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Grants, Contracts and the Division of Labor in Academic Research

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CIES DISCUSSION PAPER 0510

Grants, Contracts, and the Division of Labor in Academic Research[1]

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I Introduction

This paper aims to shed light on the division of labor among types of research sponsors and among universities. It interprets data on grants and contracts as conveying information on the sponsors' objectives and on the nature of the sponsored institutions. Building on this idea, the paper investigates some notions that appear to be fairly common: That more prestigious universities tend to rely more on grant funding relative to contract funding; that less prestigious research universities tend to rely more heavily on contracts; that grant (contract) funding tends to be associated with basic (applied) research; and that types of sponsors differ in their use of grants versus contracts, depending on their institutional commitment to knowledge as a public good.

These issues clearly have policy relevance. University administrators and other research policy makers should understand the division of labor among research institutions and the division of preferences among research sponsors. Theoretical and

[1] I am indebted to David Zilberman who, in his capacity as my orals chair, provided the basic idea that got this paper, based on Binenbaum (2002), started. My other oral committee members, Ethan Ligon, Dave Mowery, and Dick Norgaard, as well as my advisor, Brian Wright, also gave good comments. This paper would not have been possible without two separate data sets for which I depended on Joyce Friedman and Neil Maxwell of the Sponsored Projects Office at UC Berkeley, and on Allen Moore and Dennis Unglesbee, CRIS staff members at the USDA. My understanding of these data was also helped by conversations with Cherisa Yarkin of the Office of the President of UC and Kelly Day-Rubinstein of USDA-ERS. Participants at the Australian Economists' Meeting in Adelaide, October 2002, provided insightful discussions.

empirical analysis leading to information and insights about potential competitors, collaborators, and funders, may provide a firmer basis for strategic decisions.

Similarly, the present study should be of interest to scholars of innovation systems. The division of labor among research institutions and the division of preferences among research sponsors are crucial aspects of innovation systems. Furthermore, the distinction between basic and applied research is both problematic and important. The present study proposes (1) to conceive of "basicness" and "appliedness"[2] in bivariate and continuous terms, and (2) to use data on the relative use of contracts and grants for research funding to draw inferences on basicness versus appliedness. These ideas may be useful for future studies of innovation systems, because many data sets – in contrast to the Berkeley data set used here – fail to supply direct information on the basic or applied nature of research. Among existing literature reviewed by me, Goldfarb (2001) comes closest to the theme of the present paper. He postulates that "the majority of US academic research sponsors have utilitarian goals that conflict with the goal of producing fundamental results" (p.1) and proceeds to analyze this "goal conflict" (p.1). His empirical results, on projects sponsored by the National Aeronautics and Space Administration (NASA), indicate that there is indeed a goal conflict. This is reflected in a high rate of attrition among academic researchers involved in the NASA projects[3] and in a research output from the projects that is not highly valued in academic terms.[4] The

[2] Instead of *basicness* and *appliedness*, I use the related terms *quality* and *relevance*, as explained below.
[3] Many researchers quit the NASA projects "for two reasons: 1) Sponsors drop researchers who do not produce enough sponsor-relevant output, and 2) academically successful researchers seek less restrictive, academically oriented funds from other programs that have a less utilitarian bent" (Goldfarb 2001:3).
[4] As measured by publications and citations.

present paper differs from Goldfarb (2001) in several respects.[5] Rubinstein et al. (2003) analyze CRIS funding data, but without a discussion of incentives and decision making.[6]

Section II, the theoretical part of this paper, employs drastically simplifying assumptions to cut to the core themes. The three main propositions involve differences among categories of sponsors in their propensity to use grants rather than contracts (Proposition 1) and the relationship between academic "quality" and reliance on grant funding versus contract funding (Propositions 2 and 3.) Propositions 1 and 3, along with a number of auxiliary hypotheses, are confronted with two data sets. The first of these (section III) pertains to funding received by all academic departments of the University of California (UC) at Berkeley. The second data set (analyzed in section IV) is a subset of the Current Research Information System (CRIS) of the United States Department of Agriculture (USDA). The two data sets – one from a set of recipients, the other from a set of providers of research funds – complement each other.

