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AGRICULTURAL ECONOMICS

STAFF PAPER

THE EFFECT OF TECHNOLOGY ON THE U.S. GRAIN SECTOR

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April 1990

No. 90-7

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PREFACE

This paper was written to satisfy in part the requirements of an award received from the National Institute of Agricultural Economics and Rural Sociology of the Japanese Ministry of Agriculture, Forestry and Fisheries. The award supported Professor Forker's visit to Japan during the period February 27-March 30, 1990. During that period Professor Forker interacted with the staff of the Institute and made eight presentations in various parts of Japan to audiences that included members of prefectury diets (legislative bodies), prefectury research centers, national and prefectury universities, and the agricultural community from both production agriculture and the food processing sector.

THE EFFECT OF TECHNOLOGY ON THE U.S. GRAIN SECTOR

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Introduction

Yield increases in the U.S. grain sector during the past 50 years have been dramatic. Year-to-year variations are substantial because of varying weather conditions and public policy, but the general trend has been continually upward. The ability to produce more with less land and labor has resulted in the continual pressure on the supply/demand balance with a consequence of continually lower real prices over time.

Some of the yield increase has resulted from a more intensive use of fertilizers, pesticides, and herbicides, the use of which is under attack by environmentalists and food safety advocates. It is possible that the political pressures from these advocates will decrease the rate of yield increases. Economic and political pressure is resulting in more interest in Low Input Sustainable Agriculture (LISA) technologies. However, despite this caution, yield increases are expected to continue.

Annual percentage increases in yields of major grains during the period 1960-1982 have been as follows: corn, 2.6 percent; rice, 1.2 percent; soybeans, 1.2 percent; and wheat, 1.6 percent (Table 1). Yield increases since 1982 have been at least on trend.

The yield improvements and increased efficiencies overall are due to new and increased use of technology. Several types of technologies have been important: increased use of fertilizer, new seed varieties, increased and more efficient use of pesticides and herbicides, improved tillage methods to conserve moisture and reduce energy requirements, expanded use of irrigation, and the adoption of new information technologies.

During the balance of this paper I will describe the impact of various technologies, discuss their relative importance, and make some comments about the future.

Technology as a Substitute for Land and Labor

The various technologies, when combined, have reduced the amount of land and labor required to produce the nation's grain crop. For example, in 1910 U.S. farmers produced 120 million tons of grain on 192 million acres of land. In 1979 they produced 216 million tons on 162 million acres. The 7.6 billion bushel corn crop produced in 1979 on 69 million acres would have required 272 million acres at the 1910 yield levels (Carlson).

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The agricultural output per farm worker for all commodities in the U.S. increased by 10 percent during the nineteenth century (from 1800 to 1900). From 1900 to 1980 output per farm worker increased by over 200 percent (Manchester et al.). In 1950, labor accounted for almost 40 percent of the value of all resources used in farming. By 1977 it had declined to 14 percent. It is less now in 1990.

To provide more insight into the effect of the various technologies on grain production, I will discuss each separately and then present the results of a study that tried to determine the relative importance of the various technologies.

Type of Technology

Fertilizer

Fertilizer use in its various forms (liquid and dry) and in various combinations of nitrogen, phosphorous, and potassium, increased dramatically during the period 1950 to 1980 -- a twelvefold increase. Over that time farmers and scientists learned to apply the best combination of nitrogen, phosphorous, and potassium. As new application methods are developed it is expected that more effective use will be made of the fertilizer that is applied.

New Seed Varieties

Improvement in the genetics of seeds has been one of the more dramatic sources of increased yields, either in terms of using soil nutrients more effectively or more effectively utilizing more intensive levels of fertilizer application. The most dramatic improvement in seeds has been in corn. However, improvements have also been recorded in wheat and soybean production. Redesigning the genetic makeup of grain seeds through gene splicing will at some future date result in greater yield increases per unit of input, but for most crops such developments are 10 to 20 years away.

