Agricultural Productivity in the United States. By Mary Ahearn, Jet Yee, Eldon Ball, and Rich Nehring, with contributions from Agapi Somwaru and Rachel Evans, Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agriculture Information Bulletin No. 740.

Abstract

Increased productivity is a key to a healthy and thriving economy. Consequently, the trend in productivity, economywide, is one of the most closely watched of our common economic performance indicators. Agriculture, in particular, has been a very successful sector of the U.S. economy in terms of productivity growth. The U.S. farm sector has provided an abundance of output while using inputs efficiently. Agricultural productivity growth has been an important source of U.S. economic growth throughout the century, but the years since 1940 have seen an even faster growth in agricultural productivity. The annual average increase in productivity from 1948 to 1994 was 1.94 percent. This reflects an annual growth in output of 1.88 percent per year and an actual decline in agricultural inputs of 0.06 percent per year. This report describes changes in U.S. agricultural productivity, and its output and input components, for 1948-94. The report also discusses factors that have affected productivity trends and provides detailed, technical information about the USDA system for calculating productivity.

Keywords: productivity, efficiency, agricultural production, outputs, inputs

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Contents

Summary

Increased productivity is a key to a healthy and thriving economy. Consequently, the trend in productivity, economywide, is one of the most closely watched of our common economic performance indicators. Agriculture, in particular, has been a very successful sector of the U.S. economy in terms of productivity growth. The U.S. farm sector has provided an abundance of output while using inputs efficiently. Increased productivity improves society's general standard of living because productivity gains are passed on to the consumer in the form of lower product prices. If productivity levels in a sector of the economy rise, resources will be released for use by other sectors of the economy. In the case of agriculture, the high levels of productivity have freed up resources that would otherwise have been used to meet basic food needs of the population. In addition, lower real prices for agricultural products have contributed to the favorable U.S. trade position in international agricultural markets. This report examines the trends in agricultural productivity, output, and input use during 1948-94 and describes the factors that contribute to agricultural productivity growth.

Productivity captures the growth in outputs not accounted for by the growth in inputs. In this sense, productivity is measured as a residual. It is most commonly expressed as total factor productivity (TFP), which is a ratio of total outputs to total inputs. If the ratio of total outputs to total inputs is increasing, then the ratio can be interpreted to mean that more outputs can be obtained for a given input level. The "conventional" approach to measuring agricultural TFP is to include only those outputs and inputs that are under the control of the farmer and for which a market exists.

Economists and others have identified several factors contributing to agricultural productivity growth. This report provides a brief summary of the research on the importance of the major factors affecting productivity. The factors include research and development, extension, education, infrastructure, and government programs. These factors, along with nonmarket environmental services, can be viewed as "nonconventional" inputs in production.

Total U.S. agricultural output grew at an annual average rate of 1.88 percent between 1948 and 1994. Output growth can be attributed to growth in conventional inputs and growth in productivity. Real expenditures on agricultural inputs declined by 0.06 percent during this period. Thus, output growth during this period was the result of the 1.94-percent annual average increase in productivity.

Agriculture's productivity performance, compared with all other industries in the U.S. economy, is noteworthy. Agriculture has one of the highest rates of productivity growth in the economy. However, because agriculture is a relatively small industry, accounting for less than 1.5 percent of the gross domestic product of businesses in the U.S. economy, its productivity rate has little effect on the productivity of the overall economy.

Because productivity indicators are key indicators of the fundamental health of the economy, they are tracked very closely by public and private decisionmakers. Some of the major uses of agricultural productivity indicators include:

- monitor the health of the agricultural sector,
- make performance comparisons across different industries of the economy,
- make performance comparisons across different countries, and
- inform public policymakers regarding policies to enhance productivity growth.

This report provides detailed, technical information about the USDA system for calculating productivity, and introduces new approaches to measuring agricultural productivity. For example, the previous method did not adjust for the changing quality of labor hours over time. Overall, the current revisions in historical estimates reported here have had little effect on the bottom-line estimates of productivity, compared with past methods. However, there are more significant changes in some individual input and output measures and in the total output and total input measures.

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Introduction

Total U.S. agricultural output grew at an annual average rate of 1.88 percent between 1948 and 1994. Output growth can be attributed to growth in inputs and growth in productivity.[1] Real expenditures on agricultural inputs declined by 0.06 percent during this period. Thus, output growth during this period was solely the result of the 1.94-percent annual average increase in productivity.

Importance of Productivity Growth

Increased productivity improves society's general standard of living by producing products with fewer inputs. This increased efficiency in production has two important effects. First, if productivity levels in one sector of the economy rise, resources will be released for use by other sectors. As agriculture provides "necessities" goods, the high levels of productivity have freed up resources that would otherwise have been used to meet basic food needs of the population.

Increased productivity levels also lower the real prices of goods and services. Agricultural productivity gains are passed on to the consumer in the form of lower food prices and, in effect, raise the standard of living. However, U.S. agriculture's high level of productivity is not fully translated into reduced food prices because agriculture's share of our food bill is only about 22 percent (Elitzak, 1996). For every dollar spent on food, 22 cents is for farm products and 78 cents is for the food sector to process, package, and transport the product. Unfortunately, the food products sector has not experienced as high a level of productivity as has the agricultural sector. In fact, the average annual productivity growth rate of 0.8 percent in food and kindred products for 1949-93 was well below agriculture's high levels and below average for all manufacturing combined (U.S. Dept. of Labor, 1996).

As increased productivity lowers real agricultural output prices, the international competitive position of U.S. agriculture improves. The United States is the leading agricultural exporter. Given the persistent U.S. trade deficit overall, the trade surplus in agricultural products is critical to the health of the U.S. economy. The share of U.S. agricultural production exported is more than double that of other major U.S. industries.

Major Uses of Productivity Indicators

Because productivity indicators are such key indicators of the fundamental performance of the economy, they are tracked very closely by public and private decisionmakers. Some of the major uses of agricultural productivity indicators include:

To monitor the performance of the agricultural sector. Annual productivity indicators for agriculture can be compared over time. Higher levels of productivity indicate that the sector is efficiently utilizing inputs in the production of farm products, compared with earlier years. High levels of productivity bode well for the sustainability of the farm sector given the links among productivity, output prices, and competitiveness. Increased efficiency can translate into increased farm income, at least in the short run. (In the long run, additional farms adopt the more efficient practices, leading to increased supply, thereby lowering farm output prices and farm income.) Relative to productivity, farm income is a preferred

[1] Only "conventional" inputs and outputs are included in the measure of productivity. By conventional is meant inputs and outputs under the control of farmers and for which a market exists. Important unconventional inputs and outputs include public agricultural research and the effects of agricultural production on natural resource depletion and environmental degradation. ERS is researching approaches to adjust the conventional accounts to allow for consideration of some "nonmarket" effects.

indicator of the shortrun health of the farm sector, in large part because it is measured in dollars. However, even traditional farm income indicators do not fully capture the well-being of the people engaged in farming because they do not show how that income is distributed among those who provide land, labor, and capital to agriculture.[2]

To make performance comparisons across different industries of the economy. Because of the fundamental advantages of high productivity growth, productivity estimates can isolate the different factors that spur high levels of productivity for some industries relative to others. This understanding can be used in the formulation of public and private policies to enhance productivity in slower growing industries.

To make performance comparisons across different countries. Agricultural productivity is one of the key forces behind the continued ability of the United States to export agricultural products in international markets. Productivity measures of the agricultural sectors of major competitors can help U.S. officials understand the implications of alternative positions as they negotiate trade agreements with other countries.

To inform public policymakers regarding policies to enhance productivity growth. Knowledge of the sources of productivity can help policymakers formulate policies to increase productivity. Factors contributing to productivity growth include research and development, extension, education, infrastructure, and government programs. For example, if public and private investment in agricultural research are found to increase productivity, policymakers may want to continue public funding for agricultural research and create incentives for private research. As another example, if changes in the quality of machines are found to improve productivity in an industry, policymakers may want to change the tax laws to induce firms in the industry to buy newer equipment.

[2] Traditional net farm income indicators are limited as long-term indicators of the health of the agricultural sector. This is because income is calculated as the residual income which accrues to farm operations for their contributions of owned land and capital, unpaid labor, and management. The residual income directly corresponds to changes in the way in which these inputs are acquired and provided in the production process. For example, trends in net farm income will correspond to trends in the share of land that is rented from owners outside the farm operation.

What Is Productivity?

Productivity captures the relationship between outputs and inputs in production. It is most commonly expressed as *total factor productivity* (TFP), which is a ratio of total outputs, measured in an index form, to total inputs, also measured as an index.[3] If the ratio of total outputs to total inputs is increasing, then the ratio can be interpreted to mean that more outputs can be obtained for a given input level. In addition, the **rate of growth** in productivity can be calculated as the difference between the **rate of growth** in outputs and the **rate of growth** in a cost share-weighted sum of inputs.

