The Changing Demand for Farm Labor and Structure of Agriculture: U.S. and Selected States, 1970-2005

By

Wallace E. Huffman

This paper provides an updated assessment of changes in the demand for farm labor and in the structure of U.S. agriculture over the past three decades. We focus on an overall picture for aggregate U.S. agriculture and then choose California, Florida, and Iowa for more detailed analysis. California and Florida are the two leading states in the employment of crop labor and Iowa is the largest producers of agricultural products in the interior of the United States. California and Florida are known agriculturally for their fruit and vegetable production, and the harvesting of fresh produce is quite labor intensive. The harvesting of fruits and vegetables for processing has been mechanized. California is also known for tree nut production, which has also been mechanized. We show that structural changes are different in California and Florida agriculture than in other states far from the border, e.g., Iowa.

The USDA’s estimate of total hired farm workers peaked in 2002, immediately following 9-11 and since then has decreased significantly for the U.S. as a whole and for California. The real wage for farm workers rose to 2003 and then backed of a little, but the real wage for NAWS crop workers continued to increase to at least 2004. Wages of U.S. hired farm workers rose relative to those of U.S. manufacturing over 1987 to 2000 but no further changes occurred. Hence, the decline in hired farm worker numbers without a significant change in the real wage for hired farm labor is puzzling. The share of U.S. crop workers who were born in Mexico has been rising, at least since the

♣ The author is C.F. Curtiss Distinguished Professor of Agriculture and Professor of Economics, Iowa State University. Xing Fan provided helpful research assistance. The paper is for the conference, “Immigration Reform: Implications for Farmers, Farm Workers, and US Agriculture, Washington, D.C., June 14-15, 2006. The research work was support by the Iowa Agriculture and Home Economics Experiment Station, Ames, IA.
1980s, and now comprises about 80 percent. The share of crop workers who are undocumented has also been rising since the Immigration Reform and Control Act (IRCA 1986). The demand for farm labor is affected not only by the prices of various inputs but also by technical change that has been relatively rapid in agriculture. However, mechanization of labor intensive crop production, like harvesting fresh produce, has not been successfully mechanized because of problems affecting produce quality and cost.

We first present a brief overview of technical change in U.S. agriculture over the past two decades. Second, we summarize the performance of aggregate U.S. agriculture and the national agricultural labor market. Third, we review the performance of agriculture in California, Florida, and Iowa. We conclude with a few comments.

**Agricultural Production and Changing Technology**

Agriculture is production by biological processes. Plant growth and development are very sensitive to day length, and crop production is land-surface area intensive. For non-greenhouse plants, day length and temperature trigger plant stages. Although the completion of any phase of crop production can sometimes be accelerated by using new technology, the timing from planting to harvest is largely unaffected. Furthermore, because crop farming uses large amounts of land surface area, where mechanization occurs it must be largely through the use of powered machines that move through the fields (e.g., tractor-drawn planters, self-propelled combines). Packing and processing operations can be completed in the field or in packing/processing facilities, where stationary power can be used (Huffman 2002; Huffman 2005; Huffman and Evenson 2006).

**Milk Production**

Historically, milk production has been relatively labor intensive, with year-round twice or three times per day feeding and milking. The labor intensity of dairying has been reduced by mechanized milking, automated milk production and feeding records, automated feed distribution
based on performance, and automated cleaning of dairy barns. Although totally automated milking systems exist that use electronic sensors, robotic milkers and video cameras, they have not been popular with U.S. dairy farmers. Farmers who have large dairy herds have recently discovered that immigrant farm workers are more cost effective than totally automated milking systems.

**Crop Production**

In vegetable and fruit production, major technical advances have been associated with drip irrigation, fertigation, plastic mulch and new plant varieties. Irrigation is an important supplement to natural precipitation in most of the cropland west of the Mississippi River and in the sandy soils of Florida and other southern states. Drip irrigation 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 plants. This dramatically reduces water percolation out of the root zone or from evaporation, as in flood, moving rig, or center pivot irrigation systems. Also, it dramatically reduces the amount of labor used relative to irrigation with portable surface pipes.

