BIOTECHNOLOGY AND THE LAND-GRANT UNIVERSITY: THE EVIDENCE FROM SAMPLE SURVEYS

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Introduction

As a number of state and local governments seek ways to expand their economic base, high technology, including biotechnology, has taken on increased importance in the minds of policy-makers and elected officials as ways to produce major and long-lasting improvements to the industrial and service sectors. Aaron S. Gurwitz has referred to "the new faith in high tech," which, to him, is a "fad fraught with major problems (Gurwitz, 1982).

In contrast to Gurwitz's skepticism about the future of high technology as an engine of economic development, Brewster Denny (Denny, 1982) sees the possibility that competition among states and municipal governments for high-tech industry will produce social benefits from attempts to lure such industries through the adoption of policies which encourage public and private investments in education and research, tax structures that reward research and development (R & D), and taxing consumption and after-profits income. He foresees advances in urban and rural infrastructure, corporate philanthropy, and cooperation among the public, private, and nonprofit sectors on many fronts, particularly in labor relations. Denny also envisions competition among states and municipalities for high-tech industry as ensuring the competitiveness of the United States in international markets through encouraging regional diversification and specialization in different aspects of high technology.

A case study (Dorfman, 1983) of the emergence of Boston's "Route 128" center for high technology, however, found that the development of this regional high technology economy was largely indigenous and spontaneous, and did not result from strenuous efforts to attract industry to the Boston area. Dorfman attributes the Route 128 phenomenon to proximity to the area's universities and their research laboratories, a strong existing technological infrastructure, positive externalities from the co-location of related high-tech firms, and the previous success of local minicomputer manufacturers (notably Digital Electronic Corporation). Other researchers (e.g. Klausner and Van Brunt, 1987; Trewhitt, 1985) have assessed various regions' or cities' likelihood of joining the front ranks of biotechnology research centers.

In the rush to bring in high-technology industries, leaders of the dominant companies have a major role to play in concert with government officials and with universities that place a heavy emphasis on technology-relevant research. Hagstrom (1982) reports, though, that the successful communication of high-tech industry needs to elected officials often is difficult because political authorities, who are ready and willing to offer assistance, commonly fail to understand the complexities of this emerging sector of the economy, particularly its demands for engineering talent, capital, and entrepreneurial effort.

An assessment by the U.S. Bureau of Labor Statistics (Riche, Hecker, and Burgan, 1983) suggests that the common arguments by elected officials that high technology will generate large numbers of high-quality new jobs may be misleading. The study found that high-technology industries accounted for a relatively small proportion of all new jobs created nationally from 1972-1982, with 60% of high-technology jobs concentrated in the most populous states, and that high-technology industries will account for only a small proportion of new jobs created through 1995. Nonetheless, the common perception that high-technology industry is a solution to unemployment generally and manufacturing-sector unemployment in particular is widely shared. This equation of jobs with high-technology commonly involves the promotion by major universities of economic growth and development through selectively encouraging research in relevant areas of science and technology. Examples of this include Stanford in California and the Massachusetts Institute of Technology. Other states tend to encourage closer university-industry relationships (commonly abbreviated as UIR's) when economic conditions or expectations dictate the political need to become active in job creation (e.g., Abelson, 1983). David (1983: 28) argues that "the nation's fine research universities are still largely untapped as an element for innovation despite increasing connections between industry and the universities" and that "[i]ndustry can lend new life to at least some university research by sponsoring work related to corporate objectives by encouraging creativity by avoiding the bureaucratic impediments of government funding." Thus, one view, which we take to be widely shared by many in both industry and academia (if not by many in government, as well) holds that universities are indispensable to the success of high-technology endeavors, that research universities can and should do more to promote economic development, and that universities, in turn, will benefit at least in some of their research endeavors from both the infusion of industry's resources and the lack of bureaucratic red tape.