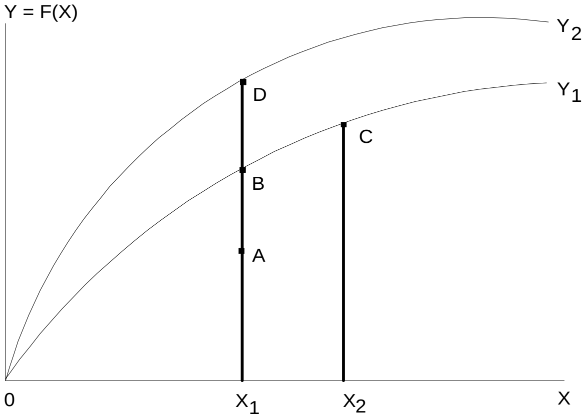
Productivity, or TFP, captures the growth in outputs not accounted for by the growth in production inputs. The notion of TFP is based on the economic theory of production. A basic concept in production theory is the production function, which expresses the amount of output possible from a bundle of inputs using a given production technology. The production technology describes how the inputs are transformed into outputs, for example, as output is expanded. Differences in agricultural TFP over time can result from several factors. These include:

- differences in efficiency (less than the maximum output is produced from a given input bundle in some time periods);
- variation in "scale" or level of production over time, as the output per unit of input varies with the scale of production; or
- technological change.

A graphical depiction of a production function illustrates what a measure of productivity can capture. In the simplest case, a single output (Y) is produced with a single input (X). In figure 1, any point along the curve, Y_1, indicates the maximum of Y that can be obtained for a given level of X. Any X,Y combination below the curve (point A, for example) would represent "technically inefficient" production since more of Y *could* be produced with the same level of X. In reality, a bundle of inputs—not just one—is used in production and a certain amount of flexibility

[3] USDA first published TFP estimates in the 1940s (Barton and Cooper, and Cooper, Barton, and Brodell) and later redeveloped the estimates in Loomis and Barton in the early 1960s.

Figure 1
Production relationships and productivity
Productivity changes result from differences in efficiency, scale of production, or technological change.



exists in how these inputs can be combined in production. Another type of inefficiency—"allocative inefficient" production—results when a producer selects a bundle of inputs that is not the least costly combination given the relative prices of inputs.

The curvature of the production function in figure 1 depicts a production technology with decreasing returns to scale. Not only is X required to produce Y, but at some point, more of X is required to produce each unit of Y than is required at lower levels of production. For example, at point B, less is required to produce a unit of Y than at point C. If, over time, producers expand their production level, given the curvature of Y_1, they will realize lower levels of output per unit of input.

Additional units of Y can be produced for a given level of X through technical innovation. Clearly, the production technology of U.S. agriculture in the 1990's differs significantly from that of the 1940's. A production technology change could be depicted in figure 1 as a shift in the production surface from Y_1 to Y_2. At each scale of production, more output is produced with the new technology represented in Y_2 than with the original technology, Y_1. For example, when the production technology is represented by Y_1, an input level of X_1 will result in the output of point B. However, after a technical innovation leading to the new production technology represented by Y_2, the same input level of X_1 yields output at point D. This increased output would be captured by a measure of TFP over time.

Partial Productivity Measures

Historically, economists have used and developed productivity measures that are based on the relationship between one or more outputs relative to a single key input, such as an acre of farmland or an index of farm labor input. These indicators are called partial factor productivity indicators. The most common partial productivity index economywide is a labor productivity measure. The usefulness of a labor productivity measure for an industry varies depending upon the importance of the labor input in that industry. For agriculture, labor productivity measures can be misleading if used as the primary productivity indicator. This is because other types of agricultural inputs have been increasing at varying rates over time and because many work activities, previously performed onfarm, have now moved off-farm. For example, animal feed preparation used to be almost totally an onfarm work activity. The labor used now in the off-farm processing of purchased animal feeds is not included in the farm labor input estimate. These labor-based partial productivity measures are analogous to an oft-cited, but misleading, indicator of how many persons a U.S. farmworker feeds today compared with a previous time. For example, a U.S. farmworker was said to have supplied 96 persons with farm products in 1990, compared with 14 persons in 1948 (USDA, 1992).

Trends in Agricultural Productivity, Output, and Input Use

Agriculture's productivity performance in the U.S. economy is noteworthy. Agriculture has one of the highest rates of productivity growth of all industries. Agricultural productivity increased at an average annual rate of 1.94 percent over 1948-94 (fig. 2, table 1).[4]

[4] Table 1 and corresponding implicit price indexes and quantity indexes are available electronically in USDA, 1998. Productivity estimates are updated routinely in USDA's *Agricultural Outlook* magazine.

Table 1—Farm output, input use, and productivity, 1948-1994 (1948=100)

		Livestock and livestock products				Crops							
Year	Total farm output	All[1]	Meat animals	Dairy products	Poultry and eggs	All[2]	Food grains	Feed crops	Oil crops	Sugar crops	Cotton/ cotton-seed	Vegetables and melons	Fruit/ tree nuts
1948	100	100	100	100	100	100	100	100	100	100	100	100	100
1949	100	106	105	103	114	95	86	91	91	105	110	103	89
1950	99	110	113	97	123	91	80	93	107	132	68	103	86
1951	104	116	120	98	131	95	79	90	98	105	104	95	95
1952	107	117	123	98	134	98	101	93	97	109	103	91	94
1953	108	119	122	103	137	99	93	92	94	123	114	101	95
1954	108	123	127	104	145	96	82	95	107	137	95	104	99
1955	112	127	134	105	143	100	77	103	121	123	104	104	102
1956	113	129	129	106	159	100	81	98	142	125	92	102	104
1957	112	128	126	106	162	99	76	107	141	145	76	105	106
1958	118	130	129	105	172	108	112	114	173	142	80	104	97
1959	121	135	138	104	178	110	90	115	153	159	101	107	106
1960	123	134	134	105	175	114	107	120	164	194	101	104	112
1961	126	140	141	108	189	115	98	111	191	217	102	112	116
1962	127	141	143	108	188	116	91	114	193	223	104	108	117
1963	131	145	150	107	192	120	96	119	202	278	107	108	113
1964	130	149	154	109	199	116	106	109	203	283	106	99	116
1965	133	145	147	107	205	123	109	124	243	259	103	100	121
1966	133	147	152	103	217	122	109	123	261	258	66	112	124
1967	138	151	159	102	227	128	123	135	273	252	54	114	124
1968	140	152	161	101	221	131	131	131	308	296	72	120	121
1969	142	152	162	100	226	135	121	135	314	299	86	116	143
1970	142	158	171	101	236	129	113	126	319	290	72	114	137
1971	151	160	173	102	239	144	133	153	354	298	72	116	142
1972	152	162	175	104	246	144	127	149	356	313	94	118	127
1973	158	164	182	99	239	154	140	154	429	292	88	114	153
1974	149	161	177	102	239	141	149	129	344	268	80	119	157
1975	159	153	162	100	234	161	176	153	431	317	63	120	168
1976	161	160	168	104	253	160	175	154	363	326	79	124	162
1977	171	163	169	106	259	174	165	165	494	293	95	128	172
1978	174	163	168	105	272	179	153	178	525	295	73	136	169
1979	184	166	171	106	277	196	179	189	638	268	99	139	181
1980	178	173	178	111	296	179	199	160	492	281	74	140	196
1981	195	176	177	114	308	205	235	192	560	313	106	142	193
1982	195	174	171	117	309	207	228	197	608	276	78	150	193
1983	171	179	174	120	310	162	193	129	458	281	54	145	192
1984	193	176	170	116	319	202	214	191	527	275	88	154	191
1985	201	181	170	123	333	212	200	212	582	279	89	165	189
1986	195	182	171	123	347	200	176	202	536	297	65	166	182
1987	198	186	172	123	377	203	176	178	533	326	100	180	209
1988	186	190	176	125	386	178	160	131	437	311	104	164	224
1989	201	191	176	124	402	204	175	180	531	311	81	171	214
1990	211	194	176	127	427	219	226	185	529	316	104	187	212
1991	212	199	181	127	446	217	172	181	568	328	118	197	211
1992	225	203	182	130	467	237	211	212	605	343	109	203	219
1993	211	205	183	129	486	211	202	161	516	325	108	191	236
1994	237	213	188	132	511	250	203	216	696	364	134	215	241
Compound annual average growth rate:													
1948-94	1.88	1.65	1.37	0.60	3.55	2.00	1.54	1.67	4.22	2.81	0.63	1.67	1.91
1948-60	1.72	2.44	2.46	0.42	4.66	1.11	0.58	1.53	4.13	5.50	0.08	-0.00	0.95
1960-70	1.45	1.64	2.44	-0.39	2.98	1.24	0.53	0.47	6.63	4.06	-3.33	1.31	2.00
1970-80	2.26	0.93	0.36	0.90	2.30	3.23	5.64	2.39	4.34	-0.32	0.25	2.06	3.61
1980-90	1.68	1.14	-0.09	1.38	3.66	2.03	1.27	1.47	0.74	1.17	3.38	2.89	0.77
1990-94	2.96	2.32	1.64	0.91	4.48	3.37	-2.59	3.83	6.83	3.52	6.27	3.51	3.17

See footnotes at end of table.

