EVALUATING COST AND OUTPUT LEVELS FOR AGRICULTURAL UTILIZATION RESEARCH

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Public expenditures for research and development have increased very rapidly in the last two decades. Despite the apparent high payoff from this research, there is an increasingly greater reluctance on the part of legislative groups and the general public to support such research. This problem revolves around the question of social priorities, but it also involves an assessment of the value of the research investment.

There are a number of ways to evaluate research investment. From the standpoint of society as a whole, scientific research can contribute to our standard of living in three ways: (1) by providing knowledge about the world and how it works on a systematic basis, (2) by providing a group of highly trained specialists who can be very useful in solving a wide variety of problems, and (3) by creating a knowledge bank which is a source of ideas and devices that ultimately lead to technological change and innovations.

Previous attempts to evaluate research output have been concerned with estimating the economic value of innovations produced from a research program by comparing changes in consumer surplus to research costs, i.e., with emphasis on the final or end product of the research investment [1, 2, 3, 5, and 7]. This paper takes a somewhat different approach, however, by emphasizing evaluation of intermediate levels of output for a research program as a whole rather than specific innovations. Intermediate output indicators will not necessarily provide estimates of the final value of research, but they can provide a more direct method of evaluating research output from an administrative standpoint. Historical estimates of intermediate output for the agricultural utilization research program of the U.S. Department of Agriculture are presented along with related costs and performance levels for this program. The objective is to provide a framework for making administrative judgments about the past performance of the program with primary emphasis on the knowledge output of the program and how it is disseminated rather than an assessment of the social or economic benefits of specific discoveries or innovations.

PROGRAM EXPENDITURES AND COSTS

The agricultural utilization research program at the federal level was established in 1939. It is an organized effort through science and technology to create new and improved products and processes for agricultural commodities.[1] The research is conducted in five regional laboratories with commodity or functional specialization related to commodities most prevalent in these regions. Primary emphasis is on basic research related to the chemical, physical, and biological properties of farm products. However, applied and developmental research is also conducted to help insure commercial development of research findings that appear most feasible for practical application.

Major costs of the program include expenditures for physical facilities, scientific manpower, supporting personnel, materials and supplies, and administrative overhead. Construction costs have

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[1] For a description of the types of work and general organization of the program see [4, 8].

been made on a non-recurring basis with major expenditures being made during two periods: the 1939-1940 period when initial costs of four of the regional laboratories were incurred, and the mid-1960's when a new regional laboratory was constructed in the Southeast and some of the older laboratories were renovated. Annual operating expenditures have increased gradually over the past three decades, from a level of less than one million dollars in 1939 to approximately $39 million in 1971 (Table 1). The program now represents about 12 percent of the U.S. Department of Agriculture research budget.

The general magnitude of a research program can be represented statistically by two key variables: number of active projects and number of professional personnel. These variables are influenced by many underlying factors, however, such as budgeting problems, national priorities, the interests and capabilities of scientists, and problem area delineation. Nevertheless, the number of projects and personnel in the agricultural utilization research program have shown substantial increases over the past three decades.

Since 1949 the number of domestic projects active in any given year has varied from 300 to 450 (Table 2). Wide year-to-year variation in projects is due to termination rates and new projects initiated. There has been only a slight upward trend in number of active projects since the early 1950's. However, annual costs per project have increased substantially, from a level of $25,000 in 1949 to nearly $100,000 in 1971. When deflated by the consumer price index, cost increases were much less, with annual costs per project rising from $24,800 in 1949 to $57,700 in 1971.

The number of professional personnel in the program has also increased gradually over the years, reflecting the broadened scope of research activities. There are now more than 1,100 professional workers in the program (Table 2). Each professional worker is supported, on the average, by one other worker, either technical or administrative, and there are between two and three professional workers per project. Total personnel employed in the program was estimated at nearly 2,300 in 1971 compared to about 1,600 in 1949.

The cost of employing scientific workers in this program has increased substantially over the last two decades. Annual operating costs per professional worker rose from a low of about $10,400 in 1949 to $34,200 in 1971 (Table 2). Costs have shown a substantial increase since the mid-1950's even though there has been considerable year-to-year fluctuation.

Table 1. ANNUAL OPERATING EXPENDITURES FOR AGRICULTURAL UTILIZATION RESEARCH, 1939-1971.

