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What Drives Academic Bioscientists: Money or Values?

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No examination of the role of GE crops in the sustainability of U.S. agriculture is complete without understanding what drives academic bioscience. The National Research Council's 2010 report on the role of genetically engineered (GE) crops in U.S. farm sustainability underscores not only their successes, but the challenges they now introduce. The challenges include protecting against herbicide resistance, tracking and controlling water pollution, measuring and guarding against gene flow to non-GE varieties, and attending to such potentially public-good issues as climate change mitigation, minor-crop development, and nitrogen fixation. In the shorter term, successes in these areas will depend on commercial trait development and on the farm management practices linked to it. In the longer term, however, it will depend on the drivers influencing academic bioscience, where most fundamental research underlying genetic modification—and much of the translational work bridging the gap between proof-of-concept and product development—begins.

Such drivers increasingly can be understood in supply-and-demand terms because universities increasingly view themselves as suppliers of research deliverables and demanders of research money. On the other side of these two markets, journals, governments, and firms seek research deliverables and public agencies and firms supply research monies. Yet part of the reason most professors work at universities is to pursue noncommercial interests. Predicting academic research directions thus requires we consider professors and administrators as seekers of both monetary resources and professional satisfaction.

Bioscientists' Motives

To capture the personal and commercial aspects of university bioresearch, we consider four of its dimensions: (a) the bioscience discipline—reflected in the scale of the research object, from sub-cellular to entire ecosystem; (b) the position of the research on the basic-to-applied continuum; (c) the potential for patentability or other types of excludability—of the finding; and (d) the interest group served. It is important to ask how the scientist's human and institutional capital, program funding, academic culture, and market environment affect these characteristics and contribute to human welfare.

Funding agencies' research budgets can offer some answers. But the variety of scientific activity hidden in those gross statistics rarely distinguishes among the many issues that research policy makers need to understand. For example, aggregate data don't allow distinguishing between a scientist's willingness to engage in, and an agent's willingness to fund, a particular line of research. Such distinctions are best drawn by examining the individual scientist's behavior.

Social scientists have theorized about, and tested for, what motivates scientists to do what they do. Early analysts argued that institutional influences, such as university structures and cultures, played dominant roles, leaving little discretion to the individual scientist. More recently, scholars have thought of individual scientists as having their own motives and abilities and facing their own constraints in research program development. We draw on both the institution-based and individual-based theories here to examine how academic scientists make decisions about the types of research questions they ask.

Our data for doing so come from a 2003 – 2004 national survey of academic bioscientists who conducted research on molecular or cellular structures with implications for agriculture, forestry, or aquaculture. The scientists identified by their department chairs as conducting such research were drawn from a random sample of 20 Land-Grant, 25 public non-Land-Grant, and 25 private universities. Each researcher was sent an on-line questionnaire asking about their annual budgets by funding source, types of laboratory assistants, grant-based inputs such as equipment and cell lines, university resources, the respondent's bioscience discipline and current main study topic, the basicness and potential excludability of their approach to that topic, academic rank, and intensities of view on a range of professional scientific norms. Sixty-four percent of the 1441 scientists we contacted responded, giving a total sample of 922.

We asked each respondent to indicate the percent of his research portfolio that was basic—adding to fundamental knowledge—and the proportion that was applied—creating a new product or a solution to a problem. We also asked him to estimate the proportion of his research he expected to be nonexcludable in the sense of not being property-right protectable —and hence *not* restrictable to paying parties. The meanings of basic and applied, and nonexcludable and excludable, may vary somewhat across bioscience disciplines. In order to reduce the potential for conflicting interpretations, we provided definitions and examples of these four research characteristics. That respondents showed little evidence of inconsistency is suggested by the fact that when asked to indicate their projects' basicness and excludability on a 6-point Likert-scale, such as "how basic was your research?", their responses were highly correlated with their percent-of-program responses.

Sixty-seven percent of the mean respondent's research portfolio was basic and 33% applied. Eighty-five percent was reported to be nonexcludable and the remaining 15%

excludable. The average current annual laboratory budget was $229,000 from federal and state public sources, 18% of that from the National Science Foundation (NSF), 33% from the National Institutes of Health (NIH), 18% from the U.S. Department of Agriculture (USDA), and 17% from state governments. Nearly $51,000 was derived annually from private sources, 53% of it from industry firms and trade associations and 47% from foundations. Forty-seven percent of the scientists were from Land Grant universities, 35% from public non-Land-Grant universities—such as the University of Texas—and 18% from private universities such as Stanford. Medical school faculty were strongly represented, suggesting a significant overlap between human-health and agricultural biotechnology.

