An Analysis of Experiment Station Funding Decisions

Fred C. White and A. A. Araji

The decision-making process by which academic departments within an experiment station allocate funds among commodities is examined. The decision to conduct research on some commodities and not on others introduces a problem of censored dependent variables. In order to overcome this problem, a simultaneous equations model with selectivity was used; it was applied to data from the Idaho Experiment Station. The results indicated a simultaneous relationship between research funding levels and expected benefits. Marginal products of one dollar in research investment were $53.80 for applied research, $33.60 for basic research, and $8.49 for maintenance research.

Key words: applied research, basic research, maintenance research, marginal product of research, and two-stage probit.

The principal objective of the state agricultural experiment station, as mandated by the Hatch Act of 1887, is to address the location-specific problems of farmers and to build a core of basic scientific knowledge related to agriculture (Kerr). With respect to the underlying conflict between applied and basic research, the Hatch Act clearly favored finding solutions to farmers' immediate problems through applied research. The conflict over the appropriate mix of applied and basic research in experiment stations has mounted in recent years with such developments as biotechnology. The focus of experiment station research also has broadened to account for numerous other issues, including environmental quality, health, and safety of the food supply (Schweikhardt and Bonnen). Hence the role of the state agricultural experiment station has expanded considerably since the signing of the Hatch Act.

Previous research efforts in agricultural economics which have analyzed agricultural research decisions can be categorized into three broad groups. First, several attempts have been made at developing frameworks for setting research priorities within institutions (Brazzel; Fishel). These efforts may augment *ex ante* measurements of benefits with other areas of interest. Second, numerous efforts have been directed at measuring the benefits of agricultural research in *ex post* analysis, primarily through a production function approach (Ruttan 1980). These efforts do not directly consider research allocation decisions. Third, a few studies have analyzed the factors contributing to the allocation of research funds without explicitly considering benefits of research (Huffman and Miranowski). This study bridges these various approaches by analyzing a research allocation process while explicitly accounting for *ex ante* estimates of research benefits.

The objective of this study is to examine the allocation of research funding within an agricultural experiment station. More specifically, the article develops a theoretical economic model explaining the relationship between research funding and research benefits, identifying the exogenous factors likely to influence these variables. Then the economic model is applied to experiment station data as a case study.

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A Model of Research Allocation Decisions

Explaining the relationship between research benefits and research funding is similar to the one addressed by Tobin's model in which a consumer durable is purchased if the consumer's desire is high enough. The consumer's desire, which can be thought of as an indicator function, is measured by the amount spent on the durable good. However, no measure of the desire is obtained if no purchase is made. In this study the socioeconomic-political pressures, both inside and outside the experiment station, calling for research on a particular commodity can be thought of as an unobserved indicator function which is reflected by the level of research expenditures on that commodity. On the other hand, no measure of these socioeconomic-political pressures is obtained when no expenditures are made.

It is recognized that each discipline within an experiment station may conduct research on only a few of the commodities being produced in the state. Benefits from research activities are expected to accrue only for those commodities for which research funding has been allocated. Some benefits for other commodities might have accrued if research related to these commodities had been conducted. However, the decision not to allocate research expenditures for some commodities is based on socioeconomic-political factors. For example, the expected benefits for some commodities might be less than expected costs of research. Hence the simultaneous relationship between research benefits and research expenditures involves a censored dependent variable.

The research allocation model contains two regimes described by a set of simultaneous equations:

$$
(1)\quad \left.\begin{aligned} RB &= \alpha_1 RE + \beta_1{}'X_1 + \mu_1 \\ RE &= \alpha_2 RB + \beta_2{}'X_2 + \mu_1 \end{aligned}\right\} \text{ if } I^* = \gamma' Z + \epsilon > 0,
$$

and

$$
\left.\begin{aligned} RB &= 0 \\ RE &= 0 \end{aligned}\right\} \text{ otherwise.}
$$

RB is present value of expected research benefits; *RE* is research expenditures; X_1, X_2, and Z are (possibly overlapping) sets of exogenous variables; I^* is an unobserved indicator function; α, β, and γ are matrices of coefficients; and μ and ϵ are random residuals having a multivariate normal distribution.