Year	Costs[a]	Year	Costs[a]	Year	Costs[a]
	(mil. dol.)		(mil. dol.)		(mil. dol.)
1939	0.8	1950	9.1	1961	18.2
1940	1.0	1951	8.6	1962	18.8
1941	2.9	1952	8.4	1963	23.9
1942	3.7	1953	8.2	1964	24.5
1943	4.4	1954	8.3	1965	29.9
1944	4.5	1955	9.2	1966	29.7
1945	4.8	1956	9.6	1967	31.6
1946	5.1	1957	11.1	1968	31.8
1947	5.8	1958	13.2	1969	33.2
1948	7.8	1959	15.8	1970	36.3
1949	8.4	1960	16.1	1971	39.1

[a]Annual costs include primarily salaries, expenses, maintenance, and overhead costs. Figures exclude nonrecurring expenditures for buildings and equipment which amounted to $8.5 million in 1939-41, and $21 million in 1965-68.

Source: U.S. Congress, Senate Document No. 34 [8]; U.S. Department of Agriculture [9]; and unpublished documents.

Table 2. NUMBER OF PROJECTS, PERSONNEL REQUIREMENTS, AND ANNUAL COSTS PER PROJECT AND PER PERSON FOR AGRICULTURAL UTILIZATION RESEARCH, 1949-1971.

Year	Projects Currently Active[a]	Actual Cost per Project[b]	Deflated Cost per Project[c]	Professional Personnel[d]	Cost per Professional Worker[b]	Deflated Cost per Professional Worker[c]	Professional Workers per Project	Total Personnel Employed[e]
	(number)	(dollars)	(dollars)	(number)	(dollars)	(dollars)	(number)	(number)
1949	334	25,269	24,823	798	10,576	10,389	2.39	1,611
1950	329	27,568	26,817	802	11,309	11,001	2.44	1,622
1951	329	26,213	23,615	690	12,499	11,260	2.10	1,462
1952	352	23,906	21,081	640	13,148	11,595	1.82	1,357
1953	365	22,471	19,660	650	12,618	11,040	1.78	1,380
1954	345	24,113	21,004	650	12,798	11,148	1.88	1,281
1955	331	27,725	24,235	740	12,401	10,840	2.24	1,401
1956	396	24,300	20,931	740	13,004	11,201	1.87	1,398
1957	451	24,546	20,415	797	13,886	11,552	1.77	1,497
1958	416	31,648	25,626	822	16,017	12,969	1.98	1,588
1959	406	38,884	31,232	823	19,182	15,407	2.03	1,658
1960	324	49,765	39,371	866	18,619	14,730	2.67	1,693
1961	299	60,849	47,613	887	20,512	16,050	2.97	1,783
1962	306	62,099	48,027	922	20,610	15,940	3.01	1,822
1963	368	64,925	49,599	928	25,746	19,669	2.52	1,842
1964	419	58,666	44,243	960	25,605	19,310	2.29	1,920
1965	462	64,710	48,005	991	30,168	22,380	2.14	1,982
1966	440	67,647	48,772	1,050	28,347	20,438	2.39	2,100
1967	441	71,803	50,353	1,168	27,111	19,012	2.65	2,336
1968	451	70,562	47,485	1,100	28,930	19,469	2.44	2,200
1969	447	74,445	50,662	1,144	29,088	18,575	2.56	2,288
1970	411	88,269	53,303	1,158	31,329	18,918	2.82	2,316
1971	392	99,767	57,669	1,144	34,186	19,761	2.92	2,288

[a]Includes only domestic projects active at end of the fiscal year. Data from annual summary reports [9].
[b]Based on non-deflated annual operating costs with construction costs omitted. Costs taken from Table 1.
[c]Deflated by the Consumer Price Index using a 1947-49 base.
[d]Includes all scientific and professional personnel in the program. Figures from 1967 to 1971 were converted from Scientific Man Year totals. Data for 1964 and 1966 estimated by interpolation.
[e]Figures from 1964 to 1971 estimated on the basis of one supporting worker per professional employee. Prior years from unpublished documents.

On a deflated basis the increase in costs has been much less, ranging from the $10,000 level in the early 1950's to the $20,000 level in the late 1960's (Figure 1). Thus, deflated costs per professional worker have doubled since 1949 whereas actual monetary costs have more than tripled. Since the number of employees has increased only about 44 percent while deflated costs have doubled, it is apparent that the real cost per worker has increased during this period.

INTERMEDIATE RESEARCH OUTPUT

One of the first and most visible measures of research output is the stock of information and knowledge produced. This knowledge in its most basic form is recorded in laboratory notebooks and internal reports. It is then documented in more formal statements and released to the scientific community or the general public.

