I. The Evolving Food and Agriculture System

Once food was viewed strictly in terms of commodities produced in bulk and meant to be plentiful and affordable. But, in the decades of prosperity in the last half century, the concept of food and our expectations have changed and taken on a new significance.

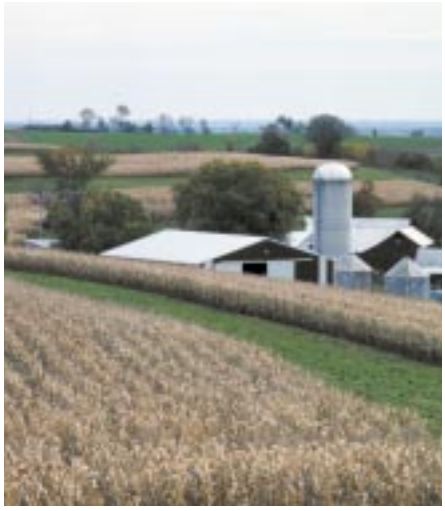
American consumers today have come to expect a great deal more of the food system, as well. And, there is no doubt that it delivers—more nutritious food with wider variety; improved safety, with less environmental impacts; and greater convenience than at any time in the Nation's history. The drivers of change in society at large—fundamental changes in our family structure and workforce, globalization of markets and culture, booms in information and biological and other technologies—are at work in agriculture and food markets and throughout the value chain, as well.

As food and fiber have changed, so have farmers and their farms. Postwar economic prosperity drew people off farms into jobs providing a growing array of goods and services. At the same time, agriculture experienced an explosion in its productivity. Today, the approximately 150,000 farmers produce most of our food and fiber are among the world's most competitive, able to fully meet domestic needs and also supply large quantities to foreign markets. These farmers are the foundation of the Nation's food security and underpin the agricultural economy.

But, these operations make up just one segment of U.S. agriculture. USDA counts another 2 million farmers who meet the criterion of selling at least $1,000 worth of product annually, many of whom have other occupations but enjoy rural lifestyles. A vast diversity of farms emerges out of this multitude: niche farms, hobby farms, hunting preserves, dude ranches, you-pick operations, farms that sell directly to consumers through farmer's markets, bed and breakfasts, and more.

While the American landscape is dominated largely by agriculture, these operations vary widely to cope with different soils, water conditions, and markedly distinct weather patterns. The close interactions between farming practices and natural resources, always important, have been in the spotlight since the 1960s.

Environmental quality matters a great deal to Americans today, whether preserving wetlands, improving wildlife habitat, or maintaining water quality in rivers, streams, and lakes. Agriculture, vast as it is, holds a special responsibility for resource stewardship. How farmers address this environmental responsibility, whether on a large commercial corn and soybean farm or a part-time cattle operation, has



shown steady improvement, but remains a matter of both public and private concern.

It is a particularly challenging task to ensure that this complex and diverse farm and food system works to most Americans' satisfaction. Although farming itself employs only about 1 percent of the workforce and accounts for less than 1 percent of the Nation's gross domestic product (GDP), it is the critical component of the entire food and fiber system—spanning farm inputs, processing, manufacturing, exporting, and a wide range of ancillary services—that contributes $1.5 trillion (16 percent of GDP) and employs 17 percent of the labor force. Helping this system remain efficient and competitive globally, especially as markets shift from commodities to high-value products, is not only critical to the financial well-being of farmers but also very important to the U.S. economy.

When the Federal Government first considered its responsibilities with respect to agriculture, George Washington suggested Congress establish a National Board of Agriculture. Around the mid-1800s, the enduring importance of a strong science base for farming was recognized in the creation of the U.S. Department of Agriculture and the federally supported State agricultural research and extension at land-grant universities.

In the 19th and 20th centuries, as our great urban centers came to dominate our economy, the smooth functioning of markets was essential to ensure the flow of food and fiber from farm to city. The New Deal supported farmers who produced basic commodities, and thereby helped to ensure plentiful food supplies. Attention was paid to how well markets worked, and the Federal Government helped level the playing field by bolstering the flow of information between buyers and sellers and also monitored their commercial transactions.

Ensuring food safety, promoting nutritious and convenient foods and products, delivering food assistance to low-income consumers, protecting environmental quality, and keeping markets functioning efficiently are all added service requirements of the last century. Today, a new challenge is before us: the ongoing transformation of U.S. agriculture into the still-emerging, global, consumer-driven food system. How do we make the enormous shift from the largely

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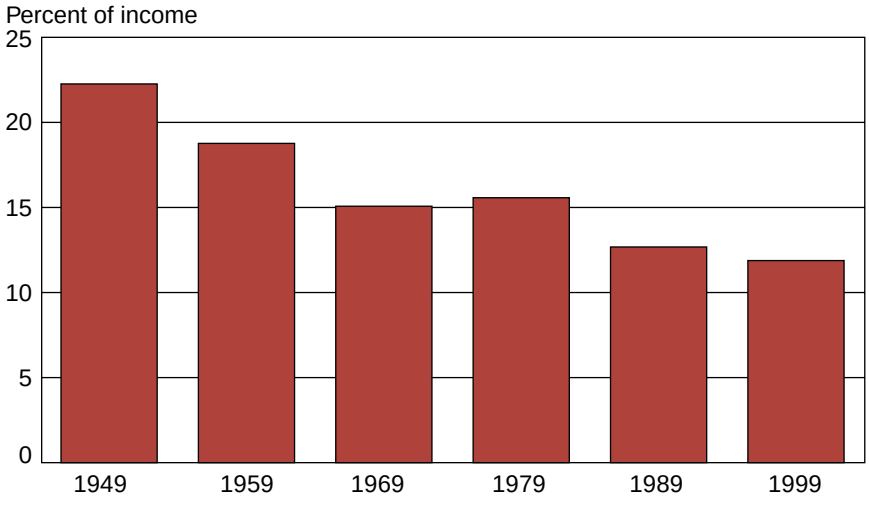
commodity-oriented focus of the past 75 years to the much different products and function focus required for the new century? What is the appropriate Federal role in this task and, if one, how extensive should it be?

Consumer-Driven Agriculture

Historically, farmers' main objective was to keep up with the food demand generated by a growing population. Over time, people wanted not only to ensure that their basic energy requirements were met, but also to eat better through access to a wider variety of nutritious foods. Economic progress depended on the physical well-being of a nation's people, and much of the success of the Industrial Revolution turned on having a well-fed workforce. The Industrial Revolution also made agriculture much more efficient as it changed production processes, tools used, and resources needed. For example, the switch from horses to tractors early in the 20th century, followed by the adoption of a succession of new technological practices, helped assure Americans an adequate food supply. At the same time, it dramatically changed the farmers' way of life.