This paper may be of methodological interest. It contains theoretical as well as empirical non-results. Contrary to naïve falsificationism (see Caldwell 1991), a proposition with no testable implications may help us understand the real world. Proposition 2, a theoretical non-result, helps interpret the empirical non-results.

Section V provides a summary, implications, and suggestions for future research.

II Conceptual Issues and Theoretical Modeling

[5] The theoretical model presented here is less rich than Goldfarb's in that it ignores competition between grant applicants, but richer in that it allows for sponsors to care about fundamental results (or "quality", as it is called here) as well as about utilitarian results (called "relevance" here). Above all, in contrast to Goldfarb (2001), the present paper focuses on the distinction between grants and contracts. Thus, none of the hypotheses developed or tested here are developed or tested in Goldfarb (2001).

The grants / contracts distinction is an instance of the contrast between two relationship types: gift and exchange. Grants can be thought of as a type of gift, whereas contracts can be seen as a form of exchange, namely the purchase of "deliverables", or answers to pre-specified research questions. In practice this distinction may not be quite as clear-cut. Legal concepts do provide a clear dividing line: research contracts, but not grants, are breached if the recipient fails to deliver the deliverables.

Sponsors may of course care about a wide range of research outcomes. I propose here to collapse these into two variables: quality and relevance. These concepts correspond to basicness and appliedness, respectively. Quality and relevance are performance variables: successful basic research is thought of here as having high quality; successful applied research is thought of as having high relevance. The modeling of quality and relevance as continuous variables reflects the difficulty in drawing a clear-cut dividing line between basic and applied research. Research activity, as conceived here, simultaneously has quality and relevance dimensions, and these are best thought of as – at least – two distinct and continuous variables. It is too simple to think of research as being either basic or applied – a single binary variable. However, the Berkeley data set used below uses precisely the latter concept: it contains a basic / applied dummy variable, based on subjective assessments by participants in research projects. Over-simplified though it is, this is still a useful variable: the more research is oriented towards fundamental rather than directly utilitarian results, the more likely the research will be to be reported as being basic rather than applied. This dummy is included in the empirical

[6] In addition to the sources cited here, various literature searches yielded surprisingly little in the way of previously published work to be built on (Binenbaum 2002).

part of this study, allowing a test of its relationship with the propensity to use grant funding.

The model used is simple: Assume a single period, a single contract, a single grant, a single sponsor, a single research unit, scalar quality and relevance, and full certainty. The sponsor's utility *U* is a function of quality output $Q \geq 0$ and relevance $R \geq 0$: $U = U(Q, R)$. Q and R are produced by the research unit; they both depend on the unit's funding F and the relative emphasis a the unit puts on R vis-à-vis Q, with $a = 1$ denoting full emphasis on R and $a = 0$ denoting full emphasis on Q. In addition, they depend on the unit's level of scholarship, *S*: $Q = Q(a, F, S)$ and $R = R(a, F, S)$.

The research unit, with utility *V*, is assumed not to care about relevance, only about quality output and about the amount of funding: $V = V(Q, F)$. This obviously does not do justice to real-world universities whose research missions are partly impact-oriented. The main point is that sponsors tend to care more about relevance vis-à-vis quality than do academics because of the latter's powerful incentives to make basic contributions (Goldfarb 2001). It would be possible to include *R* as an argument in the research unit's utility function and impose some condition that formalizes the unit's greater preference for *Q*, but this would unnecessarily complicate the model.

Both production functions and both utility functions are assumed to be twice continuously differentiable and strictly increasing in their arguments, except for Q being strictly decreasing in a. The utility functions are assumed to be concave and the production functions strictly concave. In addition – letting subscripts denote first and second derivatives – $Q_{aF} < 0$, $R_{aF} > 0$, $Q_{FS} > 0$, and $V_{QF} \geq 0$ are natural assumptions.