--Continued

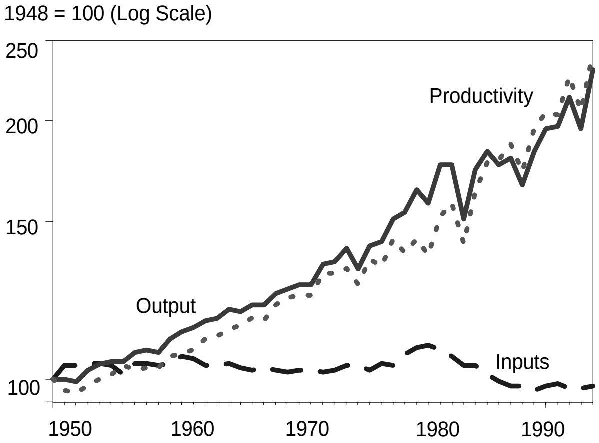
Table 1—Farm output, input use and productivity, 1948-1994 (1948=100), continued

Year	Total farm input	Intermediate inputs: All[3]	Fertilizer	Pesticides	Fuels/ electric.	Feed/seed/ livestock[4]	Labor: All	Hired	Self-employed	Capital: All	Durable equipment	Real estate	Inventories	TFP
1948	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1949	106	112	103	118	111	104	98	93	99	111	118	102	108	95
1950	105	113	124	152	114	103	94	97	93	121	136	103	107	94
1951	107	118	123	138	117	108	90	94	89	129	152	105	110	98
1952	107	118	130	119	123	107	88	91	86	137	165	106	115	100
1953	105	119	126	109	126	109	83	89	81	141	172	107	118	102
1954	102	112	130	143	125	100	81	84	80	145	180	108	116	106
1955	107	122	131	186	129	113	82	82	82	147	183	109	119	104
1956	107	126	139	257	129	117	77	75	78	148	184	109	121	106
1957	106	130	140	184	126	123	72	72	72	147	181	110	118	106
1958	106	135	138	217	123	130	69	73	68	146	178	110	122	111
1959	109	143	158	271	125	131	69	71	68	146	178	110	126	111
1960	108	141	162	164	127	130	67	71	66	147	180	110	128	114
1961	105	138	168	190	129	125	65	71	63	144	177	107	130	120
1962	105	140	144	205	131	129	64	70	63	143	174	105	134	121
1963	106	144	160	205	133	134	63	70	60	143	174	106	138	124
1964	104	143	179	196	136	130	59	63	58	144	176	105	140	125
1965	103	143	189	216	138	128	58	60	57	144	179	105	135	129
1966	104	152	216	236	140	139	54	54	54	146	184	104	142	128
1967	104	154	216	302	140	139	51	50	51	150	191	107	143	134
1968	102	150	164	293	140	140	49	48	50	151	200	105	146	138
1969	102	155	178	315	142	148	48	49	48	151	203	104	149	139
1970	103	157	183	339	142	153	48	49	47	151	205	104	150	138
1971	102	154	184	378	139	148	47	49	46	153	207	106	148	149
1972	102	158	185	440	138	153	46	48	46	152	207	104	156	149
1973	105	162	214	445	140	152	47	49	46	157	211	108	159	151
1974	104	165	236	427	133	152	43	52	40	162	223	109	165	143
1975	102	159	211	403	157	144	43	53	40	163	232	108	160	155
1976	106	168	228	481	176	151	43	54	39	165	237	109	169	152
1977	104	165	230	428	184	144	41	52	38	167	244	109	164	164
1978	110	188	234	568	193	167	39	51	36	167	250	108	170	158
1979	112	199	246	690	176	178	38	51	34	170	258	109	173	164
1980	114	203	294	688	171	188	37	50	33	174	266	111	183	156
1981	111	192	261	716	164	178	37	50	34	173	266	111	171	175
1982	108	185	198	691	155	184	36	45	33	171	261	109	184	180
1983	105	186	192	613	150	187	35	49	31	161	249	102	181	162
1984	105	181	230	742	156	168	35	45	31	164	236	107	160	184
1985	102	176	221	718	140	170	32	40	30	161	224	106	172	197
1986	98	172	255	707	130	172	31	40	28	155	208	103	166	199
1987	96	174	215	777	144	168	30	40	27	147	192	100	162	205
1988	96	172	198	677	144	166	32	47	28	144	182	99	157	193
1989	95	171	192	786	143	158	31	38	29	143	174	101	147	212
1990	96	178	197	764	142	171	31	38	28	142	169	103	154	219
1991	97	181	199	849	143	172	31	38	29	141	166	99	160	218
1992	96	180	203	852	142	173	30	36	28	139	161	99	159	235
1993	96	188	226	842	142	175	28	35	26	137	155	98	166	220
1994	97	192	221	882	147	177	29	35	27	136	151	98	158	245
Compound annual average growth rate:														
1948-94	-0.06	1.42	1.72	4.73	0.83	1.24	-2.73	-2.27	-2.88	0.67	0.90	-0.04	0.99	1.94
1948-60	0.61	2.86	4.01	4.10	1.97	2.21	-3.33	-2.87	-3.48	3.22	4.90	0.76	2.03	1.12
1960-70	-0.46	1.08	1.26	7.29	1.16	1.59	-3.36	-3.66	-3.27	0.28	1.28	-0.54	1.64	1.91
1970-80	1.02	2.56	4.73	7.08	1.86	2.06	-2.61	0.11	-3.64	1.40	2.63	0.66	1.96	1.22
1980-90	-1.68	-1.30	-4.01	1.04	-1.83	-0.92	-1.88	-2.58	-1.56	-2.05	-4.53	-1.05	-1.70	3.36
1990-94	0.18	1.85	2.86	3.60	0.74	0.84	-1.71	-2.21	-1.51	-1.05	-2.84	-0.42	0.56	2.77

[1] Includes wool, mohair, horses, mules, honey, beeswax, bees, goats, rabbits, aquaculture, and fur animals. These items are not included in the separate groups of livestock and products shown. [2] Includes tobacco, floriculture and ornamentals, Christmas trees, forest products, mushrooms, legume and grass seeds, hops, mint, broomcorn, popcorn, hemp fiber and seed, and flax fiber not shown separately. [3] Includes purchased services such as contract labor services, custom machine services, machine and building maintenance and repairs, irrigation fees paid public sellers of water and miscellaneous farm production items. [4] Includes broiler- and egg-type chicks and turkey poults and imports of livestock for purposes other than immediate slaughter.

Figure 2
Growth in productivity, output, and inputs, 1948-94

Productivity is the driving force behind changes in agricultural output.



Source: Economic Research Service, U.S. Department of Agriculture.

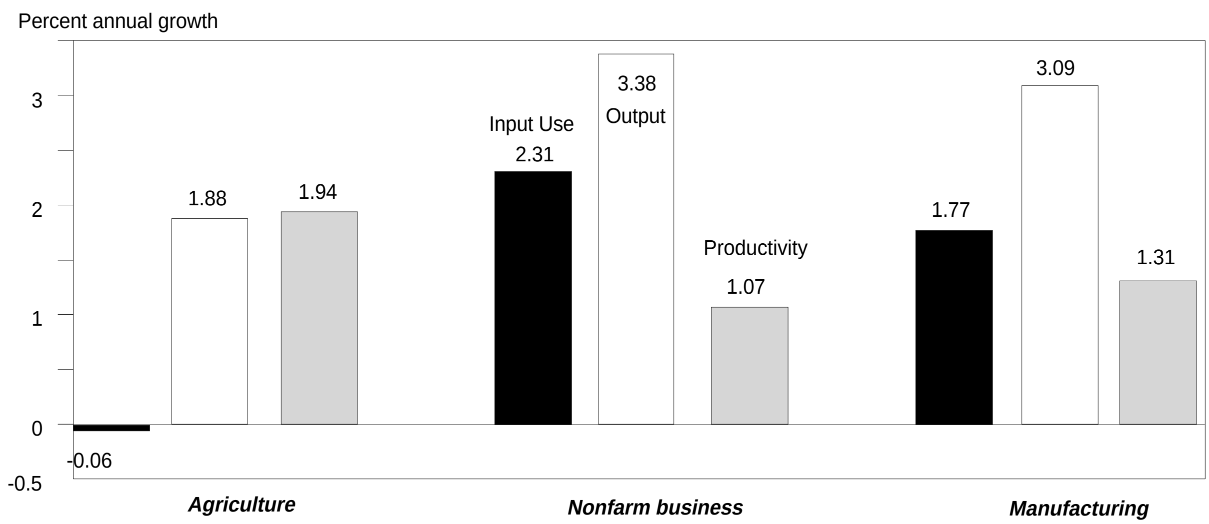
In addition, productivity growth is a more important source of output growth in agriculture than it is for other industries. For example, while output growth in agriculture was entirely the result of productivity growth, output growth in the rest of the business economy was largely the result of growth in real (inflation-adjusted) dollars spent on inputs (fig. 3). During 1948-94, one-third of the increase in nonfarm business output growth resulted from increases in productivity. For manufacturing alone—an industry considered to have relatively high rates of productivity and second only to services as an employer in nonmetro areas—only 40 percent of the increase in output growth came from productivity growth.

During 1948-94, the conditions facing the agricultural sector varied greatly. For example, during most of this period, a major concern of policymakers was excess productive capacity in agriculture. However, during key periods (after World War II and during the Korean War; the mid-1970's opening of significant export markets for agricultural products), scarcity was the major concern.

