An Economic Analysis Of Expenditures On State Experiment Station Research

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Abstract
The last decade can be characterized by a growing skepticism of the agricultural research establishment. Some have argued that agricultural researchers have been captured by the interests of large farmers or by large private farm input supply firms. Others have argued that the agricultural research establishment has been unresponsive to human resource, environmental, and income distributional issues. Some of these concerns have been expressed in recent changes made in the type of federal support for agricultural research.

Disciplines
Behavioral Economics | Economic Policy | Economic Theory | Operations and Supply Chain Management

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AN ECONOMIC ANALYSIS OF EXPENDITURES ON
STATE EXPERIMENT STATION RESEARCH*

by

Wallace E. Huffman and John A. Miranowski**

Staff Paper No. 97

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INTRODUCTION

The last decade can be characterized by a growing skepticism of the agricultural research establishment. Some have argued that agricultural researchers have been captured by the interests of large farmers or by large private farm input supply firms. Others have argued that the agricultural research establishment has been unresponsive to human resource, environmental, and income distributional issues. Some of these concerns have been expressed in recent changes made in the type of federal support for agricultural research.

The primary sources of funds available to U.S. state agricultural experiment stations have been federal funds appropriated on a formula basis and funds appropriated for agricultural research by state governments. Although formula funds are granted to the states on a matching basis, non-federal support of research, which is largely state appropriations, has been at a level that substantially exceeds the federal matching rate in all states. In recent years, state appropriations for research have averaged about 60 percent of the total funds for state agricultural experiment station research. The U.S. Congress has recently established a federally funded competitive research grant program for agricultural research open to all scientists. Also the administration has attempted to substitute competitive grant funds for formula funds. These changes have caused a reassessment by the directors of the state agricultural experiment stations of their funding base.

Only a few studies have attempted an analysis of expenditures on agricultural experiment station research.\(^1\) Peterson (1969) attempts to identify through regression analysis a few factors that influence the allocation of funds to agricultural research. In his simple model, state nonfarm income
emerges as the most important variable explaining total funds available to experiment stations. In the first attempt to model the determination of agricultural research expenditures, Guttman (1978) applies a theory of public interest groups. The interest group purchases policies that are favorable to its members, in this case agricultural research, in exchange for support (votes and funds) for candidates for public office favoring policies sought by the group. In applying the model to cross-sectional expenditures on poultry, grain and dairy research in 1969, research expenditures are explained by a limited set of variables hypothesized to affect the demand for research. The analysis, however, ignores the supply of research, an important determinant of the real quantity of research.

We present a model of resource allocation for state produced research at agricultural experiment stations consisting of both demand and supply functions for research and a governmental revenue allocation equation. From this model, we derive a reduced-form expenditure equation that includes a traditional set of economic variables determining the demand for research and the supply of research and a few interest group variables. Our model is tested with cross-section data on the 48 states of the U.S., pooled together for the years of 1960, 1965 and 1970 for total expenditures by state agricultural experiment stations.

The outline of the paper is as follows. The first section specifies a theoretical model of resource allocation to state experiment station research. In the second section, the data base, the empirical specification
of the model and the regression results are presented and discussed. The last section presents the summary and conclusions.

A MODEL OF RESOURCE ALLOCATION TO STATE EXPERIMENT STATIONS

We propose a model of resource allocation for state produced research at agricultural experiment stations consisting of demand and supply functions for applied research and a state revenue allocation equation. We assume that demanders and suppliers of research in a state interact through the state legislature to determine the "equilibrium" size of expenditures on experiment station research.

The research of experiment stations is heavily oriented toward agricultural production. Much of agricultural research produces increments to basic knowledge or intermediate products (e.g., discoveries of new biological, chemical, physical, economic, or sociological relationships and advances in the methodology of experimental design and hypothesis testing) that enlarge the set of possibilities available to applied researchers (Binswanger and Ruttan, p. 23) but that do not directly increase production efficiency. However, without advances in basic knowledge, the applied research potential would be rapidly exhausted, because at any time, properties of the environment and the state of basic knowledge limit the set of applied research possibilities. Applied research produces final research products. Some maintain previous biological advances against adverse environmental conditions that might depreciate gains in crop yields and animal productivity (Evenson 1978), and others (e.g., new or improved inputs, decision-making aids and schemes, and final agricultural products) attempt to increase output. Non-agricultural research includes efforts to enhance the efficiency of household production and of rural and community development.
Demand

We hypothesize a state level aggregate demand function for indigenous agricultural experiment station research. At the state level, farmers are the primary beneficiary of agricultural research. The elasticity of demand for an individual state's agricultural products is generally higher than at the national level. If a state produces a small fraction of total national or world output of an agricultural product, state specific agricultural research lowers its farmers production costs, increases its output relative to national output, and only slightly lowers the output price. Thus, a state's farmers should demand state-specific final research products that improve their comparative advantage relative to farmers in other states. The benefits accrue largely to them as producer's surplus and to the owners of inputs that are very inelastic in supply (Evenson 1979), e.g., land and water, other things equal.