Fertigation uses the same drip irrigation system to deliver liquid fertilizer efficiently to the roots of plants. A farmer usually applies dry fertilizer before planting vegetables and then supplements during the 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 in the production of vegetables, tomatoes, and strawberries, and plastic mulch is frequently used with raised and rounded seedbeds. Long clear sheets of plastic are laid over the entire bed, pierced only where the young seedlings or plants are planted. Plastic mulch reduces weeds, promotes growth, especially in hot-season plants like tomatoes, and blocks micro-organisms from moving from the soil to the plant. It reduces the need for hand weeding, herbicides, fungicides, and other plant protection measures.
Plastic also raises the soil’s temperature, reduces water evaporation and increases the total photosynthetic activity in most plants.

No-till farming has greatly reduced the demand for labor and some other inputs in major field crop production in the Midwest and South. 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 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, for large horsepower tractors, mould board plows, heavy disks and for fuel. These savings are partially offset by increased demand for chemical herbicides, herbicide-tolerant plants, and specialized no-till equipment.

Mechanical harvesters have 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.

**Tomato Production: A Case in Point**

Tomatoes are one of the largest U.S. fruit and vegetable crops and the technology has been changing over the past 3 decades (Huffman 2002). Fresh tomato production is concentrated in Florida and processed tomato production is concentrated in California. Fresh market tomatoes are handpicked and processed tomatoes are mechanically harvested.¹

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¹ Wine grapes are another crop that have undergone changes in technology. Grapes for medium to high quality wines are hand picked but the grapes for low cost wines are mechanically harvested.
Fresh market tomato varieties have been developed that are medium sized, firm when purchased by the consumer, and generally flavorful. To reduce disease and insect pest problems, these tomato plants are tied to individual wooden stakes or to lines strung between stakes, which is also a labor-intensive operation.

Controlled-environment tomatoes (greenhouse and hydroponically grown) that are harvested when vine ripened have experienced rapid growth since 1999. In the past, these tomatoes have been largely imported from the Netherlands, Canada and Israel, but U.S. producers are entering the expanding market. The tomatoes have greater uniformity than open-air tomatoes, and it is claimed, improved taste. Many are being marketed “on-vine” in clusters to convey an appearance of freshness to consumers. The hand labor in the hothouse is somewhat different from that for traditional open-air staked tomatoes and can approach year-round work.

In contrast, processed tomatoes have been bred for a pear or cylinder 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 harvested mechanically (Schmitz and Seckler 1970). The mechanical tomato harvester was developed and adopted widely in the California processed tomato industry in the late 1960s. It operates much like a 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 of chunks of dirt and green tomatoes from the 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.

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. The sorters also have improved the quality of the product delivered to processors by largely eliminating the green tomatoes and dirt from loads of ripe tomatoes.

**Performance of Aggregate U.S. Agriculture and the National Agricultural Labor Market**

U.S. agriculture has experienced steady output and productivity growth over the 20th century, but this review will focus on the period from 1970-2005. A world grain shortage occurred in the early 1970s that doubled world grain prices for a few years. High grain prices, in turn, reduced the profitability of livestock production. Once farms discontinued livestock production, they were reluctant to re-introduce it. Growth in farm output over the 1970s was 2.24 percent per year and for the whole period, 1970-2002, averaged 1.79 percent per year (figure 1). Over the 1970s and 1980s crop output grew faster than livestock output, but this differential reversed in the 1990s, when factory style production methods were rapidly adopted in poultry, swine, and beef growing and fattening (Huffman and Evenson 2001; Huffman and Evenson 2006, p. 247-258).

Farm inputs consist of inputs under the control of farmers – capital (durable equipment and land); labor (hired and self-employed, including unpaid family labor); and materials (farm origin materials, energy, agricultural chemicals, and purchased services, including contract labor). At the U.S. level, input growth was slightly negative over the whole period (figure 1). It was positive over the decade of the 1970s, at 0.8 percent per year, but negative over the decade of the 1980s, at -1.63 percent per year. Over 1990-2002 there was little change in the farm input index.

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2 These data on aggregate U.S. agriculture were prepared under the leadership of Eldon Ball and are available at the USDA, ERS website.

