A Price Index for Deflating State Agricultural Experiment Station Research Expenditures

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Abstract *The extent to which inflation has eroded the real purchasing power of public agricultural research budgets is poorly understood Official Government research and development (R&D) statistics use the gross national product (GNP) deflator to express research expenditures in constant dollars, despite the serious shortcomings of such a broad indicator of inflation for deflating research expenditures A State Agricultural Experiment Station (SAES) research price index is calculated in this paper and compared with the GNP deflator The GNP deflator substantially underestimated the rate of inflation in SAES research in recent years mainly due to real growth in faculty compensation during the 1980's The divergence between the SAES research price index calculated in this study and the GNP deflator indicates that the purchasing power of SAES research is significantly less than estimates based on the GNP deflator would suggest*

Keywords. *Price index, Laspeyres, State Agricultural Experiment Stations, research, GNP deflator*

Nondefense research budgets have stagnated or declined in many sectors of the U S economy during the 1980's, increasing concern among those who feel this will hamper productivity growth and international competitiveness Although the decline has been substantial for many types of research, little is known about the extent to which inflation has further eroded the real purchasing power of research budgets No widely accepted and fully satisfactory price index exists for measuring the impact of inflation on research Government R&D statistics use the implicit price deflator for gross national product (GNP deflator) to express research expenditures in constant dollars, despite the serious shortcomings of such a broad measure of inflation for a highly specialized activity like research The GNP deflator has tended to underestimate the rate of inflation in industrial and academic research expenditures in recent years (*8, 12, 20*) [1] Reports by the General Accounting Office (*28*) and the Office of Technology Assessment (*22*) have recommended the use of alternative price indexes for research

Several agricultural research price indexes (RPI's) have been constructed Some have been based on personnel expenditures or average salaries for one type of personnel, for example, associate professors (*4, 5*) The most serious shortcoming of personnel-based RPI's is that they assume that changes in the relative prices of nonpersonnel research inputs have been identical to the trend in prices for personnel inputs (or a subcategory of personnel) This assumption may introduce some bias because others have found that prices for personnel and nonpersonnel research inputs have increased at different rates and that subcategories of research personnel have increased in price at different rates (*12, 15, 17*)

Murphy and Kaldor (*15*) developed a Laspeyres RPI for the State Agricultural Experiment Stations (SAES) for fiscal years (FY) 1973/74 to 1978/79 Survey data on personnel and nonpersonnel direct research expenditures were obtained from 25 SAES Five categories of nonpersonnel (scientific, professional, technical, clerical, and administrative) and five categories of nonpersonnel research expenditures (travel, supplies, equipment, utilities, and other) were included in this index Proxy price indexes were used to represent the price trend in each of the nonpersonnel input categories Murphy and Kaldor's index increased an average of 6 2 percent per year between 1973/74 and 1978/79 compared with 7 9 percent for the GNP deflator (July-June FY basis) The lower average rate of inflation in agricultural research came mainly from scientists' compensation, a major component of research costs, which rose an average of 5 9 percent per year during this period Eddleman (*7*) updated Murphy and Kaldor's index through FY 1979/80

Pardey and others (*19*) developed two current weighted Paasche indexes for SAES research The first index covered FY 1889/90 to FY 1984/85 and was based on three research input categories (land and buildings, plant and equipment, and research labor plus recurrent operating expenses) The second Paasche index covered FY 1930/31 to FY 1984/85 and included four input categories (labor and operating expenses were separated) Both indexes used proxy price indexes for all input categories Comparison of these indexes to the GNP deflator in recent decades reveals that the GNP deflator tended to overstate the rate of inflation in SAES research during the 1970's relative to Pardey's index During the first half of the 1980's, the average annual rate of inflation was underestimated by the GNP deflator

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[1] Italicized numbers in parentheses cite sources listed in the References section at the end of this article

Huffman and Evenson (*9*) constructed a Laspeyres price index for U S public (USDA and SAES) agricultural research for 1888 to 1985 They used an index of average salaries paid to college and university faculty members as a proxy for all personnel expenditures, and the wholesale price index deflator served as a proxy for nonpersonnel expenditures The estimated average annual rate of inflation based on this index was slightly less than the GNP deflator during both the 1970's and the first half of the 1980's