Although I^* is unobserved, it is possible to characterize commodities into those with research funding and those without funding. The dummy variable I has a value of one when research expenditures exist and zero when they do not exist. $I = 1$ if $I^* > 0$, $I = 0$ otherwise. The observed dummy variable I can be used to estimate γ by the probit method. The model thus becomes a simultaneous equations model with the selectivity criterion of the probit type. Other researchers who have used similar models for different problems include Roberts, Maddala, and Enholm and Kenny et al.

The research allocation model is appropriate for commodity-specific research conducted by the various disciplines within an experiment station. The overall model depicted in (1) contains three behavioral relationships. The first of the three equations is a probit model explaining the decision by a disciplinary department to conduct research for a particular commodity. In the broadest sense, we expect this decision is influenced by numerous factors including the relative importance of the commodity, the level of research resources, the personal interests and expertise of the faculty and administration, etc. The relative importance of the commodity, as measured by gross cash receipts, is used to explain the decision whether to invest. The number of scientist-years available within the discipline is used to reflect research resources. We expect that an increase in the number of scientist-years within a discipline would increase the number of commodities being researched. The interest and expertise of the faculty and administration are not observed and hence cannot be considered. The level of investment is dependent upon potential benefits and various other factors identified below.

In the second equation the present value of research benefits is related to the other endogenous variable, the level of research funding, and selected exogenous variables explaining the type of research being conducted. The potential benefits of research depend partially on the value of production for the commodities. A given increase in yield will have a greater impact for an important commodity, as measured in terms of cash receipts, than for a less important commodity. In order to account for this difference the amount of cash receipts for each commodity is used to explain the present value of research benefits. According to Huffman and Miranowski, the research of an experiment station is heavily production oriented, with applied, basic, and maintenance research aimed at increasing output directly or indirectly. Applied, basic, and maintenance research are expected to have differential impacts. In the equation for present value of benefits, applied research and basic research, as percentages of total research expenditures, are used as exogenous variables in explaining how different types of research contribute to benefits. Basic and applied research are compared to maintenance research, which is omitted from the model but implicitly captured in the intercept term.

In the third equation research expenditures are hypothesized to be affected by the characteristics of commodities and disciplines conducting the research. This equation is formulated as a reduced form for supply and demand of research. Hence, there are both supply and demand factors in the equation. The endogenous variable "research expenditures" is hypothesized to be related to the endogenous variable "research benefits." More expenditures are expected to be allocated where benefits are greater. Farm structure has been postulated as influencing the level of public support for agricultural research in several studies (e.g., Huffman and Miranowski). Larger farms are expected to effectively demand higher levels of research funding for those commodities being produced by the large farms (White). Size of farm is used to explain the effect of farm structure on allocating research expenditures. While experiment station research primarily addresses location-specific problems, there is a concern that such research systems may be unduly limited in their capacity to reallocate scientific and financial resources from traditional areas of concern to new areas (Ruttan 1982). In order to test how responsive the experiment station is to changing problems, the growth rate in yields is considered as an exogenous variable in explaining the allocation of research expenditures. The rate of growth in yield reflects the impact of previous research on increasing yield. If a commodity has already experienced a large increase in yield, then less research may be needed in the current period. Thus, past yield increases are hypothesized to have a negative impact on the level of research expenditures allocated to a particular commodity. The cost of conducting research per dollar of benefit may vary by discipline, because either the costs of inputs for crop production versus livestock production, for example, may differ, or the productivity of such different research activities may differ. Since the equation on research expenditures includes the research benefits variable, there is a control for aggregate benefits. However, dummy variables for plant sciences and animal sciences are used to detect if there are significant differences among disciplines in cost per dollar of benefits. Disciplines such as agricultural engineering and biotechnology that apply to both animal and plant sciences are captured in the intercept.

Data

All current research projects in the Idaho Agricultural Experiment Station during 1986–87 were reviewed to determine potential benefits and level of research expenditures for each project. An initial classification by research problem areas was made. Personal interviews of all researchers and extension specialists, including Agricultural Research Service personnel, in the Experiment Station were conducted during fiscal year 1986–87. The interviews were conducted to determine the initiation and termination dates for each research project, the number of scientists involved (full-time equivalent), actual time required to achieve the objective, the probability of research success, the probability and rate of adoption, expected adoption time profile, the magnitude of the commodities affected by each research project, research and extension resources required to implement and maintain the new technology, research and extension resources used to maintain currently applied technology, and costs to farmers for implementing the research results. Information also was obtained on the impact of the implementation of the research results on changes in yield, quality, and cost of production.