Research Basicness and Excludability

The right mix of basic and applied, and of excludable and nonexcludable, discoveries for addressing GE crop challenges depends on the problem context. We can begin that inquiry however by asking about the *factors* affecting these research program features. Funders use their requests-for-proposals to influence the type of research they seek, for example a study on crop biofuels. On the other hand, every funder serves a variety of interest groups and supports research in a variety of areas. And academics have their own preferences among potential funders. So it is useful to ask how another dollar from a particular money source influences a researcher's objectives. To do that, we must control for factors other than the money the scientist receives. We also must account for his human capital—represented for example by his academic rank, his university culture, and the professional norms that partly guide his research life and choices.

When we do so, we find that the proportions of a bioscientist's program that are basic and nonexcludable are strongly influenced by her professional norms regarding the value of theoretical research, scientific curiosity, patenting, and nonexcludable—public—benefits. Our scale for measuring these norms runs from 1 to 7, increasing numbers reflecting more intense agreement with the norm. The more she says she is constitutionally oriented toward achieving theoretical breakthroughs or indulging her scientific curiosity, the more she engages in basic research. The more she is oriented toward patenting, the more excludable her research turns out to be. The statistical significances of these normative factors were greater than for any of the other factors, such as type of funding source, we considered.

Table 1. Factors Affecting Bioscience Research Basicness and Nonexcludability[a]

Factors	**Basicness and Nonexcludability**	
	Percent Basic	***Percent Nonexcludable***
Research Program Characteristics		
Percent Basic		0.16
Percent Nonexcludable	0.27	
Research Funding		
Public Funding ($1,000)	0.03	-0.01
Private Funding ($1,000)	-0.16	0.03
Scientist's Norms		
Contribute to Theory (1 – 7 scale)	6.60	
Scientific Curiosity (1 – 7 scale)	4.12	
Chance to Patent (1 – 7 scale)		-5.72
Create Nonexcludable Benefits (1 – 5 scale)		1.65

[a] *Numbers are changes in the percent of the scientist's research portfolio that is basic or nonexcludable caused by a one-unit change (shown in parentheses) in the indicated factor.*

The influence of each factor is shown in Table 1. As one would expect, more nonexcludable research programs tend to be more basic, and more basic programs more nonexcludable. But those relationships aren't very strong. Boosting the basic portion of a scientist's portfolio one percentage point boosts the nonexcludable portion by only 0.16 points. This is a potential impact of the Bayh-Dole Act and related court rulings, which have expanded the range of basic scientific innovations that can be patented. The Bayh Dole Act allowed recipients of federal research funding intellectual property control of the inventions and other intellectual property that resulted from such funding.

Neither the source nor amount of the scientist's funding has a statistically significant impact on the proportion of her work she regards as excludable. Public money, in other words, is just as likely to encourage patentable or otherwise market-protectable research as is private money, another likely Bayh-Dole influence. Funding source does, however, affect research basicness. While a $1000 rise in the publicly funded portion of the scientist's portfolio boosts the *basic* content of her research program by only 0.03 percentage points, a $1000 rise in the privately funded portion boosts its *applied* content by 0.16 percentage points. Speeding up GE crop innovations by shifting to more downstream research can be accomplished by allocating more funding to the private sector. This, however, will be effective only if foundational science doesn't suffer too greatly as a result.

Research Basicness and Object Size

The research topics in bioscientists’ laboratories also can be characterized through the sizes of the objects they examine. Because GE crops, such as in Bt cotton, are often produced through manipulation of sub-cellular material, the innovation rates depend directly on the magnitude of laboratory effort at the sub-cellular and cellular levels. Yet the implications of these discoveries, such as the non-target-insect mortality associated with Bt technology or the watershed effects of shifting to more herbicide resistant crops, are understood only at the organism and ecosystem levels. Research at those larger scales therefore provides useful information for future sub-cellular innovation. As it turns out, a research project's object size is only moderately correlated with its basicness. Thus, accounting separately for these two bioscience program features is important for understanding the rate, character, and control of genetically engineered innovations in agriculture.

We asked four academic bioscientists who did not participate in our survey to examine each of our 922 respondents' research topic descriptions and classify each by object size. Thirty-five percent of the topics focused on sub-cellular particles, 11% on cells, 9% on organs, 25% on organisms, 12% on natural ecosystems, and 8% on managed ecosystems. Respondents who said they were biochemists or cell or molecular biologists—60% of our sample—conducted work mostly at the sub-cell or, to a lesser extent, cell or organism level. Pathologists—10% of the sample—were predominantly in organism research, and geneticists—20% of the sample—in sub-cellular or organism research. For simplicity, we here combine sub-cell and cell topics into a "cellular" group, organ and organism into an "organism" group, and natural and managed ecosystems into an "ecosystem" group.

