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Keywords
food prices, energy prices, migrant labor, immigrant labor, agricultural labor, labor intensive agriculture, agricultural technologies

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[♦] The author is C.F. Curtiss Distinguished Professor of Agriculture and Life Sciences and Professor of Economics, Iowa State University. Phil Martin provided information on new developments in labor intensive crops, and the Iowa Agricultural Experiment Station provided financial support. The paper was prepared for the conference, "Rising Food and Energy Prices: U.S. Food Policy at a Crossroads," Oregon State University, October 2, 2008.

Rising Food and Energy Prices:
Projections for Labor Markets 2008-18 and Beyond

Since 2002, the world price of crude oil has steadily increased from $25 per barrel (in 2007 prices) to $58 a barrel in 2005 and then to $140 per barrel in the summer of 2008. Moreover, the average rate of increase in world oil prices over the past 5 years has been 23%. Over the same five year period, the U.S. ethanol production capacity has increased by 23.6% per annum (Babcock 2008). Corn is currently the main commodity used by the U.S. to produce ethanol, and the U.S. used 1.1 billion bushels or roughly 12 percent of its 2002 corn crop of 9.5 billion bushels for ethanol. In contrast in 2007, the U.S. used 2.9 billion bushels or about 23 percent of its 13.1 billion bushel corn crop for ethanol. Hence, both U.S. production of corn and the share of its corn crop used for ethanol have increased significantly over the last 5 years. During late spring of 2008, the world corn, soybean, and wheat prices were roughly twice as high as they were two years ago and at record levels. As Babcock (2008) emphasizes, high crude oil prices signal that substitute fuels are needed, and currently the prime source is biofuels. If biofuel feed stocks continue to compete for U.S. farmland used to produce feed, food and fiber as they have most recently, this strengthens the link between the price of crude oil and the prices of food (and feed). Corn for ethanol is largely produced in the U.S. Midwest, which has some of the best cropland in the U.S. and world.

The objective of this paper is to examine how the likely growth in the ethanol industry over the next decade will impact U.S. labor markets, especially migrant crop labor, which is largely immigrant labor. To build the background for making projections for 2008-2010 and beyond, the paper reviews and critiques: (i) the size and composition of the U.S. farm labor market, (ii) the demographics and wage of hired farm workers, (iii) the supply of farm workers, and (iv) the factors affecting the demand for farm labor, including new technologies. The final section provides some projections taking account not only of likely trends in energy prices but other likely changes, for example technologies, that will affect labor markets of the future.

The Size and Composition of the U.S. Farm Labor Market

The number of U.S. farm workers has been declining for roughly 70 years. The number of farm workers in 1960 was 7 million, in 1980 was 3.8 million, in 2000 was 3.19 and in 2006 was about 3 million (figure 1). For the U.S. as a whole, hired farm workers have always been outnumbered by farm operators and unpaid farm family workers. The number of hired workers in 1960 was 1.9 million workers (27% of total farm workers), in 1980 was 1.4 million (36% of the total), in 2000 was 1.1 million (35% of the total) and in 2006 1 million (33% of the total). Hence, roughly one third of all farm workers are currently hired labor.

For the post-War II period, the average number of family and hired workers per farm, including contract workers, peaked in 1960 with 1.91 workers, and of this total, 0.51 workers per farm were hired or contract labor. In 1980, the total number of workers per farm had declined to 1.55 workers and 0.6 workers were hired or contract labor, and in 2000, the total was 1.47 workers with 0.52 being hired. In 2006, these numbers were roughly unchanged.

The number of U.S. farms peaked in 1920 at roughly 6.5 million. The number declined slowly to 1940 and then relatively rapidly to1990 (figure 2). The number of farms in 1960 was about 4.0 million, 2.4 million in 1980 and about 2.2 million today. Clearly, the decline in U.S. farm workers over time is due largely to the decline in the number of farms, even as the average farm size in acres operated (figure 2) or real value of sales has increased dramatically. U.S. farms have also become more specialized over time and the average number of commodities produced per farm has declined from roughly 4.0 in 1950 to 1.2 in 2002 (figure 3). The labor intensity of U.S. agriculture decline dramatically over 1960 to 1980, but changes have been much slower since then (Huffman

2008). In addition, Huffman and Evenson (2001) show how changing farm size and specialization have impacted farm productivity.

Expenditures on farm labor have generally declined over the post-War II period, but labor share of total cash expenses increased slightly, from 14% in 1996 to 15% in 2006 (Kandel 2008). Labor's share of total cash expenses differs greatly across agricultural products produced by farmers. For corn, soybeans, wheat and general cash grains, labor's share is roughly 5-6%. For hogs, cattle, and general livestock, labor's share is 8-11%, and for tobacco, cotton and peanuts; poultry; and dairy and other field crops, labor's cost share is slightly higher, at 12-13% (figure 4). However, the production of fruits, vegetable and nursery crops has by far the largest labor cost share of about 37%. Over the past decade noticeable declines in labor's cost share have occurred for the production of soybeans and for tobacco, cotton and peanuts. The latter commodity group is dominated by cotton. New genetically modified soybean and cotton varieties were introduced in 1996 and they have significantly reduced labor's cost share over the past decade for these crops.

We have shown above that the use of hired and contract labor in agricultural production depends on the agricultural commodities being produced. However, the distribution of production is greatly affected by geo-climatic regions (see Huffman and Evenson 2006, p. 271) and transport costs. California and Florida are the states leading in the production of labor-intensive fresh fruits and vegetables, and they have the largest expenditures on hired farm and contract farm labor (Figure 5). Washington, Texas, and Oregon are intermediate users of hired farm and contract labor. North Carolina, Wisconsin, Michigan, Minnesota, New York, Pennsylvania, Illinois, Iowa and Nebraska are states with modest rates of use of hired farm and contract labor.

Demographics and Wages of Hired Farm Workers

Since 1965, the rate of illegal immigration to the U.S. has increased, with roughly one-half working as undocumented in the labor force. However, we know very little about the legal status of immigrants because the various federal agencies that undertake the population, labor force, and employment surveys have chosen not to ask about the legal status of individuals that they contact for information because they fear a backlash that would significantly cut non-response rates on surveys. Since many individuals who are in the U.S. illegally eventually obtain a green card (Hanson 2006), this may be a rational response of these agencies. The National Agricultural Workers Survey (NAWS) administered by the Labor Department is an exception in that it does ask workers whether they are authorized to work (are legal) or are unauthorized (are illegal).

Instead of legal status, the Current Population Survey (CPS) inquires whether an individual (and his or her family members) are citizens or noncitizens. Non-citizens may possess a green card that permits them to work, may possess a visa permitting them to study in the U.S. or to accompany a spouse or parent who is studying in the U.S., may possess a visa for legal temporary work, may possess a tourist visa, or may be in the U.S. illegally. Based on CPS data, 62% of U.S. hired farm workers in 2006 were citizens and 38% were noncitizens. For hired farm workers that were citizens, 12% were Hispanic, 56% were between the ages of 21 and 44 years of age, and 90% had more than 9 years of schooling. In contrast, for farm workers that were noncitizens, 95% were of Hispanic ethnicity, 74% were between the ages of 21 and 46 years, 63% had less than 9 years of schooling and 53% entered the U.S. during 1996-2005. Hence, the demographic attributes of farm workers who are citizens differ greatly from those who are noncitizens.

The National Agricultural Workers Survey (NAWS) is a Labor Department survey that is focuses on the socio-demographic attributes of hired crop workers. More than 90% of these workers are either from Mexico or the United States. In 1989, the share from Mexico was 55% and from the U.S., 40 percent. Over the next two years, these shares converged by a few percentage points, and then they diverged up to 2000, when individuals of Mexican nationality comprised about 81% and from the U.S. about 17% of hired crop workers. Over 2000-2002, there was again some convergence in sources, and since then, Mexican is the nationality of roughly 70% of crop workers and the U.S. is nationality of only 25%.

In contrast to the CPS, the NAWS asks farm workers whether they are authorized to work in the U.S. (have legal status) or are unauthorized. In 1989, only 12% of hired crop workers were unauthorized, but this share rose steadily to 55% in 2000. Following Sept 11, 2001, the share of crop farm workers that were unauthorized declined to 48% in 2004, but the share that is undocumented has since risen by about 4 percentage points. Unauthorized crop farm workers are more strongly attached to farm work than those who are authorized to work in the United States. For example, over 1989 to 2006 hired crop workers who are authorized have about a 5 percentage point higher rate of expectation of taking nonfarm U.S. employment within a month than those who are unauthorized (Kandel 2008, p. 13).

Real wage rates of hired farm workers have a long history of being below those of other workers, for example production workers in manufacturing (Huffman 1996), and were roughly one-half of the manufacturing wage over 1950-1990. Figure 6 shows that the real wage rate (2005 prices) was $9.11 per hour in 1975, but declined to $8.28 in 1985. Thereafter, the real wage increased slowly over 1985 to 1995 (a total of only 4.4%). There was a significant increase over 1995 to 2000 to $9.48 (a 9.2 % increase) and a further increase to $9.87 in 2006. Given that undocumented Mexicans have been major suppliers of labor to U.S. agriculture, an increase in the intensity of immigration enforcement in the mid-to-late 90s (Hanson 2006) may have been a factor causing the rise in the wage to hired farm workers over 1995-2000.

Wage rates for hired crop workers are at least 10 percent lower than for other hired farm workers. Also, wage rates for all hired farm workers and for hired crop workers are higher in the Western Corn Belt than in California, which is in turn higher than in Florida (table 1).

The Supply of Farm Workers

Farm households are one major supplier of farm workers. They include the farm operators, who are engaged in decision making but also undertake some farm work; unpaid family members, for example, wives and children; and paid farm household members, for example, children. We have seen a steady decline in the number of farms and the average size of farm families over the post-War II period. Also, figure 1 shows that since 1980, farm households have supplied about 1 farm worker per farm and nonfarm households have supplied about one-half of a worker per farm.