For each research project annual expenditures from the initiation of the project through 1986 were determined from Experiment Station records. A 5% annual increase in expenditures for years after 1986 was used to estimate total expenditures for the duration of the project. The benefits to farmers from implementing the research results were estimated under prevailing farming conditions. The collective judgment of the principal investigator, coresearcher, and the extension specialists involved, based on their past experience and familiarities with farming conditions in the areas affected, was used to determine a conservative estimate of the potential benefits to farmers from implementing the research results. In general, only 60% of the benefits under controlled experimental conditions were assumed to be realized under farming conditions.

Research and extension personnel were asked to classify their respective project(s) into maintenance research, applied research, or basic research. Research programs classified as maintenance research included: (*a*) soil conservation research to reduce the loss of top soil; (*b*) economic research to analyze the impact of new technology and price relationships on agricultural sector efficiency and to develop agricultural policies compatible with the relationships; (*c*) pest control research for maintaining present productivity including surveys of insect populations and determination of infestation levels, testing of new pesticides and herbicides to replace chemicals banned or scheduled to be banned by the Environmental Protection Agency, and controlling pests on large acreages of rangeland; and (*d*) research in such areas as cultural practices, disease control on crops and livestock, environmental stress to maintain yield and quality, and information management.

Research programs in the applied area included: (*a*) improvement of conception rates and feed efficiency and reduction of livestock death loss; (*b*) development of a coordinated pest management program that includes selection of resistant varieties and development of biological control methods to reduce reliance on chemicals; (*c*) development of a fertilizer management system that will increase fertilizer use efficiency, improve product quality, and increase yields; (*d*) design of low-cost efficient irrigation systems and improvement of pumping efficiency; (*e*) development of mechanical and biological methods to reduce postharvest loss; (*f*) development of management and marketing information for efficient resource use in the production and marketing of agricultural products; and (*g*) development of high yielding varieties and/or varieties that are resistant to specific pests or environmental stress.

Research programs classified as basic research included: (*a*) development of a gene marking system to link to disease resistance and quality that will provide basic information to plant breeders in the selection of varieties that are resistant to specific viruses or fungi; (*b*) research in gene design, embryo physiology, and growth regulators to provide animal and plant breeders with basic information to select more efficient breeds of animals and breed and select plant varieties that are high yielding, are more vigorous, require less energy, and are resistant to disease and environmental stress; (*c*) bioengineering and biomass conversion research to utilize agricultural waste in the development of protein supplements, polyphenols, and amino acids; and (*d*) identification of hormones that regulate the feeding and egg-laying behaviors of insects and thus the development of effective biological control of various insects on plants and animals.

The probabilities of research success and of adoption of research results differed by project within the areas of maintenance research, applied research, and basic research. The probability of success in maintenance research ranged between 80% and 100% with probability of adoption ranging between 60% and 90%. In the applied area, the probability of research success ranged between 55% and 85% with probability of adoption ranging between 50% and 75%. For basic research, the probability of success ranged between 30% and 55%, and probability of adoption ranged between 50% and 75%.

The *ex ante* model developed by Araji, Sim, and Gardner was used to measure potential benefits from the various research projects. The flow of benefits from each research project was estimated and summed for each function using the following equation:

$$\beta_{jt} = A_{jt}[(\Delta P_{jt} V_t - V_0) - \Delta C_{jt}], \tag{2}$$

where B_{jt} is the benefits accruing to the jth technology in year t, A_{jt} is the expected total production affected by the jth technology in year t, ΔP_{jt} is the expected change in net productivity of the affected crop or livestock due to the jth new technology in year t, V_t is the expected price of each unit of output of the affected crop or livestock in year t; and $V_t = V_0 + V_0(f\Delta P_t)$, where f is the price flexibility of demand or inverse of the price elasticity of demand, V_0 is the price per unit in the base year, ΔC_t is the expected change in production cost of the affected crop or livestock due to the

jth new technology in year t. Farm-level estimates of national price elasticities of demand used in this study were from George and King (pp. 64–66). Using national elasticities assumes that changes in productivity occur throughout the nation simultaneously.

