Miscellaneous Publication 8--1981
Minnesota Agricultural Experiment Station
University of Minnesota

Evaluation of Agricultural Research

Proceedings of a Workshop Sponsored by NC-148
Minneapolis, Minnesota May 12-13, 1980

THE CHANGING COST OF PERFORMING AGRICULTURAL RESEARCH: AN INDEX APPROACH

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Introduction

Inflation erodes the purchasing power of dollars in every budget in our society. Budgets of agricultural research organizations have been no exception. Inflation has been defined as an increase in the average of prices {1}. A popular indicator of the rate of inflation is the annual percentage change in the Consumer Price Index (CPI) {2}. The CPI is intended to apply to consumer purchases, yet the concept implies that a similar indicator of the annual percentage change in prices of inputs purchased by agricultural research organizations conceivably could be developed.

This paper reports an attempt to develop a quantitative measure of changes in the purchasing power of dollars appropriated from 1973 to 1978 for agricultural research in state agricultural experiment stations (SAES). It is intended to be a complete agricultural research price index, constructed to provide an accurate index for deflating the rising dollar expenditures for agricultural research to constant purchasing power. It is hoped such an index will lead to more accurate forecasting of the rate of increase in the cost of doing research and thus help agricultural science administrators adjust for inflation in budget making and expenditure programming.

Background

Price Indexes

A price index is produced by an averaging process which describes a central tendency of changes in prices of a complex of products. A price index will indicate how much more or less could be purchased of the same combination of inputs but not how the mix should be changed. That is, an index of price level changes does not help to decide how much a research organization should change the conbination of inputs.

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The first recorded inquiry into price fluctuations was in 1739 by deFerrace Dutot {3}. In 1923, Irving Fisher produced a major and influential work, The Making of Index Numbers {4}. Three more recently developed published measures of inflation are the Consumer Price Index, the Producer Price Index (formerly known as the Wholesale Price Index), and the Implicit Price Deflators for Gross National Product. Each of these measures averages a different set of prices using a different set of component weights; each produces a different measure of inflation for a different clientele. Yet there is some relationship and correlation among the indices.

None of these price indices may be entirely appropriate for indicating agricultural research cost increases, because none use only the prices of the inputs purchased for agricultural research and none averages the price changes by weighting with the appropriate quantities of inputs for agricultural research. However, the existing published indices might be useful if highly and predictably correlated with changes in agricultural research inputs. If all prices including those for agricultural research inputs moved in the same direction at the same rate, the weights would be unimportant. The extent to which a price index might also serve as an agricultural research cost index can only be known once a good agricultural research cost index is constructed to permit comparison with other indices.

A price index number is relevant for any purchaser of several factors and is only as appropriate as the set of commodities used and the manner in which the set of prices was weighted. The wider the percent variation in price changes, the more important is the choice of weights. Hence, the wider the variation in the mix of purchases among experiment stations, the more critical is the selection of the weights to average the prices. In fact, with wide divergence in both prices and quantities, each station would experience its own rate of inflation and would need an index of agricultural research cost of its own. Fortunately, the prices of most agricultural research inputs rise at a similar rate. Furthermore, the variation in expenditure proportions is not great between stations or over time. Thus, a single national index of the cost of performing agricultural research seems feasible and reasonably accurate for all stations.

The derivation of all indices, including an agricultural research cost index, is constrained by accuracy and detail of available data. In the case of this effort, inaccuracy, inconsistency, and incompleteness in the data on prices paid and quantities purchased provided by the 50 SAES reduced somewhat the quality of the index produced. Accounting data on both price and quantity for non-manpower purchases was lacking. Only classification of non-manpower expenditures was possible. This required use of a proxy price index specially weighted by average station expenditure proportions. This substitution made it possible to produce a complete index but one that may have some estimation error or bias that cannot be known or eliminated.