Funding is constrained and can be given in the form of a contract and/or a grant: $F = C + G \leq \bar{F}$. At any optimum, $\bar{F}$ will be exhausted. The difference between grant funding and contract funding is that the latter specifies deliverables, represented by a minimum relevance level $\underline{R} > 0$, whereas the former comes without any strings attached. Contract payment C occurs conditional on $R \geq \underline{R}$. Q is assumed to be noncontractible.

Decision-making is assumed to occur in two stages. First the sponsor chooses G and the contract variables C and $\underline{R}$; then the research unit chooses whether to accept or reject the contract, and also chooses the research emphasis a.

This modeling setup gives rise to an analytical problem: The sponsor may to a certain extent be indifferent between grants and contracts. This fungibility is typical of hybrid gift/exchange relationships: Part of an exchange may be a subsidy that might as well have been transferred separately as a gift. In order to deal with this complication, I assume that there is an infinitesimally small transaction cost $T = \varepsilon C$ associated with contract funding. This assumption avoids the problem that given any optimal (from the sponsor's perspective) $C^* < \bar{F}$, any $C \in \left[C^*, \bar{F}\right]$ will be optimal as well in combination with the same $\underline{R}$. This assumption seems reasonable because contracts entail legal and other costs that grants do not, while these costs tend to be relatively small.[7]

[7] Absent this assumption or any other choice rule, one would have to assume a uniform distribution over the set of optimal *C*. This assumption ensures that the lower bound of this choice set is chosen; relaxing it would imply that – in expectation – its midpoint, which varies monotonically with the lower bound, is chosen instead. Thus, relaxing this assumption would not affect the main propositions.

I also assume that parameters are such that we have interior solutions: $G^* > 0;\ C^* > 0;\ \underline{R} > 0; a^* \in (0,1)$ (asterisks denoting sponsor optimality). This assumption avoids complications with corner solutions that do not occur in the data.[8]

Under the assumptions made, the research unit can increase *V* by decreasing *a* as long as the minimum-relevance constraint is slack. Thus, the minimum-relevance constraint is binding, yielding a unique $a^*:\ R(a^*, \bar{F}, S) = \underline{R}$. Due to the transaction-cost assumption, it will be optimal for the sponsor to set C so that the unit's participation constraint is binding as well:

$$V\left(Q\left(0, \bar{F} - C^*, S\right), \bar{F} - C^*\right) = V\left(Q\left(a^*, \bar{F}, S\right), \bar{F}\right). \tag{1}$$

For a parsimonious derivation of the main results, I assume linear $U(\ )$, i.e. $U = qQ + R$, where $q \geq 0$ is a quality preference parameter. This assumption is not as restrictive as might appear at first sight. Both *Q* and *R* can be perceived of as partial utility indices, in which case $Q(\ )$ and $R(\ )$ are hybrid utility/production functions. In this interpretation, research produces an information set to which the subjective values *Q* and *R* are assigned. Thus, linear $U(\ )$ is equivalent to $U(\ )$ being linearly separable in $Q(\ )$ and $R(\ )$. Allowing for monotone transformations that redefine $Q(\ )$ and $R(\ )$ such that both are still strictly monotonous and strictly concave, a fairly wide class of utility functions (such as Cobb-Douglas utility functions) satisfy the linearity assumption.

The symbols (0) or $(*)$ will be used to denote evaluation of functions and their derivatives on the left-hand side or right-hand side, respectively, of equation (1).

[8] Without this assumption, the main propositions would still hold, but with weak inequalities rather than

Consider exogenous changes in *q* and *S*. Total differentiation of first-order condition $qQ_a(*) + R_a(*) = 0$ and equation (1) yields, respectively,

$$da* \;=\; -\;\frac{Q_a(*)}{qQ_{aa}(*) + R_{aa}(*)}dq \;-\; \frac{qQ_{aS}(*) + R_{aS}(*)}{qQ_{aa}(*) + R_{aa}(*)}dS \text{ , and} \qquad (2)$$

$$dC* \;=\; \frac{V_Q(*)Q_S(*) - V_Q(0)Q_S(0)}{V_Q(0)Q_F(0) + V_F(0)}dS \;-\; \frac{V_Q(*)Q_a(*)}{V_Q(0)Q_F(0) + V_F(0)}da*. \qquad (3)$$

Proposition 1. Contract (grant) funding as a proportion of total funding varies strictly negatively (positively) with the sponsor's quality preference: $\left(dC*/\bar{F}\right)/dq < 0$.