Basicness was measured by asking the scientist to indicate on a six-point scale the degree of basicness of the typical project in his current research portfolio, in contrast to the proportion of her research program used above. We called "basic" any topic with a response in the 1-to-3 range, and "applied" any topic in the 4-to-6 range. Finally, we categorized each topic according to the combination of basicness and object-size it fell into: basic cellular, applied cellular, basic organism, applied organism, basic ecosystem, or applied ecosystem. We used statistical methods to determine how the scientist's human capital and institutional culture, professional norms, and funding sources affected the likelihood she would conduct research that fell into each of these six categories. To our knowledge, this is the first investigation of such relationships.

Influences on Basicness and Object Size

Table 2. Funding-Source Impacts on Research Basicness and Object Size[a]

Funding Source and Type	**Object Size**		
	Cell Level	**Organism Level**	**Ecosystem Level**
USDA			
Basic	-0.14	-0.08	-0.02
Applied	0.22	0.21	0.08
Industry			
Basic	-0.95	-0.14	-0.05
Applied	0.17	0.39	0.12

[a] *Numbers are the changes in the percent of research at the indicated basicness and object size caused by boosting funding from the indicated source by one percentage point, and reducing NSF funding by the same amount. Impacts of NIH and state funding are not shown.*

Table 3. Professional-Norm Impacts on Research Basicness and Object Size[a]

Professional Norm	**Object Size**		
	Cell Level	**Organism Level**	**Ecosystem Level**
Theory Norm			
Basic	5.35	2.19	1.12
Applied	0.29	-2.63	-1.72
Patenting Norm			
Basic	-2.70	-0.95	-0.73
Applied	2.61	2.81	-1.45

[a] *Numbers are the changes in the percent of research at the indicated basicness and object size caused by a one-point rise in the importance of the indicated professional norm. Impacts of NIH and state funding are not shown.*

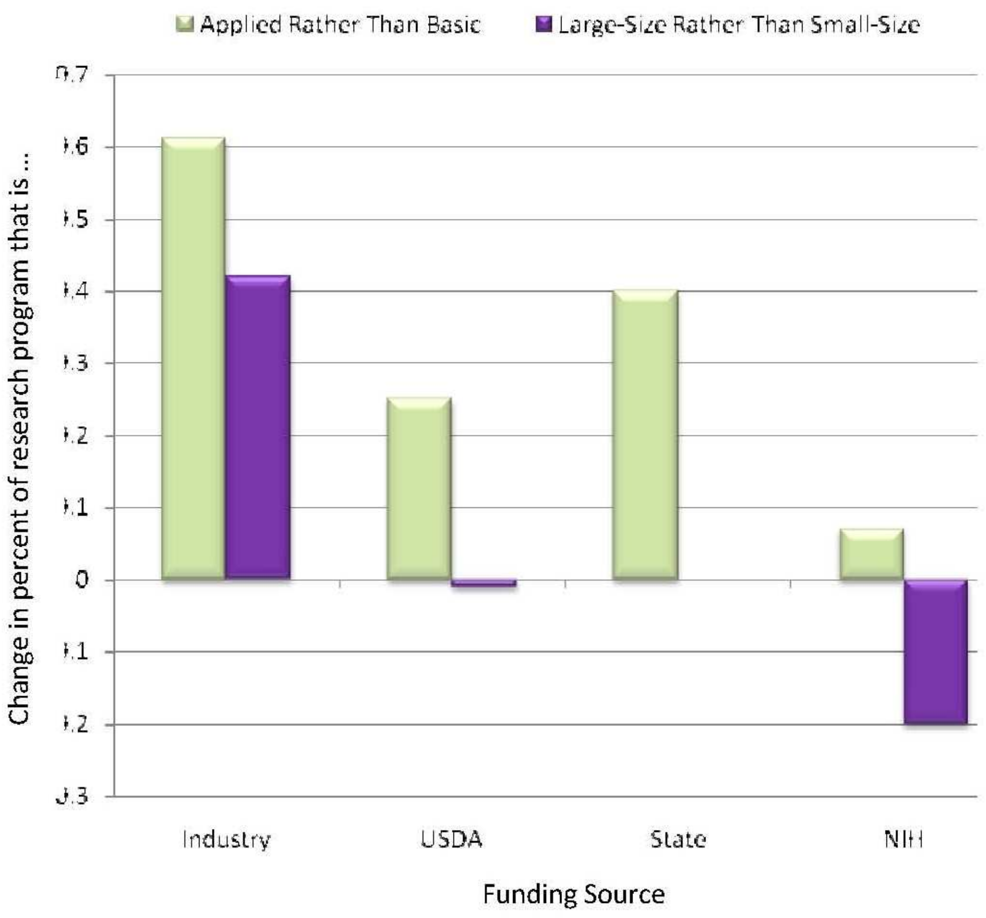
The scientist's rank and university type had, by themselves, little influence on these research choices. But the sources and amounts of her funding, and her professional norms, were important. USDA and industry funding effects are given in Table 2, while patenting-norm and theory-norm impacts are presented in Table 3. The USDA and industry sections of Table 2 show the research-choice effects of boosting USDA or industry funding by one percentage point while reducing NSF funding the same amount. Because NSF is the most basic-research-oriented of the major funders, this reveals the net effect of shifting funding from the most basically inclined to the more application-oriented agencies. For example, boosting USDA funding one percentage point brings a 0.22 percentage-point rise in applied cellular research. Table 3 shows the research-topic impacts of a one-point rise in the scientist's normative orientation toward, respectively, theoretical contributions and patenting. We selected these norms not as a dichotomy but as two topical scientific issues of high relevance to bioscience.