For U.S. agriculture, as well as for the construction and hotel and restaurants sectors, Mexicans are major suppliers of work. Mexicans first made a grand entry into the U.S. labor market starting with the Bracero Program, which enabled Mexican (and Caribbean) workers to fulfill short term labor contracts in the United States over 1942-1964. At its peak, 300,000-450,000 migrant workers from Mexico entered the U.S. annually under the Bracero Program. The vast majority of these braceros worked on U.S. farms. All of them were required to return to their home country after their contract was completed.

After working in the U.S., many braceros returned to Mexico where they assisted later generations to migrate to the U.S. They accomplished this by helping to establish informal networks through which earlier migrants helped new migrants enter the U.S., find housing in U.S. cities, and obtain jobs with U.S. employers. This activity built networks often embedded in relationships involving family, kin, or community of birth, which gives them a regional component (Hanson 2006). Consequently, there is strong historical persistence across Mexican regions in channeling migrants to the United States. The highest Mexican to U.S. migration states are from central Mexico, roughly 750-1,500 miles from the U.S. border, and hence, not from states closest to the border.

In 1965, the U.S. changed its "national origins" based immigration program to one of family unification. Consequently, about one-half of U.S. immigration flows consist of immediate family members of authorized immigrants. In contrast, one-third to one-half of all new immigrant flows are unauthorized individuals. It is estimated that a total of 10-13 million individuals are currently in the U.S. illegally and roughly one half of them are undocumented workers. The end of the Bracero Program marked the beginning of large-scale illegal immigration from Mexico to the United States, with a majority of unauthorized immigrants from Mexico entering the U.S. simply by crossing the border illegally.

By the mid-80s, a political solution to the illegal immigration problem was being debated. New legislation was proposed that laid out the guidelines for granting legal status to some of the illegal immigrants, imposed sanctions on employers who knowingly hired illegal workers, and authorized added expenditures to "close the U.S. borders to illegal immigration." This new immigration legislation was the Immigration Reform and Control Act (IRCA) of 1986 (Martin et al. 1995; Hanson 2006). A total of 1.1 million individuals were granted legal status under the agricultural workers program, and another 1.6 million were granted legal status under non-agricultural worker provisions. Hence, a total of 2.7 million individuals were legalized over 1986-1990.

IRCA was effective in dramatically reducing the number of illegal workers in the United States. For example, the share of crop workers who were undocumented (illegal) fell to 12% in 1989. However, IRCA was ineffective in permanently lowering the number of undocumented workers. There were two primary reasons. First, IRCA did not contain provisions for the treatment of family members of newly legalized workers. Second, the newly legalized workers experienced a major jump in expected lifetime earnings and spent part of this income on improved transportation equipment. As a result, the newly legalized workers under IRCA became a conduit for a steady stream of illegal Mexican workers: their immediate family members plus friends (Huffman 1996). As supporting evidence, the share of illegal crop farm workers had risen to 56% in 2000.

Why is illegal immigration from Mexico such a large problem? First, the U.S.-Mexican border is long—roughly 2,000 miles in length across deserts and rough country. Second, second real wage rates are much higher in the U.S. than in Mexico. For example, Hanson (2006) reports that the purchasing power of parity (PPP) adjusted wage differential for individuals who are 23-27 years of age with 4 to 8 years of schooling is $6.40 per hour higher in the U.S. than Mexico. Third, over time Mexicans have accumulated major social network capital that reduces the expected costs to their relatives for crossing the border illegally, finding a place to live and a job in the United States.[1] Fourth, although the U.S. spends what seems like large sums of money on immigration control and enforcement by policing borders, airports and ports of entry, Hanson (2006) emphasizes that a surprisingly large share of these funds go to border control enforcement in a few key border cities and little goes toward apprehension effort away from the border, including establishment inspections.

[1] Hanson (2006) reports that relatively few of the lowly educated Mexicans, those with less than or equal to four years of education engage in immigration to the United States. The group that immigrants is dominated by those with 4-8 years of educations.

Solid evidence now exists that the illegal immigration rate is responsive to economic conditions in the U.S. and Mexico, for example, see Torok and Huffman (1986). More generally, a rise in Mexico's unemployment rate or fall in real wage rates increases illegal immigration to the United States, and illegal Mexican immigration seems to be quite responsive to large negative macro-economic shocks in Mexico. Also, a reduction in the U.S. unemployment rate and rise in real wage rates increases the rate of illegal immigration. Additional resources spent by the U.S. on immigration control and enforcement also reduce the flow of illegal immigrants. However, U.S. enforcement is imperfect and Hanson (2006) concludes that it is subject to U.S. political cycles, e.g., dropping during election years.

A new topic of immigration enforcement is "the Fence" resulting from the Security Fence Act of 2006. The law instructed the Department of Homeland Security to secure about one-third of the U.S.-Mexico border with 700 miles of double-layered fencing supplemented with cameras, motion sensors, and other types of barriers by the end of 2008. Only a small fraction of the new barriers resemble anything like the images of formidable three-layer fencing envisioned by the initial proposal, where 75-yards of no-man's land exists between outer-boundaries of the fences, containing a sandy corridor with pole-topped lighting, cameras, radio systems and radar units, and where unauthorized migrants can be chased down by border agents before entering the United States.

The construction of the fence has faced major hurdles. First the estimated average cost per mile was $1 million, but the cost actually has been an average of $7.5 million per mile for the segments completed. Second, owners of right of way for the fence have in some cases gone to court to block government acquisition of their land, for example, in Texas. Third, the Department of Home Land Security has indefinitely halted work on the "virtual fence" of sensors because they were easily fooled, and are instead redirecting virtual-fence funding to building the physical fence and vehicle barriers. Fourth, infrequent but powerful rain storms along the border have, and will in the future, create heavy runoff that will carry vegetation and trees into segments of the fence and most likely undermine the foundation of the fence and vehicle barriers.

Although enforcement of immigration policy is a public good to most U.S. citizens, the production of this public good is subject to the weakest link public good production technology (Sandler1997). This means that even though the new fence on the border may in some segments lead to dramatic reductions in illegal immigration, the illegal immigrants are mobile. Furthermore, they are frequently aided in their border crossing by highly experienced border crossing intermediaries, called coyotes (Hanson 2006), who charge something like $2,000 per assisted person. Thus, one suspects that the fence on the U.S.-Mexico border will be of limited success in stopping illegal immigration, but divert immigrants to the weakest link(s). Hence, it seems likely to be expensive to maintain.

Hanson (2006) concludes that it is surprising that illegal immigration from Mexico to the U.S. is not much higher. U.S. immigration authorities implicitly determine the level of illegal immigration by selecting the intensity with which they enforce the U.S. border against unauthorized entry and monitors employment practices of U.S. business. The U.S. makes stark choices in its enforcement by heavily policing selective border cities but maintaining a lighter presence in less populated areas, and seldom inspects U.S. worksites.

Factors Affecting the Demand for Farm Labor

The demand for farm labor (and other inputs) is determined by the wage, the price of other inputs that are substitutes and complements, the prices of outputs produced, and technology. Agriculture is largely production by biological processes that are affected by their environment—

climate, weather, soils, and air quality—and technology. The productivity of field crop production has advanced most rapidly over the past 50 years, of livestock enerprises has increased more recently, and specialty crop production has advanced more slowly, especially for the harvesting of fresh fruits and vegetables where uniformly high quality of fresh products is required.

Technology

Starting in the 1940s, application of chemical insecticides has been the main method for controlling insects in many crops, and since the 1970s, herbicides have replaced cultivation and hand weeding for control of weeds in most U.S. field crops. In 1999, U.S. expenditure on insecticides was 3 billion dollars, or 33 percent of the world market. Forty-five percent of the insecticides applied were devoted to the agricultural sector. Although insecticides were initially hailed as a miraculous method to eliminate pest problems, the widespread use of particular insecticides has resulted in the development of tolerance by the target pests (Zilberman 2004), high rates of insecticide application, and low effectiveness of these chemicals in some areas. In addition, high rates of application of insecticides have frequently caused environmental and human contamination.

In the United States, the use of herbicides has increased dramatically since the 1950s; herbicide use is now greater than the combined use of insecticides and fungicides. Plants exhibit varying levels of tolerance to herbicides. Some plants are highly sensitive and can be damaged or killed by very low doses of certain herbicides, while plants that have high tolerance can be unaffected by herbicides that kill other plants. Hence, farmers have used herbicides developed by the private sector to selectively control weeds in field crops for more than 40 years. New private-sector developed crop varieties that carry herbicide-tolerant genes have been developed to survive and to be minimally affected by application of a particular herbicide, while at the same time killing targeted weeds. To farmers, currently available herbicide-tolerant crops represent an innovation that allows them to simplify herbicide application to a single broad-spectrum herbicide, thereby simplifying farm management decision making.

In dry-land farming, the gradual change from intensive seedbed preparation and cultivation to no-till farming started with the relatively high fuel prices of the mid-70s (Rahm and Huffman 1984) and was speeded along by the soil conservation requirement of the Food, Agriculture, Conservation and Trade Act of 1990. The net impact of less tillage and fewer field operations has been reduced demand for labor, large horsepower tractors, mould board plows, heavy disks and fuel. These savings are partially offset by increased demand for chemical herbicides, herbicide-tolerant plants, and specialized no-till equipment. No-till farming and new herbicide-tolerant and insect resistant and protected crop varieties have greatly reduced the demand for labor and some other inputs in major field crop production in the Midwest and South.

Field crops. The U.S. has experienced improvements in the productivity of field crops over most of the last half-century, and in some cases longer. This improvement is the result of genetic improvement of crop varieties but also due to improved cultural practices and management.

The U.S. has a 75 year history of steady improvement in hybrid corn varieties and shorter periods of steady improvement in other field crops. The private sector assumed the role of inbred line development for new corn hybrids in the 1980s (Huffman and Evenson 1993, p. 160), and figure 7 shows that the increase in Iowa corn yields has been approximately 2 bushels per acre per year since 1955. Before 1975, all commercial soybean varieties were developed and released by the private sector (Huffman and Evenson 1993, p. 164). This was a period of slow varietal improvement (average yield increase of roughly 0.2 bushel per acre per year), and because soybeans are self-pollinated non-hybrids, farmers were able to save and plant their own seed. However, during the 1980s, the private sector began developing new soybean varieties, and in 1983, the public sector varieties accounted for only 21 percent of harvested varieties. Now, all commercial soybean varieties are produced by the private sector, and farmers plant new seed each year.