Proof. Set $dS = 0$ in (2) and (3). *Q.E.D.*

Proposition 2. Assume $Q_{aS} < 0$ and $|qQ_{aS}| > R_{aS}$. Even under all the assumptions made so far, the overall effect of an exogenous change in the research unit's level of scholarship *S* on grant funding $G*$ or contract funding $C*$ cannot be signed.

Indication of proof. Set $dq = 0$ in (2), yielding $da*/dS < 0$ under the auxiliary assumptions. However, the term $V_Q(*)Q_S(*) - V_Q(0)Q_S(0)$ in (3) cannot be signed. This can be seen as follows. Comparing the left-hand side of equation (1) with its right-hand side, $a* > 0$ and $\bar{F} > \bar{F} - C*$. To ensure equality in (1), we must have $Q(*) < Q(0)$. Comparing $V_Q(*)Q_S(*)$ to $V_Q(0)Q_S(0)$, the relevant second derivatives do not all point towards either term being greater: $Q_{aS} < 0$ makes the former term greater, while $Q_{FS} > 0$, $V_{QF} \geq 0$ and $V_{QQ} \leq 0$ point to the latter term being greater. *Q.E.D.*

This result is interesting in part because it is counterintuitive. The assumptions $Q_{aS} < 0$ and $|qQ_{aS}| > R_{aS}$ have straightforward interpretations. An increase in *a* represents

strict ones.

a shifting of research inputs away from production of quality and into production of relevance. A higher level of scholarship *S* has a positive impact on the unit's marginal output of quality; this is expressed by $Q_{aS} < 0$. The condition $|qQ_{aS}| > R_{aS}$ reflects the notion that a research unit with higher *S* has a comparative advantage in the production of *Q* vis-à-vis *R*. Note that R_{aS} may be positive, zero, or negative. A negative R_{aS} could be called the "absent-minded professor assumption": It would imply that research units with higher scholarly ratings would be less capable of producing practical results. The comparison between $|Q_{aS}|$ and R_{aS} is weighted by the quality preference parameter *q*.

Given that a higher *S* confers a comparative advantage in the production of *Q*, one might expect an increase in *S* to be unambiguously associated with a decrease in contract funding (which is used to induce production of *R*) vis-à-vis grant funding (which is the preferred method for funding *Q*-oriented research). Why is this not the case? Because a unit with higher $|Q_{aS}|$ must be compensated more lavishly for the opportunity cost of not focusing entirely on *Q*.[9] This is especially true if Q_{FS} is low, i.e. if one additional dollar earned by accepting the contract does not greatly improve the *Q*-productivity of *S*. The latter effect may be called the "compensation effect", as opposed to the "comparative advantage effect".

The model so far has focused on a single research unit, thus ignoring competition for research funds. Inclusion of competition into the model would necessitate further complications to avoid winner-take-all outcomes. In practice, competition is imperfect,

[9] Note that a high $|Q_{aS}| > R_{aS} / q$ has another, opposing effect, namely to increase $|da^* / dS|$ according to (2), which affects dC^* / dS via the last term of (3).

and researchers specialize in a multitude of niches. In modeling terms, this would imply multiple outputs. Such modeling challenges are beyond the scope of this paper. Instead, I provide a brief informal argument leading to Proposition 3.

Competition does not equally affect grant funding and contract funding. Under competition, it is not true that grant funding and contract funding for one unit move in opposite directions, as was the case in the simple model above. Maintaining the assumptions $Q_{aS} < 0$ and $|qQ_{aS}| > R_{aS}$, units with higher *S* will have an unambiguous advantage in securing grant funding, but not an unambiguous disadvantage in securing contract funding. This is because the compensation effect is relevant to the distribution of contract funding, not to the distribution of grant funding. Units with greater S will demand greater contractual compensation, but it may still be attractive for sponsors to offer them contracts if they have a (perceived) absolute advantage in the production of *R* ($R_{aS} > 0$). In summary,

Proposition 3. Under competition, grant funding for each research unit varies positively with *S*; the relationship between *S* and contract funding per unit cannot be unambiguously signed. However, the proportion of grant funding to contract funding varies positively with *S*.