B_{jt} is the maximum benefit that could be obtained from the implementation of the research findings developed by various research projects in the state agricultural experiment station. However, the outcome B_{jt} is uncertain in nature because it depends on the probability of research success, $P(S)$, and probability of adoption, $P(A)$. Thus, the expected flow of benefits from investments in state agricultural experiment station research is estimated by equation (3):

$$E(B_j) = \sum_{t=1}^{n} B_{jt} P(A_t \cap S_t), \tag{3}$$

where n is the number of years for which the technology, j, affects production and cost. The present value of the expected flow of benefits from the investments in experiment station research is obtained by "discounting" the right-hand side of equation (3), using an 8% discount rate. The 1986 production year was used as the base year to calculate changes in productivity and costs resulting from the implementation of research results. The 1983–86 average price received by farmers was used to calculate the flow of benefits.

There are 17 commodities and seven disciplines involved in experiment station research at Idaho. The estimated present values of the expected flow of benefits and the research expenditures were classified by different commodities and different disciplines. The expected research benefits for a given commodity were summed over all projects within a given discipline. Likewise, research expenditures for a given commodity were summed over all projects within a given discipline. This process was repeated for applied research, basic research, and maintenance research, as well as for the total of these three categories. With seven disciplines and 17 commodities, there was a potential of 119 observations. However, no observation was considered in which animal disciplines researched plants nor plant disciplines researched animals. Hence, there were 85 observations for the probit model with 56 nonzero values for research expenditures.

Other variables associated with commodities used in the model were obtained as follows. Growth rate in yield was obtained by calculating the average annual growth rate in yield of each commodity for Idaho only between 1970/72 to 1983/85. Farm size was calculated as cash receipts divided by number of farms for each specific commodity. These data were found in *Idaho Agricultural Statistics 1988* (U.S. Department of Agriculture) and *Census of Agriculture 1987* (U.S. Department of Commerce). Two dummy variables were created to identify whether or not disciplines affect the distribution of research expenditures. The selected disciplines considered were plant science and animal science.

The models were estimated in a log-log form by taking logarithms of all variables with only positive values. This excluded the dummy variables; the growth in yield variables, which had some negative values; applied research as a percentage of total research; and basic research as a percentage of total research. The reason for using a log-log model was to obtain marginal products of research as in other studies (e.g., Bredahl and Peterson).

Estimation Procedure

Lee, Maddala, and Trost report estimation procedures for simultaneous equations models with selectivity. The procedure is described briefly here. Consider the reduced-form model for the first endogenous variable:

$$y_{1t} = \pi_{1t} X^*_{1t} + v_{1t}, \tag{4}$$

where y is the endogenous variable, π is a matrix of coefficients, X^* is a set of exogenous variables, and v is the error term. A problem occurs because

$$E(v_{1t} \mid I > 0) = -\sigma_{1t}\phi_1/\Phi_1,$$

where $\phi = f(\gamma' Z)$ from the probit model is the standard normal density and $\Phi = F(\gamma' Z)$ from the probit model is the cumulative normal density. Using results from the probit model, the reduced-form model can be rewritten as

$$y_{1t} = \pi_{1t} X^*_{1t} - \sigma_{1t}\phi_1/\Phi_1 + \eta_{1t}, \tag{5}$$

where η is an error term. This reduced-form model can be estimated by least squares.

The estimated procedures for the structural parameters also must account for the fact that the expected value of the original model's error term is not zero. The first structural equation can be written as:

$$(6)\qquad y_{1t} = \beta_{12}y_{2t} + \ldots + \beta_{1m}y_{mt} + \gamma_{11}X_{1t} - \sigma_{1t}\phi_1/\Phi_1 + \xi_{1t},$$

where ξ is an error term. This equation can be estimated with an instrumental variables method by using predicted values from equation (5). Let $\epsilon_1 = -\sigma_{1t}\phi_1/\Phi_1 + \xi_{1t}$.

