TECHNICAL CHANGE AND AGRICULTURE: EXPERIENCE OF THE UNITED STATES AND IMPLICATIONS FOR MEXICO*

Gary W. Williams**

TAMRC International Market Research Report No. IM-1-95
June 1995

* Invited paper presented at the Innovation in Agriculture and Agribusiness Conference (Innovación Tecnologica en la Agricultura y la Agroindustria) in Mexico City, May 31-June 2, 1995, sponsored by the Institute of Economic Research and the Center for Technological Innovation of the Autonomous National University of Mexico (Universidad Nacional Autónoma de México).

** Professor of Agricultural Economics and Director of the Texas Agricultural Market Research Center, Texas A&M University, College Station, Texas 77843-2124.

TECHNICAL CHANGE AND AGRICULTURE: EXPERIENCE OF THE UNITED STATES AND IMPLICATIONS FOR MEXICO

Texas Agricultural Market Research Center (TAMRC) International Market Research Report No. IM-1-95, June 1995 by Dr. Gary W. Williams, Texas Agricultural Market Research Center, Department of Agricultural Economics, Texas A&M University.

ABSTRACT: Technical change has played a critical role in the evolution of U.S. agriculture and has been driven primarily by a continuing search for ways to increase efficiency and reduce cost. Technical change, however, has had a significant impact on the structure of U.S. agriculture. At the same time. technical change in U.S. agriculture has also had important impacts on the agricultural sectors in developing countries like Mexico. The process and effects of technical change in U.S. agriculture, the implications of that change for the Mexican agricultural sector, and currents issues for needed technical change in Mexican agriculture are analyzed.

The **Texas Agricultural Market Research Center (TAMRC)** *has been providing timely, unique, and professional research on a wide range of issues relating to agricultural markets and commodities of importance to Texas and the nation for more than two decades.* **TAMRC** *is a market research service of the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service. The main* **TAMRC** *objective is to conduct research leading to expanded and more efficient markets for Texas and U.S. agricultural products. Major* **TAMRC** *research divisions include International Market Research, Consumer and Product Market Research, Commodity Market Research, and Contemporary Market Issues Research.*

TECHNICAL CHANGE AND AGRICULTURE: EXPERIENCE OF THE UNITED STATES AND IMPLICATIONS FOR MEXICO

EXECUTIVE SUMMARY

Technical change has played a critical role in the evolution of U.S. agriculture since at least the American revolution and has been driven primarily by a continuing search for ways to increase efficiency and reduce cost. Technical change has allowed U.S. agriculture to maintain profitability and stay competitive in the face of growing world food demand and competition but has also had a significant impact on the structure of U.S. agriculture. At the same time, technical change in U.S. agriculture has also had important impacts on the agricultural sectors in developing countries like Mexico. The process and effects of technical change in U.S. agriculture over time are briefly reviewed in this paper. The implications of that change for the Mexican agricultural sector are also analyzed along with currents issues for needed technical change in Mexican agriculture.

American agriculture has already passed through two revolutions of technical change since the late 1700s and currently is in the throes of a third. A fourth revolution may be in the offing. The first revolution involved a change from manpower to animal power which continued through the late 1800s and into the early 1900s. With animal powered mechanization, farmers could efficiently and systematically farm more land and increase the level of output per acre of farmland. During this period, several seminal events occurred that have continued to ensure global leadership for the U.S. in the development and diffusion of new agricultural technologies, including the establishment of the U.S. Department of Agriculture (USDA) through which the current federal system of agricultural research and extension developed and the passing of the Morrill Land Grant College Act and the Hatch Experiment Station Act of 1887 by Congress.

The second revolution was a shift from animal power to mechanical power that began in the late 1800s and was virtually complete by the end of the World War II. This revolution essentially involved a continuation of the development and adoption of mechanical, labor-saving technologies but with a change in power source that enabled even greater substitutions of machinery and power for scarce labor resources.