Important technological changes to the agricultural sector came immediately after World War II, sometimes referred to as the "second American agricultural revolution" (Rasmussen and Stanton, 1993). This period saw the completion of the transition from animal to tractor power and the application of more scientific lessons to farming: the use of hybrid seeds, adoption of improved livestock breeding, and the use

Figure 3
Input use, output, and productivity for agriculture: nonfarm business sector and manufacturing, 1948-94

Productivity growth is a more important source of output growth in agriculture than it is for the rest of the economy.



Source: Economic Research Service, U.S. Department of Agriculture, and Bureau of Labor Statistics, U.S. Department of Labor.

of more agricultural chemicals, both fertilizers and pesticides. Adoption of many of the practices required additions to the capital complement and specialized information systems.

Productivity Trends

Annual productivity growth rates were generally positive during 1948-94. Through the mid-1950's, however, productivity growth was very slow or even negative as agriculture and the whole economy adapted to two major wars. The outmigration of farm labor was significant, and capital and intermediate inputs increased at very high rates, capturing the rapid movement toward mechanization on U.S. farms.

Productivity growth remained fairly stable in the 1960's. Growth in agricultural output of 1.45 percent per year was somewhat below average, labor continued to decline sharply, and intermediate inputs (with the exception of pesticides) increased only moderately.

During the 1970's, demand for U.S. exports increased significantly and many U.S. producers geared up to meet the demand. The average annual rate of growth in agricultural output exceeded 2.2 percent per year. The average annual rate of growth in productivity during the 1970's, however, was not even two-thirds of the growth rate of the 1960's, since nearly half of the growth in output over this period was accounted for by growth in inputs. Growth in intermediate inputs increased over 2.5 percent per year during the 1970's (table 1). Despite a three-fold increase in the price of petroleum fuels following the 1973 oil embargo, energy consumption in agriculture increased nearly 2 percent per year in the 1970's.

Short-lived concerns over food scarcity in the 1970's gave way to expectations of chronic economic surpluses in the 1980's. In 1983, the land area set aside totaled 80 million acres as a result of the Payment-In-Kind program. Growth in agricultural output averaged only 1.68 percent over 1980-90, but total factor input decreased at the same rate. Negative growth rates were observed in all major input categories (but pesticides), as the sector went through financial restructuring. Although labor had consistently declined since 1948, capital (equipment and land) and intermediate inputs also declined during the period. The decline in inputs resulted in fairly high rates of growth in total factor productivity. The early 1990's saw a continuation of above-average rates of growth in productivity. Not only was growth in input levels fairly low in 1990-94, but output growth was at historically high levels.

Measuring Productivity

USDA uses a growth accounting approach for measuring productivity. This approach uses aggregated farm sector production and financial accounting data—such as receipts from the sale of farm products, output prices, expenditures on farm inputs, and farm input prices—in an index number procedure to calculate farm output and farm input indexes.

Farm output consists of all crop and livestock products. Farm inputs include capital (durable equipment and real estate), labor, and intermediate inputs. Intermediate inputs consist of fertilizer, pesticides, energy, feed, seed, and intermediate livestock inputs.

As is often the case, there are several decisions that must be made in translating economic theory into applied measures. The basis for making these decisions pertains to the primary uses of the estimates, coupled with the practical measurement considerations. The more important questions for agricultural productivity measurement are:

What index number procedure should be adopted? And, what assumptions does this imply about the characteristics of the agricultural production function?

How should changes in the quality of inputs over time be accounted for?

What are farm products?

How should the effects of government farm programs be accounted for?

These issues and additional detail on measurement methods are described in the appendix to this report.

Output Trends

The average annual growth in farm output of 1.88 percent over 1948-94 reflects a 1.65-percent rate of growth for livestock products and a 2-percent rate for crops. While cattle (and other meat animals) represent the largest component of livestock output, poultry and eggs were the fastest growing component of livestock output (3.55 percent vs. 1.37 percent for meat animals). Although production shifted regionally, dairy output at the U.S. level was remarkably stable during 1948-80. Since 1980, dairy output has increased at a moderate rate, reflecting increased capital investment in facilities. However, dairy's early stagnation results in an average output growth of less than 1 percent per year during 1948-94.

The 1.88-percent annual growth in output over 1948-94 has been in fits and starts (fig. 2). Output variability results from variability in yields (measured as output per acre) and in acres in production. The late 1940's through the 1960's, characterized by unusually mild weather, also saw unusually stable crop yields. In contrast, since the 1970's, a return to more usual, and variable, weather conditions has witnessed extreme weather in 1983 (high temperatures, mild drought, and early frost), 1988's drought, and 1993's extensive floods (Peterlin, 1997).[5]

Input Trends

Total input use has grown slowly over much of the period, with the exception of the middle and late 1970's. Measures of input use in agriculture account not only for changing quantities but also changing qualities of major inputs. For example, labor input considers not only the hours worked in agriculture, but the quality of those hours worked as measured by such characteristics as the educational attainment of the workers. Therefore, input growth in agriculture over the period can be decomposed into two components: the simple quantity (or unweighted stock) and input quality components. The contribution to total input growth of each component is measured as the product of each component and its input cost share.

Quality changes in labor and capital have significantly contributed to input growth and, therefore, output growth. Quality change in input categories over 1948-94 contributed 0.19 percent per year to output growth. Although seemingly small, this contribution equals one-tenth of the annual contribution of productivity growth.[6]

The fairly stable total input level over 1948-94 disguises larger shifts in particular inputs. For example, intermediate inputs increased 1.42 percent per year over the period, but energy inputs increased less than 0.9 percent (table 1). In contrast, the fastest growing input category, pesticides, increased at nearly 5 percent per year.

Synthetic pesticides were just beginning to be used in the late 1940's. For example, 2,4-D, still a major pesticide today, was registered in 1948. The technology was adopted rapidly. By the early 1970s, a significant share of the acres in major crop production were being treated. Total pounds of pesticides applied peaked in the early 1980's.

Although pounds applied has been relatively stable since the early 1980's, the mix of pesticides used has changed considerably, with important implications for productivity measurement. Most importantly, pesticides have changed in terms of their ability to kill selected target pests and in their effects on the environment and human health. These changes on average have represented improvements in the pesticide input. (Both the changing quantity and quality are captured in the pesticides index of table 1.) Figure 4 shows the continued increase in the quality-adjusted pesticide input index through 1948-94, compared with total pounds of pesticides (active ingredients) applied to all acres, which has been relatively stable since the early 1980's.

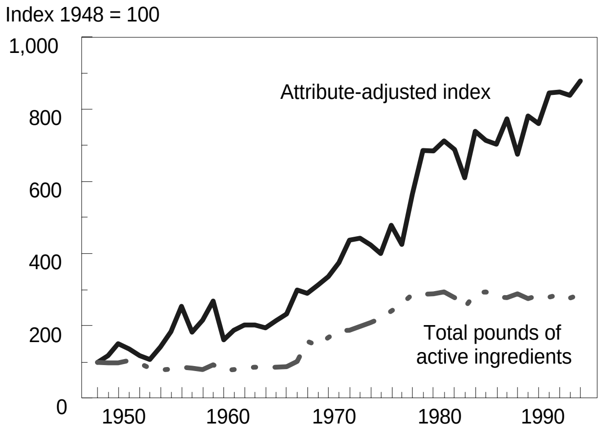
Labor input in agriculture decreased consistently over 1948-94. In 1948, 7.6 million people were employed in agriculture, compared with 3.4 million in 1994. The labor input index dropped at an average rate of 2.73 percent per year. While the number of workers employed in agriculture and total hours worked have declined, the quality per hour worked has increased. For example, in 1964, only about one-third of all farmers had completed high school, compared with more than three-quarters of farmers by 1990. (The labor index in table 1 accounts for both change in

[5] The year 1983 is also noteworthy as the year of the Federal Payment-In-Kind program, a major supply-control program, during which producers were paid with government stocks of commodities in exchange for keeping land out of production. After this program was established, important producing areas of the country experienced severe weather conditions, unexpectantly lowering output even further in that year.

[6] Had input quality change not been captured in the measurement of input use, but instead been accounted for in the TFP residual, the TFP growth would have been larger by an average of 0.19 percentage point or 10 percent per year.

Figure 4
Pesticide input in agriculture, 1948-94

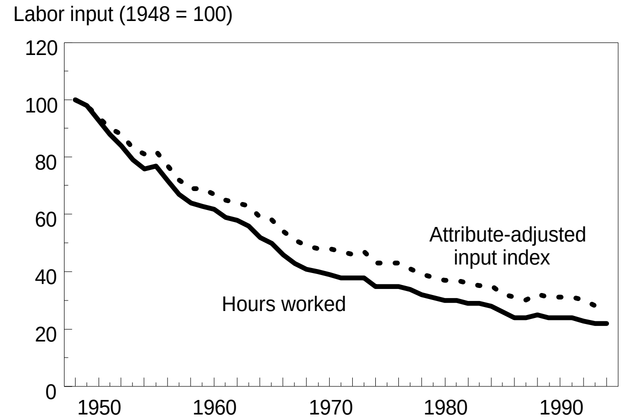
Pesticide use increased significantly, in large part due to changing characteristics.