The two-stage least squares estimator of the parameters in (5) can be written as:

$$(7)\qquad \hat{\Theta} = (W_1^{*\prime}W_1^*)^{-1}W_1^{*\prime}y_1,$$

where

$$\Theta' = [\beta_{12}, \ldots \beta_{1m}, \gamma_{11}, \sigma_{\epsilon_1\epsilon}],$$
$$\sigma_{\epsilon_1\epsilon} = \mathrm{cov}(\epsilon_{\epsilon_1,\epsilon}), \text{ and}$$
$$W_1^* = [\hat{y}_2, \hat{y}_3, \ldots \hat{y}_m, Z_1, -\hat{\phi}/\hat{\Phi}].$$

The asymptotic covariance matrix is

$$(8)\qquad \begin{aligned} \mathrm{var}(\hat{\Theta}) = {} & \sigma_{\epsilon_1}^2(W_1^{*\prime}W_1^*)^{-1} \\ & - \sigma_{\epsilon_1\epsilon}{}^2(W_1^{*\prime}W_1^*)^{-1}W_1^{*\prime} \\ & \cdot(A - AX_1(X'\Lambda X)^{-1}X_1'A) \\ & \cdot W_1^*(W_1^{*\prime}W_1^*)^{-1}, \end{aligned}$$

where

$$\Lambda = \mathrm{diag.}[\phi_1{}^2/\Phi_1(1 - \Phi)],$$
$$A = \mathrm{diag.}[Z_1'\delta(\phi_1/\Phi_1) + (\phi_1/\Phi_1)^2], \text{ and}$$
$$\sigma_{\epsilon_1}^2 = \mathrm{var}(\epsilon_1).$$

Empirical Model and Estimation Results

The empirical model is:

$$(9)\qquad I = f(CR, SMY),$$

$$(10)\qquad RB = f(RE, AR, BR, CR), \text{ and}$$

$$(11)\qquad RE = f(RB, YIELD, SIZE, DA, DP, CR),$$

where *RB* is the present value of benefits (logarithm) for research conducted by a discipline on a particular commodity; *RE* represents the research expenditures (logarithm) by a discipline for a particular commodity, $I = 1$ if $RE > \$0$ and 0 otherwise; *AR* represents applied research as a percentage of total research expenditures by a discipline for a particular commodity; *BR* denotes basic research as a percentage of total research expenditures by a discipline for a particular commodity; *CR* equals state-level cash receipts for the particular commodity; *YIELD* is the growth rate in yield of the particular commodity; *SIZE* represents cash receipts from the particular commodity per farm; *DA* is the dummy variable for animal sciences conducting research on the particular commodity; and *DP* is the dummy variable for plant sciences conducting research on the particular commodity.

Regression results for two approaches—two-stage least squares and two-stage probit—are reported in table 1. While the two-stage least squares procedure does not take into consideration whether research ought to be conducted on a particular commodity, these results are presented for comparison purposes. Unlike the two-stage least squares procedure, the two-stage probit procedure takes into account the decision of whether or not to conduct research on a particular commodity.

The probit model is statistically significant at the 1% level, having an *F*-statistic of 11.83 with two and 82 degrees of freedom. Both cash receipts and scientist-years have positive coefficients in the probit equation. Although these findings were expected, they have significance for statistical estimation of the rest of the model. In particular, these findings indicate that the two-stage probit model is appropriate rather than the two-stage least squares model. Comparison of the results from the two models is useful for determining potential bias from failure to correct the data for selectivity.

In equation (10) of the two-stage probit model the present value of research benefits is significantly affected by research expenditures, as hypothesized. With log-log models, the coefficients are elasticities, but marginal products can be calculated by multiplying the elasticity by the ratio of average present value of benefits to average research expenditures. The two-stage probit coefficient of research expenditures indicates that each dollar investment in research generates \$8.49 in benefits. In comparison, the two-stage least squares estimate indicates that each dollar of investment in research generates \$4.95 in benefits. Relative to the probit model, the two-stage least squares procedure underestimates the benefits from research by \$3.54 or 42%. These empirical estimates are similar in magnitude to previous estimates. Griliches estimated the marginal product of agricultural research and extension to be \$13. Bredahl and Peterson estimated the marginal products for various commodities as: \$14.09 for cash grains, \$19.58 for poultry, \$25.93 for dairy, and \$41.76 for livestock. Lyu, White, and Lu estimated the marginal product of research for the Mountain Region to be \$12.45.