III Analysis of the Berkeley Data Set

The Sponsored Projects Office (SPO) of UC Berkeley supplied data for the seven-year period 1994-2000 (fiscal years) on funding received by departments and other research units of the campus. The data set contains one dollar amount per combination of the following categories: research unit, sponsor type, activity type, funding type, and year.

For the purpose of hypothesis testing, each multi-year aggregate dollar figure is counted as one observation. All figures are adjusted for inflation.[10] The sponsor types include Federal, Non-Federal Governmental, Not-For-Profit, UC, and Industry. The activity types include applied research, basic research, services, training, and other. For this study, the only activity types of interest are applied research and basic research. The funding types include grant, contract, and cooperative agreement, but I consider cooperative agreements to be contracts. The grants were all awarded competitively.

I used this data set for a test of Proposition 1 and auxiliary hypotheses.[11] One might estimate Proposition 1 with an ordinary least squares (OLS) regression, using the ratio of grant funding over grant funding plus contract funding (or "grant funding ratio") as dependent variable and NRC rating as explanatory variable. However, OLS estimation in this case has two shortcomings. First, the grant funding ratio is constrained to the interval $[0,1]$, making it likely for the true relationship to level off at either end, while predicted OLS values could fall outside of this interval. Second, OLS estimation would give equal weight to observations with vastly different dollar amounts. For these reasons OLS is not the ideal way to estimate the impact of various factors on the use of grants vis-à-vis contracts. A weighted logistic regression appears to be more appropriate. The logistic formula yields values between zero and one, approaching each extreme asymptotically (i.e., the "leveling off" property is satisfied). Hence, this method addresses the first shortcoming. The second shortcoming is dealt with through weighting. Recall that there is one dollar figure for each multi-year observation. These dollar

[10] For this purpose, I chose the U.S. Bureau of Labor Statistics' Employment Cost Index.

amounts are used as weights. This procedure predicts the probability that one dollar of research funding is awarded through a grant, conditioned on a number of characteristics of that dollar. The weights were scaled so as to leave the number of observations – used by the statistical software package STATA for significance calculations – unchanged.

The dependent variable is a dummy that takes on value 1 if the funding type is grant, and value 0 if it is a contract. Funding is aggregated over the seven-year period 1994-2000 for each combination of categories other than year. All explanatory variables included in the regression are dummy variables. The first seven dummies in Table 1 denote broad academic areas of research. These dummies are included to control – and test – for area-specific fixed effects. When all of these dummies equal zero, the area of research is Humanities, which encompasses *inter alia* history, journalism, and languages. The seven other categories are Biological Sciences ("biology"), Economics and Business ("econ+bus"), Engineering, including medical engineering ("engineer"), Medical Sciences, excluding medical engineering ("medical"), Physical and Mathematical Sciences ("phy+math"), Social and Behavioral Sciences, excluding economics ("social"), and a residual category ("other"), which includes research units that cover several of these broad areas, or whose research mandates cannot be readily inferred from their names.

The next four dummies, only featured in Table 1b, comprise a set of sponsor types; when all of these are 0, the sponsor type is Not for Profit. These include Federal, Industry, Non-Federal Governmental ("nonfedgov"), and University of California

[11] In addition, I used to test Proposition 3, and obtained a significant result. However, this test is not robust because it involves a comparison across academic fields at a single campus, with only one observation of *S* – measured by National Research Council ratings (Goldberger 1995) – per field (Binenbaum 2002).

("UC"). Last comes a binary dummy ("basic") that takes on value 1 for basic research and value 0 for applied research.

Table 1 reports a simple test of the association between basic research and grant funding. In Table 1a, the "basic" dummy is strongly significant; in Table 1b, this dummy is significant at the 10% level, but not at the 5% level. This implies that sponsor types differ in their propensity to fund basic rather than applied research. The sponsor types in Table 1b pick up some of the relationship between the "basic" dummy and the "grant" dummy. These results indicate a fairly strong to strong relationship between the use of grants (as opposed to contracts) and the funding of basic (as opposed to applied) research.