Source: Economic Research Service, U.S. Department of Agriculture.

Figure 5
Labor input in agriculture, 1948-94

Adjustment for labor quality lowers the rate of decline in the labor input index.



Source: Economic Research Service, U.S. Department of Agriculture.

hours worked and change in the quality of those labor hours.) This adjustment for labor quality lowers the rate of decline in the labor input index (fig. 5).

Factors Affecting Agricultural Productivity

The sources of the productivity gains over 1948-94 were both internal and external to agriculture. Obviously, weather is a major, unpredictable factor affecting year-to-year variation in productivity, but other external shocks to the economy indirectly affect relative prices and resource allocations in agriculture. In fact, pressures on relative prices (for example, fuel) are often cited as an important source of technical innovation in agriculture—the so-called induced innovation concept.

Farmers are sensitive to changes in the relative prices of inputs. For example, if the price of labor increases relative to the price of capital (because labor becomes more scarce relative to capital or because of general wage increases in the nonagricultural sector), farmers will try to use more capital in place of labor. This change in relative prices may also induce private firms (for example, farm machinery companies) to develop new technologies that save on the relatively more expensive input.

Growth in output results from either increased input use or increased productivity. Measures of inputs provide an indicator of the role of individual inputs in output growth. Since the productivity “residual” is calculated as the difference between the rate of growth in output and the rate of growth in inputs, productivity is the result of technical change and many other factors. Productivity measures do not provide any information about the separate role of each of these factors. However, an understanding of the potential sources of productivity growth is of interest simply because of the important economic links between productivity growth and a society’s standard of living.

Several factors have been identified in the social science literature as the most important sources of productivity change in agriculture:

- Research and development,
- Extension,
- Education,
- Infrastructure, and
- Government programs.

Research and Development

Agricultural research is performed by both the private and public sector. The social objective of agricultural research is to increase productive capability or lessen the environmental degradation caused by agriculture. The end result of agricultural research includes higher yielding crop varieties, better livestock breeding practices, more effective fertilizers and pesticides, and better farm management practices. Agricultural research is required not only to increase agricultural productivity, but to keep productivity from falling. For example, yield gains for a particular plant variety tend to be lost over time because pests and diseases evolve that make the variety susceptible to attack. Thus, a large share of agricultural research expenditures is devoted to maintenance research.

Public agricultural research is performed in State agricultural experiment stations, land-grant and other universities, and the U.S. Department of Agriculture. Agricultural research is also performed by the private sector, mainly in the areas of farm machinery, agrichemicals, and food processing. Previous economic analyses have shown that both public and private research have positive effects on agricultural productivity, with public research having a greater impact than private research (e.g., see Gopinath and Roe, forthcoming, and Yee, 1992). Private research expenditures have increased dramatically during the past three decades and now surpass those of the public sector (fig. 6). By contrast, the rate of growth in public research expenditures has slowed significantly since the mid-1970's. While public research expenditures have stagnated, the demands on the agricultural research system have expanded beyond reducing the cost of agricultural production to include environmental protection and food safety.

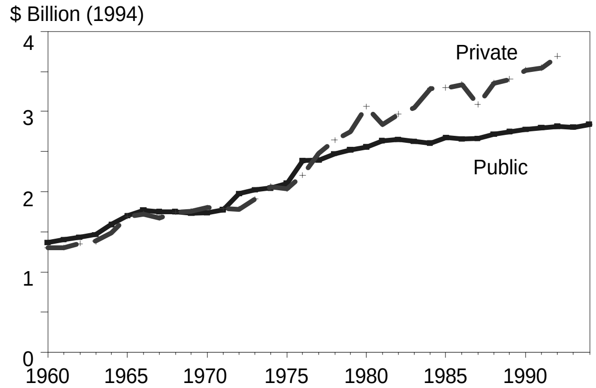
Farmers benefit from agricultural research in the short run because of lower costs and higher profits. However, the longrun beneficiaries of agricultural research are consumers who pay lower food prices. Agricultural research also helps the United States maintain its competitiveness in world markets.

Agricultural research can also reduce inequality in incomes and living standards because lower food prices benefit low-income people more than high-income people. (Low-income people spend a larger share of their income on food than do high-income people.) Moreover, the major portion of public agricultural research is paid for by taxes from middle-income and high-income people.

Figure 6

Public and private agricultural research expenditures in the U.S., 1960-94

Private agricultural research expenditures now surpass public research expenditures.



Source: Economic Research Service, U.S. Department of Agriculture.

There have been a number of studies conducted to measure the impact of public agricultural research on productivity and to measure the benefits of public agricultural research relative to the costs. Summaries of studies appear in Ruttan, 1980, 1982; Echeverria, 1990; Huffman and Evenson, 1993; and Fuglie et al., 1996. Most studies have found rates of return to public investment in agricultural research of 20 percent to 60 percent.

The tax system may bias upward the estimates of rates of return to public agricultural research.   When government expenditures are financed by tax collection, distortions are introduced in input and output markets, leading to what economists call deadweight losses. These deadweight losses may be large as a fraction of tax revenues collected and should be counted among the social costs of public programs, thereby lowering the rate of return to public agricultural research. Yee (1995) finds that consideration of deadweight losses reduces the rate of return to public agricultural research from 49 percent (assuming no deadweight losses) to 43 percent.

Public research expenditures may have an impact on private research expenditures. However, public research expenditures may either stimulate private research expenditures (by making private research more productive) or depress private research expenditures (by acting as a substitute for private research).

There is some evidence (Pray, Neumeyer, and Upadhyaya, 1988) that public investment in research increases the amount of private research. To the extent that public research stimulates private research, the returns to public research are underestimated.

Extension

Agricultural research expenditures affect productivity with a time lag. First, a particular research project may take several years to complete. Second, it takes time for farmers to learn of the innovation. The sooner the benefits from research are received, the higher the rate of return to that research expenditure.

The agricultural production extension system is aimed at reducing the time lag between the development of new technologies and their adoption. Extension agents disseminate information on crops, livestock, and management practices to farmers and demonstrate new techniques as well as consult directly with farmers on specific production and management problems. Unlike research, it is reasonable to assume that extension has an immediate effect on productivity.

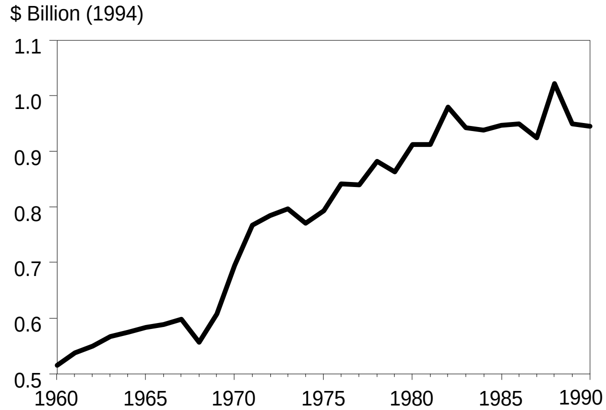
Public extension expenditures have grown little in real terms since 1980 (fig. 7). The Federal share of public extension expenditures has fallen steadily during the past few decades. The bulk of extension services now come from State and county governments and, increasingly, the private sector. For example, private crop consultants offer advice on pest and nutrient management practices. Farmers may also use farmer cooperative or chemical company representatives for advice on pest and nutrient management strategies (Ferguson, Yee, and Fitzner, 1996).

The empirical evidence on the rate of return to extension is more mixed than for research. Estimates range from 20 percent to over 100 percent (Fuglie et al., 1996). More recent studies (Huffman and Evenson, 1993) find a low rate of return to public extension. A major problem in estimating the rate of return to extension is data-related. The data reporting system for public extension expenditures is less complete than for research expenditures.

Figure 7

Public extension expenditures, 1960-90

Public extension expenditures have increased little in real terms since 1980.



Source: Huffman and Evenson (1993).

Education

In contrast to the more applied focus of extension activities, education provides individuals with general skills to solve problems. Education is thus an investment in "human capital" analogous to a farmer's investment in physical capital. Education hastens the rate of development of new technologies by training scientists. Education also speeds the rate of adoption of new technologies by farmers. Farmers who have more education may be better able to assess the merits of and successfully adapt a new technology to their particular situations. The current measure of labor input accounts for the changing educational attainment of the farm workforce over time. Gains in education accounted for 8.6 percent of the increase in output from 1948 to 1994.

Another, though less obvious, effect of education is to help consumers better evaluate the potential risks posed by new products and technologies. The potential benefits of a new technology may not be realized if consumers do not buy products using the new technology. Livestock growth hormones are cases in point. Firms may be hesitant to develop a new technology if regulatory approval or consumer demand for products using the technology are uncertain.

Infrastructure

Some of the decline in productivity for the U.S. economy in the 1970's was perhaps due to declining rates of public capital investment (Aschauer, 1989). Since that time, a number of other studies have investigated the impact of public infrastructure (highways and streets, water and sewer systems, schools, hospitals, conservation structures, mass transit, etc.) on productivity.