New wheat and other small grain variety development have been largely a public research sector activity, and starting in the mid-60s, new wheat varietal development also included varieties with CIMMYT ancestry (Huffman and Evenson 1993, p. 167-177; Pardey et al. 1996). Although U.S. wheat production is largely on rain fed land in the Great and Southern Plains regions. Growing conditions in these areas are more limiting than, for example, corn in the Midwest. Figure 8 shows how Kansas winter wheat yields have improved over time. Almost no improvement in state average wheat yields occurred over 1900 to 1950, but yield increases have been at the rate of 0.5 bushel per acre per year since then.

The discovery of DNA in 1953 and a gene splicing technique in 1973 set the stage for genetic engineering of new crop varieties in the 1990s. This was largely accomplished by the transfer of insect resistance genes into commercial crop cultivars. One type of insect resistance (IR) has been obtained by insertion of *Bacillus thuringiensis* (Bt), soil bacteria that makes many insects become ill and die, and this new Bt technology has been effective in controlling particular insect pests in some field crops. For example, Bt cotton is mainly effective in controlling tobacco budworms, and less effective in controlling the cotton bollworm. Early Bt corn varieties provided resistance primarily to the European corn borer and were somewhat protective towards the corn earworm, the Southwestern corn borer, and to a lesser extent, the cornstalk borer (Fernandez-Cornejo and McBride 2002). Hence, insect resistant crop varieties have emerged as another solution to farmers' plant insect pest problems.

Newly developed GE/GM crop varieties that are available to farmers can be broken down into 3 types of GE traits: "IR (insect resistant)", "HT (herbicide tolerant)" and "stacked (combinations of HT and IR)". With Bt genetically engineered into a crop variety, plant parts become toxic to target insects and kill them. With HT genetically engineered into a crop variety, the plant is resistant to a particular commercial herbicide; for example, Monsanto's Roundup contains the active ingredient glyphosate. Hence, for Roundup Ready soybean varieties, farmers plant the HT variety and, roughly one month after emergence of the crop and accompanying weeds, the farmer applies the commercial herbicide Roundup, which kills all of the plants in the field except for the Roundup Ready Soybean plants. This then leaves the treated soybean fields largely free of weeds. Moreover, the effectiveness of applying the herbicide Roundup to Roundup Ready soybean plants is not sensitive to modest deviations in the application date, which is a major advantage to farmers that have off-farm jobs, other competing uses for their time, or face uncertain rainy weather conditions. Because farmers always face weed problems in their fields and soybean plants are not competitive against tall weeds, and because of the wide window for applying Roundup to the soybean varieties, HT soybean varieties have become very successful in the United States.

In contrast, corn is a strong competitor against weeds, and HT corn varieties have been less successful than HT soybean varieties. Likewise, European corn borer infestation is random, not occurring every year. Hence Bt for European corn resistance has not been as popular with farmers as HT. The recent development of GM protection to corn root worm holds more potential because the rootworm is a persistent pest. Hence, GM corn varieties have one to three main traits. GM soybean varieties are primarily herbicide-tolerant. GM cotton varieties have one or two traits, for Bt and/or HT.

In 1995 no significant acreage of U.S. field crops was planted to biotech crop varieties, and in 1996 the rate of adoption was low, being higher for Bt cotton and HT soybeans than for HT corn and cotton or Bt corn (figure 8). Bt cotton has been adopted in some areas of the South, but not in other areas where insect problems, including tolerance to chemical insecticides, were less severe. The HT cotton adoption rate surpassed Bt cotton adoption by 1998, reflecting the fact that weeds are a persistent problem in cotton, and HT cotton experienced higher adoption rates than Bt cotton through 2007.

Although the adoption rate for HT soybeans was initially lower than for Bt cotton, HT soybean varieties have experienced very rapid adoption rates over 1997-2007, except for a brief setback in 2000. The adoption rate in 2007 was about 90 percent of planted acres. HT and IR corn varieties were adopted more slowly by U.S. farmers, but by 2007, HT and IR corn variety adoption rates had reached about 50 percent (figure 9). In the U.S. in 1996, biotech crop variety shares for planted acres were 17 percent for cotton, 7 percent for soybeans and 4 percent for corn. But in 2007, these shares had increased to 91 percent for soybeans, 87 percent for cotton and 73 percent for corn. For non-hybrid GM crops, farmers must sign a waiver when they purchase the seed that they will not save or sell seed from their harvest.[2]

Field crop production today has been reduced largely to two operations: planting and harvesting. In 50 years, seed corn planters have advanced from 4-40 inch row planters to large sophisticated 24-30 inch row (30-20 inch for soybeans) planters that plant seeds with high spacing accuracy, depth control and firm seed-soil contact for rapid germination. Early corn planters might have applied starter fertilizer, but these new planters also apply starter fertilizer and, if needed, pre-emergent herbicide. Also, new planters have the capacity to be linked to GPS to more accurately control planting, fertilizer and pesticide application rates. These planters can also be quickly folded into an easily transportable piece of farm equipment. These new planters are major labor-saving devices.

In 50 years, the harvesting of corn has been converted from two-row pickers to 12 and 16 row corn combines. These new corn combines have electrically controlled smooth feeding of stocks, low ear loss, large 150-350 bushel grain tanks and easy maintenance. Likewise, soybean and small grain combines have experienced a dramatic increase in cutting bar length from 12 to 30 or even 40 feet and improvements in threshing effectiveness. The new combine heads have a flexible cutting

[2] With hybrid corn, saved seed is a poor performer and hybridization provides natural intellectual property right protection.

platform that can float over the terrain of the field being harvested. New combines have yield monitors and also have the potential for use of GPS data by the combine's computer such that the combine is computer guided through the field while adjusting the height of picker and cutting bars and maintaining peak harvesting speed. With the new enclosed comfortable cabs on combines and GPS controls, farmers can harvest more grain with less of their own energy, less fatigue, and work longer days. Hence, these new harvesting combines are major labor-saving or labor-augmenting devices relative to early vintage combines and corn pickers.

Specialty Crops. For specialty crops such as vegetables and fruits, major technical advances have been associated with drip irrigation, fertigation, plastic mulch and new plant varieties. Irrigation is an important supplement to natural precipitation for all crop production in California and Florida, some of the crop production in Texas and very little in Iowa. Although flood, moving rig, or center pivot irrigation systems have been used for irrigating horticultural crops, they are being replaced by drip irrigation, which is a water- and labor-saving way to irrigate plants. Hoses with regularly spaced drip holes are laid permanently (or temporarily) at the center of beds. When the water is turned on, the drip system delivers water at the root base of the growing plants. This dramatically reduces water percolation out of the root zone and from evaporation, as in flood, moving rig, or center pivot irrigation systems. Also, it dramatically reduces the amount of labor used relative to that with irrigation from portable surface pipes.

Fertigation uses the same drip irrigation system to deliver liquid fertilizer efficiently to the roots of growing plants, especially in fresh vegetable production. With this method of application, a farmer usually starts the growing season by applying dry fertilizer before planting vegetables and then supplements during the later growing season with fertigation. A positive externality of fertigation is reduced water pollution from leaching and runoff of agricultural chemicals.

Plastic mulch is frequently used with raised and rounded seedbeds to produce vegetables, tomatoes, and strawberries in California, Florida and Texas. This plastic mulch is placed on raised or rounded seedbeds. Long clear (or sometimes black) sheets of plastic are laid over the entire bed, pierced only where the young seedlings or plants are planted. Plastic mulch reduces weed growth, promotes desired plant growth, especially in hot-season plants like tomatoes, and blocks micro-organisms from moving from the soil to the growing plants. It reduces the need for hand weeding, herbicides, fungicides, and other plant protection measures. Plastic also raises the soil temperature, reduces water evaporation and increases the total photosynthetic activity in most plants.

Since 1999, controlled-environment tomatoes have been grown hydroponically in green houses. These plants obtain all of their nutrients from a liquid solution surrounding the roots of growing plants. The hand labor in the hothouse is somewhat different from that for traditional open-air staked tomatoes and can approach full-time year-round work. These tomatoes have been attractive to consumers because of their greater uniformity than open-air tomatoes and, it is claimed, improved taste. Many of these tomatoes are being marketed "on-vine" in clusters to convey an appearance of freshness to consumers. US production of hydroponic tomatoes is now replacing the traditional Netherlands, Canada and Israel sources.

Although the Flavr-Savr tomato was the first genetically modified (GM) crop to be introduced to farmers in the U.S. (by Calgene 1994), they had a relatively short life because of a number of mistakes made in the development and positioning of the product. They were withdrawn from the market in 1999. Monsanto released the Russet Burbank New Leaf Potato in 1994, which was resistant to the Colorado potato beetle. Although the GM technology was effective, fast food and the supermarket chains failed to purchases or distribute the product, and it was withdrawn from the market in 1999. The main success in GM fruit and vegetable crops has been the GM papaya, which is resistant to the ringspot virus. This GM technology was developed by the public sector and released to the growers on the large island of Hawaii in 1998, and it has been effective.

The consumer resistance to GM food crops, e.g., potatoes and wheat, seems to be greater than to GM field crops that are used largely for livestock feed or fiber, e.g., corn, cotton and soybeans (Colson et al. 2008, Rousu et al. 2007). Continued resistance to transgenic GM crops, which transfer one or more genes across species, for example from soil bacteria to hybrid corn varieties, and large genetic diversity in some vegetable crops have provided the opportunity for the development of new crop varieties that use intragenic rather than transgenic GM technology. Intragenic GM technology transfers genes within the same specie. For example, the potato has been grown by farmers for 12,000 years under diverse geoclimatic, food and economic needs, and it has in its genome useful consumer traits that do not exist in the North American Russet potato. Furthermore, the potato is propagated by planting a small piece of potato with an eye or tiny sprout on it and is very difficult to manipulate by conventional plant breeding methods. This has provided an opportunity for scientists to develop new intragenic GM potato varieties where genes for high antioxidant and vitamin C levels from primitive potato varieties are swiftly moved into commercial Russet potato varieties. Thereby, genomic and metabolic pathway discoveries can be rapidly introduced into established commercial varieties to fast-track the breeding process for potato, tomato and perhaps other crops (Rommens et al. 2004). These intragenic GM methods are expected to important to be the future development of food crops that contain consumer traits.