All the agricultural RPI's discussed above, except Murphy and Kaldor's, suffer from the same shortcoming scientists' compensation, perhaps the most critical component of research expenditures, was represented by various proxies, such as average salaries for all college and university teachers Price indexes based entirely on proxies are valuable if those proxies are reasonably accurate But, a variety of factors may reduce the accuracy of the proxies that have been used for SAES faculty salaries Recent faculty salary surveys have revealed much variability in average salaries in different academic fields (*1, 17*) Average faculty salaries in fields like engineering and business have been inflated by bidding wars that have boosted salaries for junior faculty Weak job markets in other fields have depressed average salary levels Faculty salaries at institutions with collective bargaining contracts have averaged 13 percent higher than salaries at institutions without collective bargaining (*14*)

The purpose of this paper is to construct an agricultural RPI using salary data for the SAES and appropriate proxy price indexes The model and data are described in the next section, followed by a comparison of the calculated agricultural RPI to the GNP deflator. Implications for agricultural research policy are discussed in a concluding section

Model and Data

A Laspeyres formula was used to construct an agricultural research price index (AG-RPI) I selected the Laspeyres formula because it is widely used and is better understood by users than the Divisia formula The Paasche formula could not be used because expenditure weights were not available on an annual basis The calculated index consists of four main components or subindexes Each subindex is weighted by its relative share of total expenditures to produce the aggregate index·

$$\text{AG-RPI} = w_f I_f + w_a I_a + w_o I_o + w_n I_n, \quad (1)$$

where w_f, w_a, w_o, and w_n are expenditure weights for faculty compensation, research administrator compensation, other personnel compensation, and nonpersonnel direct research expenditures, respectively, and I_f, I_a, I_o, and I_n are subindexes of faculty compensation, research administrator compensation, other personnel compensation, and nonpersonnel direct research inputs respectively The subindex of faculty compensation is further broken down into four components

$$I_f = w_{dh} I_{dh} + w_{fp} I_{fp} + w_{ap} I_{ap} + w_{as} I_{as}, \quad (2)$$

where w_{dh}, w_{fp}, w_{ap}, and w_{as} are expenditure weights for SAES department heads, full professors, associate professors, and assistant professors, and I_{dh}, I_{fp}, I_{ap}, and I_{as} are subindexes of department head, full professor, associate professor, and assistant professor compensation

The faculty compensation subindexes were based on average annual salaries in SAES (table 1) Average salaries for each of the four faculty categories were divided by their respective average prices in FY 1981/82, the price base period, to produce faculty salary subindexes I used data on fringe benefits as a percentage of average salary by academic rank in public, doctoral-level institutions to adjust salaries to reflect total compensation Fringe benefits as a percentage of average academic salaries have steadily increased over time, so omitting the trend in fringe benefits would result in a slight downward bias in the resulting RPI [2] Data on fringe benefits as a percentage of salary were not available for department heads Table 2 shows the faculty compensation indexes by academic rank and a weighted index of faculty compensation across all ranks, based on equation 2 The average share of total SAES faculty salary expenditures for FY 1980/81 to 1982/83 served as the weights, as follows department heads (0 093), professors (0 505), associate professors (0 232), and assistant professors (0 170)

One of the assumptions of a fixed-weighted price index, such as the proposed AG-RPI, is that the "market basket" of items included in the index remains constant over time Although it was not possible to test this assumption for all items, data were available to test if the faculty weights remained relatively constant Figure 1 shows the share of total SAES faculty salary expenditures by academic rank for the period covered by the AG-RPI Faculty shares appear to have been reasonably stable throughout the period A test for trends in proportions based on Kendall's statistic S was carried out for each faculty rank (*3*) The null hypothesis of no trend was tested against an increasing trend alternative for professors and a decreasing trend alternative for department heads, associate