3 The USDA continues to ignore advice to combine contract farm labor with “hired” and self-employed labor.
Figure 2 permits a deeper penetration into the farm input index by showing how its three major components performed. Farm labor declined rapidly over 1970-1986, at -2.86 percent per year. However, during the post-IRCA (1986) period, the farm labor index had only a slight negative trend (-0.5 percent per year), which was a dramatically different rate than during 1970-1986.

Farm capital service input grew during the 1970s at 0.9 percent per year, but with the deregulation of interest rates in the late 1970s and a switch from negative to positive real borrowing interest rates, farm capital input declined over the decade of the 1990s by -0.7 percent per year. The decline continued over the remainder of the period, but at a slower rate (figure 2).

Farm materials input grew very rapidly over the decade of the 1970s, at 2.4 percent per year. With the farm crisis of the 1980s, the farm materials input then declined at -1.0 percent per year. The decade of the 1990s brought a return to rapid positive growth of the materials input, at 1.5 percent per year. The materials input index was the only one of the three major farm input groups that ended 2002 at a greater value than when it started in 1970 (figure 2). Hence, there was a major shift from farmer supplied to purchased inputs.

Figure 3 provides added perspective on farm labor input and purchased services, including contract labor and other purchased services, that have a large labor share. U.S. hired farm labor increased over 1970-1975 by 1.5 percent per year and then had a negative trend over 1975-1986 at -1.45 percent per year. After the IRCA (1986) the amount of hired labor was untrended through 2002. The self-employed category, including unpaid family labor, trended downward for the whole period. However, it had a strong negative trend over 1970-1986, at -3.2 percent, and thereafter only a slight decline to 2002.

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4 Recall that nominal interest rates were de-regulated in 1979 and interest rates shot up abruptly over 1979-83 (U.S. President 1986, p. 256). Real interest rates, the nominal interest rates less the rate of inflation, also show up over this period (U.S. President, p. 256). With a positive and higher real interest rate the cost of capital services rose.
Farm purchased services grew rapidly during the 1970s, at 2.6 percent per year (figure 4). Over the decade of the 1980s, there was no trend in farm purchased services. However, over the 1990s, the trend rate of growth was positive again, at 2.6 percent per year. Hence, farm purchased services have become an input of growing importance to U.S. agriculture over the past three decades. One component of these services is labor obtained through farm labor contracts (Martin and Taylor 1995).

Figure 4 shows that the ratio of capital services-to-farm labor in U.S. agriculture grew steadily over 1970-1986, at 2.6 percent per year, but thereafter, this ratio remained unchanged. In contrast, the farm materials-to-labor ratio has a positive trend over the whole period, growing at an average of 2.5 percent per year.

Multifactor (MFP) and labor productivity (LP) in U.S. agriculture have been growing steadily over the 1970-2002 period, at 2.01 percent per year. This is a fantastically high rate, given that MFP need not change at all when growth in output is due to growth in inputs under the control of farmers. Labor productivity, which is a single factor or partial productivity measure, has been growing even faster than MFP. For the whole period, labor productivity grew at a very high 3.46 percent per year.

In 1950, when there were about 10 million farm works, 20 percent were hired workers; in 1970, when there were 4.5 million farm workers, 26 percent were hired; and in 2000, when the number of farm workers was only 3 million, one-third were hired workers. Thus, the share of all farm workers that is hired has been rising over the past five decades, and the share would be even larger if all of the contract farm labor were included.

Although a key objective of the IRCA (1986) was to reduce the use of unauthorized workers in the U.S. (see Martin et al. 1995), the share of farm workers who are unauthorized (of illegal status)  

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5 These numbers are based on the USDA Quarterly Agricultural Workers Survey, which seems to under count contract workers that the USDL National Agricultural Workers Survey focuses upon.
reported by the NAWS has risen generally over time (Mehta et al. 2000). About eight percent of these workers were unauthorized in 1989, 44 percent in 1993, 52 percent in 1998, 55 percent in 1999-2000, but a slightly lower 53 percent in 2001-2002 (USDL 2005, p. ix).