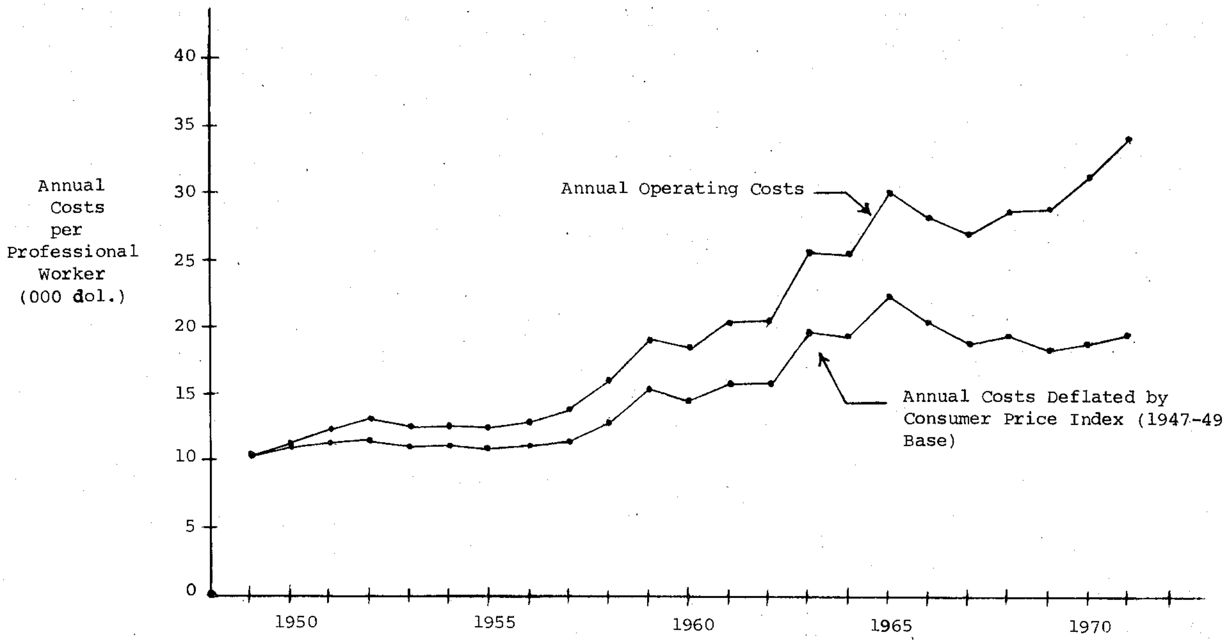

Figure 1. ACTUAL AND DEFLATED ANNUAL OPERATING COSTS PER PROFESSIONAL WORKER IN AGRICULTURAL UTILIZATION RESEARCH, U.S., 1949-71.

Intermediate research output can therefore be postulated as being a function of two components that relate to the knowledge output of the program: (1) technical papers published, and (2) patents granted. Number of publications is often used by administrators or others as an indicator of research output even though it is not a perfect indicator from the standpoint of reflecting the scientific or social merit of the work or its ultimate economic value.[2] However, scientific and technical publications are one of the primary methods for reporting original research results to scientists in the same field or closely related disciplines. Since this is a form of screening process whereby the quality or relevance of these studies is judged, it can be considered to have some bearing on both the quantitative and qualitative aspects of intermediate research output [6].

Patents are also a meaningful measure of research output, particularly in the physical sciences and engineering fields. Patents are granted for the invention or discovery of "any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof" [10, p. 10]. The key elements are that the discovery must be new and have potential utility. Patents therefore indicate that there is some degree of novelty or uniqueness attached to the individual products or processes developed. All patents from utilization research are obtained in the public interest, and the information is available to industrial corporations, agricultural business firms, and the general public.

A research output index for the agricultural utilization research program was computed based on the unweighted sum of technical papers published and number of patents used (Table 3). Even though a patent could be considered relatively more important than a research publication in some situations, there is no way to assess their relative significance except in individual cases. Since data for such comparisons were not available, an unweighted sum was used. Based on these measures, the output of the program has increased more than 80 percent in the last 12 years. The number of publications released has increased the most during this period, from a level of just under 500 in 1959 to 970 in 1971. Most publications are research papers published in technical journals or research bulletins released by the U.S. Department of Agriculture. The number of patents granted to utilization research personnel has also increased during this period, although not as fast as the number of publications. There were substantial year-to-year fluctuations in the number of patents issued, however, ranging from a low of 52 in 1964 to

[2] In a sense, technical publications are more indicative of scientific merit than they are of the ultimate economic value of research since they reflect current knowledge in a field and are usually subjected to peer group evaluation. On the other hand, the economic value of this knowledge depends on a variety of factors many of which are not quantifiable or are so uncertain that they must be heavily discounted.