The transition from animal to mechanical power in U.S. agriculture was virtually complete by the early 1950s. Government farm support programs and a growing demand for food from a rapidly growing population in the post-war years fueled a search for new types of technologies to relieve the constraint of an agricultural landbase that had not increased appreciably for 50 or 60 years. The national agricultural system responded by developing a stream of "land-saving," biological and chemical innovations which helped relieve the land constraint by substituting new inputs for land and utilizing the available labor resources more effectively.

American agriculture is now at the threshold of a new information technology revolution - the so-called "information super highway" - with the potential to significantly enhance efficiency in the production, processing, and marketing of agricultural and food products. While mechanical, biological, and chemical innovations enhance the efficiency and productivity of agricultural land and labor resources, information technology works to improve the efficiency of managerial resources. Access to such a large volume and variety of information should greatly remove risks in production and facilitate greater levels of output per unit of farm input in future years.

The U.S. agricultural technology revolutions have been both good and bad for Mexico. Mexico has benefited from access to new U.S. agricultural technologies but the transfer of those technologies from the U.S. has not always been successful. At the same time, new technology development and adoption in Mexico has lagged behind that of the U.S. leading to an erosion in Mexico's agricultural comparative advantage. With continuing economic reforms in Mexico and the opening of the Mexican economy to world trade under NAFTA and GATT, Mexican agriculture has begun competing directly with the more efficient agricultural sectors in the U.S. and other more developed countries. A long-run consequence will be pressure for change in the structure of Mexican agriculture similar to that experienced by the U.S., particularly since the 1940s.

In the absence of appropriate labor-using, land-saving technologies, Mexico has historically opted for a political solution to the land constraint problem through land reform. The *ejido* system, instituted in the early 1900s, was an attempt to allow a more intensive use of labor per unit of land. As the *ejido* system undergoes adjustment to allow larger farm units, however, investments to develop and adapt technologies to promote labor-intensive activities will be critically needed. Otherwise, massive agricultural labor displacement could be the result with all the attendant implications for unemployment and Mexican labor migration to the United States.

Four problems generally characterize current investments in technology for the Mexican agricultural and agribusiness sectors, however. First, most of the investments are in capital-intensive technologies of types developed and in use in developed countries rather than more labor-intensive types. Second, current investments in Mexican agricultural and food processing technology are creating bottlenecks in production, distribution, and trade of those commodities. Third, current investments are creating a widening income disparity among Mexican farmers and agribusiness operators. Small and medium-sized farms and agribusinesses in Mexico often have much less access to new technologies than large multinational food corporations because of a lack of investment capital. Finally, much of the technology in which domestic and foreign firms are investing is being transferred from other countries and adapted for use in Mexico rather than being developed within the Mexican public/private research sector.

Investments in technology development and diffusion are crtically needed in at least four areas: (1) the adaptation and commercialization of technology developed in other countries, (2) the development of new technology adapted to the conditions of Mexican resource endowments, (3) the training of *ejidatarios* and agribusiness owners in the purpose and use of new technology, and (4) the re-training of displaced agricultural labor.

TECHNICAL CHANGE AND AGRICULTURE: EXPERIENCE OF THE UNITED STATES AND IMPLICATIONS FOR MEXICO

TABLE OF CONTENTS

TECHNICAL CHANGES IN AGRICULTURE: EXPERIENCES OF THE UNITED STATES AND IMPLICATIONS FOR MEXICO

Technical change has played a critical role in the evolution of U.S. agriculture since at least the American revolution. Inventions like the cotton gin and the moldboard plow in the late 1700s and early 1800s revolutionized U.S. agriculture and helped ensure profitability and economic viability for the agricultural industry and the entire country. The process of technical change in U.S. agriculture has been driven primarily by a continuing search for ways to increase efficiency and reduce cost. The apparent comparative advantage of the U.S. over time in the production and export of agricultural and food products has not been determined solely by basic resource endowments such as abundant fertile farmland, temperate climate, and adequate rainfall and water resources. Increased productivity of the available resources through technical change has also been necessary to maintain profitability and to stay competitive in the face of growing world food demand and competition from other countries and industries.