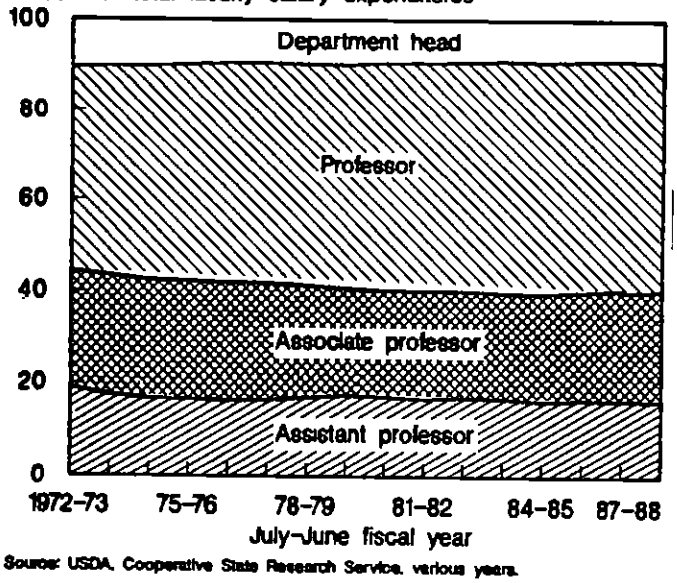
[2]Although the gains in academic fringe benefits shown in table 1 appear to be substantial, they are actually less than the average gains for private-sector employees (2, Jul -Aug 1984)

Table 1—Average State Agricultural Experiment Station faculty salaries, average research administrator salary, and fringe benefits as a percentage of average salary, by academic rank

July-June fiscal year	Number of institutions	Average faculty salaries[1]				Average research administrator salary[1]	Fringe benefits as a percentage of average salary[2]		
		Dept head	Prof	Assoc prof	Asst prof		Prof	Assoc prof	Asst prof
		Dollars					*Percent*		
1972/73	53	25,490	22,256	17,294	14,798	26,219[3]	11 4	11 8	12 2
1973/74	54	26,682	23,391	18,203	15,502	27,612[3]	12 3	12 9	13 4
1974/75	55	28,244	24,788	19,310	16,324	29,438[3]	12 6	13 2	13 8
1975/76	55	30,293	26,443	20,673	17,352	31,732	13 2	13 7	14 4
1976/77	55	31,621	27,846	21,884	18,342	33,524	13 8	14 3	15 0
1977/78	55	33,656	29,562	23,208	19,489	35,771	14 1	14 8	15 5
1978/79	55	35,449	31,494	24,762	20,792	38,416	15 1	15 9	16 6
1979/80	55	38,600	33,784	26,591	22,175	41,002	16 3	17 0	17 6
1980/81	56	42,214	37,106	28,943	24,306	46,367	17 2	18 0	18 3
1981/82	56	45,935	40,462	31,655	26,474	49,478	18 1	19 1	18 9
1982/83	56	48,737	42,758	33,688	28,133	53,523	18 5	19 5	19 8
1983/84	55	50,358	43,871	34,222	29,075	55,024	19 4[4]	20 7[4]	21 0[4]
1984/85	56	54,272	47,599	36,940	31,352	59,205	20 3	21 8	22 1
1985/86	56	57,534	50,861	39,417	33,430	63,841	20 4	21 8	22 1
1986/87	56	61,036	53,990	41,379	35,309	67,813	20 5	22 0	22 2
1987/88	56	63,653	56,077	43,164	36,845	71,286	20 2	22 0	22 3

[1]Source USDA, Cooperative State Research Service, salary analysis, various years
[2]Fringe benefits as a percentage of average salary for faculty in public, doctoral-level institutions Source Calculated from AAUP, various years
[3]Extrapolated as described in the text
[4]Obtained by linear interpolation between 1982/83 and 1984/85

Figure 1
Share of total State Agricultural Experiment Station faculty salary expenditures, by academic rank



Source: USDA, Cooperative State Research Service, various years.

professors, and assistant professors. The hypothesis of no trend could not be rejected at a 0.05 level of significance for each academic rank, lending support to the assumption of constant faculty shares over time. USDA Cooperative State Research Service (*23*) data indicate that SAES faculty shares shifted significantly during the 1960's, with professors' shares of salary expenditures steadily increasing while department head and assistant professors' shares declined. This trend appears to have leveled off by the early to mid-1970's.