As expected, the present value of research benefits has a positive and statistically significant influence on the level of research expen-

Table 1. Regression Results Explaining Research Benefits and Expenditures

	Variables[a]	Means	Two-Stage Least Squares[b]	Two-Stage Probit[b]
(9)	Probit Model with the Dependent Variable Expenditures Equal to 1 if Research >$0 and 0 Otherwise	0.659		
	Intercept	1.000	n.a.	−1.340 (1.035)
	Cash Receipts (logarithm)	10.631	n.a.	0.130 (0.095)
	Scientist-years (logarithm)	0.917	n.a.	0.495** (0.121)
(10)	Dependent Variable: Present Value of Benefits (logarithm)	7.294		
	Intercept	1.000	−3.445 (2.503)	−1.099 (0.763)
	Research Expenditures (logarithm)	4.579	0.328 (0.433)	0.562** (0.087)
	Applied Research Expenditures as a Percentage of Total Research Expenditures	25.408	0.054** (0.022)	0.035** (0.005)
	Basic Research Expenditures as a Percentage of Total Research Expenditures	31.263	0.031** (0.012)	0.022** (0.004)
	Cash Receipts (logarithm)	10.746	0.643* (0.328)	0.445** (0.080)
	$-\hat{\phi}/\hat{\Phi}$[c]	0.445	n.a.	−1.190** (0.466)
(11)	Dependent Variable: Research Expenditures (logarithm)	4.579		
	Intercept	1.000	−2.328** (0.528)	−1.788** (0.556)
	Present Value of Benefits (logarithm)	7.294	0.674** (0.033)	0.616** (0.036)
	Farm Size (logarithm)	3.691	−0.031 (0.066)	−0.023 (0.064)
	Growth Rate in Yield	0.582	−0.218 (0.144)	−0.245* (0.140)
	Animal Science Dummy	0.071	0.093 (0.276)	0.203 (0.270)
	Plant Science Dummy	0.500	0.622** (0.144)	0.544** (0.143)
	Cash Receipts (logarithm)	10.746	0.178** (0.054)	0.201** (0.050)
	Lambda	0.445	n.a.	−0.774** (0.330)

[a] (9), (10), and (11) refer to the equations so numbered in the text.
[b] Numbers in parentheses are standard errors.
[c] The correction factor from the probit model includes $\hat{\phi}$, the standard normal density, and $\hat{\Phi}$, the cumulative normal density.
Note: Single asterisk indicates significant at .10 level; double asterisk indicates significant at .05 level.

ditures [equation (11), table 1]. The marginal effects of research benefits on research expenditures can be measured by multiplying the elasticity coefficients in equation (11) by the ratio of average benefits to average research expenditures. From the two-stage probit model, each dollar of expected benefits accounts for an additional 4.1¢ of research expenditures. In comparison, the two-stage least squares estimate indicates each dollar of expected benefits accounts for an additional 4.5¢ of research expenditures. The two-stage least squares procedures overestimates the effect of research benefits relative to the probit results by .4¢ or 9%.

Other results from the two-stage probit model indicate the following. The differences in benefits from applied, basic, and maintenance research are statistically significant. Applied research yields the greatest returns followed by basic and then maintenance research. Marginal products of research expenditures are \$53.80 for applied research, \$33.60 for basic research, and \$8.49 for maintenance research. Also, the differences in research costs for animal and plant sciences are statistically significant, with plant science research more costly than animal science research. Cash receipts and growth rate in yields are statistically significant. The farm size variable is not statistically significant, indicating that experiment station allocation decisions are not influenced by concentration of production and hence farm structure.

Conclusions

The decision-making processes by which disciplinary departments within an experiment station allocate research funds were examined. A model was developed to account for the fact that departments conduct research only on a limited number of commodities at a time. Such an approach is reasonable considering that funding and number of faculty are limited.

The decision to conduct research on some commodities and not on others introduces a problem of censored dependent variables. In order to overcome this problem a simultaneous equations model with selectivity was proposed. The model was estimated with a two-stage probit procedure. These results were compared to those from two-stage least squares to measure the degree of bias that could arise from failure to account for selectivity. The bias appeared to be important, ranging from 9% to 42% for the major variables in this study.

Marginal products of one dollar in research investment were \$53.80 for applied research, \$33.60 for basic research, and \$8.49 for maintenance research. Each dollar of research benefits accounted for 4.1¢ of research expenditures. There were statistically significant differences between the returns to applied and basic research, with the returns higher for applied than basic in this instance. Returns for both applied and basic research were statistically higher than the returns to maintenance research.

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