Technical change, however, has also had a significant impact on the structure of U.S. agriculture. The agricultural sector now employs only 1% to 2% of the U.S. population compared to 64% in the mid-1800s. Likewise, the number of farms has declined precipitously from about 6.8 million in the mid-1930s to just over 2 million today, boosting the average farm size from 155 acres to 475 acres over the same period. Technical change has allowed fewer farmers to produce much more on larger farms, not only filling domestic needs but also generating large surpluses of food and fiber to help feed and clothe the world.

Technical change in U.S. agriculture has also had at least two major impacts on the agricultural sectors in developing countries like Mexico. On the one hand, the technology developed and adopted in the U.S. has been made available for adoption in Mexico. On the other hand, the rapid pace of technical change in U.S. agriculture has enhanced the U.S. agricultural comparative advantage and pressured the agricultural sector of Mexico with imports and low prices.

In this paper, the process and effects of technical change in U.S. agriculture over time are briefly reviewed with a focus on the forces determining the particular type of technical change that U.S. agriculture has experienced. Then, the implications of productivity growth in U.S. agriculture for the Mexican agricultural sector are analyzed given the current process of economic reform in Mexico and freer trade between the two countries. Finally, currents issues for needed technical change in Mexican agriculture are discussed.

Technical Change and U.S Agriculture

American agriculture has already passed through two revolutions of technical change since the late 1700s and currently is in the throes of a third. A fourth revolution may be in the offing. The first revolution involved a change from manpower to animal power which continued through the late 1800s and into the early 1900s. The second revolution was a shift from animal power to mechanical power that began in the late 1800s and was virtually complete by the end of the World War II. The current technological revolution in American agriculture revolves around biological and chemical innovations including the recent push in the area of bioengineering. American agriculture is now at the threshold of a new information technology revolution with the potential to significantly enhance efficiency in the production, processing, and marketing of agricultural and food products.

The Shift from Manpower to Animal Power

In relatively land-abundant and labor-scarce countries, like the U.S. in the 1700s and 1800s, technologies usually develop as means of relieving the labor constraint by allowing the substitution of new inputs for labor (Hayami and Ruttan). Such technologies are referred to as "labor-saving" and generally involve mechanical innovations. Such technology allows each relatively more scarce labor input to become more productive by being able to utilize (or farm) the more abundant land more effectively. Mechanical technology is designed to facilitate the substitution of power and machinery for the scarce labor resource. Labor-saving technologies involve the substitution of land for labor because higher output per worker through mechanization usually requires the cultivation of more land area per labor unit.

The Civil War in the 1860s provided the stimulus for rapid adoption of new technology in American agriculture. Labor shortages necessitated the adoption of machinery while food shortages created the demand and generated the prices to make adoption of new technologies affordable (Hurt). Importantly, a backlog of new technology in the form of horse-drawn machinery was available at that time, including steel swing and sulky plows, grain drills, seed planters, cultivators, self-rake reapers, binders, threshing machines, hay rakes, and mowers (Rasmussen). With animal powered mechanization, farmers could efficiently and systematically farm more land and increase the level of output per acre of farmland. Between 1870 and 1910, land under production increased by 125% while agricultural output expanded by over 160% (Figure 1). The 72% increase in the number of people employed in farming was less than half the growth rate in output during that period reflecting the increasing productivity of labor (Figure 2).

During this period of time, several seminal events occurred that have continued to ensure global leadership for the U.S. in the development and diffusion of new agricultural technologies. The U.S. Department of Agriculture (USDA) was established in 1862 through which the current federal system of agricultural research and extension developed. At the same time, the Morrill Land Grant College Act, passed by the U.S. Congress in 1862, essentially provided for the establishment of an agricultural "land grant" college in each state. The Hatch Experiment Station Act of 1887 provided annual federal funding of research at state agricultural experiment stations. These agricultural research stations now exist in most states as adjuncts to the land grant colleges. Their primary function is to conduct basic and applied research for the benefit of agricultural producers. Growing national appreciation for agricultural research and the rapid flow of new agricultural technologies in the late 1800s and throughout this century has been a direct result of these federal and state investments in agricultural research and extension.