Previous Research Cost Indices

In the 1960s, when research expenditures grew very fast, there was fear that available inflation measures underestimated research cost increases. In the mid-1960s, the first attempt was made to measure the rate of increase in the cost of doing research through indexing. Milton's "Cost-of-Research Index, 1920-1965," Research Analysis Corporation {5}, measured the change in the cost of research by averaging among research agencies the dollars spent per technical manyear employed in research and development. Data were gathered from various research institutes in the United States. The technical manyear cost was derived by dividing the total annual cost of each particular R&D organization participating in this study by the number of scientific and technical personnel working in the organization. Milton's "cost per manyear" increased over time not only because the salaries of scientists increased, which they did, but also because the quantity of non-manpower inputs per scientist increased as did their prices. The partitioning of the total cost increases to each source was not possible in this study. Milton concluded that while research and development expenditure had increased at 15% per year, the technical years of input have been increasing at only 5% per year. It may be concluded that Milton did not construct a research input price index but estimated only the average total cost per technical person employed.

In 1966, Roland R. Robinson wrote "Estimating the Real Level of Support Given to Research Programs at the State Agricultural Experiment Stations" {6}. Robinson's purpose was to show that increases in dollar support did not mean increases in science years employed. His effort, although still not a complete cost index, was an improvement over Milton's method. Robinson derived a cost inflation measure for one input, agricultural research manpower, by estimating across stations an average manpower cost per professional manager employed. Robinson found that the accuracy of his attempt was constrained by lack of detailed data. Expenditure prices and quantities for subcategories of manpower, i.e., professors, assistant professors, etc., were not explicitly available to Robinson. As in 1966, it is still difficult to determine the rate of shift in the mix of these subcategories of agricultural researchers, which is important to do. A shift in the mix toward lower paid assistant professors would appear as a decrease in average price of manpower and depress the index estimating the effect of inflation. Conversely, some increases in cost per science year experienced by some stations could result from losing and not replacing younger professors with lower salaries.

In 1972, the National Science Foundation (NSF) published the report, "A Price Index for Deflation of Academic R&D Expenditures" {7}. The report states that the index for each year indicates what "dollar levels of R&D support correspond to employment of a given number of scientists or engineers, but other factors ought not be ignored" (p. 5). Hence a non-manpower component was not included so that the NSF index does not fully indicate what it will cost to finance a given level of research effort in year t relative to the same research effort in year t-1. If the relative prices among manpower inputs change, then research procedures might also change. Contrarily, as new research techniques are employed then the most productive mix of personnel, supplies, and equipment would also likely change. In principle, a manpower price index like NSF constructed cannot answer the question of dollars needed to maintain constant output.

The NSF study provides an important parallel and some conceptual assistance in the construction and development of a cost of research index for SAES. NSF tested an index constructed as a weighted average of year-to-year manpower price relatives. Average salary changes at each institution were weighted by base year proportion of all salaries in that institution. The aggregated form of the NSF price index is:

$$(1) \quad NSF = \sum_{j=1}^{n} \alpha_j \cdot \frac{P_1}{P_0}$$

where the salary change at the j^{th} institution is $\frac{P_1}{P_o}$. To obtain the average over several institutions, each percent salary change is weighted by the relative size of the institution (α_j):

$$(2) \quad \alpha_j = \frac{P_{oj}\, q_{oj}}{\sum_{j=1}^{n} P_{oj}\, q_{oj}}$$

The NSF study made progress in indexing research cost. The NSF study was the first to categorize manpower, and by this strategy reduced inaccuracy resulting from shifting mix between scientists and support personnel. NSF manpower categories transformed nicely to the manpower divisions available from USDA Form AD-419: scientists (241), professional support (242), technical support (243), and clerical and other support (244). The agricultural manpower index in this study includes a fifth manpower division, administrative (245). Adding the administrative category further reduces the salary heterogeneity in the scientist category. The NSF study supported our hypothesis that heterogeneity of each input category should be minimized to increase accuracy.

An improvement that may be made in the NSF index is the addition of fringe benefits. Approximately 20% of institutional manpower expenditures today are fringe benefits. Expenditures for manpower by institutions each successive year are including proportionately larger fringe benefits. Legislatures, budget committees and collective bargainers are wrestling with wage-price guidelines, trying to increase after-tax real income in the face of higher nominal tax rates with inflation. Today, they often prefer increases in the form of increased fringe benefits.

The Agricultural Research Cost Index

The persistent constraint in constructing an accurate research cost index has been the lack of price and quantity information for each homogeneous subcategory of expenditures, both for manpower and non-manpower. Hence, consideration of these data are presented first. The model development then follows.