Although research products are a public good, a state cannot expect to borrow all of its research from other states. Research output has the characteristic of a public good; use by one economic agent does not reduce the quantity available to others. Potential users cannot be easily excluded, and for social efficiency, such information should be made available to all potential users at the marginal cost of distribution (Arrow). Basic or intermediate agricultural research produced by one experiment station has the potential for being used (borrowed) by many states, but the potential for widespread direct interstate borrowing of final (applied) research products is generally more limited because their performance is frequently sensitive to local environmental factors and resource endowments. Thus, there is not a good substitute for state-produced final research products that are state
location-specific or that are adapted more perfectly to the needs of indigenous clients than to others. Under these conditions, a demand for state-produced final research products exists.\footnote{4} We do not attempt to explain exactly how the aggregate demand function is obtained, but it is assumed to reflect the preferences of farmers, landowners, farm input supply firms, and processors of farm products.

We assume the demand function for a state's experiment station research can be written as

\[ Q_d = D(X_{ld}, \ldots, X_{kd}, P) \]

where the $X_{ld}$s are the size and other characteristics of the state's agricultural output, agricultural input prices, farmers' education, extension and agricultural research in other states, and where $P$ is the price of research.

The primary determinant of the demand for agricultural research is the size of a state's agricultural production. This emphasis on agricultural output follows from the positive contribution of agricultural research as an input in aggregate production function studies (Griliches, 1964; Evenson, 1968, 1971, and 1978; Cline, 1975).\footnote{5} Also, the expected return from agricultural research oriented to insuring previous productivity gains against adverse and unpredictable environmental conditions is related to the size of agricultural output.\footnote{6}

A state's product mix and diversity of agricultural products can affect the demand for research, given the size of output. National data for 1967 (USDA, 1969) show that the intensity -- dollars of research expenditure per dollar of commodity output -- was 1.6 times larger for crops than for livestock. Evenson (1978) reports the share of maintenance research expenditures is larger for crops than for livestock and poultry. For a state, the
intra-commodity applicability of research will generally be much higher than inter-commodity applicability. Final research products (e.g., inbred corn lines, feedlot management systems, tillage machines, and fertilizer recommendations) are generally commodity specific. Thus, increasing the number of agricultural commodities or increasing the share of crop output in total output is expected to increase the aggregate demand for research because of the increased number of commodities requiring research.

A change in (expected) relative input prices can be expected to induce new research. This research will attempt to save inputs that have become more expensive and to increase the use of inputs that have become relatively cheaper (Hayami and Ruttan, Binswanger and Ruttan).

Farmers education and extension enhance the dissemination of information on agricultural technology. Education enhances the allocative ability of farmers (Huffman, Welch 1970). Extension decodes and repackages research findings so that the technical information can be better understood by farmers and can be applied at the farm level. Thus, higher schooling levels of farmers and larger extension activities speed the adoption of superior final research products and increase the (share of) benefits from indigenous research to a state's farmers. They are expected to increase the demand for research. Outlying research centers of the experiment station also aid the information dissemination activity and influence the demand for research final products.

For a given state, Evenson (1979) has hypothesized that research output of other states may have two opposite effects on indigenous research demand. Most new research final products are not directly applicable to
environmental and resource conditions in other states, e.g., a superior corn variety. Competing farmers in other states are placed at a disadvantage unless new research products are developed for them. Thus for a given state, non-borrowable research output in competing states would increase the aggregate demand for indigenous research output. On the other hand, directly borrowable final research products (e.g., controls for livestock diseases, livestock feed additives, and farm management schemes) from other states will reduce the demand for research.8/

Supply

In our model, indigenous research is produced and supplied by a state's agricultural experiment station. The production of research requires as inputs the services of administrators, researchers (or scientists), research assistants, secretaries, scientific publications, office space and equipment, laboratory space and equipment, electronic computers, greenhouse space, experimental plots and farms, and research animals and plants.9/ As a first approximation, we assume agricultural experiment stations produce research output at minimum cost. These stations are nonprofit institutions operating within public land-grant universities that have similar missions and goals, but they place different relative weights on the products from teaching, research, and service. Directors of experiment stations are given a budget allocation to spend on inputs for research and, we assume that they behave as if they are attempting to maximize the expected output of research final products subject to their budget constraint. This objective implies that directors choose input combinations that minimize the cost of producing a given quantity of research and that they do not change cost minimizing input combinations because particular inputs (e.g., new buildings, and prestigious research staff, etc.) yield satisfaction directly to them.10/
We assume that the supply function of an agricultural experiment station can be written as

\[ Q_s = S(W_{ls}, W_{ns}; \chi_{ls}^0) \]

where \( W_{ls} \) are the prices of variable inputs and \( \chi_{ls}^0 \) represents factors that are taken as being exogenous to current resource allocation decisions. The variables included in \( \chi_{ls}^0 \) affect the efficiency of research production, and hence the cost of research. They are the entrepreneurial (administrative) capacity of the director, the quality of the station's researchers, share of time for research, the ease of a researchers' communication with extension personnel and colleagues, the borrowable research, the diversity and mix of final research products, and the size and number of research centers.

Basic and applied research are creative activities; ideas must be combined so that something "new" is produced. This activity seems to require a sustained effort, with periods of intense mental preparation followed by reflection and hopefully enlightenment and then by writing and rethinking (Ladd, 1979). This implies that a significant share of a researcher's time and mental effort must be allocated to research. Thus, the productivity of research time seems likely to be low if individuals are continually being disrupted (by nonresearch activities) or if their working hours are primarily allocated to nonresearch activities (e.g., teaching, administrative-type activities).