Figure 1: Index of U.S. Agricultural Output and Inputs, 1870-1990

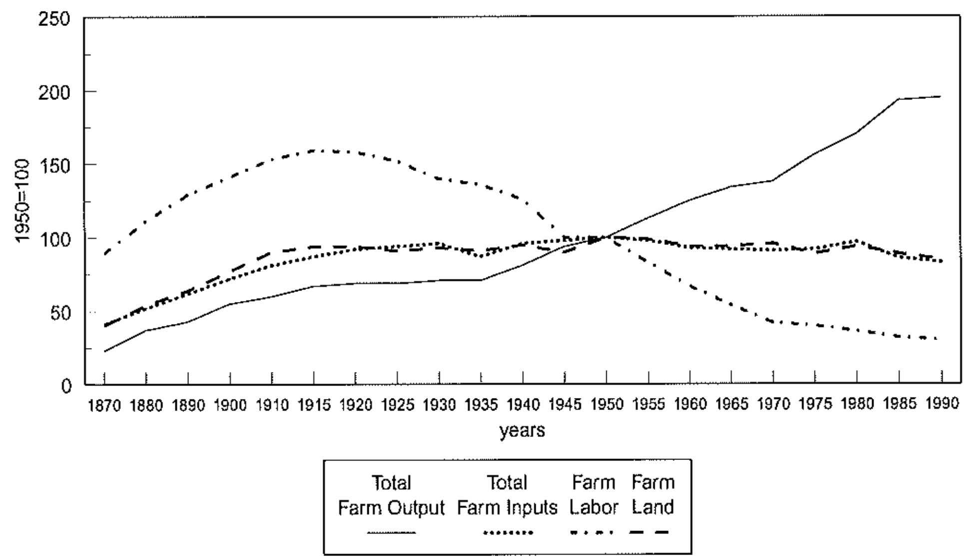
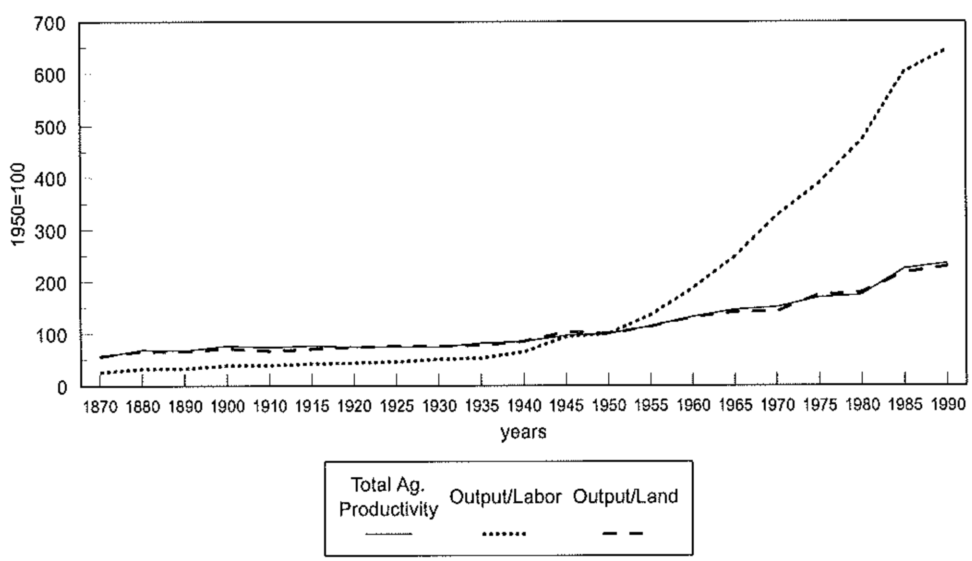