With more secure supplies of food, the consumer focus shifted to which foods were available and the services these products included. This became increasingly important as population growth slowed and Americans prospered, changing the nature of the demand for food. Today, domestic food needs grow only when the population expands, and it is growing slowly by historical standards. The share of income spent on food has fallen steadily over time (figure 1), with proportionally more now spent on housing, automobiles, education, and other goods and services. As the U.S. food market has matured, consumption growth for one food product increasingly comes at the expense of another. Aging baby boomers may be more inclined to substitute decaffeinated coffee for regular coffee, but such shifts in preferences alter total coffee consumption very little. The number of foods labeled "low-fat" or "health food"

Figure 1
Food Expenditures as a Share of Disposible Income



shows how the food system has evolved to address consumer demand.

As our markets mature, we have seen an explosion in new product introductions. Over 12,000 new food products have been introduced annually across 14 major food categories (ranging from baby food to soup). Retail food stores offer choices that provide novelty, variety, and convenience—from organic produce, exotic fruits, and marinated meat to bottled water.

Food marketing also is changing in other ways. Mass merchandisers, warehouse club stores, specialty stores, and restaurants are becoming increasingly favored over traditional supermarkets. The supermarket share of grocery food sales that was 78 percent in 1992 had fallen to 70 percent by 1997 as mass merchandisers and warehouse club operators increased their market share from 6 to 12 percent.

Meanwhile, Americans continue to eat away from home, reflecting the premium on convenience (figure 2). Some retailers have responded with strategies emphasizing greater variety, quality, and service, while others are offering lower prices on more limited lines of products and services.

The farm and food industry, of course, is enormously affected by the changing profile of this mature market. It is responding by better coordinating the supply chain so consumer signals are translated swiftly and effectively. By establishing direct ties to growers through contracts, food retailers can ensure that they provide specific product qualities tailored to consumer demand. For example, the introduction of convenience pork products, such as pretrimmed and marinated tenderloins of uniform size and quality, has emerged as the pork industry attempts to interpret and respond to consumer signals (figure 3).

Another response may focus on niche markets, which frequently exist side by side with mass retailing. For example, premium vintners thrive alongside large-volume distributors in the wine industry. And, expanding numbers of more affluent foreign food consumers are more important in a mature market.

Figure 2
Away-From-Home as a Share of Total Food Spending

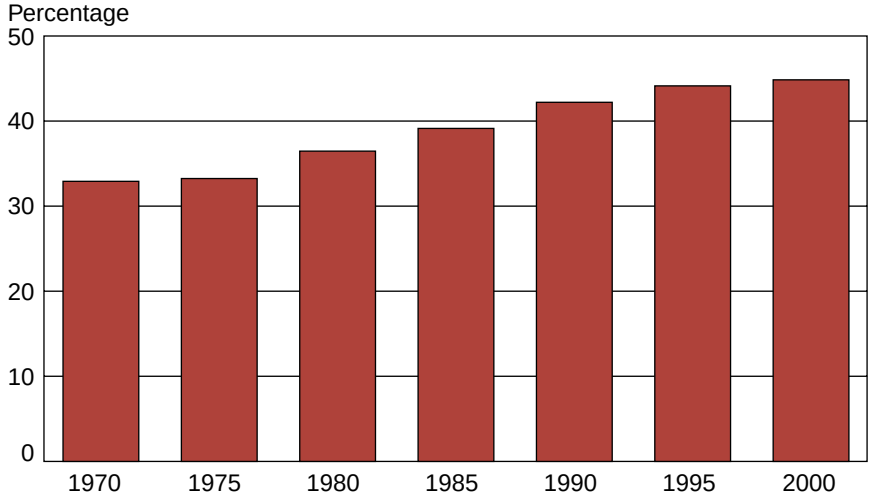
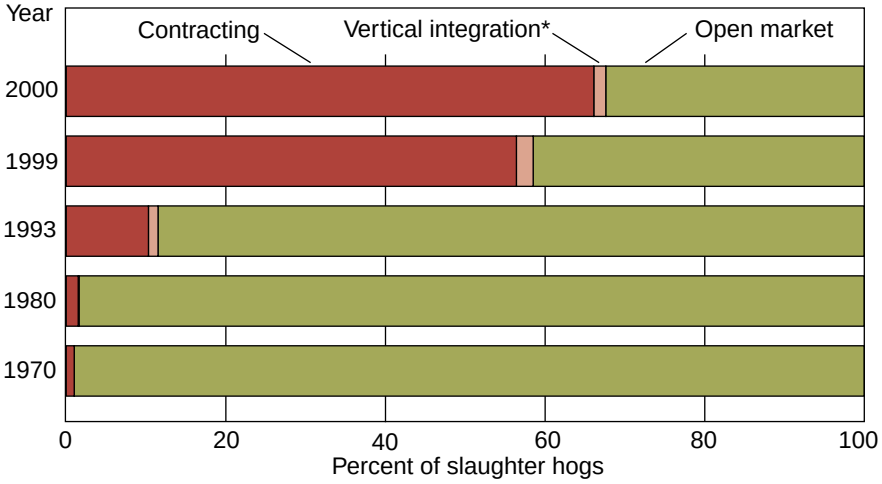


Figure 3
Share of Hogs Sold by Marketing Method



**Vertical integration defined as packer-owned hogs that are not delivered under contract.*

New Business Relationships Between Farmers and Companies Benefit All

General Mills, a leading producer of breakfast cereals, is using a specific variety of wheat to make its popular "Wheaties" brand of cereal. The types of wheat used to produce flakes can respond differently to milk and General Mills wanted one that would make flakes that curl, reducing sogginess in the consumer's breakfast bowl. General Mills forged new business arrangements with farmers to get a specific wheat type that both curls and retains crispness.

General Mills contracted with farmers to produce the specific type of grain best suited to its needs. This created new value for farmers who receive premium prices for grains with desired characteristics. Farmers also benefit by having an assured buyer. General Mills, in turn, benefits from increased efficiency by using a precise variety in manufacturing. New business relationships between farmers and food companies mean higher revenues for farmers, increased efficiency for processors, and consistent product quality for consumers.

Biotechnology is another tool that promises to help meet consumers' demand for services, illustrating how demand and technology interact to create new markets. The food sector will further capitalize on the growing interest in "functional foods," products differentiated by nutritional (and perhaps medicinal) content and appeal to consumers' concerns about diet and health. This is the promise of "second generation" biotechnology products, following the "first generation" innovations that reduced farmers' production costs or boosted yields but did not otherwise change the commodity. Designing, creating, and monitoring these second generation products are prominent opportunities for biotechnology research, and increasingly offer the promise of new and larger markets for the sector.