Researchers need sources of new ideas and knowledge. Communication with extension personnel and colleagues are one source. When extension personnel interact with farmers, they learn of new problems facing farmers. Some problems may be solved by drawing upon existing knowledge, but others need to be redefined and relayed to researchers for further analysis. Thus,
researcher's interacting with extension personnel serve as a potential source of information transmittal on problems requiring further research.

Colleagues are a source of knowledge for both basic and applied researchers. Although the potential size of the stock of available knowledge is positively related to the number and quality of researchers at an institution, information exchange must occur before efficiency gains can be realized. The organizational feature that seems most likely to foster exchange of information within and between departments of a university is a strong graduate program (Evenson 1971). Graduate courses taken by research assistants in the basic disciplines (e.g., statistics, chemistry, genetics, botany, economics) are an important source of knowledge and research techniques to be applied to station research projects. Graduate students in general may challenge the ideas of teachers and researchers and provide new ideas. Thus, a strong graduate program is expected to increase the efficiency of station research.

Borrowable research from other states is another source of new ideas and knowledge. Since the production of original research is expensive relative to distribution of results, borrowing research from other states would reduce the cost of research final products. Not all available research, however, is useful. Basic research and intermediate research products will generally have broad applicability because of their fundamental nature. Final research products tend to be commodity and geoclinal region specific, so they may not be as directly applicable in other states. To the extent that borrowing of final research products occurs, it seems likely to be confined largely to other states located in similar commodity geoclinal regions (Evenson 1978).

The number of different research final product areas, given the size of a station, and the mix of research between crops and livestock may affect the efficiency of research production. For a small station,
supplying research products for a large number of commodities may mean spreading resources thinly, allocating most resources to final products and few to intermediate research products. Low production efficiency may occur because the station cannot take advantage of economies of size in producing research. Livestock research, given the costs associated with large herds, may be more expensive for small stations than crop research.

Research centers (experiment stations and substations) are important laboratories for crop, livestock, and agricultural engineering research. The size and location of these centers are important organizational features of research (Evenson 1971 and Binswanger). When environmental factors and commodities differ widely among regions within a state, decentralized research centers facilitate adapting technology to local conditions and displaying the results at field days. However, centralization of research permits taking advantage of economies of size in the use of expensive laboratory equipment, libraries, and administrative services. Centralization is also necessary for work requiring collaboration across disciplines by highly skilled researchers.

State Revenue Allocation

Demanders of experiment station research do not directly pay the supplier, except in the case of research contracts and grants. Thus, as with most public sector services, market prices and quantities for research are seldom observed. On the other hand, research expenditure data are available, so we are forced to develop a reduced-form expenditure statement of the research market. Desired expenditures on station research can be obtained from the research demand and supply functions, (1) and (2). Funds available for spending on station research consist of federal funds, state legislative appropriations, and funds from other sources (e.g., special
endowments, fellowships, grants, sales of research animals, crop products and other products). ¹³/

We take the size of federal funds and of other nonfederal funds as predetermined and assume the equilibrating component in the experiment stations's budget is state appropriations for research. ¹⁴/ A state's equilibrium level of expenditure is assumed to be determined by the political process through direct and indirect interaction of demanders and suppliers of research with the state legislature. The rationale is that decisions on state legislative allocations for experiment station research are made collectively at the state level and not at the individual farm, firm, or household level.

The share of a state government's budget allocated to research (or the marginal propensity to spend) is treated as a behavioral relationship, but the size of total state government revenues is taken as predetermined. ¹⁵/ The director of the agricultural experiment station and interest groups, representing demanders of research, play key roles in obtaining state funds for research. The director initiates requests for research funds from the state legislature based upon his first hand information of the research cost and (presumably) of the demand for research. ¹⁶/ This latter information comes from his contact with producer groups, advisory boards, and input supply firms, from direct requests for research, and from client feedback through extension personnel. Demanders may lobby the state legislators directly and through interest groups to achieve the political influence needed to get "desired" agricultural research funds appropriated.

Groups that can be expected to be strong supporters of research funding are farm operators and owners, operators of large farms, and farm organizations. If the benefits of research accrue as producer's surplus to farm operators and as rents to agricultural inputs that are most inelastic in
supply (e.g., land), owner-operators of farms are expected to be stronger supporters of agricultural research than renters. The profitability of adopting new technology is a function of the change in cost per unit of output and the size of output. Because large farms have more units of output than smaller farms, the operators of large farms are expected to be stronger supporters of agricultural research than operators of smaller farms.

General and commodity specific farm organizations can be expected to use their political influence to get funds appropriated for research. The members of commodity specific farm organizations seem likely to be more homogeneous in their research interest than general farm organizations, permitting them to be more decisive and influential in getting funds appropriated for research. The influence of these organizations, however, may be difficult to assess because of overlapping membership, uneven geographical coverage, and withholding of membership data.

THE EMPIRICAL ANALYSIS

The data base, the empirical specification of the variables, and the regression results from fitting a reduced form of the state expenditure equation for experiment station research are presented and discussed in this section.