Figure 2: Index of Productivity in U.S. Agriculture, 1870-1990



Animal Power Yields to Mechanical Power

The second American agricultural revolution essentially involved a continuation of the development and adoption of mechanical, labor-saving technologies but with a change in power source that enabled even greater substitutions of machinery and power for scarce labor resources. The substitution of mechanical for animal power began slowly in the early 1900s but did not take off until after the Great Depression in the 1930s. Steam engines for threshing and plowing were already in use by large-scale farmers in the late 1800s (Hurt). Development of the combustion engine in the early 1900s led to the development of fossil-fuel-powered tractors, combines, and other farm machinery.

The transformation from animal to mechanical power gained considerable momentum during World War II. Increasing prices, a seemingly unlimited demand for farm products, a shortage of farm labor, and appeals from the government to gear up production to "feed the war" induced farmers to greatly increase their rate of adoption of mechanical power and machinery. The principal constraint continued to be a relative scarcity of labor compared to land. U.S. agricultural production accelerated rapidly after 1940 despite both a growing decline in farm labor that began in the 1920s and little further growth in the acreage under production (Figure 1). Although the adoption of mechanical powered innovations boosted the productivity of land by 46% between 1935 and 1955, labor productivity jumped by 157% over the same period.

The Biological and Chemical Revolution

The transition from animal to mechanical power in U.S. agriculture was virtually complete by the early 1950s. Government farm support programs and a growing demand for food from a rapidly growing population in the post-war years fueled a search for new types of technologies to relieve the constraint of an agricultural landbase that had not increased appreciably for 50 or 60 years. The national agricultural system responded by developing a stream of "land-saving," biological and chemical innovations. Such technologies helped relieve the land constraint to increased agricultural production by substituting new inputs for land and utilizing the available labor resources more effectively.

Biological and chemical technologies include hybrid seeds, commercial fertilizers, herbicides, pesticides, chemicals and management techniques to eliminate and control plant disease, and drugs to combat animal diseases. The development and adoption of these new production inputs boosted the productivity of U.S. farmland by nearly 130% in the 40 years between 1950 and 1990 compared to the 75% increase in farmland productivity over the preceding 80 years. Bioengineering is the currently the focus of much federal and private research. Genetic manipulation to tailor plants and animals to specific production and market needs holds great promise for a significant upward shift in agricultural productivity.

The Information Revolution

Rapid technological developments in information technology is revolutionizing both the way in which information is communicated and the volume of information that can instantaneously be made available to agricultural producers - the so-called "information super highway." While mechanical, biological, and chemical innovations enhance the efficiency and productivity of agricultural land and labor resources, information technology works to improve the efficiency of managerial resources. Using personal computers and specialized software and hardware, agricultural producers will increasingly have access through the Internet and the "World Wide Web" to virtually unlimited information for strategic decision making. Technological breakthroughs are making it possible for individuals to obtain direct and immediate access to corporations, libraries, news groups, government agencies, and universities around the world to obtain a wide array of information such as financial statements, bibliographic information, international currency, stock, and futures markets information and reports, up to the minute weather information, maps, and forecasts, current crop forecasts and price information from USDA or any number of U.S. and foreign and private organizations, and much more. Making production and marketing decisions based on sketchy, out dated, or inaccurate information can lead to poor decisions and financial disasters for farmers. Access to such a large volume and variety of information should greatly remove risks in production and facilitate greater levels of output per unit of farm input in future years.

Implications for Mexico

The agricultural technology revolution experienced in the U.S. over the last 150 years or so has been both good and bad for Mexico. Mexico has benefited from access to new U.S. agricultural technologies developed through investments in research and development by the U.S. government and private U.S. firms. At the same time, however, new technology development and adoption in Mexico has lagged behind that of the U.S. leading to an erosion in Mexico's agricultural comparative advantage.