Table 3. INDEX OF INTERMEDIATE RESEARCH OUTPUT AND COST PER UNIT OF OUTPUT FOR AGRICULTURAL UTILIZATION RESEARCH, 1959-1971.

Year	Measures of Research Output[a] Papers Published	Patents Granted	Total Output	Index of Output	Index of Operating Costs[b]	Cost per Unit of Output[c]	Index of Operating Costs Deflated[d]	Deflated Cost per Unit of Output[e]	Output per 10 Professional Workers[f]
	(number of units)			(1959 = 100)		(dollars)	(1959=100)	(dollars)	(units)
1959	493	96	589	100	100	26,803	100	26,407	7.2
1960	497	83	580	98	102	27,800	101	26,964	6.7
1961	600	75	675	115	115	26,954	112	25,868	7.6
1962	649	84	733	124	120	25,924	116	24,596	8.0
1963	688	79	767	130	151	31,151	144	29,194	8.3
1964	791	52	843	143	156	29,159	146	26,974	8.8
1965	835	72	907	154	189	32,961	175	29,992	9.2
1966	887	66	953	162	189	31,233	169	27,615	9.1
1967	934	111	1,045	177	201	30,302	175	26,055	8.9
1968	1,073	88	1,161	197	202	27,410	169	22,616	10.6
1969	915	104	1,019	173	211	32,657	168	25,573	8.9
1970	947	81	1,028	175	230	35,291	173	26,141	8.9
1971	970	116	1,086	184	248	36,012	178	25,558	9.5
Average	791	85	876	--	--	30,686	--	26,305	8.7

[a]Compiled from U.S. Department of Agriculture summary reports [9].
[b]Annual expenditures for program of agricultural utilization research, excluding construction costs.
[c]Annual operating costs divided by units of output.
[d]Annual operating costs deflated by the Consumer Price Index with a 1957-59 base period.
[e]Deflated annual operating costs divided by units of output.
[f]Units of output divided by number of professional workers in the program.

a high of 116 in 1971.

Even though the level of output has increased over 80 percent in the last 12 years, the level of costs has increased even faster (Table 3). Annual operating costs for utilization research have more than doubled. On a deflated basis, however, these costs have increased only 78 percent, or slightly less than the increase in output. It should also be noted that, based on these figures, the productivity of professional workers in agricultural utilization research has increased significantly over the years. Intermediate research output per 10 workers ranged from a low of 6.7 units in 1960 to 10.6 units in 1968. Thus, when both deflated costs and increased productivity of workers are considered, there has been a decline in the real cost per unit of output during this period.

RESEARCH DISSEMINATION INDICATORS

After research findings are documented and verified or screened by the scientific community, they are disseminted to individuals and groups in society in a variety of ways. In addition to the original scientific and technical publications, there are trade magazines and newspapers, industry conventions, formal conferences and seminars, speeches, public exhibits, and, of course, individual personal communication channels. A summary of some of the key measures of dissemination for agricultural utilization research from 1959 to 1971 is given in Table 4.

The primary indicators show considerable year-to-year variation in dissemination activities although there was a somewhat greater number of dissemination units during the last half of the decade. The number of formal conferences and public service exhibits held with industry and trade groups dropped substantially during this period. This was offset by a somewhat larger number of speeches, press releases, and public appearances of research personnel, and by a greater number of technical visitors to the laboratories. This changing mix of activities probably reflects the emphasis toward more basic research and recognition that certain types of activities are more effective than others.

Table 4. PRIMARY INDICATORS OF RESEARCH DISSEMINATION FOR AGRICULTURAL UTILIZATION RESEARCH, 1959-1971.