Larger farm size; specialized, more efficient production methods; and greater coordination characterize the structural change well underway in commercial agriculture. For these farms, a decided change in their role in the overall food system is occurring. Farmers once purchased inputs and sold products in arms-length transactions and largely were price takers in both markets. But, those lines are fast blurring, with differentiated products, bundled systems, and greater system coordination. Buyers and sellers of agricultural commodities and producers rely less on cash markets and more on dozens of kinds of contractual arrangements (see box). New production, a variety of joint venture/marketing arrangements, and information technology are lowering

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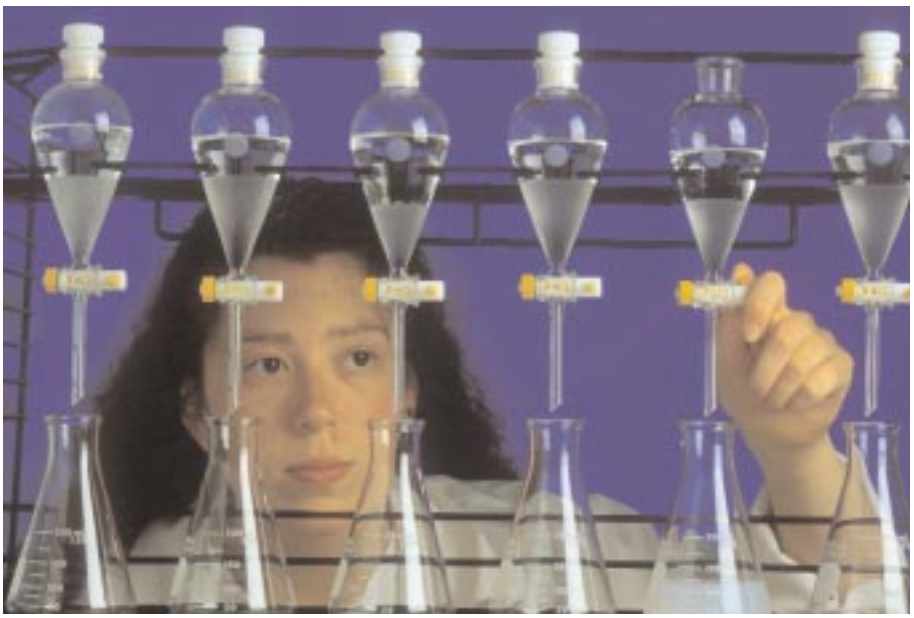


the total costs of doing business by introducing size economies and reducing transaction costs.

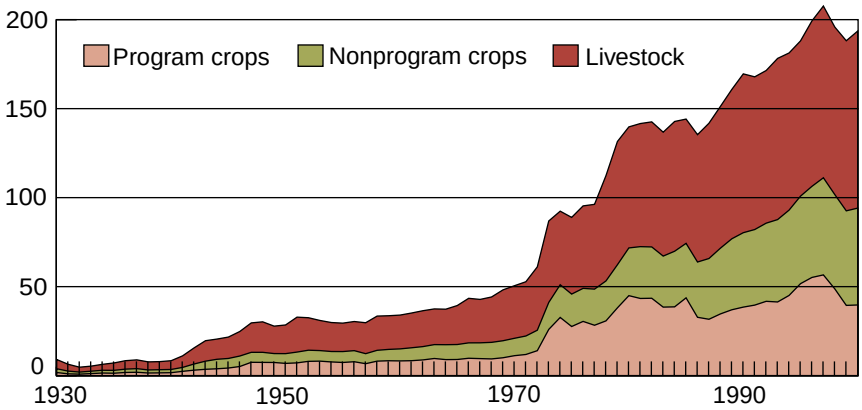
While this structural change clearly is advantageous for some, it also prompts concerns about competition, market access, and the use of market power by some participants to the disadvantage of others. Moreover, reduced competition could limit society's gain from structural change by stifling innovation or tilting the market's results in favor of those with the greatest market power.

Agricultural Diversity

Farming today consists of enormously different farms growing numerous crop and livestock products for sale in markets that range from their immediate neighbors to consumers worldwide. Farms differ in size, type and value of commodities produced, technology used, resource endowment, financial status, and many other attributes. Farmers differ in commitments of time, management abilities, business goals, and financial resources. The result is a sector that cannot be accurately characterized by any single measure or characteristic. Even the notion of a "family farm" applies to an increasingly broad range of structural configurations. However, it is essential to recognize and understand this diversity that makes up today's agriculture if we are to adequately prepare for its future.

The concentration of resources into fewer and larger farms occurred throughout the 20th century. While production doubled over the last 50 years, farm numbers dropped by more than two-thirds. Farmers produce scores of raw commodities every year and countless varieties of products even though bulk commodities—such as cotton, corn, wheat, and other food and feed grains that are the focus of government programs—are taken by many to symbolize agriculture. These program crops, which were grown on almost every farm in the 1930s, are produced today on about 30 percent of all farms, and they account for a small fraction (20 percent) of the total value of all agricultural sales today (figure 4).

Figure 4
Total Farm Cash Receipts by Category (1930-2000)



Program crops=food grains (rice, wheat), feed grains (corn, sorghum, barley, oats), cotton, and soybeans.

In the 1930s, when price and income support programs first were developed, there was little need to distinguish among farms, farmers, or farm households. In fact, farms and households (and farming communities, in many cases) were closely intertwined as a way of life and were considered inseparable. Farm fami-

lies were fully engaged in the production of commodities and the relatively simple process required few input purchases from other sectors. The industrial revolution on the farm, of course, has changed this enormously, with most commercial farms now operated as sophisticated businesses like any other. Most hire labor and use custom services to perform specialized tasks. Most inputs are purchased off-farm and financing is a standard part of their business plans. These businesses plan rigorously, manage meticulously, and invest carefully, with full expectations of profitable returns. Even so, fewer farmers are full time; instead, most choose to merge farm and nonfarm employment opportunities. Fewer households earn all of their income from farming or devote all of their financial resources to the farm business.

A place can meet the official definition of a "farm" simply by generating agricultural product sales of $1,000 or having the potential to do so, and some 2.2 million places are classified as farms. They range from places with two cows or a little more than 500 bushels of corn to multimillion-dollar operations. A simple examination of farm sector groups with common characteristics provides a new perspective with significant implications for policy design.