Data Characteristics

In 1977, each of the 55 SAES was asked to supply manpower expenditures and employment data by categories for the fiscal years 1973 to 1976. Each station was also asked to provide data about non-manpower expenditures. Responses were obtained from 20 stations--10 provided complete information for all four of the years, two more for 1975, and two more for 1976 for a total sample of 14 in the latter year. For the years 1977 and 1978, the response increased significantly, 25 stations providing data about manpower for fiscal year 1978. The reports submitted in 1979 for 1978 were considered to be accurate and highly reliable.

Investigation of "suspicious" data was conducted through direct communication with administrators and accountants of individual SAES. The stations cooperated to the extent of available resources and provided answers to numerous questions. For example, the data for one station were extremely orderly and well behaved. The expenditure by category had been estimated from staff numbers and percent salary increase. The station did not have available the actual expenditures by subcategory needed to respond to the survey format but nevertheless provided estimates. The estimates were uncharacteristically orderly, whereas the empirical data set was not.

In the first year, there were surprises in the data as initially received or as it was processed into time series of average prices. Likewise, the data provided for 1974 to 1976 resulted in average prices and the percentage change in prices moving in unexpected directions (see Table 1).

TABLE 1.

Average Scientific Manpower Prices for One Station

Fiscal Year	Average Price	Change	Scientist Years
1973	$28,354.00		169.4
1974	$26,425.00	-6.8%	178.7
1975	$29,988.00	+13.5%	164.8
1976	$28,900.00	-3.6%	205.3

If professors (category 241) are reasonably homogeneous, the average price would not be affected by changing the number of professors. However, if full professors are paid more than associates and the mix changes, as it does over time, the average price may fall even though every professor gets a raise. In practice, the observed percent change in average price and the index number confounds the effect of price changes when the mix changes. Thus, if there are heterogenous subcategories and a change in mix within subcategory, the index number change does not indicate a movement in the price alone. However, if the mix is assumed stable, then the average price fell in 1974 by approximately 7%, an unlikely movement, especially if compared to the other sample stations for the same year. This was one example of suspicious data that had to be investigated before including the simple relative prices from a station and subcategory in the index construction.

It may be that the weighted average of estimated percent salary change by subcategory of professor would provide an accurate index.

The non-manpower data, which account for approximately 29% of total costs, presented a vexing indexing problem. It was impossible to derive an average price for any non-manpower subcategory. Non-manpower data supplied by 33 stations were examined. Many stations with usable data for one subcategory of non-manpower inputs had none for other subcategories. However, the non-manpower data did provide enough categorization that proportions of expenditure by subcategory or relative expenditure weights could be derived. Thus, if from another source an appropriate index for change in prices by subcategory was available, the relative expenditure weights could be employed to construct an index for non-manpower. Expenditure weights from the sample were as much as could be provided from the existing data. An aggregate cost of agricultural research index would have to use non-SAES sources to estimate non-manpower price changes.

Administrative manpower is the smallest category with the highest average price and the most reporting inconsistencies. To identify "unusual" quantities of administrative manpower, we related variation in the number of administrative years with variation in scientist years among the stations by using simple linear regression, forcing the regression line through the origin.

There is a loose but significant relationship between the number of administrative years ($\hat{AY}$) employed and the number of scientist years (SY) employed according to 1978 SAES data (equation 3).

(3) $$\hat{AY}_{78} = .05\ SY_{78}$$

s.e. = .0099 $\qquad$ F = 25.03

t = 5.0 $\qquad$ $R^2 = .532$

Regression equation (4) shows similar results with 1976 data.

(4) $$\hat{AY}_{76} = .0495\ SY_{76}$$

s.e. = .0135 $\qquad$ F = 13.43

t = 3.67 $\qquad$ $R^2 = .4897$

On the average, one administrator is employed for 20 to 25 scientists. However, the rate varies from a maximum of one to six to a minimum of one to 85. One possible explanation for this wide range of variation is that the definition of "administrator" was interpreted differently and more or less inclusive by the various stations.

Since only approximately 50% of the variation in administrative years is explained by the variation in scientist years employed, we conclude that additional factors are involved.