Consistent with the rising share of unauthorized farm workers, Spanish has been the native language of a growing share of U.S. crop workers, e.g., 80+ percent in 1998 and 2001-2002 (Mehta et al. 2000; USDL 2005, p. 17). U.S. farm workers who were educated outside of the U.S. had a median of 6 years of schooling in 1997-98, versus 11 years for those who completed their schooling in the U.S. However, since the early 1990s, the amount of schooling completed by farm workers born outside the U.S. has been rising (USDL 2005, p. 18). Mexican workers have relatively easy access to the U.S. and have been quite effective in using ethnic social networks to substitute for knowing English and for the higher levels of education normally associated with mobility. They have spread across rural communities of the U.S. during the past 15 years (Huffman 2003). Drawing upon ethnic capital aids early entry to the U.S., but over the long term, it retards assimilation (Borjas 1999).

A growing share of farm crop workers are hired and supervised by a farm labor contractor (FLC) rather than a grower/farmer. Although FLCs have existed at least since the early 1960s, their intermediary services have grown since the IRCA. Under the IRCA, employers could be fined for knowingly hiring undocumented workers. FLCs are frequently Hispanics who have few assets, and this seems to make them a less frequent target of the INS than growers (Martin and Taylor 1995). The number of FLCs in the West and Southeastern U.S. has increased by about 50 percent since 1989, and the number of contract workers has doubled. In 1997-1998, 20 percent of farm crop workers were hired by FLCs (Mehta et al. 2000).

In 1997-1998, 20 percent of crop workers were paid a piece rate and 77 percent were paid hourly; and in 2001-2002 (Mehta et al. 2000), a lower 16 percent were paid a piece rate and a higher 79 percent were paid hourly (USDL 2005, p. 37). Not surprisingly, a larger share of contract labor is
paid a piece rate than other hired crop workers. Also, a piece rate is used most frequently in fruit and nut harvesting tasks.

Over 1989-2003, the nominal wage rate for all hired farm labor (USDA-QFLS data) rose by 50 percent, and this translated into a 21.7 percent increase in the real wage after deducting for the increase in implicit price deflator for personal consumption expenditures from the GNP accounts.\(^6\) (See table 1 and 2.). However, the real wage declined a little over 2002 to 2005 for all hired farm workers but not for NAWS crop workers (table 2). Furthermore, it is useful to compare the lot of U.S. hired farm workers with those of another major group of U.S. workers. I choose manufacturing workers. Although undocumented non-agricultural workers are more likely to be employed in low skilled service occupations and construction, the manufacturing wage represents a broad spectrum and fairly large number of workers, and is collected and reported regularly. In 1989, the wage rate for U.S. hired farm workers was roughly one-half the hourly wage of labor in U.S. manufacturing (table 2). Over 1989-2000, all hired farm workers gained relative to U.S. manufacturing workers by about 10 percent, but crop workers covered by NAWS lost relative to workers in manufacturing by about 6 percent. However, over 2000-2004, wages of all hired farm labor and hired crop labor, relative to the wage for U.S. manufacturing workers, was unchanged.

Over 1989-2000, the improvement in the hired farm labor wage was least for hired crop workers, where unauthorized workers from Mexico have provided a steady supply of low-wage, but relatively reliable, workers. The rate of increase has been higher for non-crop workers over 1989 to 2002, who most likely are fluent in English and have more education, and thus, face a better nonfarm labor market.\(^7\) Immigrant flows to the farm labor market, especially, near the U.S.-Mexican border

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\(^6\) Over 1989-2002, the prices paid by farmers for other production expense rose 22 percent.
\(^7\) However, the rise in the real wage rate for hired farm workers since 1989 is unusual relative to the 1980s (Huffman 1995).
may have been disrupted by the anti-terrorist actions in the U.S. after 2001. We do see a major deviation from a positive rate of growth of hired farm workers before 9-11 to a negative one for the whole use and a large decline for California (table 2). The adjustment in immigrant numbers, however, has at most a small effect on real wage rates of hired farm workers. Hence, there are unresolved puzzles about adjustments during the 2002-2005 period.

Performance of Agriculture in CA, FL, and IA

California and Florida lay on the southwestern and southeastern boundaries of the U.S., and are centers of labor intensive crop production, being major producers of fresh fruits and vegetables. In contrast, Iowa is located in the interior of the U.S., and is a large producer of grains and livestock, especially swine. Agriculture crops are heavily irrigated in California and Florida, but rain fed in Iowa. Data for these states cover the period 1970-1999, which is the latest available data. See Ball et al. (2002) for details on the construction of indexes of outputs and inputs.