Next, consider Proposition 1. How to test the hypothesis that sponsor types with a stronger preference for quality over relevance will furnish a greater proportion of their funding in the form of grants? The problem here is that the quality preference parameter q cannot be measured. I suggest the following solution to this problem. We can make reasonable a priori conjectures about differences in q among sponsor types. We can expect q to correspond to the extent a sponsor type is likely to care about the public-good nature of research results. Thus, among the sponsor types included here, Federal agencies – which service by far the largest group of constituents, namely the citizens of the United States, and which are more likely to care about the science and technology aspects of the country's super power status – can be expected to have the highest q. Industry, on the other hand, which is driven by short- to medium-term profit considerations, and which will highly value specific research results, can be expected to have the lowest q. The category of nonprofit non-governmental research sponsors encompasses a wide range of objectives, but can on average be expected to have a q somewhere between these two extremes. The way these dummies are defined, the latter is the default category.

It may be objected here that even federal government agencies may have strong utilitarian motivations. This is stressed by Goldfarb (2001), who notes that most federal research sponsors are mission-oriented and interested in specific research outcomes. Goldfarb raises concerns about the goal conflict between federal sponsors and academic researchers who face professional incentives to produce research results of a more fundamental nature. The empirical part of his study focuses on funding of academic research by the National Aeronautics and Space Administration (NASA).

Federal agencies sponsoring research are in fact likely to differ widely in this respect. The National Science Foundation (NSF), Department of Energy (DOE) and National Institutes of Health (NIH) may well have a higher q than most other major federal research sponsors, such as NASA and the Departments of Defense, Commerce, and Agriculture (David Mowery, pers. com., and Goldfarb 2001, fn. 1). Unfortunately, the Berkeley data set does not differentiate between federal sources. However, it should be kept in mind that federal sponsors are compared here with other categories, and it is still likely that, on average, they have higher q than these other categories. For example, agencies like the NSF, DOE and NIH are probably more important at the federal level than at the state level. Moreover, even the federal agencies that may have a lower q than these three agencies are still likely to have a higher q than their counterparts at the state level. Research sponsored by the U.S. Department of Agriculture is more likely to have nation-wide significance for agriculture than otherwise similar research sponsored at the state level. Such nationally relevant research is more likely to carry greater academic prestige. As to industry-sponsored research, here the pressure for directly utilitarian results is still likely to be the greatest, due to pressures from shareholders and other financiers to maximize the rate of return of the sponsors' investments.

Thus, Proposition 1 can be translated into two hypotheses: That the Federal dummy is positively, and the Industry dummy negatively, related to the Grants dummy. Both hypotheses are overwhelmingly confirmed in Table 1b.[12] (See the z and $P>|z|$ columns between the *basic* and *other* rows.) Interestingly, the Non-Federal Governmental dummy comes close to the Industry dummy in having a very low odds ratio and a strongly negative relationship with the Grants dummy. This indicates that agencies belonging to the State of California (in all likelihood the main component of this category) tend to have a strong preference – relative to Federal and non-governmental nonprofit Federal sponsors – for contracts, i.e. for specific research results. The University of California dummy displays a strong positive relationship with the Grants dummy. This result supports the assumption used in the theoretical part of this paper that academic policymakers are characterized by a strong emphasis on scholarly quality and prestige as opposed to practical or immediate relevance.

Finally, I estimated the relative propensity to use grants for broad academic categories (Table 1b). Compared to the default category of Humanities, all other categories have a greater propensity to use contract funding (as can be seen by the string of negative values in the z column below the *basic* row), but only Physical and Mathematical Sciences and Engineering significantly so at any of the commonly used significance levels. Engineering exhibits the strongest result here, which comes as no surprise; given the applied nature of engineering, research projects in this category are more likely than those in other categories to have narrowly focused objectives, which are amenable to inclusion in a contract as deliverables.