Our findings suggest that routing more GE-crop and other biotechnology funding through biotech firms or the U.S. Department of Agriculture pushes academic bioscientists away from basic and toward applied research at the cell, organism, and ecosystem levels. For example, the -0.95 value in the industry-funding part of the left side of table 2 says shifting one percentage point of the scientist's funding from NSF to biotechnology firms reduces by 0.95 percentage points the likelihood he will conduct basic sub-cell or cellular research. And it will raise by 0.17 points the likelihood he will conduct applied sub-cell or cellular research. However, the larger the research study’s object size, the less does industry funding push it in the applied direction. USDA support creates a similar but more modest inducement toward applied topics. And as with biotech firms, the inducement is lower on the ecosystem than on the cellular side of the object-size continuum.

Table 2 also can be read horizontally to show how industry and USDA funding affect research object size. Shifting one percentage point of the scientist's support from NSF to industry reduces the prospect of basic organism-level research by only 0.14 percentage points but, as noted above, the basic cell-level research by 0.95 points. Thus industry sponsorship leads, comparatively speaking, strongly away from basic sub-cellular and cellular work. And among applied programs, industry leads particularly toward research at the organ and organism levels. USDA sponsorship has the same general effect, albeit at slightly lower magnitudes.

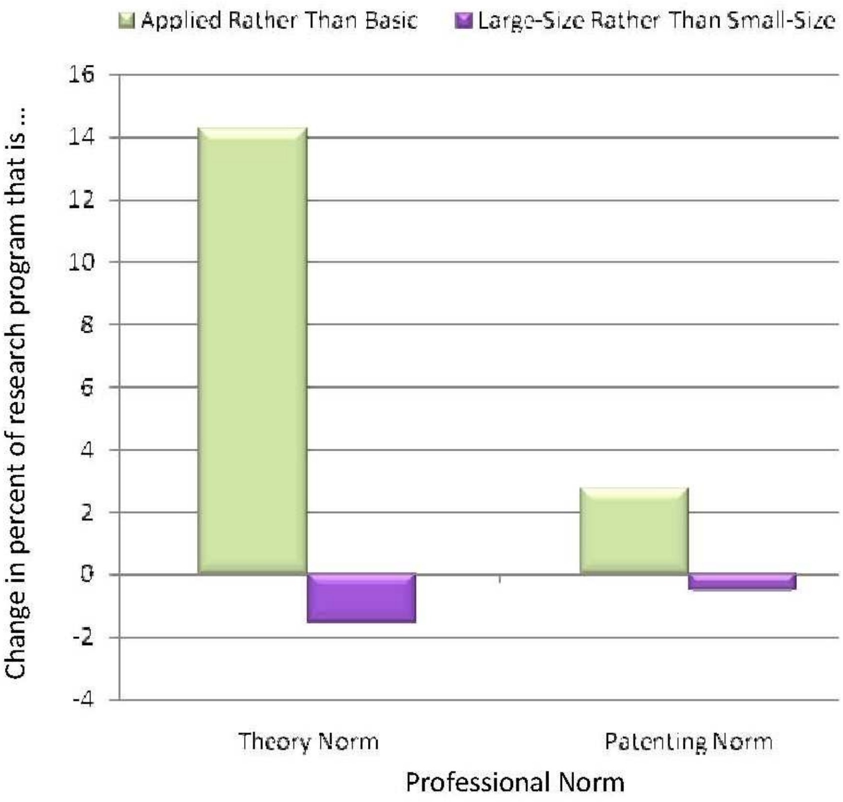
Table 3 shows professional norms exert strong influences on research-topic choice. Examples of their influences: a one point rise in the scientist's theory norm induces a 5.35 percentage point rise in the chance the scientist will be found to conduct basic cellular research, and a 1.12 point rise in the chance she will be found to conduct basic ecosystem studies. A one point rise in the scientist's orientation toward patenting reduces by 2.70 percentage points the likelihood of her conducting basic cellular research and boosts by 2.61 points the likelihood of applied cellular work, resulting in a net 5.35 percentage point net rise in the likelihood she will conduct applied research if she is sub-cellular or cellular scientist. Expressed in proportionate terms, the professional norms examined in this study had on average four times as much research influence as funding sources did.