Economic sales classes are one way to distinguish farms, with sales measured as the gross value of agricultural commodity and product sales, landlord share of commodity sales, the value of products removed under contract, and all government payments. Three common size groups of farms are $250,000 or more, $100,000-$249,999, and less than $100,000. There are 146,000 farms with sales over $250,000, 199,000 farms with sales between $100,000 and $249,000, and 1.8 million farms with sales of less than $100,000. (See table A-2 in appendix 1 for more information by sales class.)

While sales classifications are useful for communicating general points, they mask diversity within each group that is important to policy decisionmaking. Farmers and farm households have different goals and are at different stages of business development and household life. For example, in the smallest economic sales class a relatively small proportion (27 percent) view farming as their primary occupation, and the rest are either retired or consider farming a secondary occupation.

Grouping farms into three types—commercial, rural residence, and intermediate—based on both

their sales size and primary occupation reveals key differences in income sources, commodity specialization, use of government programs, and other characteristics (see appendix 1).

Today, there are 175,000 commercial farms. This group consists of large family farms with sales above $250,000 and farms that are not organized as sole proprietorships. This small proportion of farms (8 percent) accounts for 68 percent of total output. These farms have business goals that include containing costs and increasing sales, and they are profitable.

A second group of farms, nearly 1.4 million (62 percent of all farms, 8 percent of total output), combines nonfarm jobs with farming or are retired people or those who view farming as an investment opportunity and a way to enjoy rural amenities. The result is a group of households with a rich mix of vocation and career choices, much like their urban and suburban counterparts, and little dependence on the farm economy for their income. Even though most of these farms are not profitable as stand-alone farm businesses, these rural-residence farms typically have incomes comparable to those of nonfarm households.

A third group of about 650,000 farmers consider farming their primary occupation and share goals with both commercial farms and rural-residence farms. Some emphasize economic and financial objectives much like the larger, more commercial farms and are attempting to compete for resources with their commercial competitors. Others have goals that align more closely with smaller, less commercial operations. Those without substantial off-farm earnings rely on alternative uses of agricultural resources to generate income. Many use their farm equipment to provide custom work to other farms, some rent land to other farmers, and some provide hunting and other outdoor recreation as a way of generating additional income. The intermediate farms in this situation typically are not large enough to support the farm household yet require a substantial labor commitment from the operator.

Stark contrasts emerge among the three groups in terms of their numbers, shares of production, and land holdings (figure 5). Commercial farms, only 8 percent of the total, accounted for 68 percent of production and 29 percent of land use. Most farms fall in the rural-residence and

Figure 5
Commercial Farms Are Small in Number, Own Less Than 1/3 of the Land, But Produce Most of the Output (1999)

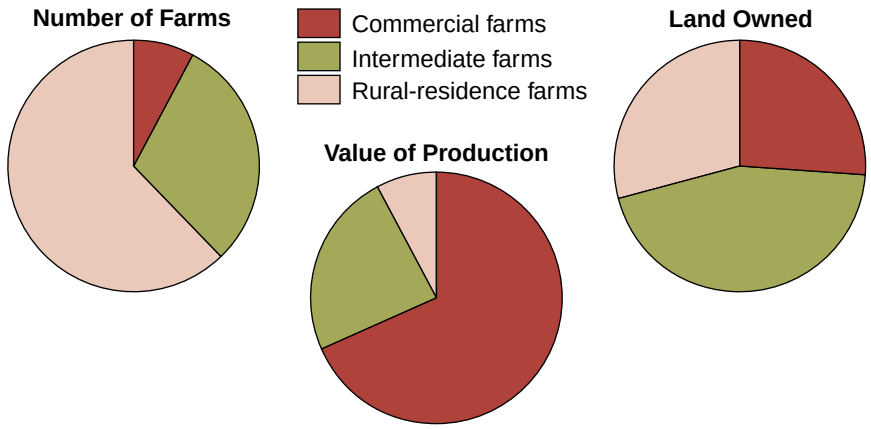


Figure 6
Low-Cost Farms Can Be Any Size, But Most Rural-Residence and Intermediate Farms Do Not Cover Production Costs with Farm Income (1999)

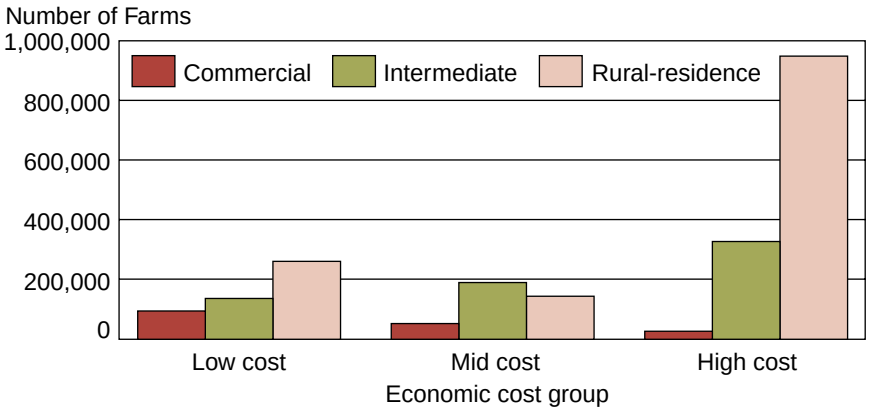
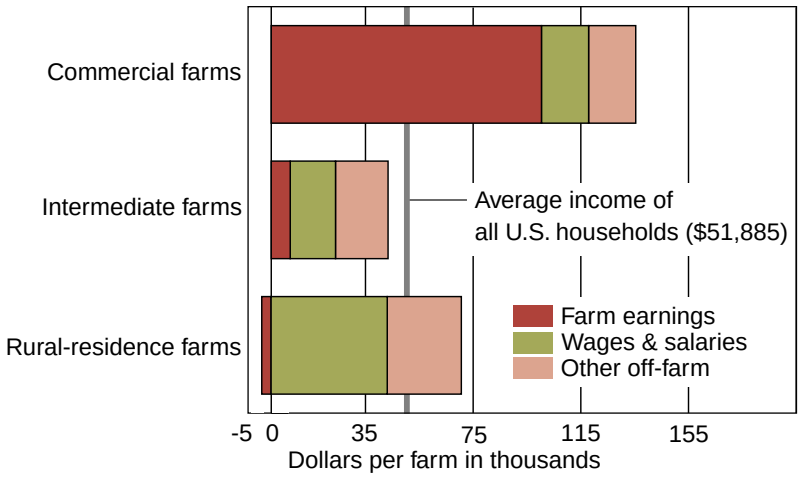


Figure 7
Sources of Operator Household Income (1999)



In contrast with the long-term trend of declining farm numbers, the 1990s saw relative stability in the number of farms and even modest increases since 1996.

intermediate categories and occupy 71 percent of the land owned by farmers.