Harvesting the produce from ripe crops, especially fruits and vegetables, has historically been labor intensive, hard and sometimes backbreaking work. Harvesting ranges from stoop-labor for vegetables such as strawberries, lettuce, asparagus, broccoli and tomatoes to standing on ladders to pick fruits such as citrus (oranges, grapefruits, lemons, limes), apples, peaches, cherries, pears and avocadoes. Labor-saving mechanization for these crops can be classified as labor aids (e.g., back-saving devices), labor-saving machines (e.g., tree shakers), and automation (e.g., electronic eyes that replace human eyes for selecting and harvesting crops) (see Martin 2006).

The most dramatic labor-saving mechanization in U.S. fruit and vegetable production continues to be the tomato harvester for harvesting tomatoes for processing (Schmitz and Seckler 1970). It was developed in the early 1960s by the University of California and spread rapidly in the processed tomato industry of California after the end of the Bracero program in 1964. Before the harvester, workers hand-picked ripe tomatoes, placing them into boxes weighing about 50 pound when full. These boxes were then carried to the ends of rows where they were dumped into specially designed trucks. In their place, the mechanical tomato harvester operates much like a conventional small-grain combine, cutting the plants off near ground level and pulling them into a separator, where the tomatoes are shaken off the vines and sorted by gravity through a screen onto rolling conveyor belts. Until the early 1990s, four to six workers were needed to ride on the machines and undertake hazardous hand-sorting, getting rid of chunks of dirt and green tomatoes so as to have a truck load of high-quality ripe tomatoes. During this era, payments to growers were frequently docked for excessive dirt and green tomatoes that accompanied ripe tomatoes delivered to processing plants.

Over time, processed tomato varieties have been bred for a pear or cylindrical shape, high-solids content, uniformity in ripening date and, generally, tough skins. With these attributes, they are less susceptible to pests while growing near the ground and can be easily harvested mechanically.

During the early 1990s electronic sorters were developed and attached to mechanical tomato harvesters. These electric-eye sorters were a major technical advance. They sense the color of material on rolling conveyor belts and use air pressure to blow green tomatoes and chunks of dirt off the belts. The remaining ripe tomatoes are then elevated into wagons or trucks. The electronic sorters have reduced the amount of hazardous hand-sorting and the number of workers riding on the tomato-harvesting machines, also eliminating the green tomatoes and dirt from loads of ripe tomatoes. The net result of the new processed tomato harvesting technology was that harvesting labor costs declined from 50 percent to 15 percent of the cost of producing processed tomatoes.

Mechanical harvesters have also been developed and widely adopted in some areas for soft fruit (e.g., cherries, peaches, plums) and hard fruit (e.g., apples) for processing, and for nuts. These harvesters have one motorized part that grips the tree and shakes it hard enough to make virtually all of the nuts or fruit fall off, either onto the ground (nuts) or onto a sloping canvas (fruit). Conveyors can be used to move fruit into boxes. After harvesting, the gripping part of the machine releases and moves to the next tree. These machines greatly reduce the labor needed for harvesting and eliminate the hazardous work of harvesting trees from ladders.

Shake-and-catch machines harvest most tree nuts, and are used to harvest some tree fruits for processing, such as cling peaches for canning and Florida oranges for juice. Other fruit crops whose harvest has been largely mechanized are mid- and low-end wine grapes, and prunes (dried plums). In each case, machines were improved as they were introduced, and then diffused rapidly as processors changed their machinery to deal with machine-harvested crops.

In some commodities, mechanical aids rather than harvesting machines are making jobs easier and workers more productive. Lettuce, celery and broccoli are generally hand-harvested and placed on a slow-moving conveyor belt by workers who follow behind the machine. This eliminates the need for carrying heavy loads of vegetables to trucks, and makes the work accessible to more women and older workers, and less likely to cause back injuries. A similar conveyor belt harvesting system has been introduced and is spreading through strawberry harvesting. Again, this worker-aid has eliminated the need to carry heavy flats of berries to pickup stations. California raisin graphs have been traditionally harvested by hand and left on paper trays in the field to dry, but new raisin grape varieties are trellised so that the ripe fruit can dry on the vine (DOV method of production) and then be harvested mechanically. Since the fruit is relatively dry when harvested mechanically, bruises and blemishes are less of a concern than for fresh produce (Green and Martin 2008). Many leafy vegetables, such as spinach, are cut by band-blade machines, and a machine can harvest fresh-market asparagus, which eliminates stoop labor.

The major problems involved in spreading tree shakers to crops such as apples, avocados, peaches and pears are the lack of uniform ripening, and excessive damage to the harvested fruit and sometimes to harvested trees. Some trees must be sprayed with a chemical to loosen their fruits so that they can be shaken off without damaging the trees.[3] However, most fresh fruit packers and processors are not set up to handle crops that include significant amounts of damaged fruit. Moreover, mechanical harvesting is easier when trees are short, and this need has been accommodated in new harvesting by planting dwarf trees at high density. For example in Washington State, delicious apples ripen uniformly but the trees are spaced far apart, making mechanical harvesting inefficient. With newer varieties, such as Fugi and Gala, the trees are dwarfs and are pruned to grow on a trellises, which positions the fruit ideally for mechanical picking, but these varieties don’t ripen uniformly and generally need picking four or more times, so mechanical harvesting in again inefficient (Green and Martin 2008).

The NAWS shows that roughly one-half of crop workers are illegal immigrants, and given that relatively few crop workers in the Midwest are Mexicans, the share of crop harvest workers in

[3] For example, it takes a 20 pound pull to dislodge oranges from their tree. In Southwest Florida, orange harvesting in highly mechanized but in other areas hand harvesting from ladders is the dominate technology. Recent high orange prices have slowed mechanization (Green and Martin 2008).

California (and Florida) that are illegal Mexicans much be much higher. In fact, the language of field work and packing houses in California is Spanish and not English. These immigrant workers have, however, obtained a reputation for being relatively reliable and productive, and growers of fresh fruits and vegetables prefer them to citizen workers.

Livestock. Huffman and Evenson (2008, pp. 252-253), Narrod and Fuglie (2000), and Yu (2008) describe how the technologies of U.S. livestock production have changed. Steady improvements in animal genetics have occurred with the use of artificial insemination, which is now widespread and pervasive in modern dairy and swine production. Cross-breeding has spread from swine to beef herds as a mechanism to improve performance. With the aid of advances in animal health, livestock production in the U.S. has become specialized into large units for broilers and layers, swine, and beef cattle finishing, which reduces labor intensity. Dairy farms have become larger in the Upper Midwest and New York (100-200 cows), but very large in many other areas, such as Florida, Arizona and California (5,000-10,000 cows). Immigrant farm workers have been integrated into the labor force for these large factory-type specialized livestock operations. Also, with the large size, some workers can be employed full time at their specialty, for example, in artificial insemination, and perhaps obtain a higher wage than if they perform a diverse set of farming activities that included artificial insemination (Yu 2008).

Projections

Rapidly rising energy prices, with corn ethanol being a major substitute, would imply sharply rising prices for farm fuel, fertilizers (especially nitrogen) and agricultural chemicals, and combined rising prices for grains and oilseeds. What is projected for the next decade? Since the production of corn is heavily concentrated in the Midwest, we can draw some implications about the likely impact on farm labor demand. First, I have fitted a system of output supply and input demand equations (Fan and Huffman 2008). Outputs are grouped into two types, crops and livestock, and there are five variable inputs: capital services, labor (family and hired labor), energy, agricultural chemicals and other materials. Quasi-fixed factors are land area, public agricultural research, availability of GM corn and soybean varieties, pre-season rainfall and trend. The model has been fitted to data for eight Midwestern States (the Corn Belt and Lake States) over 1960-2004 to obtain a set of output supply and input demand elasticities. Table 2 shows that the own-price elasticity of demand for farm labor is small, -0.055, so that, for example, a 10 percent increase in the wage reduces labor demand by one-half of one percent. Perhaps more interesting to consider is the following scenario arising from a conglomeration of reactions to high energy prices: if the prices for crop output rise 100% and for livestock output, 10%; for inputs of farm capital services, rise 25%; of farm labor, rise 10%; of energy and agricultural chemicals, rise 100% and other materials rises 50%, then how much would the demand for farm labor change? The answer is an increase of about 4.4%, which includes the effect of moving some better pastureland into crop production. However, the story does not stop here, because if public agricultural is source of new technology. In particular, if local public agricultural research increases, it would reduce the size of this increase. But, of course, if investments in public agricultural research decline, the growth in demand for farm labor would be larger.

Second, perhaps anticipating a large increase in demand for corn to produce ethanol, Monsanto has set a goal of doubling U.S. average corn yields by 2030 or in 22 years. This implies an increase from about 150 bushels per acre to 300 bushels per acre. Recall that the state average corn yield for Iowa has been increasing at roughly two bushels per acre per year. For Monsanto’s goal to be achieved, the average rate of increase in U.S. corn yields would need to be about 6.5

bushels per acre per year. Furthermore, Monsanto’s goal is also to double U.S. soybean yields, which may be driven by a projected increasing use of vegetable oils for diesel and other fuels.