Fusfeld (1980), however, argues that "[u]niversity-industry relations in science and technology have long been characterized by curious mixtures of respect and condescension, of affection and irritation, of strong mutual interactions and barriers, planned or philosophical." These interactions, he goes on, are essential to the hope for continued future progress in science and technology. Fusfeld attributes the post-World War II break in the university-industry research network to massive federal government funding for research. He finds that the "bridge" between industry and the universities was reopened in the early 1970's as federal support began to slow and to become more narrowly focused. Abelson (1986) notes the expanded role of state governments in promoting UIR's. Abelson notes that common features of state activities in high-tech promotion include research parks located in proximity to universities, incubator facilities on or near campuses, start-up support for companies, encouragement of faculty entrepreneurship, joint research centers, and extension services provided to larger numbers of companies.

In this respect, it is particularly instructive to realize that colleges and universities, combined with state and local government, account for only about 3% of the more than $100 billion spent nationally on research and development (Lindsey, 1985). However, universities, which conduct about 10% of the nation's R & D, receive nearly two-thirds of their R & D funding from the federal government and about 5% from industry. Thus, there is a large role to be filled by both industry and state governments in encouraging university R & D work. Lindsey (1985) proposes various mechanisms, modelled after the experience of North Carolina, by which states can encourage this activity. He concludes that "[t]he common feature of state efforts should be the identification and removal of public barriers and disincentives to industry/university cooperation and technological innovation; and the creation of incentives." State governments' interest in the R & D capacity of academia is easily understood by considering that roughly two-thirds of the Ph.D.-granting research universities are public institutions supported by state and local governments, and that many of the private research universities also receive some form of state support (Lindsey, 1985).

The context for considering the role of state support for research in various aspects of high technology is clear. This paper presents a portion of an extended case study in the state of Iowa of funding for research in biotechnology. We report in particular on the results and some potential implications from statewide, local, and national surveys related to the biotechnology emphasis at Iowa State University. The structure and purpose of these surveys are discussed in the context of other recent survey findings dealing with the impacts of research in biotechnology, particularly in university settings. We then present selected results from some of our core items addressed to six target groups, and employ analysis of variance methods to explore these results. Finally, the findings from a path analysis, designed to explain some of the complex perceptions regarding research in biotechnology that are held by university administrators and biotechnology corporation respondents (primarily chief executive officers and directors of research), are presented and some tentative conclusions are drawn.

The Sampling Plan

In 1985, the Iowa state legislature made a commitment to channel $17 million dollars from the state's lottery proceeds into research on agricultural biotechnology at Iowa State University, with emphasis on molecular biology. In response to a legislative provision in the funding legislation, a Bioethics Committee was established. One function of the Bioethics Committee is to look into the possible impacts on the university of this major funding for research in biotechnology.

To further the goal of evaluating the internal dynamics of biotechnology funding, surveys were mailed to what were perceived as major relevant internal and external constituent groups. The surveyed groups internal to Iowa State University included: (1) a near-saturation sample of faculty members who were listed in the then-current university Biotechnology Faculty Directory of faculty who were actively involved in biotechnology research, omitting departmental chairs and a few others; (2) a roughly one-in-seven systematic random sample of non-biotechnology faculty members; (3) a roughly one-in-ten systematic random sample of graduate students, selected without regard to their involvement in biotechnology research; and (4) a near-saturation sample of all university administrators with the rank of department executive officer (or equivalent) through the vice presidential level. A companion survey was distributed to a saturation sample of all known biotechnology companies in the United States, as listed by the Genetic Engineering News. In addition, survey data dealing with perceptions among a large random sample of Iowa farm operators were made available through the Iowa Farm and Rural Life Poll, conducted through the College of Agriculture and the Department of Sociology by Paul Lasley. The annual Farm and Rural Life Poll is based on a sample constructed as a rolling panel design by the Iowa Department of Agriculture and Land Stewardship.

Although the results for our academic respondents are drawn from a single university, Iowa State University is sufficiently similar in scope and mission to other land-grant universities in the nation that the attitudes measured by our internal surveys are quite likely to be representative of those that might be found at comparable academic institutions. Similarly, although the Iowa farm operators' survey is limited to one state and to one occupational group, theirs is a very appropriate set of perceptions to address since the farm sector is likely to feel the greatest effect from the work in agricultural biotechnology undertaken both at universities and in industry. In addition, there is no obvious reason why Iowa's farm operators would necessarily have markedly different attitudes toward biotechnology than would farm operators in the nation as a whole.