Research administrator salaries were based on data for FY 1975/76 to 1987/88 that showed average annual salaries of research administrators in "cooperating state institutions" (SAES, forestry schools, 1890 colleges and Tuskegee University, and colleges of veterinary medicine) These data were a weighted average of salaries of directors, associate directors, assistant directors, research directors, administrative technical representatives, deans, associate deans, and assistant deans The administrator salary series was extrapolated by regressing average research admin-

Table 2—State Agricultural Experiment Station compensation and salary indexes, proxy price indexes, and agricultural research price index (AG-RPI)

July-June fiscal year	Dept head salary index	Compensation subindexes[1]			Faculty compensation index	Research admin salary index	Proxy price indexes		AG-RPI
		Prof	Assoc prof	Asst prof			Other personnel[2]	Nonpersonnel[3]	
1972/73	55 5	51 9	51 3	52 7	52 2	53 0	50 5	47 4	50 3
1973/74	58 1	55 0	54 5	55 8	55 3	55 8	54 0	51 5	53 7
1974/75	61 5	58 4	58 0	59 0	58 7	59 5	58 2	57 3	58 1
1975/76	65 9	62 6	62 3	63 1	62 9	64 1	64 0	62 2	63 2
1976/77	68 8	66 3	66 3	67 0	66 7	67 8	68 6	66 1	67 3
1977/78	73 3	70 6	70 7	71 5	71 0	72 3	73 3	70 8	71 9
1978/79	77 2	75 9	76 1	77 0	76 3	77 6	78 3	76 7	77 2
1979/80	84 0	82 2	82 5	82 8	82 5	82 9	84 7	84 7	84 0
1980/81	91 9	91 0	90 6	91 3	91 0	93 7	92 2	92 9	92 1
1981/82	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0
1982/83	106 1	106 0	106 8	107 1	106 4	108 2	108 2	106 0	107 0
1983/84	109 6	109 6	109 6	111 8	110 0	111 2	114 4	111 0	112 0
1984/85	118 1	119 8	119 3	121 6	119 8	119 7	121 1	116 6	119 4
1985/86	125 3	128 1	127 3	129 7	127 9	129 0	126 9	121 2	125 6
1986/87	132 9	136 1	133 9	137 1	135 5	137 1	133 2	125 4	131 7
1987/88	138 6	141 1	139 7	143 2	140 9	144 1	140 1	131 3	137 9

[1]Derived from average SAES faculty salaries and fringe benefits as a percentage of average salary by academic rank (from table 1)
[2]Fixed-weighted price index for "State and Local Government Compensation of Employees," July June fiscal year basis Source Calculated from quarterly data, U S Dept Commerce (1986) and *Survey of Current Business*, various issues
[3]Fixed-weighted price index for "State and Local Government Purchases of Goods and Services," July-June fiscal year basis Source Calculated from quarterly data, U S Dept Commerce (1986) and *Survey of Current Business*, various issues

istrator salary on SAES department head salary and a constant The resulting coefficients were used to estimate administrator salaries for FY 1972/73 to 1974/75 Data on fringe benefits as a percentage of salary were not available for research administrators Table 1 shows average administrator salaries, and table 2 shows the administrator salary index

Because of the lack of data on average unit prices for these research inputs, proxy price indexes were used to represent the inflationary trends in other personnel compensation and nonpersonnel direct research expenditures [3] Compensation for personnel other than faculty and administrators constitutes a large proportion of SAES research personnel expenditures, and includes professional support, technical support, clerical and other support, and graduate research assistants The Bureau of Economic Analysis (BEA) index of "State and local government compensation of employees" was chosen as a proxy for other personnel compensation (table 2) Alternative proxies that were examined included two indexes published by the Bureau of Labor Statistics (BLS) a compensation cost index for civilian workers in white-collar occupations, and a compensation cost index for State and local government workers in white-collar occupations (*27*) Both of these alternative proxies closely followed the "State and local government compensation of employees" price trend, but they extend back only to 1981 and therefore could not be used