What technology exists that could rapidly boost U.S. corn and soybean yields? Impressive opportunities exist for new uses of biotechnology, including infomatics, to speed crop improvement, especially in field crops. These methods include rapid DNA sequencing followed by selection on genomic traits, marker-assisted breeding, including the use of functional markers, double haploid breeding for crossing previously incompatible species, and random DNA markers associated with desired traits. In addition, new or enhanced agronomic traits may boost yields and improve product quality. They include insertion of drought-resistant genes into corn and potentially other crops, improved root structures by GM rootworm and cutworm protection, improved stock strength and ear quality in corn by GM multi-stock borer and ear worm protection, improved weed control by GM multi-trait herbicide tolerance, and improved nitrogen usage at early growth stages in corn and other crops. In particular, Monsanto has developed a new corn hybrid variety that contains 10 transgenic genes (called a “Smart Stax hybrid variety) that provides multiple genes for herbicide tolerance, insect resistance and protection, and drought tolerance. Improved output traits may also add value: enhanced starch, oil and protein content in corn, low saturated fat vegetable oils, and antioxidants and vitamins in vegetables. Likely changes in farming practices include increasing plant populations in corn and soybeans and perhaps other field crops, better farm management using information technologies, and more intensive use of the Internet for technical and market information. Hence, I project that the new energy economy will spur the adoption of insect-resistant and tolerant corn varieties and perhaps herbicide-tolerant varieties in corn, and possibly in wheat and other small grains. Moreover, relatively high grain and oilseed prices will undoubtedly cause farmers to upgrade their farm machinery, especially the addition of large, high capacity grain combines. Overall, these changes will be labor saving.

In addition to the demand for labor for the production of grain and oilseeds in the Midwest, the rapid increase in ethanol production plants and associated byproduct industries will increase the demand for labor. However, these industries are very capital-intensive, automated and electronically controlled. So some, but not a very large, increase in labor is anticipated for this industry.

What impact will high energy prices have on fruit and vegetable growers? They imply significant increases in the cost of fuel, agricultural chemicals, transportation of workers and products, and pumping of water for irrigation. There may be some short-term substitution toward labor and away from energy, but in the longer run, incentives exist for further mechanizing and automating the harvest of fruits and vegetables for processing. However, the harvesting of fresh fruits and vegetables will continue to largely be by the hand labor of immigrant workers. The high price of fuel for transportation creates incentives for immigrant workers to stay longer on each trip to U.S. and to make fewer returns to their home country, usually Mexico. Most likely, the trend of the post-IRCA era, where recent immigrants settle in rural communities, especially in California, Texas and the Pacific Northwest, will continue.

With slowly rising real incomes, high income elasticities of demand for fresh fruit and vegetables and more labor-intensive organic produce, growing health concerns from imported fresh vegetables, and growing concerns about the U.S. obesity problem (Huffman et al. 2008), the U.S. demand for fresh fruits and vegetables is expected to grow. Given slow potential for technical change in this area, the growth will increase the demand for hired crop labor. A key question is whether this labor will be available. First, there is the uncertainty created by “the Fence” on the U.S.-Mexico border and how it will affect future flows of immigrant workers to the United States.

My guess is that the fence will be only marginally successful; the weakest links will be large enough to permit a steady stream of illegal immigrants. Furthermore, if the U.S. were to get tough enough to stop illegal immigration, it could stand to permanently damage its relations with Mexico. Moreover, the U.S. has a long history of permitting immigrants to come and work and to make a new life for themselves, even if they are at first in the U.S. illegally.

Second, a new immigrant farm worker policy might become available. Currently, this topic is quite polarized; opponents resist another wave of transition in immigration status, sometimes called an amnesty program, and demands by growers of fresh fruits and vegetables for a highly predictable and efficient work force. The most relevant of the new proposals for agriculture is AgJobs, which represents a compromise between growers, farm labor advocates, and Federal legislators. The AgJobs program would provide farm workers with temporary citizenship status and the possibility of obtaining permanent legal residence in the United States over time. It would also restructure the existing H-2A visa program for temporary agricultural workers so as to reduce administrative burdens for growers and also increase legal protections for immigrant workers (Kandel 2008).

The H-2A visa program is the only U.S. temporary or guest worker program for agriculture, and it is hardly used by growers and workers; for example, only 64,000 workers received visas under this program in 2005. Both growers and farm labor advocates criticize the program. Growers object to what they consider cumbersome administrative requirements, including timing and coordination problems, and farm labor advocates contend that the program invites abuses through a lax regulatory enforcement and the creation of a set of second class workers. Given these circumstances, my prediction is that the status quo immigration program will continue for some time in the future. That is, the U.S. will continue to have a relatively large number of illegal immigrants who want to work in agriculture. Mexicans who want to come to the U.S. for work prefer this outcome, as do some of their American relatives, and growers, on average, face minimal uncertainty about their labor force due to Immigrant Control and Enforcement (ICE) inspections or "raids" of their operations, especially if they obtain workers through farm labor contractors (Taylor and Thilmany 1993). However, over the long term, I believe that U.S. should strive to establish a functional guest-worker program for farm workers and perhaps other workers.

Finally, I believe that biofuels are not a long-term solution to the U.S. energy problem, and hence, there will come a time in the future when agricultural products will again be used largely for food, feed and fiber, but not to produce ethanol, biodiesel or any other fuel. This will help break the link between the price of crude oil and the price of food.

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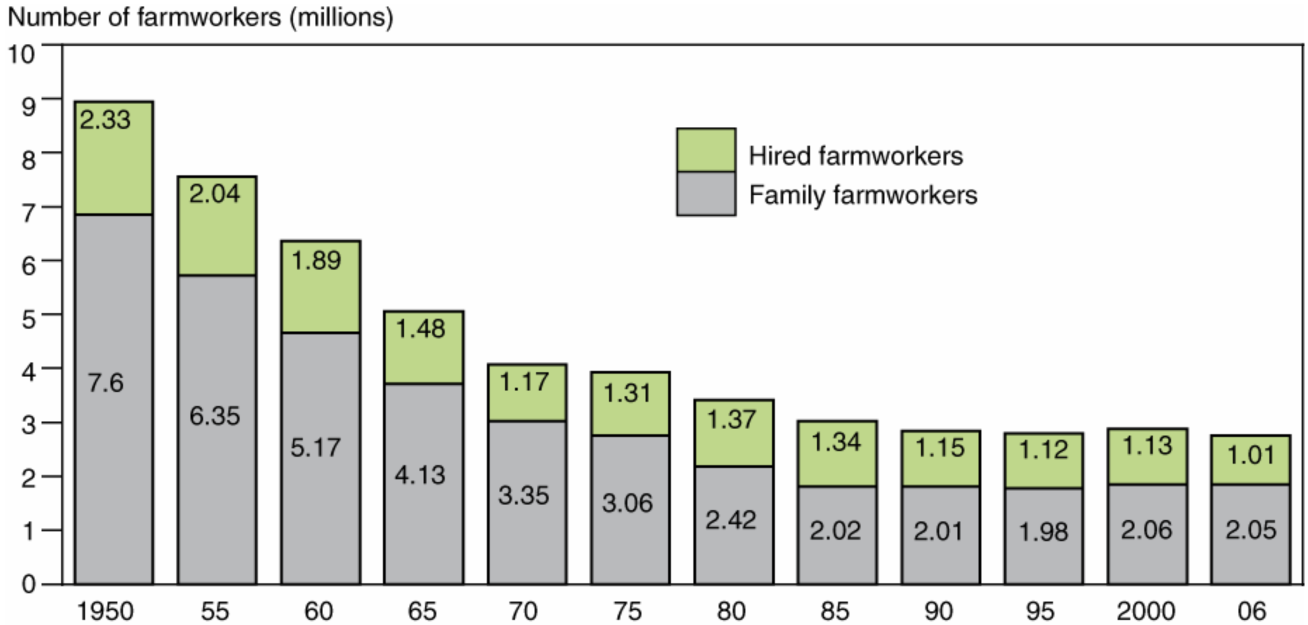
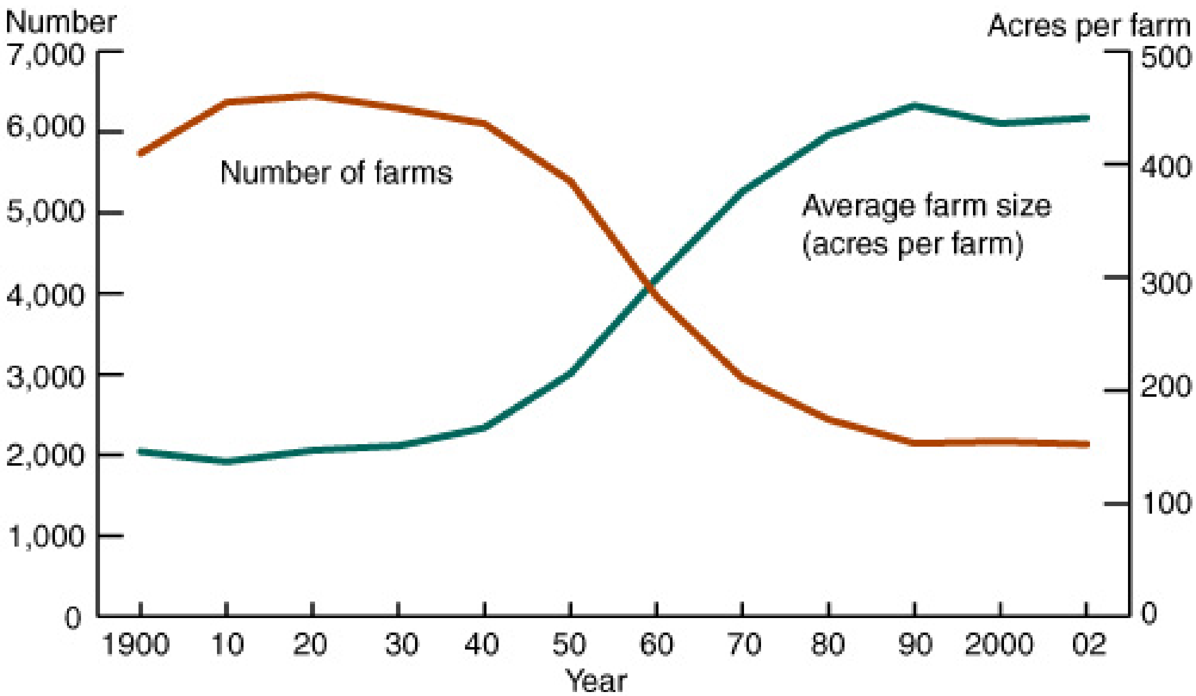
Figure 1. Total family and hired farmworkers on U.S. farms, 1950-2006