Pesticides

Pesticide use has been another major cause for increased yields and productivity in the grain sector. With the introduction of new pesticide products that require very small amounts per acre, the aggregate pesticides poundage has been declining even though acres treated remain stable or even increasing (Agricultural Outlook).

Herbicides

The use of herbicides is an effective way to decrease competition from weeds for moisture and nutrients in the soil. It has also made it possible to reduce the amount of energy required in tillage. When combined with other technologies, it has helped cause dramatic increases in wheat production in some parts of the country.

Moisture and Energy Conservation Technology

New types of farm machinery and new tillage methods have made it possible to conserve moisture in the soil and also reduce the amount of energy required to till the soil. Drought is one of the most feared weather conditions in parts of the United States. Drought caused the great Dust Bowl of the 1930s. Research on ways to conserve moisture started as early as 1915. This technology, combined with the practical experience of good farmers, has turned the area that was once called the "Great American Desert" into a "Great American Granary." Water conservation technologies have greatly reduced the risk of crop failure from below normal precipitation. Some of the new tillage techniques that conserve moisture also conserve energy (Carlson). Although no-till farming was once considered one of the most promising forms of moisture and energy conservation, it has not become as extensive a practice as many had thought it would only ten years ago.

Irrigation

The number of acres under irrigation doubled between 1950 and the early 1980s, this despite (or perhaps because of) government attempts to reduce crop acreage overall. This makes it possible to have substantially increased yields on special crops in dryland areas. However, irrigation has also become relatively common in areas of relatively high rainfall. In this latter instance the increase has been to reduce risk associated with dry years. In the Southeast, irrigation has enabled farmers to double-crop their land.

Some of the expansion of irrigation has resulted in a depletion of the groundwater aquifers. Water has also become much more expensive in the western part of the U.S., and thus expansion of irrigated land in that area has slowed down or stopped.

Information Technologies

Although not discussed very much in the scientific literature, the ability of researchers to analyze data quickly and convey this information to farmers has improved dramatically over the last 30 years. In addition, farmers and farm-input suppliers, especially, have been able to collect and analyze information much more effectively. This enables farmers to be better managers of the inputs and the enterprises that they govern. It would be hard to sort out the net effect of this on yield and total production, but it certainly is an important element.

Farm Machinery

The introduction of the use of tractors in the late '30s and '40s was merely a substitute for horse and oxen energy. However, this enabled farmers to adopt a greater variety of automated systems of tillage, cultivation, and harvest. This resulted in an increase in output per acre and also a more dramatic increase in output per farm worker. Until the early 1980s the trend was to increase the size of tractors purchased. Since the early 1980s the average horsepower of tractors purchased has followed generally a downward trend.

Integrated Systems

None of the technologies by themselves have the impact on yields or productivity in the grain sector that they do when combined in an integrated system. The yield increases that we observe are the result of farmers combining these technologies in what they view as the most effective combinations. The additional research and experience of the competent farmers will continue to increase the output from further integration of the various technologies, new and old. Probably the most dramatic yield increase from integrating various technologies is that observed for wheat in the United Kingdom. Over the last ten years farmers in the U.K. have been able to increase wheat production to over 100 bushels per acre. Average wheat production in the United States, for example, now is only 32.9 bushels per acre. Some farmers in parts of the U.S. have achieved over 100 bushels per acre by adopting the U.K. integrated techniques.

Relative Importance

Several attempts have been made to try to estimate the importance of the various technologies on yield. A good study was done by Schroder, Headley, and Finley. It is five years old, but is still relevant.

This study covered five Corn Belt states (Table 2). The average actual yield increase for those states was 47.38 bushels per acre during the period 1964-79. It is estimated that differences in the weather accounted for 42 percent of the yield increase and changes in technology accounted for 58 percent. Of the increase over that period of time, 28.25 bushels per acre resulted from the use of herbicides, fertilizer, and genetics. Fertilizer accounted for the greatest portion of the increase at 12.50 bushels per acre. Herbicides were also important at 9.55 bushels per acre, and genetics increased yields by 6.20 bushels per acre.