The empirical evidence is that public infrastructure has a positive and statistically significant impact on output and productivity. This finding is even more impressive given that much infrastructure spending goes for improving the environment and other objectives that are not captured in output or productivity measures (as conventionally measured).

An example of how public investment in infrastructure can positively affect agricultural productivity is through investment in public transportation. An improved highway system can reduce the farmers' cost of acquiring production inputs. Very little work has examined the effect of infrastructure on productivity growth in the agricultural sector. An exception to this is the work by Gopinath and Roe (forthcoming) which recently found a significant positive relationship between infrastructure and U.S. agricultural productivity.

Government Programs

The role of government in the agricultural sector is pervasive. Government programs affect productivity through the allocation of resources and outputs. Government farm programs are the most common example of government involvement in agriculture. But other examples are numerous:

- Tax policy may be used to encourage private firms to invest in the development of innovations and farmers to adopt the innovations.
- Enhanced intellectual property rights protection may increase the incentives for private firms to engage in private agricultural research.
- Regulatory policies affect the rate at which new drugs and farm chemicals reach the marketplace.

Table 2—Social rates of return to agricultural research, extension, and education

Investment	Social rate of return
	Percent
All public agricultural research	40-60
Basic public research	60-90
Private research	30-45
Public extension	20-40
Farmers' education	30-45

Source: Fuglie et al., table 7.

Relatively little research has investigated the impact of government programs on agricultural productivity, but some (Huffman and Evenson, 1993; Makki and Tweeten, 1993) find a significant positive relationship. For example, high farm prices may encourage substitution of improved capital inputs for labor and increase the rate of new technology adoption.

Summary of Estimates on Rates of Return

Most studies of the social rate of return to investment impacting agriculture have consistently found high rates of return. The rate of return seems highest for publicly supported basic research, followed by applied public research, private research, farmers' education, and, finally, public extension (table 2).

Future Prospects

Research, extension, education, infrastructure, and government programs will continue to affect the productivity of U.S. agriculture. The magnitude of their effects is uncertain. This is true both because the relationships between these factors and productivity is still not well understood and because of the uncertainty surrounding the level at which society will invest in these growth sources and programs. While it is widely acknowledged that well-directed research and development, for example, is likely to result in high payoffs to society, the competition for public dollars is great.

There is also a great deal of uncertainty about how the agricultural sector will adjust to the provisions of the new farm law, which are designed to phase out commodity programs that have been in place for more than 60 years. Will the greater producer flexibility and production restructuring result in enhanced productivity? How will the new "rules" affect the competitive position of the United States in the international markets? The experience of the 1980s—when U.S. agriculture responded to an unfavorable economic environment through a painful adjustment that contributed to today's relatively high productivity levels—should indicate that the U.S. agricultural sector has shown the ability to be flexible to market signals.

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Appendix—Measurement Methods

Productivity measurement methods have evolved over time and will continue to evolve, incorporating improved data and concepts. Agricultural productivity measurement, in particular, has been the focus of a number of well-respected economists, for example Griliches (1960) and a taskforce of the American Agricultural Economics Association (AAEA) (USDA, 1980). Many of the recommendations of the AAEA taskforce have been adopted since the release of the 1980 report, and, indeed, many methodological changes have extended beyond the committee's recommendations.[1]

There are several general measurement issues that affect more than one component of the productivity accounts. Those issues include what index number procedure to use to aggregate, how to account for changes in the quality of inputs over time, how to define farm outputs, and how to account for government farm programs. How these measurement issues are handled will affect the estimates of outputs, inputs, and productivity. Besides the USDA estimates described in this report, there are three other major alternative sources of agricultural productivity estimates (Capalbo, Vo, and Wade; Craig and Pardey; and Jorgenson, Gollop and Fraumeni). There are certain features that the studies have in common (e.g., the use of the Tornquist index and quality adjustments for labor), and there are important features that vary across the studies (e.g., differences in the application of accounting procedures in the treatment of farm origin inputs). As a result, the estimates all differ from each other, but many of the bottom-line conclusions of the trends in agricultural productivity are similar.

This appendix will first discuss general measurement issues, followed by a description of measurement methods of individual components, and a summary of the effects of the most recent revisions on the output, input and productivity levels. A 1989 handbook provides complete details on USDA's productivity measurement methods (Hauver). However, since that report several changes have been made. Where the current method represents a variation from that reflected in the 1989 handbook, the difference will be indicated. For a more theoretical treatment of the changes see Ball et al., forthcoming.

General Measurement Issues

Choice of Index Number Procedure. The measurement of total factor productivity involves computing an index of total output and an index of total inputs.[2] Total factor productivity is then computed as the ratio of the output index to the input index. The index number procedure allows for aggregation of heterogenous farm outputs and inputs. Dollars, are, of course, the unit that allows for aggregation. But dollars must be adjusted to account for changes in the value of the dollar over time, plus, the more problematic issue of changes in relative prices of inputs and outputs over time.

Recent advances in economic theory have shown how alternative index number procedures can be linked to production theory (Diewert). In particular, the economic theory of index numbers provides a link between various forms of index numbers and specific characteristics of production technologies, i.e., different types of production functions. Unfortunately, the index number procedures that currently exist correspond to only some of the simplest types of production technologies. Index number procedures that closely correspond to the real-world characteristics of U.S. agricultural production technologies simply do not exist. Hence, the choice of an index number procedure dictates the assumptions that are being made about the production function and by necessity limits the understanding of trends in TFP.

[1] In particular, two recommendations have been not adopted. (1) The taskforce recommended that USDA continue to include set-aside land in the land input. Currently set-aside land is not included in land input. (2) The taskforce also recommended that USDA use the base-period cash rental value to stock value to convert land stock to service flow. Currently, an econometric model is used to predict the expected real rate of return on the investment.

[2] An alternative approach to productivity measurement is the econometric approach, using production, cost or profit functions. An advantage to the econometric approach is that it is not necessary to assume all production is efficient. See Capalbo and Antle for a review of the approaches. For a more theoretical treatment of index numbers, see Ball et al., forthcoming.

A Tornqvist index is currently used to estimate agricultural productivity. The Tornqvist index is expressed as:

$$\log\left(\frac{x^1}{x^0}\right) \equiv \sum_i \left(\frac{s_i^1 + s_i^0}{2}\right)\log\left(\frac{x_i^1}{x_i^0}\right),$$

where the superscripts 0 and 1 denote the base and comparison periods respectively and $s_i = w_i x_i / \sum w_i x_i$, for aggregating inputs and outputs.

The Tornqvist index is an approximation of the Divisia index.[3] The Tornqvist index is exact for a homogeneous translog production function. A translog production function implies no arbitrary restrictions on substitution among factors (Diewert). The use of this index is equivalent to assuming that agricultural producers are all profit maximizers and that, regardless of the scale of production, the same amount of input is required to produce an additional unit of output (also known as constant returns to scale). In effect, the Tornqvist index would dictate that all changes in measured TFP are the result of technological innovation. Of course, we know these assumptions are not realized in the real world and that the estimates will continue to be affected by a variety of factors. To the extent that the assumptions do not hold, we must consider productivity changes as only approximations to technological innovation. One reassuring result from a recent study supports the view that the growth accounting approach using index number procedures provides productivity estimates that are very close to those yielded by an alternative approach that does not require such restrictive assumptions about the nature of agricultural production (Cox, Mullen, and Hu).

In the past, the Laspeyres index, which uses base-period weights, was used in contrast to the Tornqvist which uses prices from both the base period and the comparison period. The Tornqvist is preferred to the Laspeyres because it does not require the unrealistic assumption that all inputs are perfect substitutes in production.

[3] An alternative approximation to the Divisia is the Fisher index. Actually, indexes were computed with both the Fisher and Tornqvist indexes, and the empirical results were identical for the usual range of precision.

Treatment of Changes in Input Quality. Two types of technical innovation can be differentiated, embodied and disembodied innovation. First, some technical innovations are completely “embodied” in a particular production input. For example, newer models of computers may be faster and have more memory than older models. Improved hybrid seed corn may have higher yields. Disembodied technological change makes the current input mix (i.e., tractors, seeds, computers, etc. of all vintages) more productive. Disembodied technological change is often associated with new information or a better educated or healthier labor force. Disembodied technological change relates to the more general process of how inputs are used and combined in the production process. An example would be the new livestock management practices of rotational grazing that restructure the input mix.

The distinction between technical innovation, or quality improvements, in single inputs in contrast to quality improvements in the production process more generally, raises the question of whether input quality adjustments should be accounted for in the measurement of input use. If accounted for, we would expect the TFP estimate to be less than a TFP estimate that does not account for this change in input quality. For either inputs or outputs that have relatively constant quality levels, this issue is not relevant. However, some inputs, such as agricultural pesticides have changed significantly over time.