The Data Base and the Variables

The basic data source on expenditures and other characteristics of the agricultural experiment stations is the USDA publication, Funds for Research at State Agricultural Experiment Stations and Other State Institutions. States in the conterminous United States are the unit of observation, and expenditures for the fiscal years of 1960, 1965, and 1970 are used as the
dependent variable. Cross sections are combined to provide a more rigorous test of the model and are chosen at the above 5 year intervals to take advantage of the characteristics of agriculture reported in the Census of Agriculture.

Most of the variables are constructed on a state per capita basis by dividing them by the size of the state's population (U.S. Dept. of Commerce, 1961, 1966, and 1971). Logical alternative deflators are number of farms and value of agricultural production, but for a public good, such as experiment station research, population seems a more acceptable deflator. Guttman (1978), also, used population as the deflator, and we found that deflating by population gave the best empirical results.

The dependent variable is a state's grand total obligation of funds for the fiscal year by the experiment station (and other state institutions) less nonfederal funds available from fees, sales, and miscellaneous sources then divided by the size of its population. The fees and sales category is excluded because it is dominated by sales of livestock and crop products from research projects. Agricultural output is measured as net annual sales per capita (total value of farm products sold less purchases of livestock and poultry and of non-commercial feeds for livestock and poultry), (U.S. Dept. of Commerce, 1963, 1967, and 1973) lagged one year. An index of concentration (diversity) of a state's agricultural output is constructed as the summation of the squared production share of each of 18 different agricultural commodities or commodity groups. The index is largest if a state's agricultural output consists of only one commodity or commodity group (it is one), and is smallest if a state produces an equal value of each of 18 different commodity groups (18/324). For input prices, we use only a state's annual average hourly wage rate for hired labor, without board and room,
The education level of farm operators is a Welch-weighted (Welch, 1966, 1970) average number of years of schooling completed by farm operators (U.S. Dept. of Commerce, 1962, 1968, and 1972). Extension is the grand total of a state's expenditures on extension per capita, lagged one year (USDA).

We constructed two measures of research activity outside a given state from data made available to us by Robert Evenson and described in Evenson (1978). The relevant set of states to consider in constructing these variables was determined by the boundaries of geo-climatic regions and sub-regions derived from the 1957 Yearbook of Agriculture (see Figure 1). These areas have relative homogeneity of soils and climatic factors. The sub-regional applied research stock (competitive research) is the summation of past commodity specific livestock and crop research expenditures, and applied agricultural engineering and farm management research expenditures aggregated over states with similar agricultural subregions outside the state. Applied research expenditures were assumed to have a 30 year useful life, and linear weights were applied to aggregate over time with 7 years of increasing, 8 years of constant, and 15 years of declining weights. Basic research is applicable over a wider geo-climatic area. The regional basic research stock (borrowable research) is the summation of past basic research expenditures for states in similar geo-climatic regions outside the state. Basic research was assumed to have a 40 year useful life, and linear weights were applied to aggregate over time with 7 years of increasing, 8 years of constant, and 25 years of declining weights. Outside applied and basic research are in per capita units.
Four characteristics associated with agricultural experiment stations follow. A research center's variable is derived as the number of research stations and substations (USDA, Professional Workers in State Agricultural Experiment Stations), including main campus, per 10,000 farms. The average share of budgeted time for research is derived as the number of full-time equivalent station researchers divided by the total number of station researchers engaged full or part-time in research (USDA, Fund for Research). Two variables measuring the size of the Ph.D. degree programs are derived. The station Ph.D.-to-research faculty ratio is the (3-year centered) average number of Ph.D. degrees earned in agriculture and forestry from departments associated with the agricultural experiment station (U.S. Dept. HEW, Earned Degrees Conferred) divided by the number of full-time equivalent station researchers. The Ph.D. degrees in other areas is the annual average (2 years) number of Ph.D. degrees earned in other areas (excluding agriculture and forestry) at universities associated with agricultural experiment stations (U.S. Dept. HEW, Earned Degrees Conferred) relative to the size of the state's population.

The state budget constraint is total revenue per capita of the state government from all sources, including intergovernmental transfers (U.S. Dept. Comm., Statistical Abstract). Income generated in the state, types of taxes, and willingness of the state's people to be taxed are important determinants of the size of this budget constraint. Farm size distribution is measured as the share of large farms (sales ≥ $40,000) and the share of medium-sized farms (sales $2,500-39,999). The proportion of owner-operators is a weighted average number of full-owners and of part owners. Full owners are given an arbitrary weight of 1 and part owners a weight of 0.5. The only
accessible farm organization membership data are for cooperatives. The co-op membership variable is the total estimated number of memberships in marketing, farm supply and related service cooperatives (USDA, Statistics of Farmer Cooperatives) per capita. Since a farmer can be a member of more than one cooperative, there is considerable double counting, but this will be a desirable characteristic when a cooperative's influence is derived from "speaking for its members."

Table 1 presents a summary of the empirical variables, including the symbols associated with each variable, and the sample means and standard deviations of the variables. The table shows that the mean value of expenditures on state experiment station research over the 144 observations is $1.40 per person and the standard deviation is $0.93 per person.

The Results

The results from fitting a reduced-form expenditure equation by the method of least-squares to the 144 pooled observations are reported in Table 2. The equations are fitted with interaction terms between ln (AGOUT) and CONC and between LARGE and ln (ARES) and with two time period dummy variables. The impressive characteristic of the results is the generally good performance of the explanatory variables and of the regression model as a whole.