A Comparison of Aggregate Output and Input Growth

All three states experienced positive growth in output over 1970-1999, but input growth over the whole period occurred only in California. In California, farm output grew steadily at an average annual rate of 2.5 percent per year over 1970-1999 (figure 5). The index of inputs under the control of farmers grew slowly over 1970-1980, at 0.9 percent per year. Over 1980-1993, the input index had no trend, but then started increasing again in 1994, at 2.65 percent per year, until 1999. For California, the input index ended the period 45 percent higher than where it started in 1970.

In Florida, farm output grew rapidly over 1970-1980, at 3.6 percent per year. The only period in which growth slowed dramatically was over 1980-1985 (figure 6). Florida had no input growth over 1970-1977, but positive input growth occurred over the four year period, 1977-1981, at the rate

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8 The Administrators of ERS have decided to discontinue research efforts on the state productivity accounts. This means that state aggregate data on outputs and inputs will no longer be available on an annual basis. This certainly limits future comparisons and analyses of U.S. agriculture at the state level.
of 3.3 percent per year. Input use by farmers then declined slowly over the next nine years, at the rate of -1.3 percent per year. Starting in 1990 input growth returned, but at a slower rate. The net result over the 29 year period was little growth in the input index – a total of 7.8 percent.

In Iowa, the output index shows major negative shocks due to bad weather—droughts or floods in 1974, 1983, 1988, and 1993, but the long-term trend in output is an average annual growth rate of 1.1 percent, much lower than for California and Florida. The input index showed a small amount of growth over 1970-1980, at 1.2 percent per year, but over 1980-1996 the input index declined by -2.4 percent per year. However, the input index turned around from 1996-1999. In 1996, two major events occurred that may have affected input use in Iowa differently than in California and Florida. The 1996 Farm Bill removed production controls on grains and beans, and stopped paying farmers to set aside farmland. Also, in 1995 and 1996, new GM corn and soybean varieties became available to farmers, and they changed the methods of pest control in these crops (Huffman and Evenson 2006).

**Disaggregated Input Demand and Real Input Prices**

Next we turn to trends in demand for disaggregated farm input—capital services, labor (self-employed, unpaid family and hired) and materials, and their real prices. In California, the farm capital service input rose over 1970-1982 at the rate of 2.1 percent per year, peaked in 1982, and thereafter it declined at the rate of -1.8 percent per year (figure 8). Materials input grew at 2.9 percent per year over 1970-1979, but then declined a little over 1979-1987. It turned around in 1988 and showed strong positive growth until 1999, at 4.5 percent per year. Both capital service input and materials input were larger in 1999 than in 1970. Contract farm labor most likely was part of this post-1986 growth in materials.

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9 The real input price is the price index of a particular type of input (capital services, labor, materials) index in 1970 divided by the weighted average price of capital services, farm labor, and materials (1970 = 1.00).
The farm labor input in California showed a small amount of net growth over 1970-1975 of 14 percent, but a decline occurred over 1975-1987 of -33 percent (figure 8). Over 1978-1995 there was no net change in the farm labor index. However, starting in 1995, growth in the farm labor index returned, and in 1999 it was 28 percent larger than in 1995. The net result was that farm labor input in California ended the 29 year period 22 percent larger than when it started. Although we do not observe significant changes in the California farm labor index immediately after the IRCA, the official USDA index does not include contract labor, and California growers shifted more of their labor procurement to farm labor contractors after the IRCA (Taylor and Thilmany 1993). Therefore, the use of all types of farm labor may have actually increased after 1986 (Huffman 2002, p. 35).

We would expect major input market events, including the IRCA, to have impacts on input prices, and changes in real input prices to change the demand for and composition of inputs used by farmers. We expect farmers or growers to respond to the size of the wage paid for hired farm labor relative to the prices of all variable inputs, which we label as the real wage. In California over 1970-1982, the real price of farm capital services trended upward slowly, but over 1982-1988 the rise was more rapid (figure 9). This later period includes years when the quantity of capital services peaked on California farms (figure 8). Thereafter, the real price of California farm capital services did not have a particular trend, although there was year to year fluctuation (figure 9). The quantity of capital services used by California farmers continued to decline, suggesting that other economic forces were operating.