Technology Transfer

Although Mexico, like most developing countries, has national programs for the funding of technology development and commercialization, a considerable share of technical change in Mexico has occurred through the transfer of technology from the U.S. and other developed countries. In Mexico, federal government expenditures on science and technology amounted to only 0.4% of all government expenditures in 1988 (NF). At the same time, agriculture accounted for only 15% of federal expenditures on science and technology.

The transfer of new technology embodied in farm implements and machinery, improved seeds, breeding animals, higher yielding genetic material, and production chemicals (pesticides, herbicides, fungicides, and fertilizers) is intended to raise productivity and reduce costs of production in the recipient country. Unfortunately, the transfer of these technologies to Mexico has not always successful in achieving those goals for at least two reasons. First, technologies developed for the climatic, soil, and geographic conditions unique to more temperate-climate countries like the U.S. may not adapt well to the warmer and more tropical or arid conditions in Mexico. Years of research are often necessary to fully adapt technologies adopted from the U.S. to the specific climatic, soil, environmental, and geographic conditions of Mexico. Unfortunately, such investments have not always been made.

Second, technologies available from the U.S. for adoption by Mexico have generally been developed in response to the pressures and bottlenecks defined by commodity market and resource conditions in the U.S. which are very different from those prevailing in Mexico. The relative abundance of land to labor in the U.S. essentially resulted in the development of agriculture on the basis of mechanical, labor-saving technology which led to more capital-intensive farming methods in the U.S. Mexico, on the other hand, is relatively labor-rich and land-poor suggesting that the optimum path for agricultural development of the Mexican agricultural sector must involve land-saving technologies that relieve the land constraint and make more efficient use of labor. Consequently, labor-saving mechanical technologies imported from the U.S. may increase the productivity of labor and boost output in Mexico but are not likely the optimum technologies for balanced, sustained agricultural development. Appropriate types of technologies for transfer and adoption in Mexico include those involving the development of land and water resources, chemicals to enhance soil fertility, biological and chemical means to protect plants and livestock from pests and disease, and new crop varieties specifically adapted to the environmental conditions of the country.

The Erosion of Mexican Comparative Advantage

The technological revolutions that have enhanced the productivity, profitability, and competitiveness of U.S. agriculture have also eroded the comparative advantage and competitiveness of the agricultural sectors of many developing countries including Mexico. As the U.S. and other developed countries have invested in the development and adoption of new agricultural technologies, developing countries have been increasingly forced to choose between shielding their agricultural sectors from the effects of changing patterns of world comparative advantage through protective import policies or becoming increasingly dependent on developed countries for their food and agricultural needs. In choosing the import protection alternative, however, developing countries also sever the linkage of their agricultural sectors to world markets and, therefore, curtail the pressures for technical change and the opportunities for technology transfer. As a consequence, some developing countries, such as Taiwan, South Korea and now Mexico, have recognized the increasing technological disadvantage of their agricultural sectors and have attempted to open up their markets to international trade once again.

Economic reforms in Mexico and the opening of the Mexican economy to world trade which began in the mid-1980s and continues under NAFTA has forced Mexican agriculture to begin competing directly with the more efficient, technology-enhanced agricultural sectors in the more developed countries. Research indicates that the more highly productive U.S. agricultural sector will be a net gainer while the Mexican agricultural sector will be a net loser from the Mexican reforms and more open markets (Williams and Rosson). The U.S. is expected to gain over Mexico in a broad range of agricultural activities, including cattle and hog feeding, meat processing, grain and oilseed production and processing, dairy production and processing, production of some fruits, and manufacturing of a wide variety of further processed and consumer-ready food products. On the other hand, the combination of resource endowments and climate will maintain and even strengthen the competitiveness of several Mexican agricultural industries, including labor-intensive melon, vegetable, and cow-calf production.