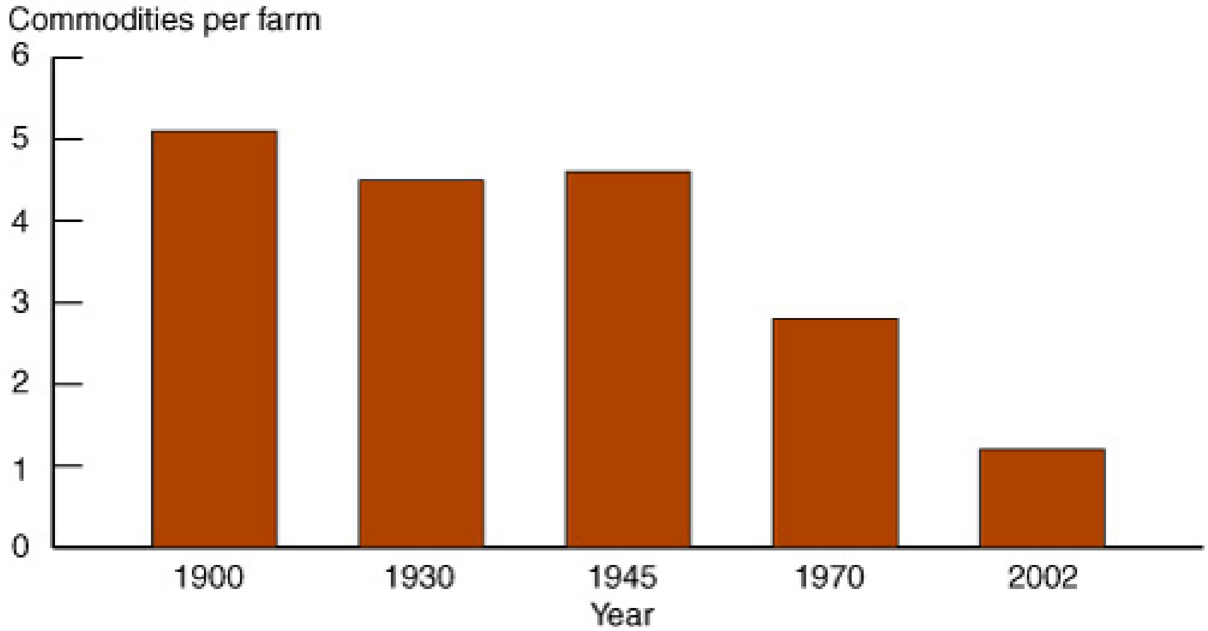
Notes: Family farmworkers include self-employed farmers and unpaid family members. Hired farmworkers include direct hires and agricultural service workers who are often hired through labor contractors. The 2006 family farmworkers figure of 2.05 million is estimated from a simple linear extrapolation from the last available annual figures for self-employed and nonpaid family farmworkers collected by NASS from 2000 to 2002.
Source: Farm Labor Survey, National Agricultural Statistics Service, USDA.

Figure 2. US farm numbers and average size



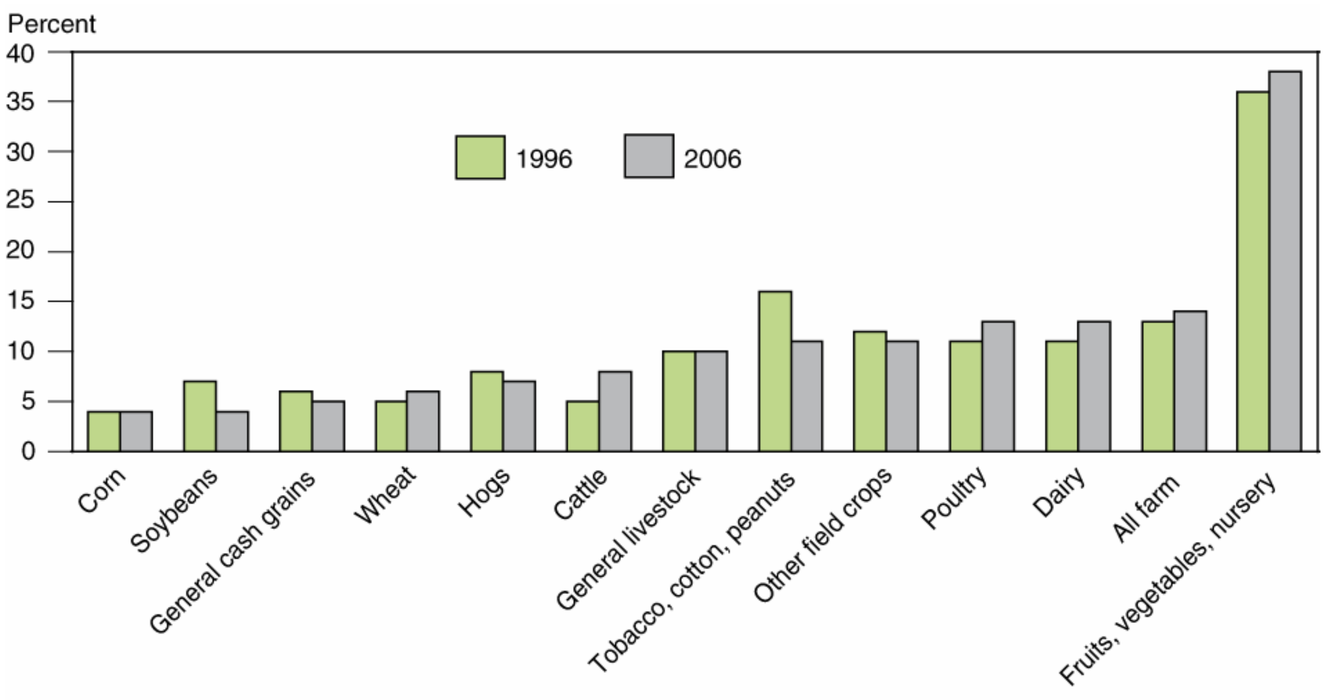
Source: Compiled by Economic Research Service, USDA, using data from *Census of Agriculture*, *Census of Population*, and *Census of the United States*.

Figure 3. Farms have become more specialized and the number of commodities produced per farm has decreased



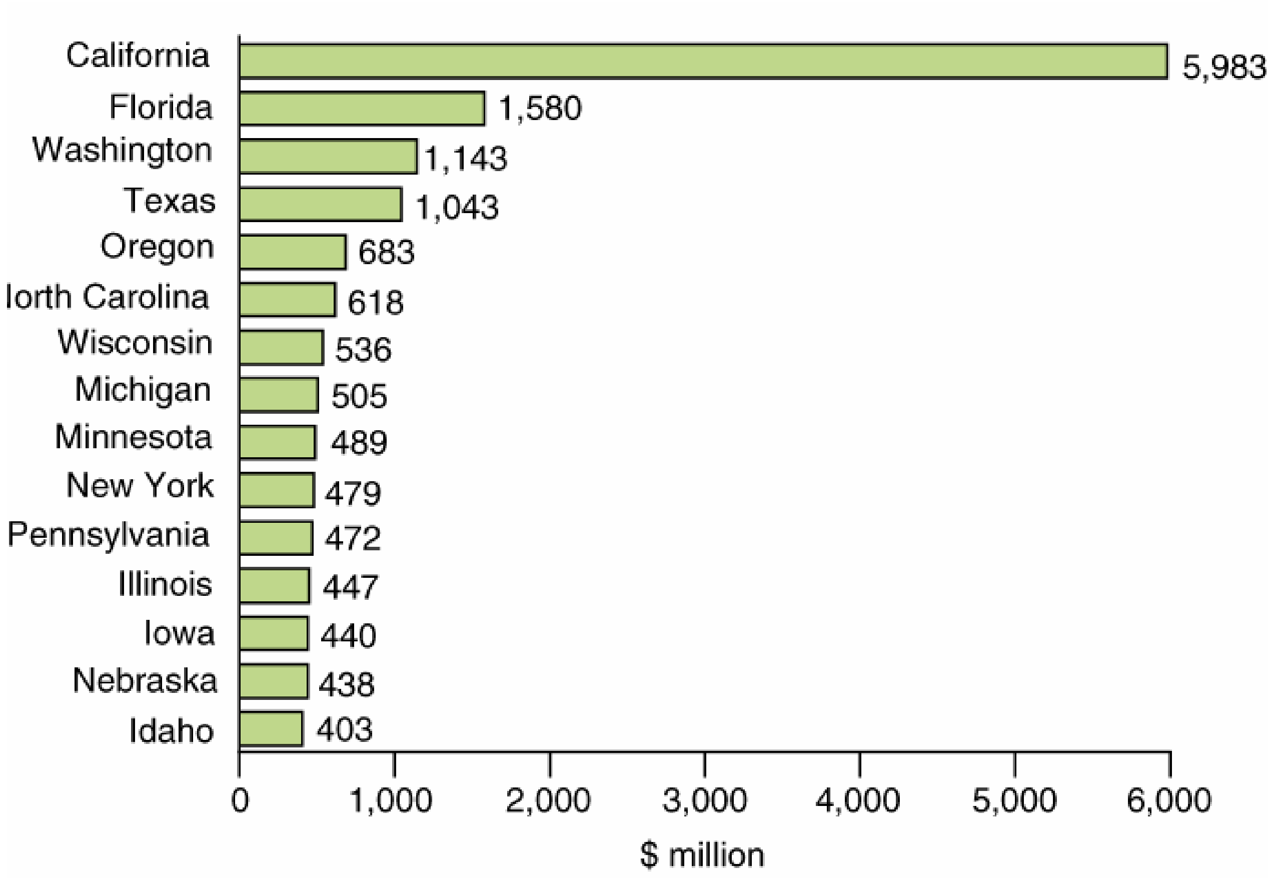
Note: The average number of commodities per farm is a simple average of the number of farms producing different commodities (corn, sorghum, wheat, oats, barley, rice, soybeans, peanuts, alfalfa, cotton, tobacco, sugar beets, potatoes, cattle, pigs, sheep, and chickens) divided by the total number of farms.
Source: Compiled by Economic Research Service, USDA, using data from *Census of Agriculture, Census of the United States,* and Gardner (2002).