The competitiveness of farms also varies systematically across the groups (figure 6). Some low-cost farms are found in all three categories, but commercial farms tend to be low-cost producers. Economies of size enable these commercial farms to have low unit costs. By contrast, most intermediate and rural-residence farms do not cover production costs from farm income. Most rural-residence farms fall into the high-cost category.

Off-farm income is important for most farmers, but particularly so for rural-residence farms, whose household income is above the national average (figure 7). While income from farming, as measured by farm sector net cash income, was $55.7 billion in 1999, earnings from off-farm sources were $124 billion. Not surprisingly, most rural-residence farms subsidize their farming activities as part of a rural lifestyle. Off-farm income also is critical for intermediate farms, but contributes only a small share to commercial farm households. Even on many larger, more commercial farms, family members frequently work off-farm at a variety of jobs, ranging from self-employment in nonfarm businesses to positions in government and private companies.

The widespread importance of off-farm income illustrates that for the majority of farm households, the health of the general economy is far more important to their well-being than the level of commodity prices. In contrast with the long-term trend of declining farm numbers, the 1990s saw relative stability in the number of farms and even modest increases since 1996. Recent prosperity in the general economy likely boosted farm numbers, particularly rural-residence farm numbers.

Today, almost one-half of the total acreage in production is rented, reflecting the fact that many landlords are not farm operators, an important consideration in policy formulation. The farm operator's ownership of the land utilized ranges from complete owners (owns all the land they operate) to tenants who rent all of the land farmed, with various combinations in between. The largest number of farms is operated by full owners but these tend to be small, contributing only a third of farm output. By contrast, only 8 percent of farms were tenant-run, but they accounted for 14 percent of output.

In many ways, diversity in the farm sector is driven by diversity in resources and climate. Weather conditions, soil types, water availability, and access to markets vary across the country and affect the types of commodities produced. For example, along southern coastal areas, the most common crops that farms grow are fruit, vegetable, nursery, and other high-value crops, while in the Upper Midwest the primary crops are wheat and other cash grains.

The concentration of farms and production likewise varies across the

country. The highest concentration of farms is in the middle of the country, contributing one-quarter of output. Farm financial circumstances also vary a great deal from one region to the next (see appendix 2 for more detail on regional characteristics of farms).

These circumstances clearly reveal a wide divergence in the realities of farming across the country, and just as clearly illustrate the shortcomings of "one size fits all" agriculture policy. The needs, concerns, and opportunities of larger, commercially oriented farms differ from those of smaller, intermediate farms, regardless of location. Moreover, the requirements of commercial farms in one region may be vastly different from those in another. Farms in the Corn Belt, for example, may be most concerned about eroding competitiveness from rising land prices directly related to farm programs, and about gaining greater access to global grain markets. In contrast, the more diversified farms in southern coastal areas producing many high-value crops may be most concerned about environmental constraints, water supplies, and continued access to specific pesticides. High land prices are also a concern in this region, but more likely reflect urban development pressures and farmland preservation issues.

Farms in the Upper Midwest tend to be more highly leveraged than those in other regions, which increases their concern over input costs, commodity prices, and other factors that affect operating margins and their ability to repay loans. A High Plains cotton farmer may be worried about water availability, energy costs, and the lack of alternative enterprises. In yet another example, more than half of all farmers in regions spanning the southern and eastern reaches of the country specialize in livestock production. Those farmers are facing new pressures for protecting water quality from animal waste. Recognizing the different realities faced by a diverse farm sector sets the stage for a new generation of policy approaches. As the old saying goes, "a problem well defined is a problem half solved."

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Forces Driving Change

Today, a small number of very powerful forces are propelling the fast-paced change occurring in every single component of the food system. Globalization, the growing competitive pressure from closer integration of business all around the world, along with a broad range of new technologies, from information advances to biotechnology, are converging to fundamentally alter the farm and food system as we know it. Understanding the nature of these "drivers" helps define the needs for agriculture and the food system, and—consequently—the needed investments and policies to support the system.

Globalization

Globalization of markets allows somebody somewhere around the globe to profit by finding and meeting consumer demand. Information about trends and tastes spreads almost instantly and effortlessly now. Accounts of next-generation biotechnology products can be found on countless Web sites, often only one click away from real-time prices of commodities and products and other information needed for business decisions.

Today, with capital markets that operate 24 hours a day and without borders, existing food companies and entrepreneurs anywhere in the world can develop a new product or an innovative process for almost any application. And, while experience shows that most of those new products or businesses fail, their cumulative impact makes the marketplace highly competitive.

The "openness" of the world economy resulting from economic and political reforms has contributed importantly to globalization. In the past, much of global trade and investment was strongly influenced by government policies and actions rather than by economic decisions driven by the marketplace. Today, much more agricultural trade is market driven because of the collapse of the Soviet Union, the end of the U.S.-European Union (EU) subsidy wars, and China's shift to more market-oriented agricultural policies. International trade agreements, reforms in domestic agricultural policies, financial market liberalization, and a constellation of other policy changes that boost competition have further hastened globalization.

Growth in international trade and investment illustrates the impact of globalization on the food system.

From 1991 to 1998, the volume of trade for all industries tripled and foreign direct investment (FDI) quintupled. A similar trend is observed for agriculture-related industries. Sales by affiliates of multinational companies show the broad influence of this investment. For example, sales by U.S. affiliates of foreign firms in the food sector increased threefold between 1987 and 1998, reaching $64 billion, far outpacing U.S. imports of $32 billion. Sales in 1998 by foreign affiliates of U.S. multinationals were even larger at $133 billion.

All parts of the food system participate in trade, foreign direct investment, and other global business relationships such as licensing or franchising. For both global trade and U.S. exports, consumer-oriented, high-value products (meats, poultry, fruits and vegetables, and processed grocery products) have been the fastest growing and largest export sector, accounting for over two-thirds of total sales and performing much more reliably in recent years than have markets for commodities.

Tremendous investment growth also has occurred in the retail food industry (supermarkets). U.S. foodservice firms, including restaurants and fast-food outlets, had foreign affiliate sales of $14.5 billion in 1996. Sales by U.S. affiliates of foreign firms in retail trade nearly tripled from 1987 to 1998 and U.S. companies also have invested overseas.