Model Development

Our index of the cost of performing Agricultural Research (ARI) consists of two components: manpower (I_m) and non-manpower (I_n). These two components, weighted by their relative expenditures, produce the complete index number:

$$ARI = .715\ I_m + .285\ I_n$$

To construct the manpower index requires only two data inputs: (1) the expenditures for the five categories of manpower for each station for each year and (2) the quantities of manpower for each category for each station for each year. Alternative formulae for calculating index numbers with different weighting strategies were tested.

Our index calculation strategy presented here is similar to the NSF index. First, manpower expenditures (e_{ij}) and employee years (m_{ij}) were summed across stations within manpower category j to obtain sample totals and a sample average price ap_j for employee category j:

$$ap_j = \frac{\sum_{i=1}^{n} e_{ij}}{\sum_{i=1}^{n} m_{ij}}$$

where e_{ij} = the manpower expenditure by the i^{th} station for the j^{th} employee category, (i=1,.....,25)

m_{ij} = the number of employee-years devoted by the i^{th} station to the j^{th} employee category, (i=1,.....,25)

ap_j = the average price of the j^{th} employee category for the sample of n stations, (j=1,.....,5)

A sample average cost per unit of manpower was calculated for each category of manpower for each year. These sample average costs are estimates of total agricultural research system cost per unit of manpower by category. These average costs are given in Table 2.

Table 3 presents cost indices for each manpower category. The indices are derived by dividing the observed average cost by the 1976 average cost for the j^{th} employee category. Table 4 indicates the rate of cost change is larger in the administrative manpower category than in others. Scientists' salaries change at the slowest rate.

A weighted average price per unit of manpower for each year is constructed by using the average prices of Table 2 and the proportion of total expenditures by category for 1976 from Table 5. That is:

$$AP_m = \sum_{j=1}^{5} \frac{\sum_i^{25} e_{ij}}{\sum_i^{25} m_{ij}} \times \frac{\sum_i^{25} e_{ij}}{\sum_i^{25} \sum_j^{5} e_{ij}}$$

Table 2. Sample Average Cost per Employee Category, 1973-1978

Fiscal Year	n	241	242	243	244	245	AP_m
1973	12	$22,050	$ 8,561	$ 7,624	$ 7,284	$21,334	$15,205
1974	13	22,746	9,031	8,125	7,503	22,169	15,764
1975	14	24,550	10,353	8,467	8,490	20,092	16,937
1976	16	25,690	11,180	9,458	9,027	27,359	18,175
1977	23	26,662	11,826	10,241	9,725	28,396	19,209
1978	25	28,552	12,769	11,041	9,987	35,420	20,550

Table 3. Cost Index of Manpower Categories, 1973-1978 (1976=100)

Years	Scientists 241	Professional 242	Technical 243	Clerical 244	Administrative 245
1973	83.1	84.2	78.9	77.8	82.8
1974	86.7	87.7	85.00	81.6	84.5
1975	93.2	94.2	88.1	93.2	90.0
1976	100.0	100.0	100.0	100.0	100.0
1977	104.7	110.0	108.5	109.4	111.4
1978	110.6	118.6	115.9	110.2	138.9

To obtain the average rate of inflation in agricultural research manpower cost the five categories must be averaged. The scientists category contains nearly half of the expenditures (see Table 5) because it has the large number of highest cost personnel.

Table 4. Average Annual Rate of Inflation of Costs of Manpower by Category 1973-78

Category	Average Annual Rate of Inflation
Scientists	5.9
Professional	7.1
Technical	8.0
Clerical	7.2
Administrative	10.9

which states that the sample average price per person for all manpower (Table 6) equals sample average cost per category (Table 2, row 4) times category portion of 1976 manpower expenditure (Table 5, all rows). The sample average weights do not vary widely among years nor does the proportion of expenditure by employee category vary widely among stations.

The average cost for all manpower by years (Table 6) shows a rate of increase or inflation of 6.7%. That is intermediate among the rates of inflation for individual manpower categories.