The real price of farm labor (self-employed, unpaid family, and hired) in California shows a slight negative trend over 1970-1985, and then the real wage index rises over 1985-1990. After 1990,

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10 Among crop workers surveyed by the NAWS, 63 percent were direct hires in 1993-1994, but only 51 percent were direct hires in 2001-2002 (USDL 2005, p. 31).

11 The real input price is the price index of a particular type of input (capital services, labor, materials) index in 1970 divided by the weighted average price of capital services, farm labor (self-employed, unpaid family, and hired), and materials (1970 = 1.00). The wage for self-employed and unpaid family labor is set at the opportunity wage (see Ball et al.). Those who would like to view relative factor prices should see Appendix A.
it flattens out over the remainder of the period (figure 9). The real price of farm materials rises over 1970-1972, and then has a negative trend to 1985. Thereafter, there is no real trend in the real material price. At the end of the period, the real price of farm labor is somewhat higher in California than in 1970, and that of materials is somewhat lower than in 1970.

In Florida, farm capital services rose steadily over 1970-1981, at 2.4 percent per year. Thereafter, the trend in farm capital services is negative, at -1.85 percent per year (figure 10). Farm materials input has no trend over 1970-1978, but then rises very rapidly over 1978-1980 by 30 percent. Immediately thereafter, the materials index declines and flattens out over 1982-1992. Growth in this materials index returns over 1994-1999. Materials input ends the period 47 percent larger than when it started, and some of the post-1990 increase may be due to increases in contract labor. The farm labor input for Florida is constant over 1970-1973, then takes a 25.7 percent decline over 1973-1975 (figure 10). Thereafter, there is no trend in the Florida farm labor input.

In Florida, the real price of farm capital services declined over 1970-1978, and this may have been a major factor causing farmers to increase farm capital use over this period (figure 11). However, the real price of farm capital services increased by 18 percent over the next four years and undoubtedly contributed to the turn-around in farmers' use of capital services. Thereafter, the real price of farm capital services was basically untrended over the remainder of the period.

Although considerable fluctuation exists in the real price of farm labor for Florida, over 1970-1989 the trend was slightly positive, at 0.3 percent year. The real price of farm labor rose over 1987-1990 and remained untrended thereafter (figure 11). Some of the short-term movement in the use of labor on Florida farms may be linked to the cyclical movement of the real price of Florida farm labor.

In Florida, the real price of farm materials rose 10 percent over 1970-1973, and then declined over 1973-1985 by an average of 4.3 percent per year. This was undoubtedly a major force behind Florida farmers' increased use of material inputs over 1975-1979 (figure 10). Over 1985-1999, the
real price of farm materials had a small positive trend. The real price of farm labor ended the period significantly higher, and that of materials significantly lower, than at the beginning of the period.

In Iowa, input use of capital services, farm labor and materials follows a surprisingly similar pattern over 1970-1999 (figure 12). Roughly, all three rise over 1970-1980, peak in 1980 or 1981, and then decline to 1999. The increase in capital input over 1970-1980 is the largest of the three input groups, at 32 percent, versus 15 percent for materials and nine percent for labor. Over 1980-1996, the average rate of decline for capital service input and labor is similar, at about -2.4 percent and -3.5 percent per year, respectively. The average rate of decline for materials input is -0.8 percent per year.

In Iowa, the real price of farm capital services declined over 1970-1973 by -24 percent, and then the real price reversed direction and increased to 1981 (figure 13). This run-up in the real price of farm capital services to Iowa farmers undoubtedly was a contributing factor to the turnaround in the growth in demand for farm capital input in 1980 (figure 12). After a dip in the real price of farm capital over 1981-1982, the real price rose sharply to 1989, and then declined a little over 1986-1989 before declining more rapidly to 1993. Over 1993-1995, the price of farm capital services rose sharply before leveling out.