FDI and the U.S. Wine Industry

The world wine industry has undergone major demand-driven changes in the last decade. Preferences have shifted toward high-quality wines, with consumers more attuned to brand name than to country of origin. And, wine retailers in developed markets have a growing influence on distribution and sales. They prefer dealing with a few consistent suppliers that offer a broad portfolio of wines, thus increasing the importance of a wine producer's ability to provide a steady supply of consistent quality. Some U.S. wineries with limited vineyards found they were unable to maintain supplies of wine grapes or ship consistently, thus forfeiting retail shelf space to foreign competitors. To remedy this, some purchased vineyards and wineries abroad to gain access to additional supplies and varieties. Through such foreign investment, U.S. wine producers have increased domestic market share at the expense of traditional European suppliers. Moreover, U.S. wine exports have grown over 20 percent annually since 1995. Countries receiving foreign direct investment have benefited as well, gaining access to new production technologies and increased demand for their grape and wine production.

Foreign-owned firms had foodservice sales in the United States of $6.4 billion in 1998. McDonald's has become the largest overseas foodservice operator, with more than 28,000 restaurants in 121 countries.

Globalization of markets pressures firms to be more competitive, to "shorten the supply chain," streamlining the system (eliminating transactions and their associated costs) to efficiently meet rapidly changing consumer demand. Businesses in the food system around the world compete against each other to provide high-quality products at the best price. Globalization makes it imperative for companies to diversify their sources of raw materials and buy from the farmer, wholesaler, or food processing company that provides the best product for the lowest price at any given time.

All of our experience and evidence points to increasingly fierce competition in the agricultural system, suggesting that the innovative, cost-effective producers will prosper. Mergers, acquisitions, and further

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globalization of the food system can be expected to continue. Helping consumers eventually get what they want can be good business, and businesses that can do this quickly and efficiently tend to succeed while those who are slow to understand key trends face rapid erosion of competitive position.

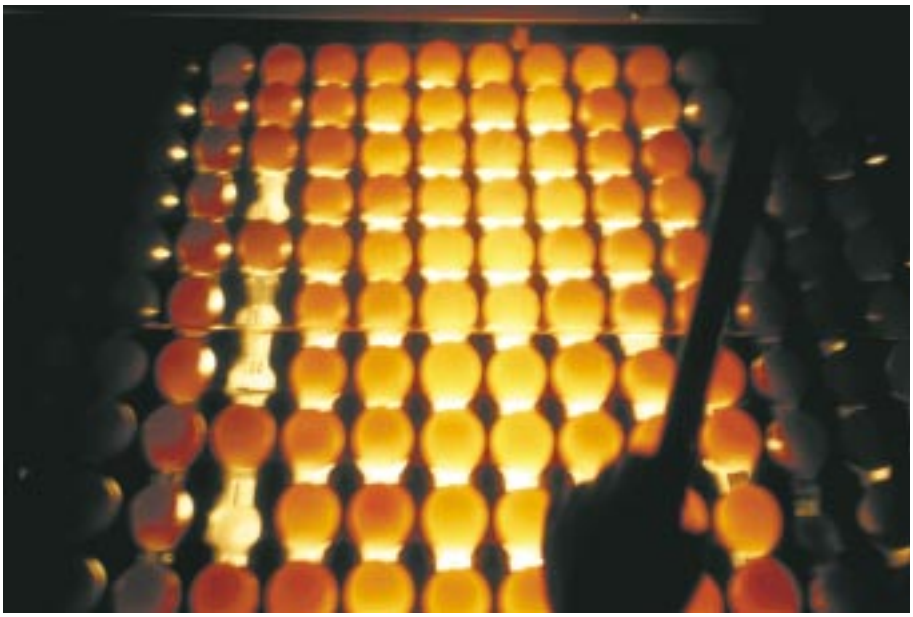
Globalization of markets clearly underscores the need for policies that support growth in competitiveness in the world's inter-related food system. These include policies that support effective trade negotiations and market expansion, as well as expanded monitoring of competition and investment to ensure the efficiency of global markets. Globalization further calls attention to ensuring adequate investment in our infrastructure to accommodate the changing environment—from stronger food safety monitoring and inspection to new research underpinning sanitary and phytosanitary regulations to new competitiveness measures.

Technology

Americans have come to rely on the producers of persistent technological innovation in every aspect of our lives, importantly including food, agriculture, and natural resources. Technological change in agriculture focused traditionally on tools and techniques to lower farmer production costs and increase yields. Such technologies, which have added greatly to production efficiency, increased profit margins of early adopters, and ultimately lower consumer prices, still have a role in today's agricultural economy (see box).

Increasingly, though, the market today is pushing technological progress in new directions, for new purposes, using new tools—all with different implications for business and policy decisionmaking. Biobased technologies promise opportunities never before imagined. Production and processing technologies are opening entirely new energy, industrial, and pharmacological markets for the Nation's farmers. Technology is shifting at every level in the production and marketing chain toward satisfying consumer demand for quality, safety, nutrition, and choice.

Production Technology. Recent advances in agricultural production technology have both reduced pro-



Productivity Growth Drives Competitiveness

Technology has driven the tremendous growth in American agriculture's productivity. The more than threefold increase in corn yields and more than doubling of wheat yields in the past 50 years is indicative of the ability of our farmers to produce more with the same or fewer resources (figure 8). Agricultural sector productivity grew approximately 2 percent annually, reflecting technological advances in plant and animal breeding, mechanization and chemical inputs, and an overall efficient use of resources. These substantial productivity gains have kept U.S. agriculture highly competitive in world markets for many products and commodities.

Yields have grown across all farms but have increased the most on commercial farms (figure 9). Higher yields help explain why most commercial farms are profitable, i.e., they produce more with fewer inputs, which reduces their unit costs. However, farms can be profitable with lower yields, but with increased emphasis on cutting costs or producing value-enhanced or niche products that improve revenues.