The price trend in nonpersonnel direct expenditures is represented by the BEA's price index for "State and local government purchases of goods and services " Alternative proxies for this component of research costs include the wholesale or Producer Price Index (*9*, *21*) and the implicit deflator for nonfinancial corporations (*8*) The BEA proxy was selected because it is based on a more relevant subsector of the economy

The subindexes were then weighted by their respective shares of SAES research expenditures and combined as shown in equation 1 The following SAES expend-

[3]Only one study has attempted to directly measure price change in nonpersonnel research inputs The Bureau of Labor Statistics (BLS) developed an experimental price index for Army research activities (*26*) The BLS effort involved selecting and pricing a large sample of goods and services representing Army and contractor research expenditures This approach proved to be feasible but expensive

iture weights were estimated by Murphy and Kaldor (*15*) for FY 1978/79· faculty (0.309), research administrators (0 019), other personnel (0 387), and nonpersonnel direct expenditures (0 285) Table 2 shows the resulting AG-RPI

Note that this research price index includes only direct research costs Indirect costs of research, which cannot be easily allocated to particular projects, include such items as the operation and maintenance of buildings, departmental and research grant administration, depreciation or use charges on facilities and equipment, and libraries Indirect costs are assumed to have changed proportionately to direct costs This assumption should tend to bias the AG-RPI downward somewhat, because the percentage of total academic research costs accounted for by indirect costs has increased in recent decades (*11*), and indirect costs have increased more rapidly than direct costs after 1973 (*16*).

Comparison with the GNP Deflator

Is the implicit price deflator for GNP—used in most Government statistics to express research expenditures in constant dollars—an adequate measure of the rate of inflation in SAES research? Figure 2 compares the agricultural research price index constructed in this study with the GNP deflator The two indexes were remarkably similar throughout the 1970's and early 1980's (the two indexes were forced to converge in the 1981/82 base year), but a widening gap appeared after 1982/83 A test determined if the observed deviation between the AG-RPI and the GNP deflator could be attributed to randomness Under the null hypothesis that deviations between the two indexes are random over time, we would expect to observe an equal number of positive and negative deviations With the Chi-square test, the null hypothesis of randomness was rejected at a 0 025 significance level Thus, evidence indicates nonrandomness in the sequence of deviations between these two price indexes, leading to a reasonable conclusion that the AG-RPI and the GNP deflator are different By 1987-88, the AG-RPI was about 12 5 percent higher than the GNP deflator, implying that use of the GNP deflator may substantially overestimate the real purchasing power of SAES research

Figure 2
Comparing the agricultural research price index (AG-RPI) with the implicit price deflator for gross national product (GNP)

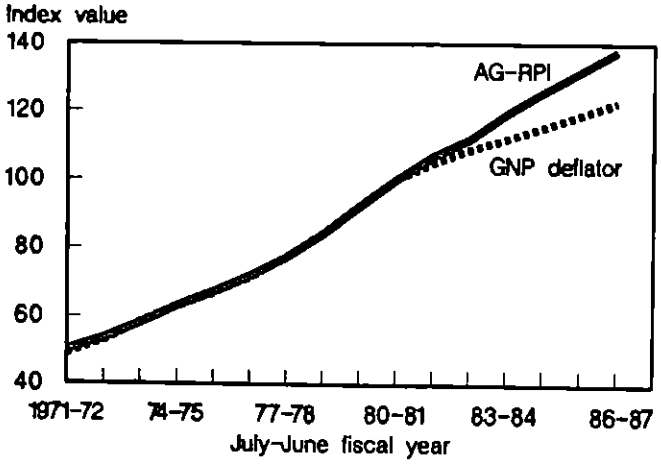


Figure 3 reveals the etiology of the divergence between the AG-RPI and the GNP deflator Personnel compensation is the major component of the AG-RPI, and these figures present a detailed picture of trends in real compensation over time Compensation for SAES faculty, faculty in public, doctoral-level universities, and faculty in private, doctoral-level universities failed to keep up with the cost of living throughout the 1970's [4] By 1980/81, the purchasing power of SAES faculty salary and benefits had dropped to more than 14 percent below the 1972/73 level for assistant professors, 12 percent for associate professors, and 13 percent for professors Faculty in public and private research universities experienced even greater declines in real compensation during the 1970's and early 1980's Faculty compensation has grown significantly in real terms in recent years, surpassing 1972/73 purchasing power by 1986/87 in most cases The 1980's have clearly been a catchup period for U S university scientists, making up for ground lost during the 1970's Figure 3(d) shows that State and local government employees—the proxy used in this study for trends in nonfaculty compensation—have also made gains in real compensation during the 1980's Trends in real compensation for General Schedule Federal employees and all nondefense Federal employees are also shown for comparison in figure 3(d)