The Mexican reforms and liberalized trade is essentially removing the protective barriers that have shielded much of Mexican agriculture from the effects of more than a century of rapid technological change in the U.S. agricultural sector. The results, therefore, should not be surprising. Mexican producers of grains, cattle and beef, dairy products, deciduous fruits like apples, peaches, and pears, and manufactured food products can expect to face strong, growing competition from U.S. imports. The long-run consequence will be a change in the structure of Mexican agriculture similar to that experienced by the U.S., particularly since the 1940s. Growing agricultural and food product imports from the U.S., and consequently lower prices, will force farm labor to migrate to urban areas and to the U.S. and create pressure to reduce the number of farms and increase farm size. The land reform provisions of Article 27 provide the legal basis for this structural change to occur. The extent of these structural changes and the implications for the future of Mexican agriculture depend critically on the response of the public and private research community in Mexico in developing and adapting new technology for use in the agricultural sector.

Needed Technical Change in Mexican Agriculture

In the absence of appropriate labor-using, land-saving technologies, Mexico has historically opted for a political solution to the land constraint problem through land reform. The *ejido* system, instituted in the early 1900s, was an attempt to allow a more intensive use of labor per unit of land. The recent changes in the land tenure system, however, suggest that the lost economies of size and other sacrifices of efficiency have apparently outweighed the social welfare benefits of the system as perceived, at least, by the government. As the *ejido* system undergoes adjustment to allow larger farm units, however, investments to develop and adapt technologies to promote labor-intensive activities will be critically needed. Otherwise, massive agricultural labor displacement could be the result with all the attendant implications for unemployment and Mexican labor migration to the United States.

The most highly labor-intensive agricultural activities in Mexico include horticultural crop production and processing, livestock raising and processing, dairy production and processing, and a large number of various low-level processing activities such as corn milling and tortilla manufacturing, bread baking, meat packing, fluid milk bottling, and ice cream manufacturing characterized by small, family-controlled businesses. Mexican corn, beans, and other basic commodity sectors are also still highly labor-intensive as well because of Mexican land tenure and agricultural policies that have encouraged a relatively high labor-to-land ratio in their production. The technologies utilized by a large portion of small and medium-sized Mexican agribusiness firms are fairly labor-intensive and typical of those used by the U.S. food processing industry 50 years ago.

Problems with Current Agricultural Technology Investments in Mexico

Four problems generally characterize current investments in technology for the Mexican agricultural and agribusiness sector. First, most of the investments are in capital-intensive technologies of types developed and in use in developed countries rather than more labor-intensive types. The consequence is that the labor intensity of Mexican agricultural and food processing industries is likely lower than might otherwise be the case, contributing to the already high level of unemployment in Mexico.

The second problem is that current investments in Mexican agricultural and food processing technology are creating bottlenecks in production, distribution, and trade of those commodities. Inadequate investments in public agricultural research and development, irrigation systems, transportation infrastructure, distribution, storage, and marketing systems, and agricultural credit and related institutions create serious bottlenecks to the full realization of the productive potential of the new or adopted technologies (Hayami and Ruttan). These bottlenecks also reduce the profit potential of additional investments in technology transfer and development. At the same time, however, such bottlenecks create increased social pay-off to investment in the development of technologies to relieve the cause of the bottlenecks. Thus, the current Mexican infrastructure bottleneck resulting from rapid growth in U.S.-Mexico agricultural trade implies that the pay-off to investment in transportation and other infrastructure technology is increased by investments in modern food processing technology in Mexico. If investment in infrastructure technology is induced by the increase in pay-off, the infrastructure bottleneck will be eased and additional employment opportunities will be created for displaced agricultural labor.

The third problem created by current investments in agricultural and food processing technology in Mexico is a widening income disparity among Mexican farmers and agribusiness operators. Small and medium-sized farms and agribusinesses in Mexico often have much less access to new technologies than large multinational food corporations because of a lack of investment capital. New-technology-based increases in production by the large commercial farms and agribusinesses in Mexico lead to a drop in market prices and incomes of small and medium-sized producers. For example, investments in fruit and vegetable processing technology that allow large Mexican producers and packers to take advantage of the export opportunities created by NAFTA also put small and medium-sized fruit and vegetable processors in Mexico at a competitive disadvantage.