Figure 8
Growth in Yields Reflects Technological Progress

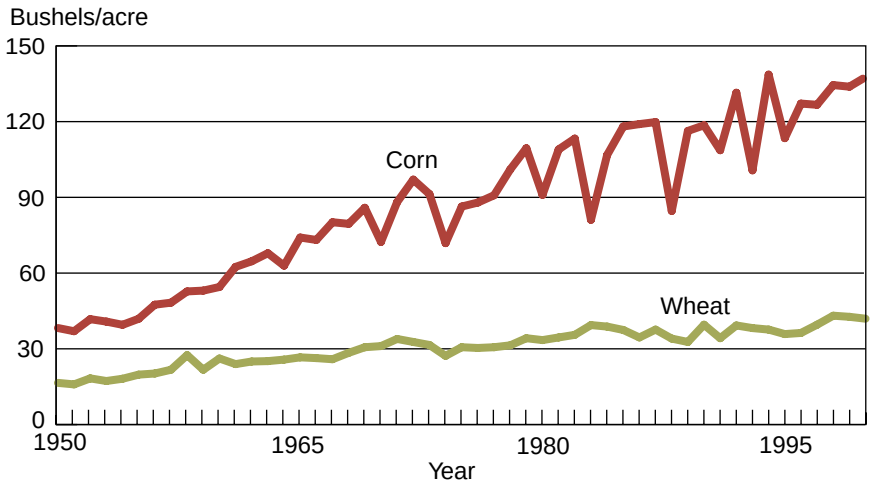
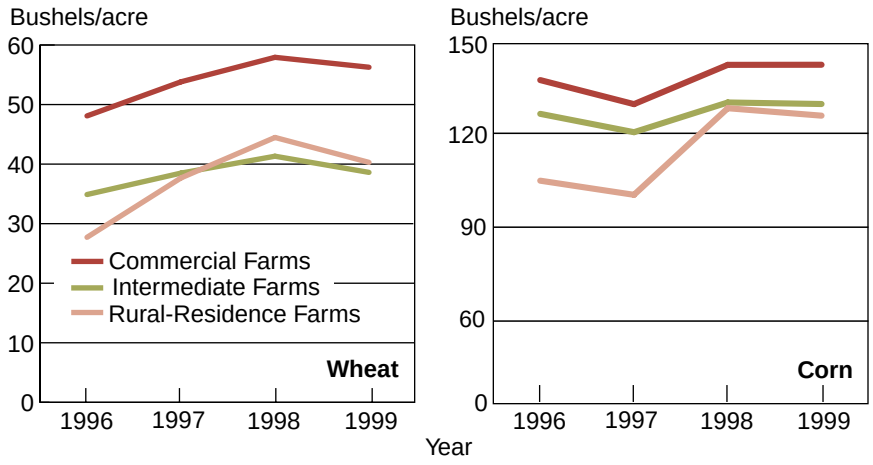


Figure 9
Highest Yields Found on Commercial Farms



ducer costs and conserved natural resources. An example is a drip-irrigation technology that has reduced water needs to support crop growth by 20 percent, a response to competition in water-scarce, densely inhabited areas of the country. Technical advances are also addressing environmental problems arising from the concentration of animal waste in large, confined animal operations. But, more generally, "precision agriculture" promises both greater production efficiency and coordination of input application with environmental considerations. The prospect is for an agriculture that uses sensors, automated responses to monitored variables, robotics, and other high-tech means to optimize both production efficiency and environmental quality (see box, page 33).

In a sense, the past success of agricultural technology presented a policy dilemma. Fewer farms or farmers were needed to produce the growing output, giving rise to both winning and losing producers as yield-enhancing or cost-reducing technologies were widely adopted. Those less able to quickly adopt newer technologies often were surprised by those who were. Future technological advances may offset losses by opening up new markets for standard commodities (see box).

Biologically based technologies are particularly promising as the source of new products and new product uses for farmers. For example, agriculture is the source of clean-burning fuel and industrial ethanol, a variety of specialty chemicals derived from plants rather than from mined stock, soy-based inks and diesel fuel, industrial adhesives, biopolymers, and films. Agricultural scientists recently announced that soybean oil can replace a significant share of petroleum-based resin used in manufacturing auto parts. The possibilities are far reaching, important, and growing. Not only do biobased advances promise to save nonrenewable resources, but they now replace options lost to many farmers as a result of technological advances in food production.

Agricultural biotechnology (see box) permits the rapid development and production of new specialty chemicals, pharmacological products, and commodities with consumer-friendly traits such as higher nutritional content, low fat, or better flavor. This consumer-driven

Cost-Reducing vs. Revenue-Enhancing Technology

Farm profit margins can be increased in only two ways, by lowering unit costs or raising revenues. Today's technology, however, enables farmers to affect margins both ways for the first time in history. Technology can reduce costs by lowering the per unit cost and increasing yields. It also can enhance revenue by enabling value-added products. Past production technologies have been heavily geared toward lowering unit costs. While beneficial to society, the profit-enhancing aspect of this approach fades as the adoption becomes widespread among most farmers and is manifested in lower prices.

Today, promising opportunities are offered by biotechnology and information technologies that may allow expanding revenues by opening new markets. Such markets include biobased energy, "farmacological" products (agriculturally grown pharmaceuticals), crops for industrial uses, and crops or livestock that embody specific traits demanded in niche markets (such as organic foods). Accompanying these developments, computer-based marketing provides access to niche markets for an array of producers, including those that cannot achieve the size economies required for efficient bulk commodity production. The significance of these technological developments is that they are overturning the old dictum of "get big or get out."

Agricultural Biotechnology

Biotechnology is a collection of powerful tools that can be used to increase production or cut costs, develop product attributes desired by consumers, or enhance environmental quality. It is a production, processing, consumer-oriented, and information technology that has application in not just one, but every segment of the food supply chain.

Agricultural biotechnology brings new products, markets, and opportunities to the food and agriculture sector. New crops are being developed to mitigate pest and disease problems, resist drought, tolerate salt, increase photosynthesis, improve nutritional characteristics of food and feed, enhance processing characteristics, and produce new specialty chemicals and human biologics. Biotechnology has introduced new options to farmers, increased profits, and made farming more environmentally friendly. It promises advances in combating hunger and malnutrition, while helping to treat and prevent some of the most debilitating diseases affecting much of the world.

Not all biotechnology applications involve the development of new transgenic organisms. Increasingly, applications in the area of genomics will enable the selection of genetically controlled activities within the genetic makeup of a given plant or animal species, enabling more rapid expression of traits now obtained through conventional breeding. Bioinformatics, the creation of data bases from which genetic clues can be culled, will foster such advances.

Additionally, the tools of biotechnology can address environmental challenges. Prospects include pollution remediation, increased bioenergy availability, enhanced carbon sequestration, and reduced fertilizer runoff. For example, biotechnology has been used to develop strains of corn that resist corn rootworm. Farmers who plant these new strains could then use less pesticides, thereby reducing environmental hazards that may be associated with pesticide use.

Capitalizing on agricultural biotechnology requires ongoing oversight to ensure the safety of an expanding repertoire of new products and assistance in helping the marketplace adjust to this increased diversity of agriculturally based products.

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product diversification and differentiation multiply opportunities for farmers.

A diversifying agricultural system, based more on end products and less on raw commodities, brings new challenges along with broad benefits. The Nation's agricultural infrastructure is built primarily around the commodity-based system. Storage, distribution, and transportation systems can be strained by the need for different products' physical segregation or identity preservation. Government can help by setting standards, monitoring compliance, or certifying agents to define the characteristics that differentiate one commodity-based product from another.