The positively and statistically significant coefficient of agricultural output supports our hypothesis that the demand for agricultural experiment station research is positively related to the size of agricultural output. The negative coefficient on the AGOUT-CONC interaction variable implies that the elasticity of research expenditures with respect to output is reduced (increased) as a state's agricultural commodities become more
Table 1. Summary statistics for expenditures on U.S. state agricultural experiment station research, 1960-1965-1970

<table>
<thead>
<tr>
<th>Variables</th>
<th>Symbol</th>
<th>Unit</th>
<th>Mean</th>
<th>St. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditures on experiment station research per capita</td>
<td>R</td>
<td>$0.1 per person</td>
<td>14.0</td>
<td>9.3</td>
</tr>
<tr>
<td>Net agricultural output per capita</td>
<td>AGOUT</td>
<td>$s of output per 1,000 people</td>
<td>2,359.0</td>
<td>2,174.3</td>
</tr>
<tr>
<td>Index of commodity concentration of agricultural output</td>
<td>CONC</td>
<td>--</td>
<td>0.21</td>
<td>0.08</td>
</tr>
<tr>
<td>Wage rate of hired farm labor</td>
<td>WAGE</td>
<td>$ per hour</td>
<td>1.20</td>
<td>0.31</td>
</tr>
<tr>
<td>Index of farmers education</td>
<td>ED</td>
<td></td>
<td>1.49</td>
<td>0.28</td>
</tr>
<tr>
<td>Extension expenditures per capita</td>
<td>EXT</td>
<td>$ per person</td>
<td>1.39</td>
<td>0.81</td>
</tr>
<tr>
<td>Research centers per farm</td>
<td>GEN</td>
<td>Centers per 10,000 farms</td>
<td>3.06</td>
<td>4.06</td>
</tr>
<tr>
<td>Subregional applied research stock per capita</td>
<td>ARES</td>
<td></td>
<td>16.12</td>
<td>19.80</td>
</tr>
<tr>
<td>Regional basic research stock per capita</td>
<td>BRES</td>
<td></td>
<td>3.92</td>
<td>5.47</td>
</tr>
<tr>
<td>Budgeted share of research time</td>
<td>SR</td>
<td>--</td>
<td>0.70</td>
<td>0.12</td>
</tr>
<tr>
<td>Ph.D. degrees earned in agriculture and forestry per full-time equivalent researcher</td>
<td>APHD</td>
<td>Ph.D. degrees per researcher</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>Ph.D. degrees earned outside agriculture and forestry per capita</td>
<td>OPHD</td>
<td>Ph.D. degrees per 1,000 people</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>State revenue per capita</td>
<td>REV</td>
<td>$1,000 per capita</td>
<td>0.984</td>
<td>1.02</td>
</tr>
<tr>
<td>Proportion large farms</td>
<td>LAR</td>
<td>--</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Proportion medium sized farms</td>
<td>MED</td>
<td>--</td>
<td>0.53</td>
<td>0.15</td>
</tr>
<tr>
<td>Proportion owner operators</td>
<td>OWN</td>
<td>--</td>
<td>0.73</td>
<td>0.09</td>
</tr>
<tr>
<td>Co-op membership per capita</td>
<td>COOP</td>
<td>Member/1,000 people</td>
<td>2.29</td>
<td>1.85</td>
</tr>
</tbody>
</table>
Table 2. Least-squares estimate of reduced form equation for expenditures on U.S. state agricultural experiment station research, 1960-1965-1970 (144 observations)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Algebraic form</th>
<th>Estimated coefficient</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net agricultural output per capita</td>
<td>ln (AGOUT)</td>
<td>0.307</td>
<td>3.56</td>
</tr>
<tr>
<td>Index of commodity concentration of agricultural output</td>
<td>CONC</td>
<td>4.455</td>
<td>2.16</td>
</tr>
<tr>
<td>Wage rate of hired farm labor</td>
<td>ln (WAGE)</td>
<td>0.550</td>
<td>2.10</td>
</tr>
<tr>
<td>Index of farmers education</td>
<td>ln (ED)</td>
<td>-0.447</td>
<td>-1.93</td>
</tr>
<tr>
<td>Extension expenditures per capita</td>
<td>ln (EXT)</td>
<td>0.473</td>
<td>6.53</td>
</tr>
<tr>
<td>Research centers per farm</td>
<td>ln (CEN)</td>
<td>0.214</td>
<td>5.60</td>
</tr>
<tr>
<td>Subregional applied research stock per capita</td>
<td>ln (ARES)</td>
<td>0.113</td>
<td>3.69</td>
</tr>
<tr>
<td>Regional basic research stock per capita</td>
<td>ln (BRES)</td>
<td>-0.019</td>
<td>-1.51</td>
</tr>
<tr>
<td>Budgeted share of research time</td>
<td>ln (SR)</td>
<td>0.344</td>
<td>2.74</td>
</tr>
<tr>
<td>Ph.D. degrees earned in agriculture and forestry per full-time equivalent researcher</td>
<td>ln (APHD)</td>
<td>-0.037</td>
<td>-1.52</td>
</tr>
<tr>
<td>Ph.D. degrees earned outside agriculture and forestry per capita</td>
<td>ln (OPHD)</td>
<td>0.057</td>
<td>2.95</td>
</tr>
<tr>
<td>State revenue per capita</td>
<td>ln (REV)</td>
<td>0.178</td>
<td>2.59</td>
</tr>
<tr>
<td>Proportion large farms</td>
<td>LAR</td>
<td>2.077</td>
<td>2.28</td>
</tr>
<tr>
<td>Proportion medium sized farms</td>
<td>MED</td>
<td>0.057</td>
<td>2.95</td>
</tr>
<tr>
<td>Proportion owner operators</td>
<td>OWN</td>
<td>0.464</td>
<td>1.69</td>
</tr>
<tr>
<td>Co-op membership per capita</td>
<td>ln (COOP)</td>
<td>0.090</td>
<td>2.94</td>
</tr>
<tr>
<td>(CONC) X ln (AGOUT)</td>
<td></td>
<td>-0.624</td>
<td>-2.41</td>
</tr>
<tr>
<td>(LAR) X ln (ARES)</td>
<td></td>
<td>-0.592</td>
<td>-2.17</td>
</tr>
<tr>
<td>D70</td>
<td>0.682</td>
<td></td>
<td>4.75</td>
</tr>
<tr>
<td>D60</td>
<td>0.362</td>
<td></td>
<td>2.03</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>-1.283</td>
<td>-1.96</td>
</tr>
</tbody>
</table>