Defining and measuring quality presents a new set of challenges for the developer of productivity estimates, but, in general, the characteristics of individual inputs are measured, along with the conventional quantities of individual inputs. Continuing with the example of pesticides, a quality characteristic of an individual pesticide is its ability to kill the targeted pest, which is related to the potency of the chemical. For many commonly used agricultural pesticides, potency, as indicated by reductions in pounds of the chemical applied per treated acre, has increased. For example, in 1971 the pounds of pesticides applied per acre for the four major crops of corn, soybeans, cotton, and wheat was 3.61 pounds. In 1995, the comparable rate was 2.13 pounds per acre (Padgitt). A quality-adjusted estimate of pesticides, therefore, should include an indicator of the trend in the ability of pesticides to kill targeted pests, along with other important production-related characteristics.

The current approach to dealing with the variable input quality issue is to account for the quality changes in key inputs, where data availability permit, through a process of measuring the component characteristics of the input that are relevant to the observed quality changes. This approach was adopted because one of the most important uses of the estimates is to gain an understanding of the sources of growth in agricultural output. If the quality adjustments had not been made to the measured inputs, then the effect of these innovations would be captured in the TFP indicator, but not be disentangled from the other factors affecting TFP.

Definition of Farm Products and Their Inputs. The productivity measures are designed to reflect the production of farm products, rather than the production of all products produced on farms, whether they be farm or nonfarm products. That distinction provides guidance for decisions about inclusion or exclusion of outputs and inputs, data availability allowing.

Pragmatic problems remain in defining farm products. For example, Christmas trees are an example of a product that is classified as a farm product in some data collection activities, but not in others.[4] A more difficult data collection problem to resolve is the separation of inputs used in the production of farm products from those used in the production of nonfarm products for businesses that produce both types of products and do not have a need to maintain this separation, and, indeed, may be technically unable to do so. For example, some farms offer for sale outdoor recreational services, such as hunting and fishing. Providing those services requires the use of farm inputs that cannot be easily separated from the total accounting of inputs.

Treatment of the Effects of Government Farm Programs. The government has been involved extensively in agriculture since the mid-1930s through a variety of programs. Consequently, it is impossible to produce an estimate of productivity that is uninfluenced by government's pervasive involvement in agriculture. While the terms of government programs have varied over time, the dominant programs have required producers to take land out of production for a set of seven commodities in exchange for receiving a subsidy (at least on part of the crop year's production) which is based on the relationship between the season average price for those commodities and an administratively set target price. Other programs provide payments for taking land out of agricultural production, either to control agricultural supply, such as land diversion programs, or to meet stated conservation goals, such as the Conservation Reserve Program. Consequently, in terms of measurement, the terms of the programs have dictated that the programs have the greatest effect on the land input measure and the price index for outputs.

The current practice is to include the per unit subsidy in the calculation of the price index for the commodities for which a specialized program exists. This approach provides a price that is more representative of the effective price faced by producers. The measure of value of farm output adopted in this report is from the perspective of the farmer rather than society. The input for land excludes from the stock of land, that which is set aside under any government programs, including commodity and conservation programs. This approach excludes land that is not contributing in a physical sense to the production of output.[5]

Gross Output

Output is a fully gross measure, even including production that will return to the farm sector as inputs, such as hatching eggs, feed fed to livestock, or seed. This differs from the previous USDA approach which did not include production that was used in further agricultural production. (However, the previous USDA approach did not include these intermediate output as inputs, to balance the accounting, either.)

Gross output of the sector is defined as sales of commodities (including unredeemed Commodity Credit

[4] Beginning in 1997, the Bureau of Economic Analysis will unambiguously classify Christmas trees as farm products for national data collection and accounting activities.

[5] Treatment of set-aside acres and the effects of output subsidies remains a controversial issue in productivity measurement (USDA,

Corporation loans) plus additions to inventory and quantities consumed in farm households during the calendar year. In the case of livestock, the measure is the estimated weight gained on farms and in feedlots, including animals purchased for further feeding. Prices received by farmers, as reported in USDA's Agricultural Prices, include an allowance for net Commodity Credit Corporation loans and purchases by the Government valued at the average loan rate. Since direct payments under Federal commodity programs are not reflected in the price data, government payments per unit of production are added to prices for wool, mohair and program crops (wheat, rice, rye, corn, sorghum, oats and cotton). Dairy assessments are subtracted from receipts for milk. The value of output is then calculated by multiplying adjusted prices by output quantities.

Intermediate Inputs

Feed, Seed and Livestock Services. This input category includes both purchased animal feed and feed produced on-farm. It is assumed that feed crops consumed on the farm during the calendar year were carried over from an earlier year (which would have appeared as opening stocks). Additions to inventory are included in output of the sector. Hence, feed crops consumed on the farm are included in both output and in intermediate input. Seed consumption is that quantity used in production in the calendar year, whether purchased or from producers' stocks. It does not include seed withheld from production of the same year for use in subsequent periods, which is included in ending stocks. Livestock purchases include expenditures for broiler- and egg-type chicks and turkey poults and purchases of livestock for feeding. The previous method only included that part of the feed, seed, and livestock purchases resulting from activities of the nonfarm sector.

Agricultural Chemicals. The characteristics of chemicals, especially pesticides, has changed considerably over time. That is, a representative pound of agricultural chemical in 1994 is a much different input than a representative 1948 pound. To properly account for changes in characteristics or quality of chemicals, price indexes of fertilizers and pesticides were constructed using the hedonic regression technique.

The technical expression of this approach is:

$$P_{it} = \sum_t d_t D_t + \sum_j b_j x_{ij} + \in_{it},$$

where, P_{it} denotes the price of chemical i (a specific grade of fertilizer or type of pesticide) in year t, x_{ij} denotes the j th characteristic of the i th chemical, D_t is a dummy variable taking on a value of one for year t and zero otherwise and $\in_{it}$ is a stochastic disturbance term. When the above model is estimated in linear form, the parameter b_j can be interpreted as the shadow price of the j th characteristic, and d_t captures the residual price change between periods that is not accounted for by changes in the characteristics. Thus d_t can be interpreted as a quality-adjusted price index. In order to obtain efficient estimates (control for heteroskedasticity), the model was estimated with quantity weights and weighted least squares regression techniques.

The prices of 52 single nutrient and multigrade fertilizer materials are expressed as a function of the proportion of nutrients contained in the materials. The sample accounts for more than two-thirds of the total tonnage of fertilizer consumption in any given year.

Price differences among pesticides are assumed to be due to differences in the following characteristics: application rate, toxicity (LD50), solubility, soil sorption, vapor pressure, persistence, leaching potential, runoff indicator, and systemic nature of chemical (Meister). Prices and attributes of pesticides are analyzed for up to 101 chemicals.

The corresponding quantity indexes are formed implicitly as the ratio of the value of each expenditure aggregate to its price index. The hedonic approach to constructing quality-adjusted chemical inputs differs from past methods which produced input indexes that were not quality-adjusted. Although the change resulted in very different estimates of chemicals, especially for pesticides, there was relatively little effect on overall productivity because of their small cost share in the total input mix.

Petroleum Fuels, Natural Gas and Electricity. ERS constructs an index of fuel prices using data from the National Energy Accounts: Energy Flows in the United States and the Monthly Energy Review (Jack Fawcett Associates, Inc.). An index of fuel consumption is then constructed as the ratio of total expenditures (less State and Federal excise tax refunds) to its price index. In the past, petroleum fuels were included in the index of service flows from durable equipment.

Other Purchased Inputs. Other purchased inputs collectively account for approximately 15 percent of the input service flow. Implicit quantity indexes are computed for purchased services such as contract labor services, custom machine services (less sectoral income from machine hire), machine and building maintenance and repairs, irrigation from public sellers of water, and miscellaneous farm production items such as small hand tools, binding materials, etc.

Labor

To account for changes in labor quality over time, a quality-adjusted approach to measurement was applied for the labor input. Building on an approach developed by Gollop and Jorgenson of labor quality in many sectors, prices and quantities of labor input were cross-classified by the two sexes, eight age groups, five educational groups and employment status. Hours worked and average hourly compensation were measured by characteristics of individual workers. No existing household or establishment survey is designed to provide annual data on the distribution of workers among the desired characteristics. However, existing surveys do provide marginal totals cross-classified by two, three and sometimes four characteristics of labor input. Missing data were estimated using techniques proposed by Golan, Judge, and Robinson. The estimated marginal distributions of demographic characteristics provide the basis for estimates of labor input and labor cost.

The value of labor services is equal to wages plus supplements paid hired workers plus the imputed compensation to self-employed and unpaid family labor. The imputed wage of self-employed workers is set equal to the mean wage of hired workers with the same demographic characteristics. The current approach differs from past USDA approaches which were based on the unweighted (by quality attributes) sum of hours worked.

Capital Input

Service flows are used to measure capital input. Service flows are not directly observable for most natural and reproducible durable inputs used in agriculture, except for service flows from public lands used for livestock grazing and custom machine hire.

Capital Stock. The perpetual inventory method is used to measure capital stock. In this method, the sequence of relative efficiencies—or varying productive capacity—of capital goods of different ages enables us to represent capital stock at the end of each period as a weighted sum of all past investments. The change in capital stock in any period is equal to the acquisition of investment goods less replacement requirements.