Year	Formal Conferences and Meetings	Speeches, Press Releases and Public Appearances	Public Service Exhibits	Technical Visitors to Laboratories	Total Dissemination Activities	Dissemination Exposure Index[a]		Dissemination Exposure Rate per Unit of Research Output[b]
			(number of units)			(units)	(1959=100)	(units)
1959	88	750	40	5,000	5,878	1,900	100	3.23
1960	51	634	28	5,500	6,213	1,669	88	2.88
1961	38	608	27	5,500	6,173	1,586	83	2.35
1962	63	685	41	5,500	6,289	1,798	95	2.45
1963	52	682	38	5,000	5,772	1,691	89	2.20
1964	59	748	23	7,100	7,930	2,011	106	2.39
1965	57	894	25	7,600	8,576	2,241	118	2.47
1966	45	921	21	7,400	8,387	2,201	116	2.31
1967	42	724	15	6,577	7,358	1,847	97	1.77
1968	38	747	22	6,006	6,813	1,804	95	1.55
1969	36	705	40	7,450	8,231	1,963	103	1.93
1970	42	687	9	3,138	3,876	1,373	72	1.34
1971	38	708	15	6,474	7,235	1,787	94	1.65
Average	50	730	26	6,019	6,825	1,829	--	2.09

[a]Based on weighted annual indexes of activity levels using a scale from 1 to 10. Formal conferences and meetings were rated at 3; speeches, press releases and public appearances at 9; public service exhibits at 1; and technical visitors to laboratories at 6. For annual indexes 1959=100. Activity weights based on probable exposure rates for different types of media.

[b]Dissemination exposure units divided by units of output.

Source: U.S. Department of Agriculture [9].

A dissemination exposure index was computed based on annual indexes of the various activities weighted by the probable exposure rates of the different types of media.[3] Specific weights were considered to be a function of the degree of exposure of research results from a given unit activity. They are at best subjective judgments since there are a wide variety of ways to disseminate research knowledge. This exposure index shows an irregular pattern of dissemination activities on an annual basis with a slight decline in these activities since the mid-1960's (Table 4). The dissemination exposure rate per unit of research output declined substantially, however, from a high of 3.23 units in 1959 to 1.65 units in 1971.

PERFORMANCE LEVELS OF PROGRAM

Based on data from the preceding sections, an index of performance for the agricultural utilization research program was calculated. For the purpose of this comparison performance was considered to be a function of three principal components of the program: (1) deflated costs per unit of output, (2) research output per 10 professional workers, and (3) dissemination activity rates per unit of output.

The relationship between these variables can be expressed as:

$$P = (C \times O) + D$$

where P = performance index expressed in total units,

C = reciprocal of deflated costs per unit of research output,

O = research output per 10 professional workers,

D = dissemination activity rates per unit of research output.

The formula for computing the performance index assumes an interacting multiplier effect between the cost and productivity variables with dissemination activity rates as a residual variable. The variables used were expressed in original data units so

[3]The weights were based on a scale of 1 to 10 for the various activities with formal conferences and meetings rated at 3; speeches, press releases and public appearances at 9; public service exhibits at 1; and technical visitors to laboratories at 6.

that a higher level of performance would be reflected by higher ratios of output per worker or lower costs per unit of output. In order to achieve this objective the reciprocal of costs per unit of output was used which was the equivalent of output per unit of $100,000 deflated annual costs. Dissemination activity rates were based on 2.5 times the exposure rate so that their average contribution to the performance index would be approximately 14 percent over the time period of the study. The latter procedure effectively limits the impact of dissemination activities on the overall performance index since research output is the primary goal of the program.

Data for the actual variables used and the annual index of performance is given in Table 5. In general it will be noted that there was very little change in the reciprocal of costs per unit of output over the 12 year period considered. However, there was a significant increase in output per worker, and this was not completely offset by the decline in dissemination activity. The net result is an index of performance that is somewhat irregular but with a gradual upward trend between 1959 and 1971 (Figure 2).

Table 5. PRINCIPAL COMPONENTS OF PERFORMANCE INDEX FOR AGRICULTURAL UTILIZATION RESEARCH, 1959-1971.