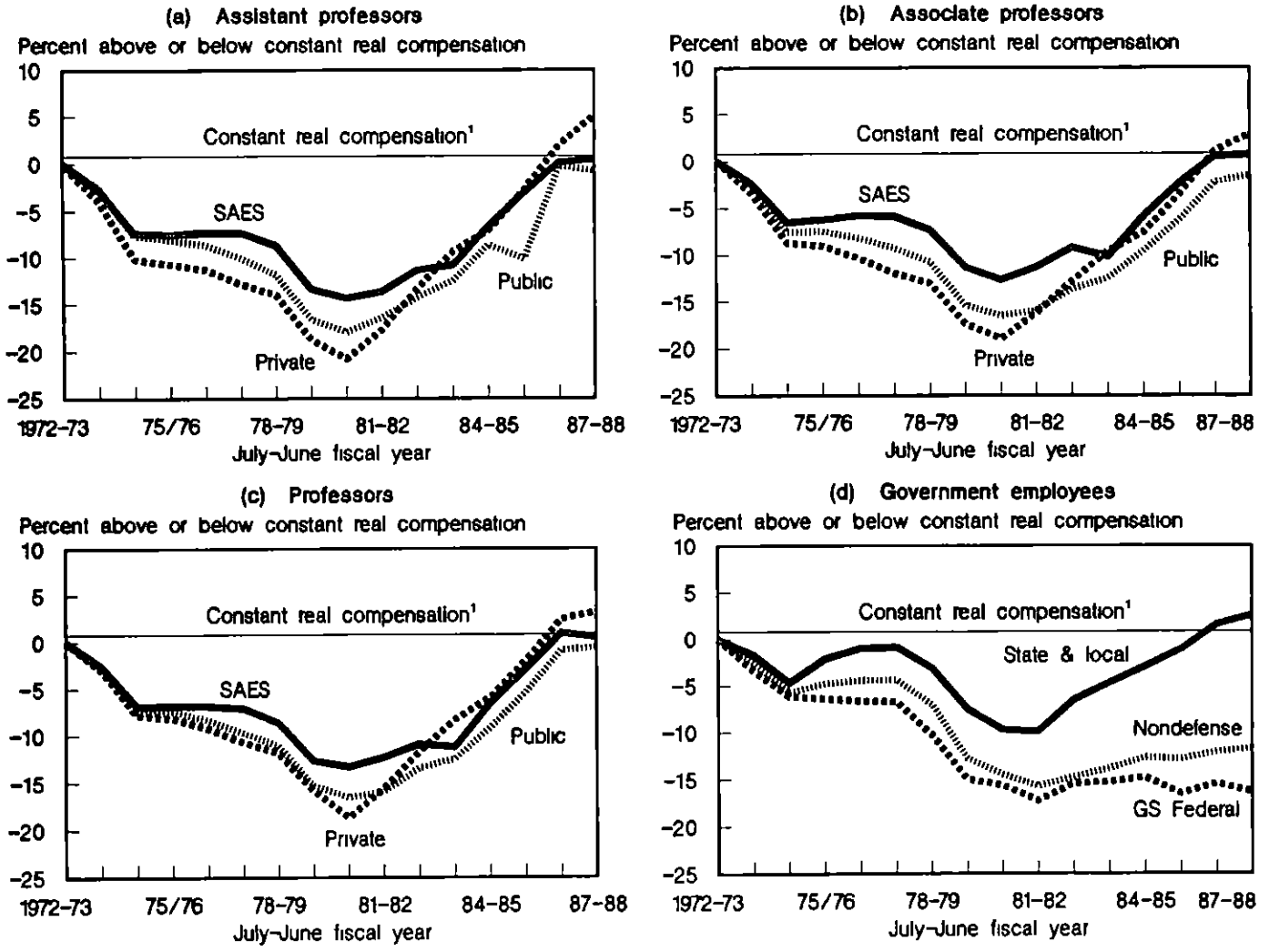
One possible explanation for the real growth in faculty compensation is the effect of collective bargaining in higher education Faculty collective bargaining agreements spread rapidly during the 1970's, and by late 1987, the faculty at 65 percent of all 4-year public institutions were represented by certified bargaining agents (*6*) Although a few public