Figure 4. Labor's share of total cash expenses, by agricultural product, 1996 and 2006



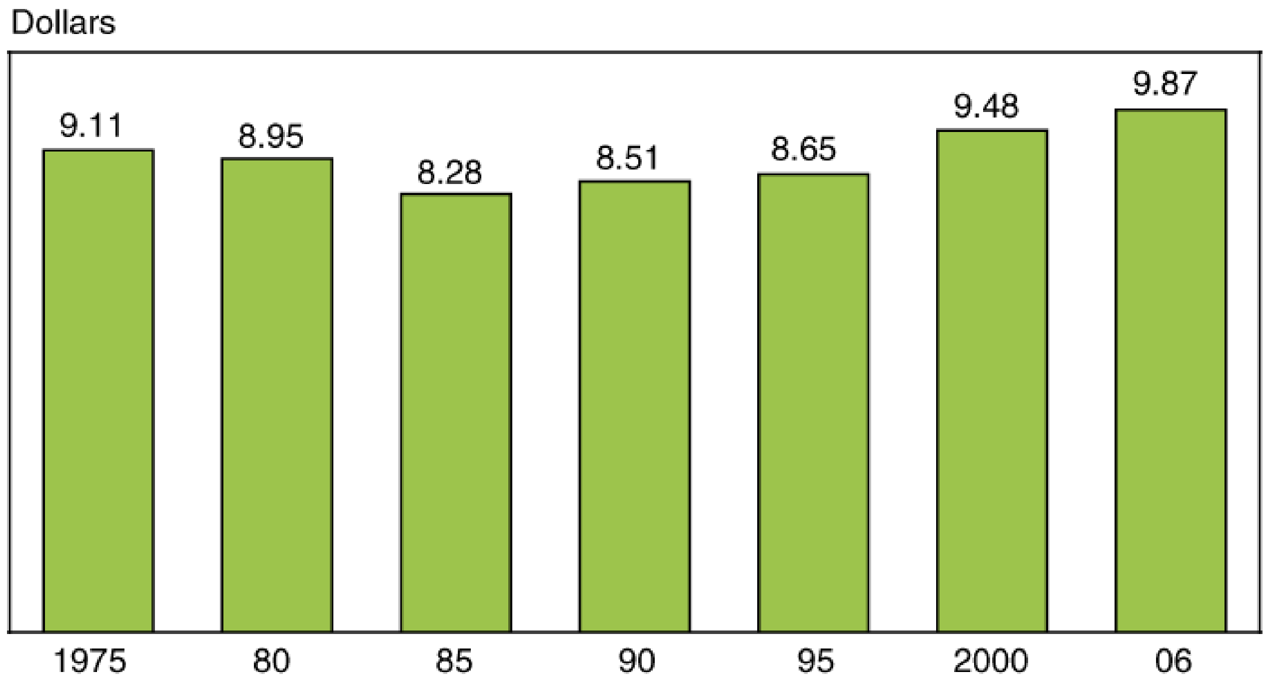
Source: ERS analysis of 1996 and 2006 ARMS data.

Figure 5. Top 15 states for hired farm and contract farm labor expenses, 2002



ource: ERS analysis of 2002 Census of Agriculture data.

Figure 6. Real hourly wages (2005) for all hired farmworkers, 1975-2006



Notes: Figures reflect wages paid to hired crop and hired livestock farmworkers, as well as supervisory and nonsupervisory workers. Nominal dollars were converted to real dollars using the Consumer Price Index (CPI).
Source: National Agriculture Statistics Service, USDA.

Figure 7

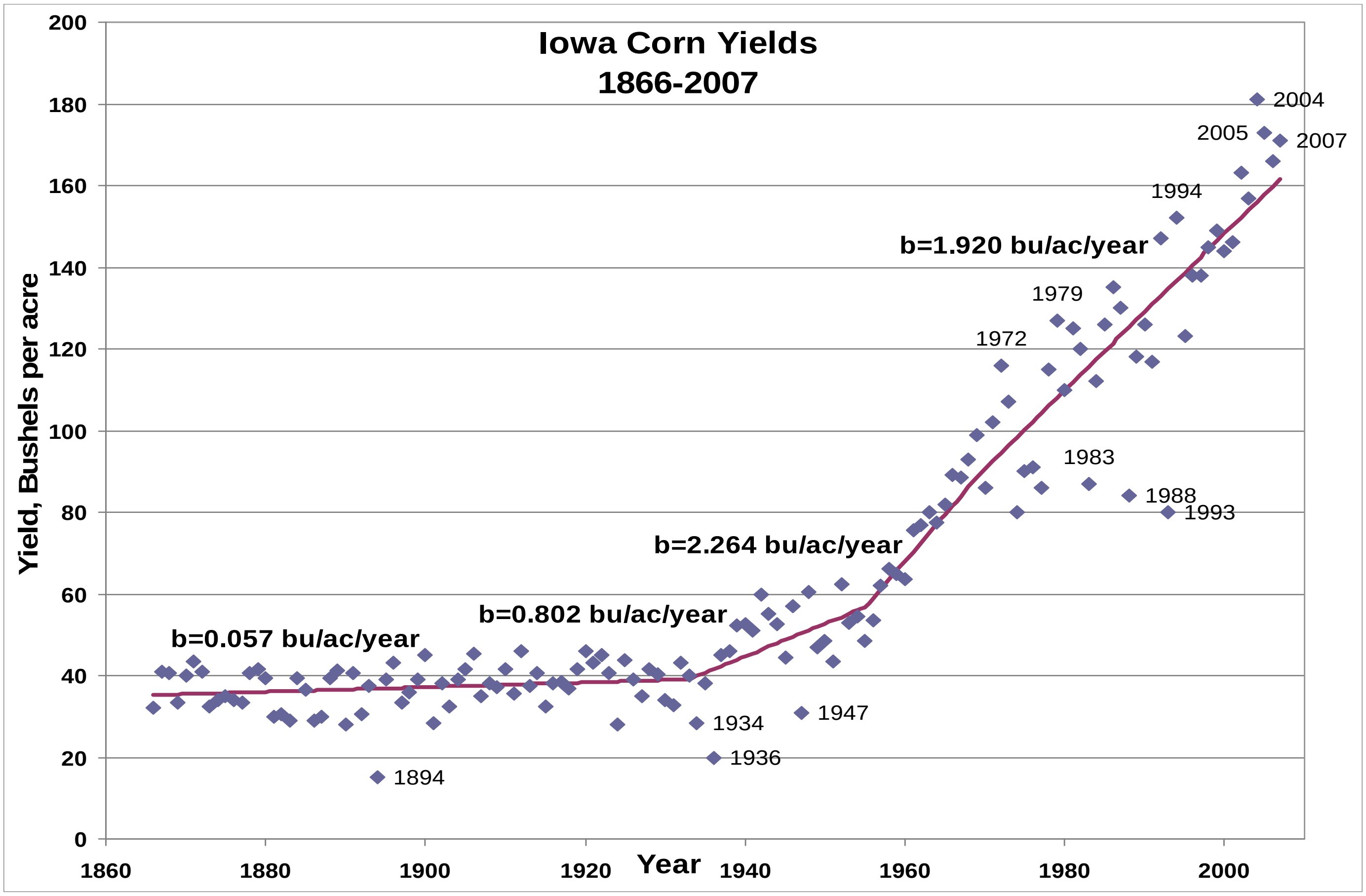

Iowa Corn Yields
1866-2007
Yield, Bushels per acre
Year
200
180
160
140
120
100
80
60
40
20
0
1860
1880
1900
1920
1940
1960
1980
2000
b=0.057 bu/ac/year
b=0.802 bu/ac/year
b=2.264 bu/ac/year
b=1.920 bu/ac/year
1894
1934
1936
1947
1972
1979
1983
1988
1993
1994
2004
2005
2007