Among organism scientists, rising patenting orientations create a similar but smaller impulse toward applied topics. At the same time, they induce modest shifts from larger to smaller-scale research, where more opportunities for patenting are found. Scientists oriented more toward theory are more likely to conduct basic research. Interestingly, they are more likely to conduct cell-level research as well. Both a pro-patenting and a pro-theory ethic thus move the scientist toward small-object research, even though the former is in an applied direction and the latter in a basic direction.



a. Positive numbers indicate a net average rise – and negative numbers a net mean decline – in the chance the scientist will conduct applied rather than basic research or large-object rather than small-object research. Figures take into account shifts into and out of organism research.

Figure 1. Net Average Impact of Funding Source on Probability of Conducting Research at the Indicated Basicness and Object Size.[a]



a. Positive numbers indicate a net average rise – and negative numbers a net mean decline – in the chance the scientist will conduct applied rather than basic research or large-object rather than small-object research. Figures take into account shifts into and out of organism research.

Figure 2. Net Average Impact of Indicated Professional Norm on Probability of Conducting Research at the Indicated Basicness and Object Size.[a]

By way of summary, Figure 1 gives each funding source's and Figure 2 the scientist's professional norm's net average impact on research basicness and object size. Positive coefficients indicate a net rise in the chance of encountering an applied rather than basic topic or a large-size, such as an ecosystem, rather than small-size, such as molecular, research object. Among funding sources, state governments and industry create the largest average impulses toward applied and large-object research. Shifting one percentage point of the scientist's funding from the National Science Foundation to biotechnology firms creates a net increase of 0.61

percentage points in the likelihood the scientist will engage in applied research. Industry funding also increases the likelihood he will engage in large-object rather than small-object research. Neither state nor USDA funding has an appreciable net effect on research object size.

Policy Implications

The importance of academic research, particularly at the basic and translational but even the development stages of the genetic engineering process, is so great that any examination of GE's future is incomplete without considering how professors decide what to study. The rate and character of genetic engineering research in agriculture depends on the balance achieved between basic and applied, excludable and nonexcludable, and micro- and macro-object investigation. In universities at least, these characteristics in turn depend on the scientist's human capital and institutional culture, professional norms, and funding sources. Our study strongly suggests professional norms have at least as great an influence as do any of these other factors.

Nevertheless, industry funding pushes academic bioscience research strongly toward the applied end of the research spectrum and toward organism or ecosystem level work. In both respects, industry support thus militates against foundational gene-modification research and toward the organism and ecosystem levels at which that research is applied and controlled. USDA and state funding has, albeit less sharply, the same effect. Taken together, these findings suggest both the private and public sector are effective in encouraging university organism and ecosystem research. Solutions to some GE crop challenges, such as weed resistance and climate change mitigation, thus can be addressed in both sectors, individually or collaboratively. In contrast, aggregate public funding boosts basic and cell-level research only because NSF and NIH push substantially in those directions.

Much has been surmised in the popular literature about money's influence on the direction and content of academic biotechnology research. The concern is justified because money source does affect what academics do. However, the relationships are more complex than often portrayed. Two factors mute the money-effect worries. The first is that professors' academic norms, influenced by their personal interests and the culture in which they work, appear to be more important than funding-agent preferences, militating against undue industry influence in public science. Understanding the factors affecting these norms should thus be a high priority in social science research. The second is that, although the privately sourced share of university funding has risen as a share of total research resources, it remains a small proportion of the total pie. In any event, USDA and state funding have much the same effects as industry. Furthermore, we have found in our analysis that public and private finance tend to compete with one another in the university laboratory, each tending to push the other away. Perhaps the most important trend to watch is the generational rise of the patenting and licensing ethic in U.S. universities (Stuart and Ding 2006), which likely is taking us toward greater commercial control of life-science technologies.

For More Information

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