Estimation of replacement requirements is based on the following relationship which relates the productive capacity to the age of the asset:

$$d_\tau = (L - \tau) / (L - \beta\tau), 0 \le \tau \le L$$

$$d_\tau = 0, \tau > L,$$

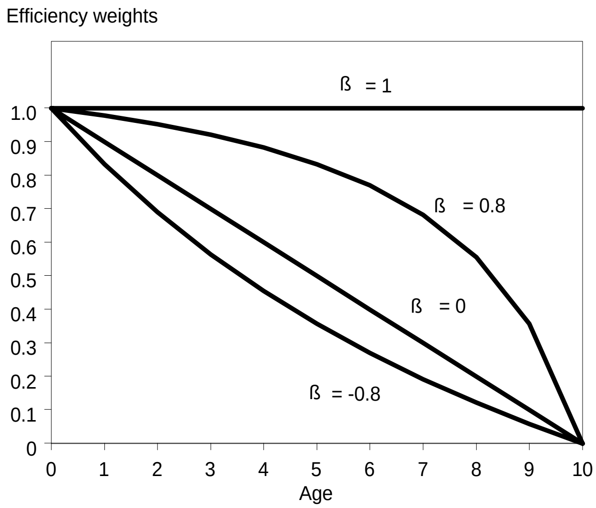
where L is the service life of the asset and β is a curvature or decay parameter.

Figure A illustrates possible relationships between capital efficiency and age of the capital, assuming L equals 10 years. The upper limit of β is one. This corresponds to the “one-hoss shay” form of depreciation. As the value of β approaches zero, decay increases at an increasing rate over time. If β is zero, the function corresponds to the formula for straight line depreciation. Finally, if β is negative, decay occurs most rapidly in the early years of service, corresponds to accelerated forms of depreciation such as geometric or declining balance. The β values chosen were 0.50 for durable equipment and 0.75 for structures. The primary basis for these choices rests on (1) empirical evidence (e.g., Penson, Hughes, and Nelson; Romain, Penson, and Lambert) that suggests the concave form of depreciation is the most appropriate and, therefore, β should be restricted to values greater than zero and (2) that the loss of productive capacity for durable equipment occurs over a greater proportion of the service life than it does for structures. Additional research has shown that the

Figure A

Decline in efficiency with age

USDA estimates assume ß equals 0.5 for durable equipment and 0.75 for structures.



growth rates of capital are not sensitive to β values within the relevant range (Ball et al., 1993).

Average service lives for the major categories of capital are based on the standard Bulletin F service lives (U.S. Dept. of Treasury). The average service lives provide the weights for the decay schedule.

Prices of Capital Services. The prices of capital services are based on (1) the present value of all future replacement investment required to maintain the productive capacity of the capital stocks and (2) the opportunity cost of invested funds. The opportunity cost of invested funds is calculated as the nominal yield on investment grade corporate bonds less the rate of inflation as measured by the implicit price deflator for gross domestic product. An ex ante rate was obtained by expressing observed real rates as an ARIMA process. The prices were then calculated holding the real rate of return constant for that particular vintage of capital goods.

Components of Capital. The three major categories of capital are: durable equipment, land, and inventories. Durable equipment includes nonresidential structures, motor vehicles, farm tractors and other equipment. Data on investment were obtained from the Bureau of Economic Analysis' Fixed Reproducible Tangible Wealth in the United States (U.S. Dept. of Commerce). The Bureau of Labor Statistics (BLS) producer price indexes for passenger autos, motor trucks, wheel-type farm tractors and agricultural machinery excluding tractors were employed as investment deflators. This was because BLS collects price information for machines of constant quality rather than pricing machines with optional equipment farmers typically purchase. For nonresidential structures, the implicit price deflator from the U.S. national income and product accounts is used. The current method differs from the past method. The past method was based on a series which consisted of expenditures for custom machine services plus maintenance and repairs, depreciation, interest on investment and fuel.

Acreage and per-acre values are available for land which is disaggregated into constant-quality land categories for each Agricultural Statistics District in each state. The benchmark acreage of the components is reported in the Census of Agriculture. The National Agricultural Statistics Service (NASS) updates annually the estimate of total land in farms. Percentages of acres in each use category were interpolated between the censuses. Land values per acre were taken from the annual Agricultural Land Values Survey (USDA, annual). The land area diverted from current production under Federal commodity programs and the Conservation Reserve was excluded from the stock of land. Service flows from public lands were estimated by means of grazing fees paid, using data from the Bureau of Land Management and the Forest Service.

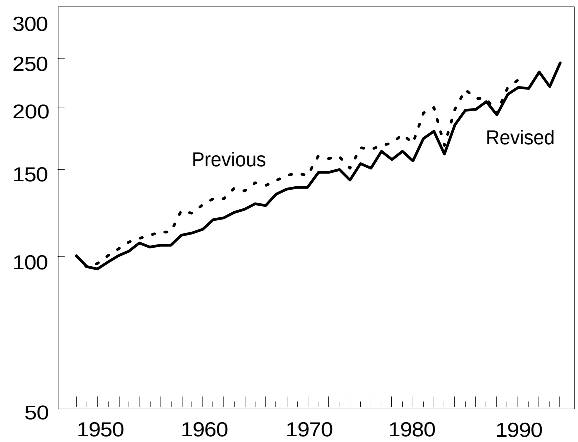
The number and value of animals on farms and grain stocks at year end are available from annual surveys. However, no distinction is made between producer-owned and commercially held stocks. Producer-owned stocks at the end of 1978 were estimated as quantities stored on farms plus producer owned stocks stored off the farm. The data on off-farm storage were obtained from Producer-Owned Grain Stocks. Quantities of commodities used as collateral for outstanding Commodity Credit Corporation loans (including commodities in the farmer-owned grain reserve) were subtracted. Stocks were then moved forward to yearend 1992 by adding, and back to year end 1947 by subtracting, estimated annual changes in quantities. December average prices were used to aggregate across commodities.

Figure B

Previous and revised USDA productivity indexes

The revised productivity index is only slightly different from the previous index.

Index 1948 = 100 (Log scale)



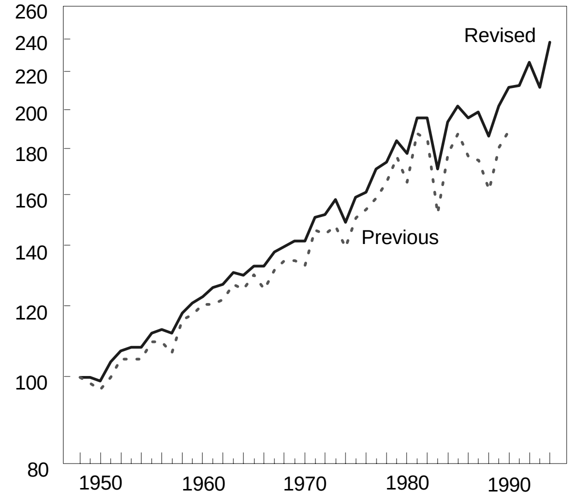
Source: Economic Research Service, U.S. Department of Agriculture.

Figure C

Previous and revised USDA output indexes

The revised output index reflects the subsidies paid under commodity farm programs.

Index 1948 = 100 (Log scale)



Source: Economic Research Service, U.S. Department of Agriculture

Effects of Revised Methods

Overall, the current revisions in historical estimates reported here have had little effect on the bottom-line productivity estimate, compared to the past methods (figure B). It is not possible to directly compare most input and output aggregates between the past and current methods because some items were transferred or added to aggregrates in the new methods. For example, fuel was a component of capital in previous methods and currently fuel is a component of intermediate inputs. Similarly, farm origin inputs, such as unprocessed livestock feed, were not included as an output or an input under the previous methods, and in the current methods, is fully accounted for as an output and an input.

The differences in input and output indexes between USDA's previous and revised methods are somewhat more significant than for the bottom-line productivity estimates (figures C and D). The major methodological change affecting the aggregate output index is the change in the procedure to weight output. The current procedure includes the subsidies paid under commodity farm programs, where the past procedure only considered market price.

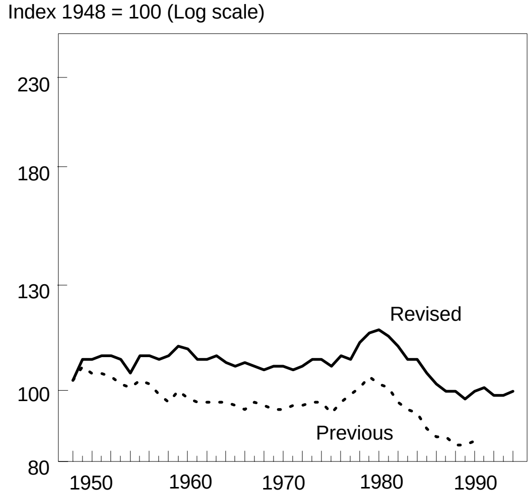
The major source of the difference between the current and previous estimates of the aggregate input index is the change in the calculation of the labor input. The previous method did not adjust for the changing quality of labor hours, and as discussed in this report, the current method does. The previous methods indicated a decline in the labor input of more than 3 percent, compared to the current estimate of a 2.73-percent decline.

Figure D

Previous and revised USDA input indexes

The major source of the difference in the revised input index results from adjustments for changing labor quality.

Index 1948 = 100 (Log scale)



Source: Economic Research Service, U.S. Department of Agriculture.