The study by Schroder et al. further indicated that each pound of fertilizer applied increased yields by approximately one-tenth of a bushel. The genetic improvements, when compared to a double-cross hybrid released in 1940, contributed about 0.14 bushel per year in increased yields.

This study should be interpreted with caution because the results depend a great deal on how the researchers account for weather, the geographical area included, and the nature of the model used in the estimation procedure.

The Future

There have been several attempts to predict the impact of future technologies on grain production. The U.S. government's Office of Technology Assessment (OTA) completed a major study in the mid 1980s. The OTA thought at that time that the most likely developments in technology would result in future increases in yields at an annual rate of 1.2 percent for corn, 1.2 percent for soybeans, 1.3 percent for wheat, and 0.9 percent for rice. It also made estimates of what would happen if there were no new technology and, as an alternative, even more new technology (Table 1).

Roy Kottman in a book titled Biotechnology of Plants and Microorganisms indicated that it should be possible (based on known technology) to produce 428 bushels of corn per acre. That compares to the current average of around 110 bushels per acre. Many Midwest farms now get over 200 bushels per acre. Some agronomists feel that maximum yields of 600 bushels per acre are possible if the genetic makeup of the corn plant can be altered so that it can take advantage of environmental conditions as they now exist in the Corn Belt area of the central U.S.

A study by McElvoy and Krause, as reported by Spinelli, predicts yield increases by the year 2030 as high as 200 percent for feed grains and wheat, 250 percent for rice, and 300 percent for soybeans (Table 3). This is the optimistic forecast. The more probable technology scenario indicates possible yield increases by 2030 of 100 percent for feed grains and wheat, 150 percent for rice, and 120 percent for soybeans.

Implications

Such increases in yields have a dramatic effect on the supply/demand balance and thus on the structure of U.S. agriculture and the manner in which farm policy is conducted. The advent and adoption of new technology have put a tremendous amount of pressure on the structure of the U.S. farm industry and also on farm policy. The Office of Technology Assessment has made several projections of the impact on structural change. These projections imply continuing pressure on the supply/demand balance and farm prices.

In 1969, 93 percent of the farms in the U.S. had sales amounting to less than $100,000 (Table 4). Only 2 percent has sales worth over $250,000. However, by the year 2000 it is projected that the smaller part-time farmers with sales under $100,000 will represent only 80 percent by number and that 14 percent of the farms will be selling products worth over $250,000.

The more dramatic way of making the presentation of the impact on agriculture is that this will dramatically affect the distribution of cash receipts by farm size. While small and part-time farms with sales amounting to less than $100,000 represented 48 percent of the cash receipts received by farmers in 1969, by the year 2000 this size farm will represent only 4 percent of all cash receipts (Table 5). On the other hand, the large-scale farms with sales over $250,000 will represent 86 percent of the cash receipts in the year 2000 compared to only 35 percent in 1969.

The impact on supply relative to demand has been dramatic and will continue to create controversy in the public policy arena. During the 1970s there was concern that the trend in agricultural yields was leveling off or perhaps even decreasing. During the decade of the 1980s it became obvious that the productive capacity of the United States and of the world was such that with continuing improvements in technology, we would continually be pushing supplies against the ability of the population to consume that supply. This continues to put pressure on the farm policy of the United States and makes it difficult for Congress to make sure that farmers continue to receive a reasonable return on their investment and adequate income to live, while at the same time adjusting policy to accommodate the impact of the changing technology on agricultural output.