Figure 8

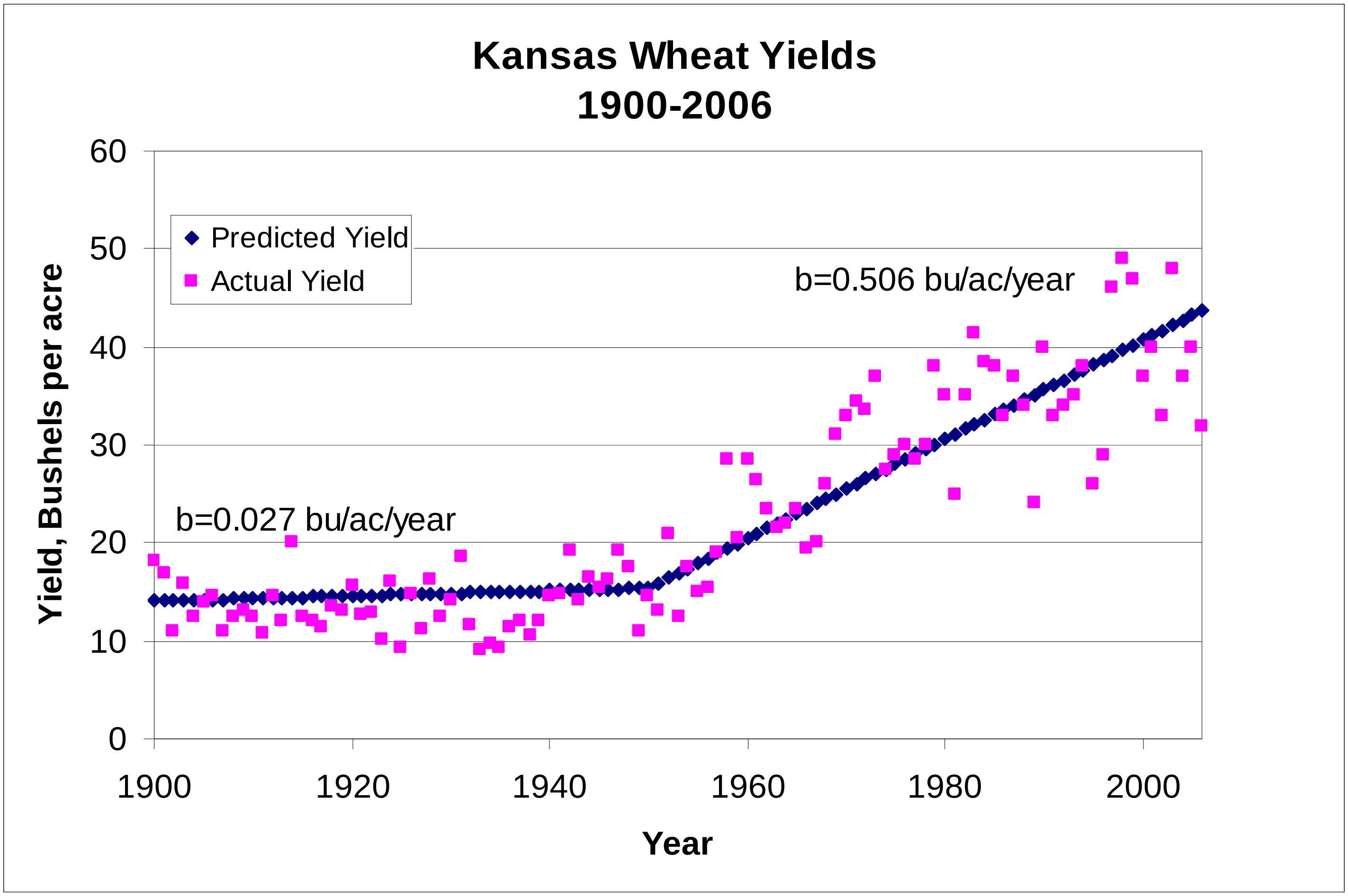
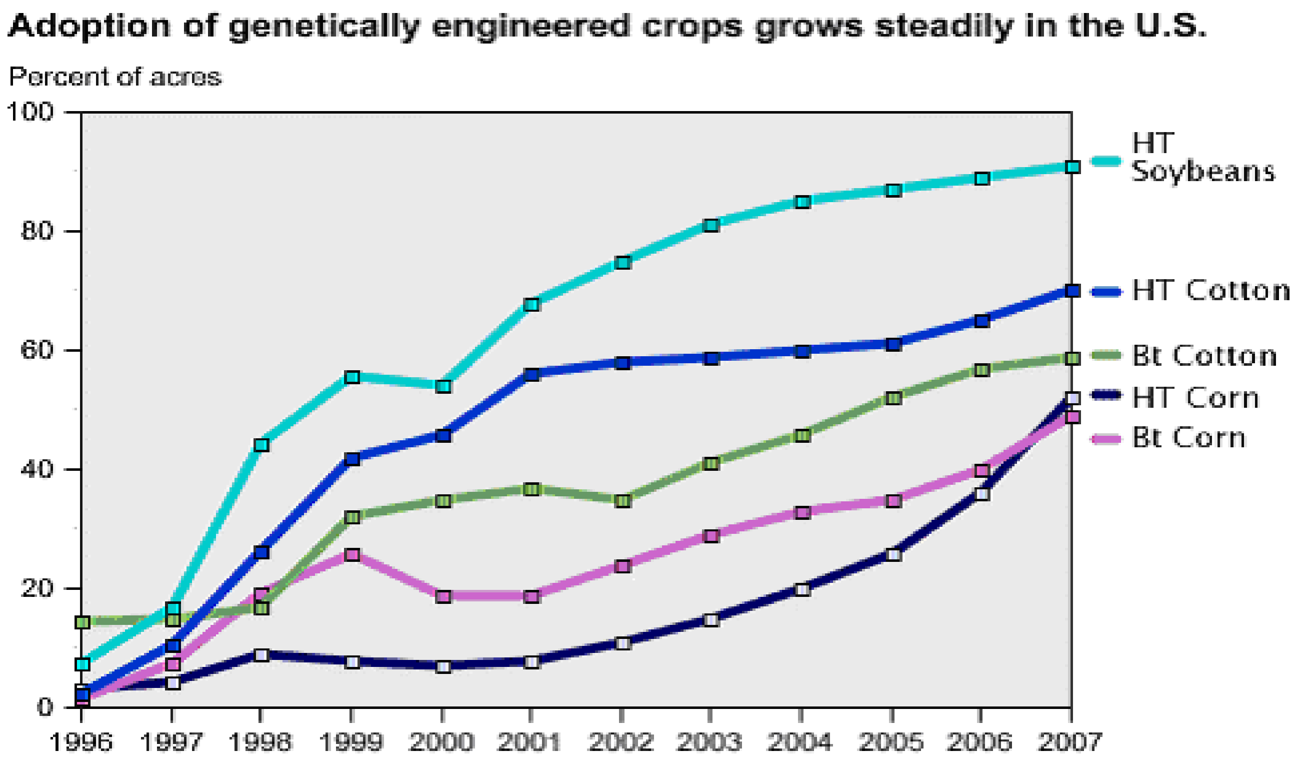

Kansas Wheat Yields
1900-2006
Predicted Yield
Actual Yield
b=0.506 bu/ac/year
b=0.027 bu/ac/year
Yield, Bushels per acre
60
50
40
30
20
10
0
1900
1920
1940
1960
1980
2000
Year

Figure 9



Source: Fernandez-Cornejo 2008

Table 1. Hired Farm Labor for the US. and Selected States: Number of Workers and Hourly Wage, 1993-2005

Year	USDA – Hired Farm Labor												USDL-NAWS
	Number on All Farms[a/]				Wage-Workers on All Farms ($/h)[b/]				Wage-Crop ($/h)[c/]				Wage-Crop ($/h)[d/]
	US	CA	FL	Cornbelt[e]	US	CA	FL	Cornbelt II	US	CA	FL	Cornbelt II	US
2005	779.5	178.0	45.0	27.0	9.50	9.76	9.46	10.16	8.69	8.81	8.50	9.00	7.77
2004	825.2	210.5	52.2	23.2	9.23	9.33	9.04	9.45	8.45	8.41	7.97	8.79	7.77
2003	836.0	227.5	54.2	23.2	9.08	9.25	9.14	9.75	8.31	8.34	8.18	8.88	7.47
2002	885.7	245.2	53.2	26.5	8.81	9.14	8.69	9.26	8.12	8.34	7.71	8.44	7.30
2001	873.3	209.0	54.3	26.3	8.44	8.67	8.54	8.63	7.78	7.89	7.66	7.99	7.11
2000	890.3	237.8	56.5	25.8	8.10	8.21	8.49	8.12	7.50	7.48	7.68	7.51	7.00
1999	929.0	277.3	53.0	24.0	7.77	7.88	8.21	8.07	7.19	7.18	7.26	7.50	6.54
1998	879.5	246.0	50.0	28.5	7.47	7.71	7.91	7.61	6.97	7.13	7.11	7.14	6.40
1997	876.5	188.8	50.3	33.5	7.35	7.32	7.47	7.10	6.66	6.79	6.76	7.02	5.81
|													
1993	803.0				6.25	6.56	6.62	6.14	5.90	5.96	6.02	5.71	5.46

[a/] Number of hired farm workers on all farms: Data taken from the USDA's Quarterly Farm Labor Survey
[b/] Average wage for hired farm labor on all farms: Data taken from the USDA's Quarterly Farm Labor Survey
[c/] Average wage rate for hired crop workers: Data taken from the USDA's Quarterly Farm Labor Survey
[d/] Average wage rate for hired crop workers: Data taken from the USDL's National Agricultural Worker's Survey
[e/] Cornbelt II includes Iowa and Missouri

Table 2. Output Supply and Input Demand Elasticities: Eight Midwestern States, 1960-2004

	Elasticity w.r.t. Prices						
Quantity	**Capital Services**	**Labor**	**Energy**	**Ag Chemicals**	**Other Materials**	**Livestock Output**	**Crop Output**
Inputs							
Capital Services	-0.011	-0.005	0.038	0.005	0.017	-0.028	-0.015
Labor	-0.003	-0.055	0.006	0.003	0.045	-0.018	0.021
Energy	0.163	0.050	-0.353	0.057	-0.009	0.016	0.075
Ag Chemicals	0.024	0.031	0.064	-2.028	0.870	0.064	0.974
Other Materials	0.007	0.037	-0.001	0.075	-0.121	0.076	-0.072
Outputs							
Livestock	0.011	0.014	-0.002	-0.005	-0.074	0.134	-0.079
Crop	0.005	-0.013	-0.005	-0.062	0.053	-0.060	0.082

Table 3. Estimates of Bias Effects in Production Decisions w.r.t. Quasi-Fixed Factors: Eight Midwestern States, 1960-2004[1]

	Fixed Factors					
Production Decisions	**Land**	**Public Ag Research**	**Precipitation**	**GM Corn Adoption**	**GM Soybean Adoption**	**Time**
Inputs						
Capital Services	-0.322	-0.340**	-0.000	-0.000	0.0126*	-0.029***
Labor	-0.605	-0.050	-0.001	-0.003	-0.008	0 .022***
Energy	0.549***	-0.373	0.005	0.006	-0.0279**	0.004
Ag Chemicals	1.203	0.646	0.005	-0.017	0.040**	-0.020
Other Materials	0.087	0.097	-0.002	0.005	- 0.004	-0.001
Outputs						
Livestock	-180.77	-70.47	-0.370	-1.650	-2.836	7.117**
Crop	140.20	54.66	0.287	1.280	2.199	-5.520**

*** Significant at 1% level
** Significant at 5% level
* Significant at 10% level