The non-manpower index requires an averaging and then an indexing of prices of a category of expenditures by SAES. The non-manpower component is comprised of a very heterogeneous group of inputs. The inputs can be categorized into four to eight groups based on homogeneity of

Table 5. Sample Proportions of Expenditure by Manpower Subcategory, 1974-78

Fiscal Year	Sample Size	241	242	243	244	245
1974	13	.473	.114	.198	.171	.035
1975	14	.472	.137	.187	.174	.039
1976	16	.479	.130	.185	.165	.043
Average (1974-76)		.475	.127	.189	.170	.039
1977	22	.437	.161	.195	.179	.028
1978	23	.432	.165	.202	.175	.027

Table 6. Average Cost per Unit of All Manpower in Agricultural Research, Index of Agricultural Research Manpower Cost and Percent Change per Year in Agricultural Research Manpower Cost

Fiscal Year	Average Cost AP_m Dollars	Manpower Index I_m 1976 = 100	Annual Change in Manpower Cost from Previous Year Percent
1973	15,205	83.7	---
1974	15,764	86.7	3.6
1975	16,937	93.2	7.5
1976	18,175	100	7.3
1977	19,029	104.7	4.7
1978	20,550	113.1	8.0

characteristics. The non-manpower expenditure data were initially classified into eight subcategories: (1) travel, (2) supplies, (3) equipment, (4) utilities, (5) land and structures, (6) communications, (7) repair and maintenance, and (8) miscellaneous. A proxy price index was used for each subcategory. Existing price indices were found that would approximate the subcategories. For example, in the transportation industry, railroads compute unweighted relative year-to-year expenditures by subcategory. However, this procedure would measure how much prices had increased only if physical volume remained constant. If the mix changed, such year-to-year percent change in expenditure would not indicate price changes because they are not price indices. An investigation of indices produced by the Bureau of Labor Statistics revealed subcategories similar in content to only some of the seven subcategories. Thus, the original seven non-manpower subcategories had to be reduced to four.

The most appropriate proxy price indices were selected by comparing definitions with the subcategories of non-manpower purchases. The final set of proxies is:

Sub-category	Proxy Component	Index
Travel	Transportation Services	CPI
Supplies	Commodities Less Food, Non-durable	CPI
Equipment	Machinery & Equipment	PPI
Utilities	Fuels & Other Utilities	CPI
Other	Other Goods & Services	CPI

The cost indices (Table 7), acting as proxies or substitutes for the unavailable non-manpower subcategory average costs, were combined into a single weighted average non-manpower price index. The weights (Table 8) for non-manpower are the sample proportion of expenditures in each non-manpower category. Supplies is the most important category with 35.2% of non-manpower expenditures. In spite of the great concern for rising utility prices, that subcategory represents only 2.8% of non-manpower station expenditure. Travel also is a closely watched expenditure but represents only 6.7% of non-manpower expenditure. All non-manpower subcategories represent 28.8% of all station expenditures.

The final step in the derivation and subsequent computation of the cost of an agricultural research index is to average the manpower and non-manpower indices. The results of the computations are shown in Table 9 for 1973 through 1978.

The index of agricultural research cost is the weighted average of manpower and non-manpower prices indices. The weights are the 1973 through 1976 sample proportion of expenditures in each (Table 10), using either the average weight or the 1976 weight.

Analysis of the Agricultural Research Index

Table 11 presents a comparison of the rate of change in the ARI index number with the rate of change in the unadjusted CPI for all items, state and local government purchases of goods and services, and the GNP deflator. The cost of performing agricultural research has risen from 1973 to 1978 by 6.3% but has risen less rapidly than prices in general (8 to 10%). Rates of inflation as measured by the three national measures are larger over the period than the Agricultural Research Index (ARI) number.

Table 7. Proxy Cost Index Numbers 1973 Through 1978 for Non-manpower Subcategories for June-July Fiscal Year

Subcategory	1973	1974	1975	1976	1977	1978
Travel	78.5	81.4	87.6	100.0	108.1	110.8
Supplies	78.8	89.0	95.8	100.0	105.2	107.4
Equipment	71.2	81.5	94.4	100.0	106.3	114.6
Utilities	69.5	82.2	91.8	100.0	110.7	114.7
Other	81.4	87.3	94.6	100.0	105.8	109.0

Table 8. Sample Expenditure Proportions by Non-manpower Subcategories, 1973-1976

Fiscal Year	Air & Auto Travel	Office & Laboratory Supplies	Capital/ Equipment	Utilities	Other[a/]
1973	.067	.339	.201	.024	.367
1974	.064	.363	.223	.024	.326
1975	.067	.356	.230	.029	.318
1976	.070	.348	.203	.033	.346
Average	.067	.352	.214	.028	.339

a/Includes telephone, animal feed, fertilizer, computer service, land and structures.