Summary

Yield increases in the U.S. grain sector have been dramatic over the past 30 to 50 years. Much of the increase was due to the development of new technologies including the use of fertilizer, new seed varieties, pesticides, herbicides, moisture- and energy-saving technologies, irrigation, information technologies, and new farm machinery. Studies indicate that over 50 percent of this increase is due to new technologies, while slightly under 50 percent is due to changes in weather conditions. The use of fertilizer accounts for the largest part of the increase while the use of herbicides and genetic selection are also very important.

The Schroder et al. study that attributes the increase in yields to only weather, herbicides, fertilizer, and genetics should be received with caution. It overlooks the importance of management, the ability of a farmer to put together the right combination of technologies, and the importance of information technologies in making sure that researchers and farmers are able to analyze and communicate research results and practical experience to each other.

Although it is expected that yield increases will continue because of continual improvements in technology and the ability of farmers to put technologies together in better combinations, it is possible that yield increases will level off due to concerns over food safety and the environment. Heavy uses of herbicides, pesticides, and fertilizers are endangering the environment to some extent. A substantial amount of research on Low Input Sustainable Agriculture is resulting in a more economical use of some of the purchased inputs. Depending on relative prices of inputs and the grains, it might mean the use of fewer inputs. If this happens, yield increases may not be as much in the future as in the past.

At this point an important point should probably be made. The limit on yield increases will be the result of market limitations and the economics of input supplies, and not limitations in the availability of new technology.

Table 1. Past and Projected Output Trends for Specified Crops and Milk Utilizing Biological and Information Technologies, 1982-2000[1]

Crop	Past yield trend 1960-82	OTA projections: 1982-2000 No new technology	Most likely technology	More new technology
	Annual percent change in yield			
Corn	2.6	0.5	1.2	1.6
Cotton	0.1	0.3	0.7	1.0
Rice	1.2	0.2	0.9	1.4
Soybeans	1.2	0.8	1.2	1.2
Wheat	1.6	0.7	1.3	1.4
Milk	2.6	1.4	3.9	4.2

[1] Note that this table refers to changes in yields, not to total production which is also a function of the number of acres farmed or cows milked.

Source: Phillips, p. 40.

Table 2. Portions of Predicted Corn Yield Changes Attributed to Weather and Technology Effects for Five Corn Belt States, 1964-79

Variable	Yield change (bushels/acre)	
Weather		
July precipitation	7.94	
July temperature	8.59	
August precipitation	3.53	
Total weather		20.06
Technology		
Herbicides	9.55	
Fertilizer	12.50	
Genetics	6.20	
Total technology		28.25
Total yield change		48.31

Table 3. U.S. Potential Crop Yields

Year	Low 2000	Low 2030	Probable 2000	Probable 2030	High 2000	High 2030	Optimistic 2000	Optimistic 2030
				Percent increase				
Crops								
Feed grains[1]	20	50	40	100	60	150	100	200
Wheat[2]	25	50	50	100	75	150	100	200
Rice[3]	50	100	100	150	150	200	200	250
Soybeans	50	60	60	120	120	180	150	300

[1] Barley, corn, oats, sorghum, corn and sorghum silages.

[2] The Southern Plains, Northern Plains, and Mountain regions will have wheat yield gains 10 percent below the national average by 2030.

[3] Rice is grown only in the Corn Belt, Delta states, Southern Plains, and Pacific regions.

Source: Spinelli, p. 11.

Table 4. Distribution of Farms by Sales Class

Sales class	Value of products sold	Distribution of farms 1969	Distribution of farms 1982	Distribution of farms 2000 (projection)
			Percent	
Small/part-time	<$100,000	93	86	80
Moderate	$100,000-$250,000	5	8	6
Large scale	>$250,000	2	6	14

Source: Phillips, p. 41.

Table 5. Distribution of Cash Receipts by Sales Class

Sales class	Value of products sold	Distribution of cash receipts		
		1969	1982	2000 (projection)
		Percent		
Small/part-time	<$100,000	48	27	4
Moderate	$100,000-$250,000	17	20	10
Large scale	>$250,000	35	53	86

Source: Phillips, p. 42.

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