Finally, much of the technology in which domestic and foreign firms are investing is being transferred from other countries and adapted for use in Mexico rather than being developed within the Mexican public/private research sector. The U.S. has been the major foreign source of technology transfer contracts (NF). Consequently, the increasing trade and investment in Mexico may not be creating the basis for the development of a strong public/private research and extension system to service the growing needs of small and medium-sized Mexican agricultural and agribusiness firms.

The Role of the Mexican Public Sector in Agricultural Technology Research and Development

Mexican public investments in agricultural science and technology declined precipitously in real terms by over 70% between 1980 and 1988. Consequently, although foreign capital is being increasingly invested in technology for the development of certain Mexican agricultural and agribusiness activities, too little is being done by the public sector to adapt and commercialize that technology for the Mexican agricultural industry in general. Of the total spent in 1987 by the National Council of Research and Technology (CONACYT), a major provider of research and development funds in Mexico, only 5.2% went for "science and technology diffusion" (NF). The majority of CONACYT funds in that year went for "human resource development." Also, only limited research is being done to develop technologies to assist small and medium-sized firms to compete in an increasingly international Mexican agricultural marketplace.

The lack of pubic research funding is a major constraint to agricultural development in Mexico. As Hayami and Ruttan point out (pp. 165-166):

> *"Public sector investment in education in the biological sciences related to agriculture and [public] research capacity is essential if a nation is to successfully test and diffuse the indigenous technology employed by its own farmers, transfer and adapt the technology developed in other countries, and conduct the basic and applied research necessary to provide its farmers with a continuous stream of new ... technology .... [F]ailure to effectively institutionalize public sector agricultural research can result in serious distortion of the pattern of technological change and resource use .... [F]ailure to invest in public sector experiment station capacity is one of the factors responsible in some countries for the unbalanced adoption of mechanical, relative to biological, technology. Failure to develop adequate public sector research institutions has also been partially responsible for the almost exclusive concentration on research expenditures on the plantation crops and for the concentration on export crops .... The major challenge for the developing countries is to develop the scientific and institutional capacity to design location-specific agricultural technology adapted to the technological and economic environment in which the new agricultural technology is to be employed."*

Critically needed investments in technology development and diffusion are needed in at least four areas to facilitate development of the Mexican agricultural sector and mitigate the structural effects of more open trade: (1) the adaptation and commercialization of technology developed in other countries, particularly for small and medium-sized Mexican agricultural and agribusiness firms, (2) the development of new technology adapted to the conditions of Mexican resource endowments, (3) the training of *ejidatarios* and agribusiness owners in the purpose and use of new technology, and (4) the re-training of displaced agricultural labor. Without a significant increase in public sector investment in technology research and development in Mexico in real terms in these areas, the consequence will likely be little technology transfer or development in Mexico beyond that which is needed specifically to support investment of specific agribusiness operations in specific locations by specific investors. In such cases, the returns to those investments in technology either might be largely expropriated by foreign investors or might create little new growth and employment in Mexico.

REFERENCES

Hayami, Y. and V.W. Ruttan. *Agricultural Development: An International Perspective.* Baltimore: The Johns Hopkins Press, 1971.

Hurt, R. Douglas, "Agricultural Technology in the Twentieth Century: Introduction," *Journal of the West* 30(2):5-8, April 1991.

Nacional Financiera (NF), *La Economia Méxicana en Cifras*, Mexico City, Mexico, various editions.

Rasmussen, W.D., "The Impact of Technological Change on American Agriculture, 1862-1962," *The Journal of Economic History*," 27(4):578-591, December 1962.

Turrent Fernández, A., "Research and Technology for Mexico's Small Farmers," in B.F. Johnston, et. al., eds. *U.S.-Mexico Relations: Agriculture and Rural Development.* Stanford, CA: Stanford University Press, 1987.

Williams, G.W. and C.P. Rosson III, "Agriculture and the North American Free Trade Agreement," *Choices* 7(4):16-19, Fall 1992.