[4]The percentage change in real compensation in fig 3 was calculated as follows

$$\{[(AC_t/AC_{72\,73}) / (CPI_t/CPI_{72\,73})] - 1\} \times 100$$

where AC_t is average compensation in fiscal year t, $AC_{72\,73}$ is average compensation in fiscal year 1972/73, and CPI is the Consumer Price Index on a July-June fiscal year basis

Figure 3
Patterns of change in average real compensation



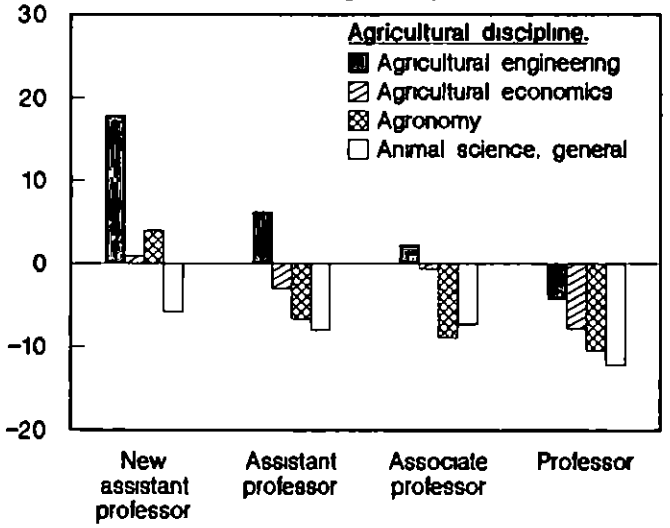
1/ Constant real compensation was measured relative to a July-June fiscal year Consumer Price Index
Sources and legend labels. SAES: Faculty in State Agricultural Experiment Stations (CSRS various years). Public: Faculty in public, doctoral-level universities (AAUP various years). Private: Faculty in private independent doctoral-level universities (AAUP various years). State & local: State and local government employees (U.S. Department of Commerce BEA, and Survey of Current Business, July issues). Nondefense: Nondefense Federal employees (U.S Department of Commerce, BEA, and Survey of Current Business, July issues). GS Federal: General Service Schedule Federal employees (U.S Office of Personnel Management, various years)

college and university systems have been entirely unionized, faculty at most of the larger and more prestigious institutions have not been organized Only about 12 percent of faculty in disciplines related to agriculture are currently covered by collective bargaining agreements, according to a survey that included 49 institutions with these disciplines (*1*) So, a direct effect of collective bargaining on faculty salaries in the SAES is unlikely But, there may have been an indirect effect Faculty salaries on non-unionized campuses may have been increased by administrators or legislators either to reduce union activity or to compete more effectively with unionized institutions (*13*)

Another part of the explanation may be that industry and academia are competing for new Ph D 's The index for SAES assistant professor compensation (table 2) has increased slightly more than the indexes for professors and associate professors in recent years, perhaps supporting the hypothesis of competitive entry-level bidding Figure 4 suggests that competitive bidding may have affected salaries in some, but not all, agricultural disciplines New assistant professors in agricultural engineering earn on average about 18 percent above the average for new assistant professors in all disciplines in land-grant institutions, with the salary differential decreasing as academic rank increases Average salaries in other agricultural dis-