In Iowa, the real price of farm labor trended downward over 1970-1980, and this was undoubtedly a factor behind the increase in farm labor input over this time period (figure 12). Over 1980-1994, the real price of farm labor had a significant positive trend. With the high unemployment rates in the U.S. economy in 1994, the real price of Iowa farm labor declined, but then returned to a positive trend thereafter. The real price of farm materials to Iowa farmers rose over 16 percent over 1970-1973, but then in 1973 started a decade-long decline. For the remainder of the period, the real materials price fluctuated some, but was largely without trend.
Factor Ratios and Productivity

Adjustments made by farmers to real output prices and technology are reflected in factor ratios and productivity. In California and Florida, the capital service-to-labor ratio rose to the early to mid-90s and then declined to the end of the period (figures 14 and 15). In contrast, in Iowa the capital-to-labor ratio trended upward for the whole period (figure 16). In all three states, the materials-to-labor ratio trended upward to 1996, with possibly a small reversal near the end of the period.

The productivity of agriculture is California, Florida, and Iowa increased over the 29 year period, although productivity of California agriculture seems to have flattened out in the mid-90s. Labor productivity can change because the quantity of labor changes, the quantity of other inputs change and/or technology changes. The growth of farm labor (hired and self-employed) productivity over the whole period was at an average annual rate of 3.2 percent for California (1970-1997), 2.8 percent for Florida, and 3.6 percent for Iowa (1970-1998).

Multifactor productivity for California, Florida, and Iowa agriculture increased at the annual average rate of 1.4 percent, 2.0 percent, and 1.7 percent, respectively, over the whole period. In California, the growth of MFP was steadily upward to 1994, and then leveled off. However, we do not have a good reason for this break in the trend. In Florida, MFP rose very rapidly over 1970-1975, and then backed off over the next four years before returning to a positive trend rate of growth. In Iowa, it is important in interpreting short term trends in productivity to ignore breaks due to droughts and floods. Doing this, we see that the trend of MFP for Iowa agriculture is steadily upward for the whole period.

Hence, although geoclimatic conditions (Huffman and Evenson 2006, p. 271) and output composition across California, Florida, and Iowa agriculture differ greatly, we see surprisingly similar trends in factor ratios and productivity. The performance of state agricultural productivity
over time is largely due to the long-run impacts of organized public agricultural research, especially in state Agricultural Experiment Stations. Each state’s station has a local clientele base that lobbies for the development of new technologies and solutions to problems that will give its farmers an advantage relative to its competitors (Huffman and Evenson 2006). This seems unlikely to have occurred if organized public agricultural research were directed from Washington (or Beltsville, MD). (Also, see Huffman and Evenson 2005.)

Conclusions

U.S. agriculture has an amazing record of output growth during the past three decades but without input growth. In fact, the USDA’s index of farm labor fell steadily over 1970-1986, and then flattened out. The level of use of farm purchased services, which includes contract labor, was flat during much of the 1970s and early 1980s, but started growing steadily in 1987. This might be coincident with the passage of IRCA 1986, but I expect there is a causal relationship. In California agriculture, the farm labor input was roughly flat over 1978 to 1992, and then it started growing. Purchased farm materials input were largely untrended over the decade before 1986 in California but then started growing steadily. In Florida, the farm labor input was untrended over 1975 to 1999, but the input of farm purchased materials started growing steadily in 1987 after being untrended over the previous five years. In Iowa, the farm labor input declined by about 25 percent over 1980 to 1985, but then was untrended over the next five years before it began a new round of declines starting in the 1990s.

The real wage for hired crop workers rose over 1987 to 2002, and over 1987 to 2000, their wages improved a little relative to workers in U.S. manufacturing. However, over 2002-2005, the real wage of hired farm workers declined a little but for NAWS crop workers increased a little. Relative to U.S. manufacturing workers, the wage of hired farm workers improved over 1987 to 2000 but then leveled off but NAWS crop workers actually lost a little relative to manufacturing workers over this
period. Anti-terrorist border control activity may have disrupted the farm labor market after 9-11-01. However, the average wage for farm workers over post IRCA period including post 9-11 do not indicated dramatic changes—either positive or negative—in the number of farm workers. We, however, do not have information on the counterfactual, so we cannot say that immigrant workers had no effect on real wages of U.S. farm workers.