Standard price signals also become harder to read as specialty products become more important. The price of No. 2 yellow corn, for example, could fail as a bellwether if identity-preserved corn products entering different market channels for different end uses become more important. As a result, price-influenced policy decisions will need to be sensitive to a far more comprehensive set of price signals than those from spot markets.

Consumer-Oriented Technology. Consumers' demands for food safety, freshness, quality, convenience, and even attractiveness have spawned brand new industries, each relying on new and unique avenues of technological advance. Examples include food safety research focused on reducing the threat of foodborne disease before an animal even becomes food. Scientists are working on feed additives to eliminate pathogens like *Salmonella* and *E. coli* from hogs' and cows' intestinal tracts before slaughter. Research is developing antimicrobial food packaging materials that would kill microorganisms in food. Rapid tests for microbial pathogens or labels that change color if pathogens are present also will help contribute to food safety.

Packaging technology is revolutionizing ways in which foods can be marketed. An example is the development of "breathable" bags that preserve washed and mixed, ready-to-eat salad greens that gave rise to an entirely new value-added segment of the food industry. Another is edible food wrap—wrap in sheet form made from 100-percent pureed fruits and vegetables—that not only

extends fresh food shelf life but also improves overall nutritional value. This is an example of "active packaging," in which the packaging material in some way interacts with the product it contains to improve its quality, safety, shelf-life, and utility.

Technical innovation in shipping and transportation has allowed U.S. agriculture to deliver food products around the globe with no substantial loss in freshness and quality. Perishable agricultural products, many of which were implausible as overseas sales just a decade ago, now account for more than one-fifth of U.S. food and agricultural exports, due in large part to new transportation technologies.

The technologically based proliferation of new products and new market possibilities is a boon to American consumers and producers alike. Nevertheless, these trends magnify business decisions about what to produce and where to market it. Competition intensifies when new products must compete with existing ones for grocery shelf space, and transportation technology allows American producers to sell in markets where others formerly dominated. Government must support the creativity, foresight, and entrepreneurship in America's farmers and agribusinesses as they respond to new opportunities created by new technologies.

Information Technology. Information technology (IT) contributes to the faster flow of information among potential buyers and sellers of food and agricultural products. It thus affects the speed at which markets operate, and it shortens the timeframe in which pur-

New Technologies Can Increase Yields, Reduce Costs

The advent of the "information age" brings new possibilities and opportunities to farmers that can significantly increase farms' economic performance. A host of new technologies are available that provide timely, site-specific information to farmers that can help increase yields, and reduce unit costs. The Global Positioning Systems (GPS) that use satellites to provide precise location information can be used by farmers to guide farm machinery. Precise navigation of farm vehicles ensures that the machine moves exactly as directed, thereby reducing overlap and increasing efficiency. GPS systems can also be linked with systems that gather information on crop yield and soil conditions, allowing farmers to determine which parts of their farm are most productive, and to take steps to improve low-yielding acreage. Since GPS systems can operate at any time, farmers can operate machinery 24 hours a day, increasing the utilization of equipment.

Digital imagery offers another tool for high-tech agriculture. Digital images of farmers' fields allow them to precisely monitor field conditions, detect plant stress, and link to mapping software to assist in field measurement and pest scouting. Early detection of pests, nutrient deficiencies, or water stress can result in reduced input and application costs or increased yields. Such site-specific information may lead to greater emphasis on management of zones within fields rather than whole fields. Conserving resources, reducing agrichemical applications, or efficiently managing nutrients from livestock waste through the application of such technology will provide enormous environmental and economic benefits.

Farmers have demonstrated a willingness to adopt this type of technology. USDA surveys indicate that 30 percent of the corn and 25 percent of the soybean acreage was harvested last year with combines having a yield monitor. In addition, farmers intend to produce yield maps for as much as 10 percent of all corn and soybean acres.

Research continues on adapting information technologies for a variety of new uses. Several new sensing devices, made for use on combines along with yield monitors, have the potential to increase food quality and enhance crop value by detecting specific crop traits during harvest, such as increased protein or oil content, thus making it possible to preserve identity traits during marketing, processing, and distribution.

chase, inventory, and pricing decisions must be made. Adoption of information technology by farmers, particularly the Internet, has occurred at the same or greater rate than in the general population or among small businesses. Growth in access to and use of computers and the Internet, as well as growth in the range of farm-specific applications, has been robust. In 2000, nearly 60 percent of all farm households had access to a computer, and nearly half of these used the Internet as part of their business.

Farmers reported over $375 million in online business purchases in 2000, and sold nearly $300 million worth of harvested crops and livestock online. Farmers are increasingly using the Internet to add value to traditional commodities through niche marketing and "branded" commodities. Identity preservation of commodities is another IT-dependent use; the characteristics of crop and livestock products and their production processes can be efficiently documented and quickly verified online.

Where Are the Drivers Taking Us?

The food system has entered a consumer-driven era and diversity within our farm sector is enormous. New waves of technology are sweeping through the entire food system. And, business must now operate in a global economic environment. This combination of forces is resulting in an increasingly product-based rather than commodity-based system—in the addition of entirely new markets for agricultural output and continued structural adjustment in every segment of the food system.

Producer responsiveness to clear consumer signals, the inducement of structural change and technological advance by market forces, and diversification and location of production to meet market demands are all essential signs of a well-functioning market. All of these rapidly emerging developments indicate that the institutions, policies, and programs that underpin our food and agriculture systems must be adapted to

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meet the new challenges.

Because the new environment promises to be so different from the relatively insular, commodity-based system of the not-so-distant past, old institutions must adapt to meet the changing needs, or new ones be formed to provide the appropriate functions. The heterogeneous product markets of the 21st century require different information to function well, and the most useful information will be "real-time" and amenable to customization by its users. Heterogeneity in markets (importing and exporting) also suggests the need for different facilitating services to test, monitor, certify, or otherwise assist branding and identity preservation processes, and for the maintenance and advancement of sanitary and phytosanitary standards.

The application of new technologies and increased investment to achieve natural resource conservation and environmental goals should be encouraged. Environmental enhancement can be consistent with a consumer-driven agriculture, since this is a "good" which consumers demand, and for which market-oriented approaches can be found.

While consumer requirements now must factor greatly in agricultural policy, so must recognition of the wide diversity among producers. Particular attention must be paid to groups that would be unable—without technical, educational, information, or infrastructure assistance—to meet the challenges and take advantage of new opportunities provided by globalization and technological advance.