Year	Reciprocal of Deflated Cost per Unit of Output[a] (C)	Research Output per 10 Professional Workers (O)	Dissemination Activity Rates per Unit of Output[b] (D)	Index of Performance[c] (P)	(I)
	(units)	(units)	(units)	(units)	(1959=100)
1959	3.8	7.2	8.1	35.5	100
1960	3.7	6.7	7.2	32.0	90
1961	3.9	7.6	5.9	35.5	100
1962	4.1	8.0	6.1	38.9	110
1963	3.4	8.3	5.5	33.7	95
1964	3.7	8.8	6.0	38.6	109
1965	3.3	9.2	6.2	36.6	103
1966	3.6	9.1	5.8	38.6	109
1967	3.8	8.9	4.4	38.2	108
1968	4.4	10.6	3.9	50.5	142
1969	3.9	8.9	4.8	39.5	111
1970	3.8	8.9	3.4	37.2	105
1971	3.9	9.5	4.1	41.2	116
Average	3.8	8.7	5.2	38.3	108

[a]Equivalent to output per unit of $100,000 deflated annual costs.
[b]Dissemination exposure rates multiplied by 2.5.
[c]Based on the following relationship: $P = (C \times O) + D$ where $I = P$ as percent of 1959 base year.

CONCLUDING REMARKS

This study attempts to evaluate historical costs and performance levels for a research program where a large number of projects were involved over a long period of time. Output of the program was based primarily on intermediate indicators of output reflected by the number of technical publications issued and patents granted to scientists. More realistic measures of intermediate output could be obtained by combining these variables with a merit index which rates the relevance or quality of publications from the standpoint of scientific contribution or potential net utility. Even though such measures can be useful to administrators and others as indicators of the internal performance of a research program in a historical perspective, they are probably no substitute for cost-benefit or return-on-investment comparisons

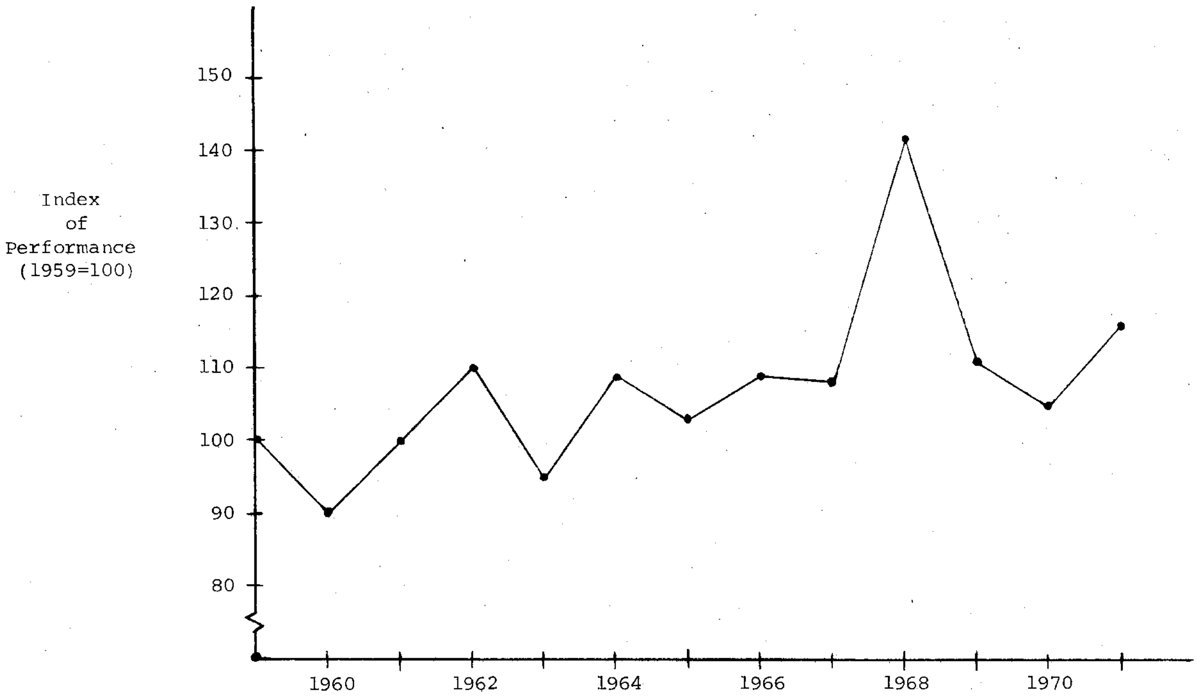

Figure 2. ANNUAL INDEX OF PERFORMANCE FOR THE AGRICULTURAL UTILIZATION RESEARCH PROGRAM, U.S., 1959-1971.

when allocating public funds for future research. Also, the performance index approach is very sensitive to specification of variables and their relationship within a prescribed model. If such a model were used to evaluate performance levels there would have to be safeguards against just counting publications or patents without regard to their social and economic value because it is too easy to publish short rather than long articles, to patent devices with limited economic value, and to establish technical journals for internal communication of dubious research results.

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