In California, Florida and Iowa, farmers responded to their environment by increasing the ratio of farm materials-to-farm labor over the 1970 to 1999 period. In California and Florida, they increased the intensity of farm capital services relative to farm labor over 1970 to 1985, but in the ratio declined thereafter. In Iowa, farmers increased the capital service-to-labor ratio steadily over the whole period. I conclude that IRCA 1986 was a factor on the subsequent size of the capital-to-labor ratios in California and Florida agriculture, which are intensive in labor-intensive crops. IRCA may have created an environment which retarded the development and marketing of some types of new labor-saving mechanization in California and Florida agriculture. Any impact of immigrant farm workers in Iowa agriculture seems muted relative to California and Florida agriculture. Anti-terrorist border control activity and ensuing debate over illegal immigration may have lead to some reductions in farm labor, especially in California. This may hasten mechanization where feasibility has been proven.
References


Figure 1. Indexes of total farm output, total farm input, and multifactor productivity: U.S. agriculture, 1970-1999 (1970=1.00)
Figure 2. Indexes of total farm input, capital input, labor input, and materials input: U.S. agriculture, 1970-1999 (1970=1.00)
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Figure 9. Index of the wage for farm labor, rental on capital services, and price of materials relative to price of all farm inputs: California, 1970-1999
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Figure 15. Aggregate multifactor productivity, labor productivity, capital-to-labor ratio and materials-to-labor ratio for Florida agriculture, 1970-1999 (1970=1.00)
Figure 16. Multifactor productivity, labor productivity, capital-to-labor ratio and materials-to-labor ratio for Iowa agriculture, 1970-1999 (1970=1.00)
Table 1. Hired Farm Labor for the U.S. and Selected States: Number of Workers and Hourly Wage, 1993-2005

<table>
<thead>
<tr>
<th>Year</th>
<th>US</th>
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<th>FL</th>
<th>Cornbelt</th>
<th>Number on All Farms(\text{a/})</th>
<th>US</th>
<th>CA</th>
<th>FL</th>
<th>Cornbelt II</th>
<th>Wage-Workers on All Farms ($/h)(\text{b/})</th>
<th>US</th>
<th>CA</th>
<th>FL</th>
<th>Cornbelt II</th>
<th>Wage-Crop ($/h)(\text{c/})</th>
<th>US</th>
<th>CA</th>
<th>FL</th>
<th>Cornbelt II</th>
<th>Wage-Crop ($/h)(\text{d/})</th>
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\(\text{a/}\) Number of hired farm workers on all farms: Data taken from the USDA's Quarterly Farm Labor Survey  
\(\text{b/}\) Average wage for hired farm labor on all farms: Data taken from the USDA's Quarterly Farm Labor Survey  
\(\text{c/}\) Average wage rate for hired crop workers: Data taken from the USDA's Quarterly Farm Labor Survey  
\(\text{d/}\) Average wage rate for hired crop workers: Data taken from the USDL's National Agricultural Worker's Survey  
\(\text{e/}\) Cornbelt II includes Iowa and Missouri
<table>
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<tr>
<th>Year</th>
<th>Nominal Wage</th>
<th>Real Wage (2000=1.00)</th>
<th>IPD-PCS</th>
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<td></td>
<td>Farm Crops(^a)</td>
<td>All(^b)</td>
<td>Mfg(^c)</td>
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<td>2005</td>
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\(^a\) Crop workers: column (1) is from the USDA's Quarterly Farm Labor Survey and column (2) is from the National Agricultural Workers Survey (USDL).

\(^b\) All hired farm workers: column (3) is from the USDA's Quarterly Farm Labor Survey.

\(^c\) Manufacturing wage: column (4) data are reported in the Economic Report of the President-2007, Table 47.

\(^d\) Real wage is obtained by deflating the nominal wage by the implicit price deflator for personal consumption expenditures, which is in column (9).
Appendix A. Supplemental Figures

Figure 17. Relative factor prices for California: Wage relative to the price of capital services, wage relative to the price of materials, and price of materials relative to the price of capital services, 1970-1999

[Diagram showing relative factor prices]
Figure 18. Relative factor prices for Florida: Wage relative to the price of capital services, wage relative to the price of materials, and price of materials relative to the price of capital services, 1970-1999
Figure 19. Relative factor prices for Iowa: Wage relative to the price of capital services, wage relative to the price of materials, and price of materials relative to the price of capital services, 1970-1999