Figure 4

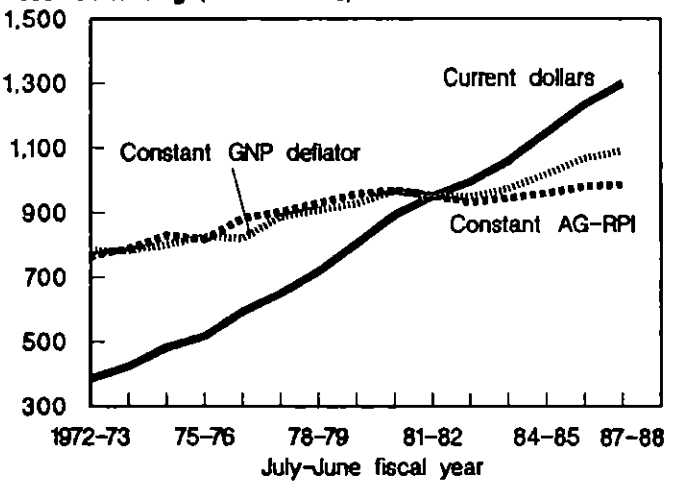
Average salary for four agricultural disciplines relative to average salary for all disciplines in land-grant institutions, by academic rank, FY 1987/88



Source: Office of Institutional Research, Oklahoma State Univ., Stillwater

Figure 5

State Agricultural Experiment Station research funding[1]



1/ In current dollars, constant 1981/82 dollars deflated with the agricultural research price index (Constant AG-RPI), and constant 1981/82 dollars deflated with the implicit price deflator for gross national product, July-June fiscal year basis (Constant GNP deflator)

Source for SAES research funding: USDA, Cooperative State Research Service inventory of Agricultural Research, various years.

ciplines, such as animal sciences, have consistently lagged behind the average for each academic rank

Conclusions and Implications

The SAES research price index calculated in this study is subject to the limitations of all fixed-weighted price indexes Mentioned earlier was the assumption that changes in prices alone, not changes in the "market basket" of included items, are important between the base period and the current period. Another limitation is that like all other price indexes used to deflate research expenditures, the AG-RPI calculated in this study is an index of research *input* prices instead of output prices Deflating current dollar expenditures with a research input price index requires the assumption of no change in the productivity of research over the relevant time period An index of agricultural research productivity should ideally be used in conjunction with a research price index The productivity of the research process is difficult to measure, however, and no satisfactory indicator is available The relatively short timespan covered by the calculated AG-RPI should preclude serious bias from being introduced due to changes in research productivity

Given these caveats, two main conclusions can be drawn from this study First, use of the GNP deflator has very likely resulted in an upward bias in estimates of the magnitude of real SAES research in recent years Figure 5 shows the trend in SAES research funding in current dollars, constant 1981/82 dollars based on the GNP deflator, and constant 1981/82 dollars based on the AG-RPI When the GNP deflator is used, real research expenditures appear to be recovering after a slight decline in FY 1981/82 and 1982/83 The estimate based on the AG-RPI has been essentially constant since the early 1980's, real expenditures edged above the 1980/81 level only in 1985/86 In FY 1986/87, the gap between the GNP deflator and the AG-RPI translates into a difference of more than $104 million in the estimate of real SAES research, about 10 percent of the total research budget. This substantial difference points out the inadequacy of the GNP deflator as a measure of inflation in SAES research The strong real growth in faculty compensation in recent years is not reflected in broad measures of inflation.

Second, nonpersonnel research dollars have been tightly squeezed as faculty compensation has risen in real terms against relatively fixed budgets The underfunding of expenditures on equipment, facilities, and other nonpersonnel research inputs may be a concern in many institutions This is likely to be a growing concern in the future The age distribution of U S faculty is such that salaries are expected to continue to rise due to strong demand: "The large surge in faculty hiring in the Sixties has resulted in a tenured U S academic faculty of largely the same age . . which will cause sharp increases in retirement, and consequent demand for new faculty" (*18, p. 4*) Additional upward pressure on faculty salaries will come from demographic trends that indicate a de-

clining production of new scientists in the next decade (*18*)

This study has shown that an alternative price index is needed for SAES research The prospects for the next decade indicate a continued need for an alternative research deflator for academic research Without a better research deflator, policymakers who decide on science and technology funding will have an inaccurate view of real resources devoted to SAES research, which could result in a misallocation of resources and underinvestment in research

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