Results of the Sample Surveys

Sample sizes and response rates varied, with the response rate highest among university administrators and lowest among biotechnology companies and graduate students. These results are presented in Table 1. The sample sizes shown here represent the number of useable responses returned to the investigators.

Topics addressed in the surveys included: a) the likely impacts of biotechnology on U.S. agriculture; b) university participation in biotechnology research; c) the role of research parks; d) university relations with biotechnology companies, with regard to patents, contracts, and the like; e) the use of lottery funds and the benefits of that funding; f) effects of the biotechnology research emphasis on the university environment, regarding salaries, teaching, and the like; g) barriers to cooperative research between industries and universities, and ways in which those barriers might be reduced; and h) relevant sociodemographic and professional background data.

Each of these sets of items was asked of various groups of respondents, although the questionnaires contained some differences in item wording and some questionnaires (for farm operators, and for university administrators and biotechnology company respondents) differed from those administered to biotechnology faculty, non-biotechnology faculty, and graduate students within the university.

A group of five common-core questions pertained to possible effects on university research agendas which might occur from the push for biotechnology applications. This set of five items addresses the sometimes uneasy research partnership among universities, industry, and government which is at the heart of many proposals for economic development, as noted in the Introduction above.

Each of the five items presented in Table 2 was structured as a traditional Likert five-point, fixed-response question. The choices provided for responses to each question were: "strongly agree" (coded as "1"), "agree" (coded as "2"), "uncertain" (coded as "3"), "disagree" (coded as "4"), and "strongly disagree" (coded as "5"). Table 2 shows the wording of each of these five items, together with the sample mean score averaged over all response values as coded above, the sample standard deviation of the responses (s), and the number of valid responses (n) for each item. A larger mean value corresponds to a greater tendency on average to disagree with a statement, and a smaller mean value indicates that respondents on average were more likely to be in agreement with a statement. Larger standard deviations, of course, demonstrate a greater degree of dispersion among the responses to a particular item.

Results of these items have been discussed previously (Shelley, Reichel, Woodman, and Lasley, 1988; see also Woodman, Reichel, and Shelley, 1988). A brief overview of the data in Table 2 reveals that some systematic differences in response structures exist between university respondents and non-university groups, and that the various university respondents' attitudes are relatively similar to each other. The consensus among academic respondents to the surveys includes agreement that it is all right to work closely with industry, that scientists should determine the direction of university research, that universities should market patent rights, and that private consulting by faculty should not be curtailed. On the contrary, research directed by scientists is opposed by both farm operators and biotechnology company respondents, both of whom also resist university control of patent rights. In addition, farmers are more inclined to favor limits on consulting and to favor increased public funding for developing new agricultural commodities.

A systematic test of these response differences is provided by a series of one-way completely randomized analysis of variance models (one for each of the five items in Table 2) of the general form

$$Y_{i,j} = \mu + \alpha_i + \varepsilon_{i,j}$$

where Y_{ij} represents the attitudinal response to each survey item, μ is the mean, α_i denotes the different respondent groups, and ε_{ij} is the random error term which is assumed to have zero mean and constant variance. Comparison of means is made by Scheffe's S procedure (Kirk, 1982). The results of these analyses are summarized in Table 3, where the low attained significance levels (p-values) for all five models demonstrate that significant differences exist among the mean levels of responses from some combination(s) of the six respondent groups. Significant pairwise differences were detected by the Scheffe procedure for all except the PUBFUNDS model. The pairwise differences that are detected in these models almost invariably reflect significantly different mean response levels for one or more of the academic respondent groups as compared to the biotechnology company or farm operator respondents. One exception to this generalization involves the model for PROBLEMS, in which the biotechnology faculty responses are significantly different from those for the graduate students.