IV Analysis of the CRIS Data Set

CRIS contains a wealth of data on agricultural research funded by the USDA and affiliated government agencies. Many of the research units identified in CRIS are not university departments. Data from those that are university departments are often difficult to match with rating data. For example, names of academic departments at various universities include Biochemistry and Microbiology; Anatomy, Physiology, and Cell Biology; Cellular and Molecular Biology; Molecular, Cellular and Developmental Biology; and several dozens more such variations. These are not easily compatible with the National Research Council ratings (Goldberger et al. 1995) which cover areas such as Biochemistry and Molecular Biology; Cellular and Developmental Biology; Molecular Biology and Genetics; and Physiology. To avoid such problems, I selected a field for which CRIS data and rating data are more readily compatible: agricultural economics. There is a readily identifiable set of U.S. agricultural economics departments.[13] While the NRC does not provide a ranking of agricultural economics departments, there are rankings available that use a similar methodology. Perry conducted two surveys of

[12] The hypothesis that industry is, more than other sponsors of academic research, inclined to use contracts rather than grants, is confirmed by Geiger's (1992:277) observations.
[13] This set consists of all departments with "economics" or "agribusiness" in their names (except for "home economics") at land grant universities which received at least some funding other than formula funding in the period 1992-2001 according to the CRIS data set. (The only departments thus identified that are called "Economics" are at South Dakota State University and Iowa State University.) In each case I checked whether the department and project in question has a sufficiently high agricultural economics content.

agricultural economists, one in 1993 (Perry 1994), the other in 1999 (Perry 1999), asking them to rank the top 20 Ph.D. programs and top 10 M.S. programs in agricultural economics, using a scale from 1 to 5. Perry then computed the average ratings of the programs and used them for separate rankings for Ph.D. and M.S. programs. Programs that were not listed by sufficiently many respondents were excluded from these rankings. The rankings do not take into account the number of responses. For example, in 1999, Oklahoma State University is ranked 20th, based on an average rating of 2.84, and Washington State University is ranked 21st with an average rating of 2.81 (Perry 1999, Table 1). However, 34 respondents listed Washington State, while only 25 respondents listed Oklahoma State. It seems reasonable to let the 9 additional respondents of Washington State carry more weight than the 0.03 higher average rating of Oklahoma State. Thus, my preferred method would be to multiply a department's average rating by the number of respondents listing it, which yields the total score. Perry recognizes this alternative ranking method (1994, fn.4), but does not use it in his tables. Perry (1999, Table 6) finds an extremely high correlation of 0.977 between his 1999 and 1993 ratings. The correlation between the alternative ratings, based on total score, for both years, is extremely high as well: 0.962.

The CRIS data used here span a ten-year period from fiscal year 1992 through fiscal year 2001. I deflated the data so that all were in 1992 dollars.[14] I then aggregated the data twice: over projects per funding type per department, and over the ten-year period. To match these data with the agricultural economics rating data, I took the average of each department's ratings, based on total score, from 1993 and 1999, and used

[14] Using the Bureau of Labor Statistics' Employment Cost Index.

the resulting numbers as explanatory variable in my regression. The extremely high autocorrelation between the 1993 and 1999 scores warrants this step.

I also compared rated with non-rated agricultural economics departments. Of the departments included in Perry's 1999 Ph.D. ranking, only one was not included in his 1993 ranking, namely Kansas State. Perry excluded Kansas State in 1993 because it was listed by only 22 out of 62 respondents. However, these gave Kansas State an average rating of 3.00 in 1993, which does not compare unfavorably with Georgia State, which was listed by 26 respondents but only rated 2.81 by them on average (Perry 1994, fn.5 and Table 1).[15] Two agricultural economics departments appear on Perry's 1999 M.S. ranking that do not have Ph.D. programs: Montana State and Arizona State. I considered these to be "ranked" for the purpose of my dummy-based regression, even though they do not have a Ph.D. rating. It makes sense to classify these two departments in this way because they are ranked high on the M.S. list: numbers 4 and 5 respectively out of 16 ranked programs (Perry 1999, Table 2). In other words, they leave most departments that have Ph.D. programs behind them on this list.