\[ R^2 \]

\[ R \]

\( T_{70} \) and \( T_{60} \) are dummy variables for the years of 1970 and 1960, respectively. The constant includes effects of the year 1965 and the proportion of small farms.
concentrated (diverse). This result supports the hypothesis of commodity specificity of research final products. The elasticity of research expenditures with respect to agricultural output, evaluated at the sample mean of CONC, is 0.18. The size of this elasticity suggests substantial economies in using research output. Although this estimate may seem small, one must remember that this elasticity is an estimate of the direct effect, holding other things constant. In a more complex multiequation model, other included variables might themselves be a function of AGOUT. The elasticity of research expenditures with respect to CONC, evaluated at the mean of ln AGOUT, is negative. We hypothesized that greater diversity (concentration) of agricultural output would shift the demand for research to the right (left) and the supply schedule upward (downward). The negative elasticity is consistent with this hypothesis.

The positive and statistically significant estimated coefficient of the hired farm wage rate supports the hypothesis of input prices inducing agricultural research expenditures. The result suggests that farmers in states with high farm wage rates have demanded research to reduce the labor costs of agricultural production.

The information related variables, except for farmers' education, have positive estimated coefficients. We hypothesized that both the demand for the supply of research would be shifted to the right by extension activities. The positive coefficient is consistent with this hypothesis. The number of research centers per farm has a significant positive effect on research expenditures. Although this variable was expected to shift the research demand schedule to the right, the supply of research might shift in either direction, so the positive coefficient is consistent with our hypothesis. The negative and statistically significant coefficient of farmers' education
is puzzling. We hypothesized that increasing farmers' education shifts rightward the demand for indigenous research and increases desired research expenditures. The estimated coefficient does not support this hypothesis. The result has the surprising implication that farmers' education substitutes for indigenous research. This might arise from a more educated farmer's ability to borrow larger amounts of applied research from other states, but the estimated coefficient of an education-applied research interaction term was not significantly different from zero. Thus, the effect of education on research expenditures does not depend on the size of subregional applied research stock.\(^{21}\)

The performance of the variables measuring the potential research stock outside a state show that external factors affect a state's research expenditures. The positive and statistically significant coefficient of subregional applied research suggests rivalry; applied research in similar subregions outside a state is competitive. A state's farmers demand indigenous research in an attempt to minimize their loss of comparative advantage to other farmers in similar subregions. Alternatively, the positive effect of ARES could be due to a rightward shift in the supply of research, if the demand for research is price elastic. The negative coefficient of regional basic research suggests that states with a greater potential for borrowing research reduce their expenditures on research. This can arise from a rightward shift in the supply of research, provided the demand for indigenous research products is price elastic (or a leftward shift in the demand for research).

The budgeted share of research time and the two Ph.D. variables are supply side control variables. Expenditures on research are positively
related to the share of research time of station research staff. Raising the share of a researchers time allocated to research should decrease distractions from other university activities and may reflect a gain in efficiency. The positive coefficient is consistent with a gain in efficiency if the demand for research is price elastic (or with a loss in efficiency if the demand for research is price inelastic).

Expenditures on research are negatively (but not significantly) related to the station Ph.D.-to-researcher ratio. Research expenditures are positively related to the number of Ph.D. degrees earned in areas other than agriculture and forestry in universities associated with agricultural experiment stations. The size of these Ph.D. programs provides an index of the quality of the graduate program in nonagricultural areas and the potential for intra-university borrowing of knowledge by station faculty and graduate students. If the demand for research is elastic, the positive estimated coefficient of OPHD is consistent with an increase in efficiency of research production as OPHD increases. This positive coefficient might also reflect the general willingness of the public to support all kinds of research at land-grant universities.

Four of the 5 variables hypothesized to affect the size of state legislative appropriations to agricultural research have coefficients that are statistically significant. The coefficient of state revenue is positive and the revenue elasticity of expenditures is 0.18. Thus, other things equal, states with greater financial ability do spend more on experiment station research. This finding supports Schultz’s observation (1971) that wealthier states spend more on agricultural experiment station research than do less wealthy states and Peterson’s finding (1969) that
expenditures on experiment station research are positively related to a state's level of nonfarm income.

