reach the market. Lack of roads, transportation and communication networks, or storage facilities can impede effective productivity growth.

Legal, political, and financial institutions must also support market development. Private investment from foreign sources will not be forthcoming without a strong demand by farmers and a well-functioning infrastructure. Direct financial aid may be needed in some cases to improve the infrastructure and institutions that currently act as barriers to internal and foreign private investment.

Inconsistencies in intellectual property rights (IPR) protection between countries have also been a barrier to technology transfer. IPRs for agricultural innovations generally are granted in several ways: patents, copyrights, and Plant Variety Protection Certificates. These rights encourage private investment in R&D by giving firms a way to retain a greater share of research benefits than if the rights were not protected. IPRs can offer substantial incentives for development of technologies to increase agricultural productivity.

However, strong IPRs held outside the less developed country may inhibit the flow of new knowledge. Many in less developed countries have expressed concerns that firms in developed countries control so many intellectual property rights that innovations targeted for agricultural development may be impeded. The strength of IPRs also can affect incentives for investment by public research sectors in developed countries. In multilateral trading agreements, the U.S. has stressed the need for more consistent IPR protection between developed and developing countries. To overcome the concern that access to innovations will be impeded, international public and private partnerships that share, pool, or license rights could offer incentives for research while encouraging innovation that serves the public good. Strong IPRs in developing countries could then help these countries gain access to needed technology from the private sector.

The third barrier to technology transfer is the lack of a strong technology research capacity within many developing countries. Development of new technologies and practices is a complex process. Each innovation must be adapted to the specific characteristics of an application. Geographic, climatic, and cultural factors differ substantially between countries, so technologies can seldom be directly transferred without adaptation. Local scientific expertise is needed to take advantage of the knowledge found throughout the world, and to establish environmental and food safety safeguards to ensure that both the positive and negative potential impacts of a new technology are adequately assessed.

Basic research findings made in one application spill over and can be used to enhance productivity in both developed and developing agricultural economies. Site-specific adaptations are often required, however, and a locally based research capacity is needed to reap the benefits of the technology transfer. Developed economies can help poorer countries build research and development capacity and facilitate the transfer of productive and appropriate technologies.

Improving research infrastructures in the poorest regions can be accomplished through direct investment in facilities and education in the developing country, and through support of organizations like the World Bank and the Consultative Group on International Agricultural Research. International collaboration in public agricultural research has been very successful in transferring basic knowledge throughout the world.

Public investment in research to increase the agricultural productivity of the poorest nations could have many benefits. Better nutrition and higher incomes would improve lives, and incentives for private investment would increase as regions gain the economic resources to participate more actively in the global marketplace. With less developed and developed countries active in the market, there is potential to increase the benefits of globalization in terms of equity, prosperity, and global food security for more of the world's population. AO

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For further information:

"Does Land Degradation Threaten Global Agricultural Productivity & Food Security?" *Agricultural Outlook*, AGO-292, June-July 2002.

"Talking Turkey: Science, the Economy, and the Community," *Science and Technology Policy Yearbook: 2002*, American Association for the Advancement of Science, 2002.

"Coming to Grips with Globalization," *Choices*, Winter 2001-2002.

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