Some Extensions of the Findings

One area of particular interest for this research is the extent to which the biotechnology corporation respondents and responding university administrators had overlapping perceptions regarding cooperative research arrangements between industries and universities. The method of principal components was applied to a wide range of survey items common to those two respondent groups, followed by varimax rotation of the extracted factors (see, e.g., Harman, 1976). These results are available in detail in Reichel (1988). Reliability of the resulting scales was evaluated by Cronbach's alpha (Cronbach, 1951). The six scales which were thus created (see Table 4) were then used as the variables in a path model. The path coefficients for these composite variables are given in Table 5, with the corresponding path diagram shown in Figure 1.

All paths but the one between X2 and X5 are statistically significant. New university policy directions regarding cooperative research (X6), then, are related directly to the presence of a high degree of consensus on the direction of university participation in biotechnology research (X2) and to the existence of strong university-based approaches to reduce impediments to cooperative research (X5). An indirect path connects consensus (X2) to new policy directions (X6) through university-based approaches (X5). Other indirect paths relate new policy directions (X6) to likely production-related impacts of biotechnology on U.S. agriculture (X1) through consensus (X2) and through both consensus (X2) and university-based approaches to reduce impediments (X5).

References

Abelson, Philip H. (1986). Evolving State-University-Industry Relations. Science 231 (24 January): 317.

Abelson, Philip H. (1983). High-Technology Jobs. Science 219 (21 January): 243.

Cronbach, L. J. (1951). Coefficient Alpha and the Internal Structure of Tests. Psychometrika 16: 297-334.

David, Edward E., Jr. (1983). High Tech and the Economy: What Does It All Mean? Research Management (September/October): 27-28, 30.

Denny, Brewster C. (1982). The High-Technology Fix. Science 217 (27 August): 781.

Dorfman, Nancy S. Route 128: The Development of a Regional High Technology Economy. Research Policy 12: 299-316.

Fusfeld, Herbert I. (1980). The Bridge Between University and Industry. Science 209 (11 July): 221.

Gurwitz, Aaron S. (1982). The New Faith in High Tech. The Wall Street Journal October 27: 32.

Hagstrom, Jerry (1982). High-Tech Leaders Have Their Own Ideas Of What Government Can Do for Them. National Journal May 15: 861-865.

Harman, Harry H. Modern Factor Analysis, third edition revised. Chicago: The University of Chicago Press, 1976.

Klausner, Arthur and Jennifer Van Brunt (1987). Regional Development: Striving for an Edge. Bio/Technology 5 (February): 134-136.

Lindsey, Quentin W. (1985). Industry/University Research Cooperation: The State Government Role. SRA Journal (Fall): 85-90.

Reichel, Brian J. (1988). Public Policy and University-industry Research Relationships in Biotechnology: Organizational Kudos and Caveats. Unpublished Master's thesis, Iowa State University.

Riche, Richard W., Daniel E. Hecker, and John U. Burgan (1983). High Technology Today and Tomorrow: A Small Slice of the Employment Pie. Monthly Labor Review (November): 50-58.

Shelley, Mack C., II, Brian J. Reichel, William F. Woodman, and Paul Lasley (1988). "Perceptions of the Role of University Research in Biotechnology: Town, Gown, and Industry." In Proceedings of the 1987 Iowa State University Agricultural Bioethics Symposium. Ames, Iowa: Iowa State University Press.

Trewhitt, Jeff (1985). U. S. Midwest Makes Pitch for Biotech-Research Firms. Chemical Engineering (April 15): 27, 29.

Woodman, William F., Brian J. Reichel, and Mack C. Shelley (1988). "University-Industry Relationships in Biotechnology: Convergence and Divergence in Goals and Expectations." In Proceedings of the 1987 Iowa State University Agricultural Bioethics Symposium. Ames, Iowa: Iowa State University Press.

Table 1

Sample Structure for the Biotechnology Surveys

Respondent Group	Valid Responses	Response Rate
Farm Operators	1,930	55%
Biotechnology Companies	130	38%
University Administrators	115	71%
Biotechnology Faculty	137	68%
Non-Biotechnology Faculty	118	47%
Graduate Students	94	38%

Table 2

Summary Descriptive Statistics for Five Biotechnology Survey Items

PRIVATE: Universities should work closely with private businesses and industry, including the agri-business sector.