The size distribution of farms affects research expenditures. Expenditures are positively related to the proportion of large farms and to the proportion of medium sized farms. The size of the marginal effect of LARGE on research expenditures depends on the size of the subregional applied research stock. The estimated coefficient of the interaction term between LARGE and In ARES is negative. It suggests that operators of large farms have greater ability to borrow (or have a greater incentive to search and experiment with) applied research from the available stock in similar subregions outside their state than are other farmers. This borrowing seems to reduce the demand for indigenous final research products. At the sample mean value of In ARES, the estimated percentage change in research expenditures due to a one percentage point change in the share of large farms is 0.80. Since the estimated coefficient of MED is 0.057, a one percentage point increase in the share of large farms has a much larger effect on research expenditures than does a one percentage point increase in the number of medium sized farms.

We hypothesize that farm owner-operators are stronger supporters of agricultural research than renter farm operators. Although the estimated coefficient of OWN has the correct sign, it is not significantly different from zero at the 5 percent level.

The estimated coefficient of co-op membership is positive and significantly different from zero. Membership in this type of farm organization seems to influence state appropriations for agricultural research. Multiple membership in cooperatives also seems to be a significant factor in explaining
research expenditures because alternate empirical definitions of the co-op variable that removed some or most of the overlapping membership performed less well.

IMPLICATIONS AND CONCLUSIONS

Our results show that agricultural experiment station research expenditures have been responsive to economic and institutional forces. Experiment station research has been substituted for farm labor in an era of rising wage rates. Undoubtedly, much of this research has been oriented to developing labor-saving techniques. Likewise, the finding of positive effects of the proportions of large, medium-sized and of owner-operated farms on research expenditures suggests that these groups affect the nature of research undertaken. However, the support for station research by the operators of large farms declines if there is a large quantity of applied research available from similar subregions in other states.

The wealthier (based upon per capita state government revenues) and more agriculturally oriented states (as measured by size of agricultural output per capita) have supported and will likely continue to support public agricultural research in the future (Schultz, 1971). In an era of relatively declining federal support, the implications for agricultural research stations in less affluent and less agriculturally oriented states are rather pessimistic. Farmers in these states may have to borrow research products from states with similar geoclimatic regions to slow their decline in comparative advantage. If other states in similar geoclimatic regions are suffering similar economic fates, the potential for borrowing basic research will be reduced. Also, if these states are characterized by smaller sized farming operations, the capacity of these farmers for borrowing final research products from other states is small.
The supply side of our model includes some implications for the organization of the experiment station. Expenditures for research are positively related to the budget share of staff research time and to the number of research centers per farm and negatively related to agricultural Ph.D.'s earned per full-time equivalent station researcher. Assuming the demand for agricultural research is price elastic, these results suggest that increasing the regional specificity of research within the state through more research centers and decreasing nonresearch commitments of researchers will increase productivity of the station. Increasing the ratio of graduate students to station researchers may actually decrease productivity. In periods of fiscal restraint and declining real resources due to inflation, it may be tempting for directors to reduce the number of outlying research centers, reduce the share of research time per scientist, and substitute less costly research assistants for scientists in an effort to economize. One can infer from our results that such actions would be counterproductive with respect to funding and may decrease the productivity of the experiment station.

Past research has shown that improved information has a positive impact on the demand for new agricultural inputs. In this study we find that extension expenditures have a positive effect on research expenditures but that farmer's schooling has a negative effect. Extension aids in the dissemination of information and research final products and in the identification of farm problems needing research. This complementarity should not be overlooked by the state legislatures, especially if the federal government implements reductions in both research and extension funding. Although the education result is troublesome, holding all other factors constant, it may indicate that better educated farmers realize the pervasive nature of public
research and attempt to capture the benefits through private agricultural research. Thus, they may engage in their own research or purchase privately supplied research inputs.

Coop membership has a positive effect on research expenditures. To the extent that coop membership is a proxy for membership in farmer-oriented public interest groups, these results suggest that if a state's farmers are better organized (Guttman, 1978), they will have a stronger effect on state allocations to agricultural research. Our results also imply that the multiplicity of farmer membership in these public interest groups increases their effect on research expenditures.

The impact of potential cutbacks in federal funding for state experiment stations is a concern of the agricultural research system. In our model, federal funds for experiment station research are included in the state revenue variable. For 1960, 1965, and 1970, federal funds for experiment station research averaged 0.09 percent of total state revenues and the state revenue expenditure elasticity of research expenditures was 0.18. Thus, a 10 percent decrease in federal support for station research implies a 0.9 percent decrease in state revenue and a 0.15 percent fall in state expenditures on agricultural research. Our analysis implies that the adjustment for an experiment station in an average state would not be drastic, but for stations in states where the federal funding of station research is a larger than average share of total state expenditures, the adjustment may be more severe. We leave for future research the analysis of the effects of shifts by the USDA from formula funding of agricultural research to competitive research grants.
FOOTNOTES

1/ Schultz (1971) first explicitly recognized the potential economic significance of disparities in funding state experiment stations. Hayami and Ruttan have argued for an economic analysis of public institutions involved in economic growth and development.