Table 9. Estimated Cost Indices for Manpower, Non-manpower and Total Research Cost

Fiscal Year	Manpower	Non-manpower	Research Cost
1973	83.7	77.8	82.0
1974	86.7	86.1	86.5
1975	93.2	94.3	93.5
1976	100	100.0	100
1977	104.7	105.9	105.0
1978	113.1	109.7	112.1

Table 10. Expenditure Proportions for the Sample and Four-year Average Used as Relative Weights Between Manpower and Non-manpower, 1973-76

	n	Manpower	Non-manpower
1973	27	.719	.281
1974	27	.7065	.2935
1975	31	.707	.293
1976	33	.715	.285
Average		.711875	.288125

An application of the Research Index can be made by comparing actual year-to-year total expenditures with the ARI deflated expenditures for all SAES in 1973-1978. Actual expenditures are available in the Inventory of Agricultural Research (Volume III, Table IV-E-6). As indicated in Table 12, substantial growth in agricultural research dollar expenditures by SAES occurred in each year. Expenditures in real terms also increased over the period. However, the expenditures in current dollars increased more rapidly than expenditures in real terms, resulting from the rise in input costs.

Conclusions

The study examines changes in SAES input costs from 1973 through 1978. From data reported by a sample of stations a cost index was derived for manpower and non-manpower inputs. Funds to agricultural research increased steadily over the period but the level of effort changed eratically. Inputs cost changes for agricultural research are not the same as other measures of inflation.

We estimate that the cost of performing agricultural research rose 6.3% per year from 1973-78 which is less than the cost of purchases by state and local government, 8.1%. The low rate of agricultural research cost resulted mostly from the fact that scientists compensation rose at only 5.9% per year while the CPI increased 7.9% per year in the same period.

The availability of an agricultural research index permits evaluation of the need for it. This study demonstrates that it is technically feasible to construct such an index. Also, it has shown that there does not seem to be a close functional relationship between changes in agricultural research costs and other measures of inflation. Tentatively, it seems that the average cost of manpower by category is the most valuable and the least cost component of the cost of the agricultural research index.

References

{1} Leftwick, Richard H. and Sharp, Ansel M. Economics of Social Issues. Dallas: Business Publications, Inc., 1980, p. 292.

{2} Branson, William H. Macroeconomic Theory and Policy. New York: Harper and Row, 1972, p. 7.

Table 11. Comparison of Aggregate Agricultural Research Index Rate of Inflation With Other Published Series Rates

Index	73-74	74-75	75-76	76-77	77-78	Avg.
CPI: All items	8.9	11.1	7.1	5.8	6.8	(7.9)
ARI	5.5	8.1	7.0	5.0	6.8	(7.4)
Producer Price Index: All Commodities	16.1	16.9	5.3	5.4	6.2	(10.0)
State & Local Government	7.7	10.5	6.7	7.0	7.8	(8.1)

Table 12. Actual Deflated Expenditures by State Agricultural Experiment Station 1973 Through 1978

Fiscal Year	Actual Expenditures ($ Mil.)	Percent Change	Deflated Expenditures ($ Mil.)	Percent Change
1973	385	--	460	--
1974	415	7.8	480	4.3
1975	480	15.7	525	9.4
1976	525	9.4	525	0.0
1977	585	11.4	570	8.6
1978	653	11.6	590	3.5

{3} Samuelson, Paul A. Foundations of Economic Analysis. New York: An Therum, 1974, p. 146.

{4} Fisher, Irving. The Making of Index Numbers, New York, 1929.

{5} Milton, Helen. "Cost of Research Index, 1920-1965." Research Analysis Corportation, 1966.

{6} Robinson, Roland R. "Estimating the Real Level of Support Given to Research Programs at the State Agricultural Experiment Stations."

{7} National Science Foundation. "A Price Index for Deflation of Research and Development Expenditures." NSF72-310. 1972.