	Mean	s	n
Biotechnology Faculty	2.254	1.081	134
Other Faculty	2.611	1.191	113
Graduate Students	2.411	1.160	90
Administrators	2.263	1.040	114
Biotechnology Companies	1.686	0.922	121
Farm Operators	2.10	0.91	1,911

PROBLEMS: Scientists, rather than the agri-business community, should determine what types of problems need to be investigated.

	Mean	s	n
Biotechnology Faculty	2.614	1.202	132
Other Faculty	2.726	1.128	113
Graduate Students	3.156	1.235	90
Administrators	2.842	1.110	114
Biotechnology Companies	3.642	1.083	120
Farm Operators	3.48	1.13	1,917

PATENTED: New discoveries by university scientists should be patented by the university and sold to the highest bidder, who would then make these products commercially available.

	Mean	s	n
Biotechnology Faculty	2.432	1.173	132
Other Faculty	2.598	1.035	112
Graduate Students	2.736	1.163	91
Administrators	2.327	0.901	113
Biotechnology Companies	2.958	1.177	120
Farm Operators	3.00	1.42	1,913

CONSULT: The amount of private consulting by university faculty should be curtailed.

	Mean	s	n
Biotechnology Faculty	3.820	1.065	133
Other Faculty	3.616	1.059	112
Graduate Students	3.473	0.993	91
Administrators	3.652	1.052	115
Biotechnology Companies	3.689	1.053	122
Farm Operators	3.07	0.89	1,902

PUBFUNDS: More public funds should be used to support the development of new uses for agricultural commodities.

	Mean	s	n
Biotechnology Faculty	2.149	1.037	134
Other Faculty	2.339	1.027	112
Graduate Students	2.411	0.959	90
Administrators	2.157	1.065	115
Biotechnology Companies	2.213	1.070	122
Farm Operators	2.07	0.97	1,912

Table 3

Summary Results for Completely Randomized Design ANOVA

Dependent Variable	p-value (PR F)	Significant Scheffe Comparison (alpha=.05)
PRIVATE	.0000	5 with 1,2,3,4,6; 6 with 2
PROBLEMS	.0000	1 with 3,5,6,; 2 with 5,6; 4 with 5,6
PATENTED	.0000	1 with 6; 4 with 5,6
CONSULT	.0000	6 with 1,2,3,4,5
PUBFUNDS	.0017	None

Group codes for Significant Scheffe Comparisons:

1 = Biotechnology Faculty
2 = Other Faculty
3 = Graduate Students
4 = Administrators
5 = Biotechnology Companies
6 = Farm Operators

Table 4

Summary of Variables Used in the Path Analysis

Variable	Description
X1	Production-related impacts of biotechnology on U.S. agriculture
X2	Directions of university participation in biotechnology research
X3	Outcomes of university participation in biotechnology research
X4	Industry-based approaches to reducing impediments to cooperative research
X5	University-based approaches to reducing impediments to cooperative research
X6	University policy directions as a result of cooperative research

Table 5

Path Coefficients for Biotechnology Company and University Administrator Respondents Regarding Cooperative Research in Biotechnology

Dependent Variable	Independent Variables	R^2	B	SE B	Beta	T
X2	X1	.10622	.559752	.103948	.325911	5.385*
	(Constant)		6.294978	.998078		6.307
X5	X2	.00446	.032465	.031055	.066778	1.045
	(Constant)		6.870058	.372432		18.446
X4	X5	.01647	.179979	.089028	.128349	2.022**
	(Constant)		7.917207	.659369		12.007
X6	X5	.09495	.183204	.041704	.268696	4.393*
	X2		.044402	.020275	.133949	2.190*
	(Constant)		1.218397	.375432		3.245
X3	X2	.19347	-.266982	.034897	-.439856	-7.651*
	(Constant)		15.041832	.418512		35.941

* Statistically significant paths at p = .01
** Statistically significant paths at p = .05

Figure 1

A Path Model For Biotechnology Company and University Administrator Respondents Regarding Cooperative Research in Biotechnology