2/ Consider two geographic regions supplying \( Q^s_i = S_i(P, \delta_i), \ i = 1, 2 \). \( P \) and \( \delta_i \) are the price received by suppliers of \( Q \) and a supply function shift parameter, respectively. The market demand function for \( Q \) is \( Q^d = D(P) \), and market equilibrium requires \( Q^s = Q^d \). However, the demand function facing region 1 is \( Q^d_1 = D(P) - S_2(P, \delta_2) \) and the price elasticity of demand for region 1 is

\[
\eta_{Q_1P} = \left( \frac{Q_1}{Q_1} \right) \eta_{QP} - \left( \frac{Q_2}{Q_1} \right) \varepsilon_{Q_2P}, \quad \eta_{QP} \leq 0, \quad \varepsilon_{Q_1P} \geq 0,
\]

where \( \eta_{QP} \) is the market price elasticity of demand for \( Q \), \( \varepsilon_{Q_1P} \) is the price elasticity of supply of region 1.

Also, the effect of a shift of the supply curve of region 1 due to advances in technology in that region on the market price of \( Q \) can be summarized as

\[
\frac{\delta_1 P \partial P}{P \partial \delta_1} = \frac{(Q_1/Q)\varepsilon_{Q_1\delta_1}}{-\eta_{QP} - (Q_1/Q)\varepsilon_{Q_1P} - (Q_2/Q)\varepsilon_{Q_2P}}
\]

where \( \varepsilon_{Q_1\delta_1} \) is the elasticity of supply of \( Q_1 \) with respect to \( \delta_1 \).

At the national or international level, consumers are the primary beneficiaries of agricultural research. At this level, the price elasticity of demand for agricultural products is low so the long-term impact of agricultural research is to lower the price of agricultural products and to benefit consumers.
The benefits to users vary, however, and some individuals may be made worse off as more individuals use research output.

Studies by Griliches (1957) of hybrid corn and by Evenson (1978) of agricultural productivity show the incomplete nature of research spillover effects across state boundaries.

Future output depends on current and past research but research expenditures depend on past output and expectations about its future. The issue of causality is simplified here by assuming that current research expenditures are a function only of past output (Griliches 1979).

Evenson (1978) estimates that 30-50 percent of agricultural research expenditures on crop and livestock and poultry research in 1967 was directed to maintenance research.

The extension variable may add to the dimension of potential simultaneity.

These research products might be supplied by input supply firms, professionals (veterinarians), extension personnel, or farm magazines and other publications.

The final and intermediate products of experiment station research consist of technical publications (books, journals, and station bulletins), nontechnical publications, blueprints, new crop varieties or lines, new feed rations and additives, new environmental controls, new decision making schemes, and training of researchers.
In 1960, 1965, and 1970, personal services and personnel benefits accounted for 69, 64, and 72 percent, respectively, of total state agricultural experiment station obligations (USDA, Funds for Research). Ruttan (1978) argues that in the U.S. the combination of centralized (USDA) and decentralized (state) systems of agricultural research results in an organizational structure that behaves similar to firms in a competitive market. Other researchers e.g., [Alt, et al.] have assumed cost minimization for models of resource allocation in universities. Interdisciplinary research effort may also be important in facilitating communications across disciplines.

For Federal matching funds, each state must at least match the federal funds with nonfederal funds, including state appropriations, in order to qualify for the federal support of research. In all states, nonfederal funds for experiment station research are considerably larger than the minimum required to be eligible for federal grant funds. Thus, at the margin, additional federal matching funds have an income but not a price effect.

McMahon uses the same methodology for constructing a model to explain public expenditures on education.

State revenue collections may be affected by the size of past research expenditures.

The budgeting process through which the director of the experiment station registers funding requests with the state legislature -- directly or indirectly through a university president and perhaps some governing board -- may be an important factor in determining state budget allocations to research.
The main source of variation in other farm input prices is transport costs, except for land. Land rental data for comparable agricultural land do not exist, and land price differences reflect quality differences and a number of economic forces that are not related to its current rental value for agricultural production.

The time shape for the weights is based upon the results of a partial correlation scanning analysis across varying time shapes by Evenson (1978). The pattern was chosen which gave high correlation of the research variable with agricultural productivity. The same time shape is imposed on all states.

Basic research is research expenditure in the general area of crop and of livestock research that could not be allocated to a specific crop or livestock commodity.

In solving for the reduced form equation, two variables are lost due to substitution. They are the commodity mix of agricultural output, which appears in the research demand and supply equations, and the entrepreneurial capacity of the director of the experiment station, which appears in the supply and allocation equations.

It is possible that there are enough positive indirect effects of education that the net effect of higher schooling levels of farmers is to increase research expenditures.

We find that variables measuring the size of farm output per capita and the proportion of farms by size class is a superior specification to the number of farms per capita in each size class.

When the interaction term between LARGE and ln ARES is excluded from the regression, the estimated coefficient of LARGE is positive but has a t-ratio of only 1.0. The estimated coefficient of an interaction between MED and ln ARES was not significantly different from zero at the 5 percent level.
The size of a state's rural population relative to its total population is never a significant explanatory variable.

One approach was to count only memberships in marketing co-ops. Another approach was to use volume of business, excluding interco-operative purchases and sales.
REFERENCES


U.S. Department of Agriculture, Cooperative State Research Service. Funds for Research at State Agricultural Experiment Stations and Other State Institutions, Washington, various years.