I conducted regressions for four types of funding: Cooperative Agreements and Other Contracts (in short, Contract Funding); NRI Competitive Grants; Special Grants; and Other Grants.[16] Cooperative agreements are really a type of contracts. NRI Competitive Grants differ from Special Grants in that the latter are not awarded

[15] On the other hand, there was a large gap between the Ph.D. programs ranked in Perry (1999) plus Kansas State and the other Ph.D. programs in terms of number of respondents listing the department.

[16] I lumped together the CRIS categories "USDA Cooperative Agreement," "Cooperative Agreement," and "USDA Contract" under "Cooperative Agreements and Contracts." I included the CRIS category "CSREES Grant Program" under "Other Grants." I did not consider various types of so-called formula funds, funds allocated by formula to states, universities, and agricultural experiment stations. These are not suitable for tests of my hypotheses. Part of them may arrive at university departments 'automatically' (i.e.

competitively. Instead, the latter are a subset of "earmark grants," awarded through political processes in Congress, with Congress members acting on behalf of their home constituencies (pers. com. Allen Moore; de Figueiredo and Silverman 2002:2). In other words, Special Grants are a form of so-called "pork barrel" spending. Other Grants are awarded competitively, but they tend to cover more applied topics then do NRI Competitive Grants. They are often more focused on particular commodities than are NRI Competitive Grants. A typical example of the category "Other Grants" is a grant to the National Center for Peanut Competitiveness at the University of Georgia's Department of Agricultural and Applied Economics. Among the project's objectives are the following: "To determine the economic efficiency of current and potential peanut production practices and to assess these alternatives in improving the overall competitiveness of US peanut production."[17]

Using the CRIS data set in combination with Perry's (1994, 1999) ratings, I conducted a series of regressions, for which I used a different method than for the ones in section III, reflecting differences in the data. In contrast to the Berkeley data set, CRIS contains data for multiple research institutions per discipline, but only accounts for a fraction of the funding received by each institution. Thus CRIS cannot be used to construct grant funding ratios per institution. On the other hand, CRIS lends itself for cross-institutional comparisons for each specific type of funding.

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by formula as well), and part of them may be allocated as competitive grants by agricultural experiment stations to academic departments, but the CRIS data set does not provide this information.

[17] According to project description on CRIS website (Accession Number 0190721), downloaded September 2, 2002, from http://cris.csrees.usda.gov/.

My subset of the CRIS data set only lists the departments that received funding of at least one of the types included. This selection criterion appears to yield a complete list of agricultural economics departments in the U.S. For any funding type there was a significant number of departments that did not receive funding in that category. Because of the large number of observations with zero values for the dependent variable in all of these regressions, I used Tobit regressions that are left-censored at zero. Again, STATA was used. I used exclusively funding of the various types as dependent variables, and rating-related variables as explanatory variables. The latter was either rating itself or a rated/non-rated dummy. I thus conducted eight regressions (Table 2), one for each combination of funding type and rating or rated/non-rated dummy. The results of these are striking, in spite of the small sample size. The two regressions for NRI Grant Funding yield clearly significant results. Departments that are ranked by Perry (1994, 1999) have a very strongly significant edge over those that are not in securing NRI funding (Table 2c). Furthermore, among the ranked departments, the higher-ranked ones are significantly more successful in obtaining NRI funding than the lower ranked ones at the 2% level (Table 2d). All of the other agricultural economics regressions yield very clearly insignificant results. The two other categories of grants in the CRIS database, Special Grants and Other Grants, are not awarded preferentially to departments that are ranked or ranked more highly (Tables 2e, f, g and h). This can be explained as follows. Special Grants are dependent on political processes and are presumably awarded to departments that have better Congressional connections, which are not necessarily the ones that are more highly ranked. “Earmark grants” (of which the Special Grants of this dataset are a subset) bypass the competitive peer review process; de Figueiredo and

Silverman (2002) show empirically that investments in Congressional lobbying for earmark grants pay off for academic departments. Other Grants, in contrast, are awarded competitively, but as pointed out tend to fund projects that are more applied in nature than the ones funded by NRI grants. Contract Funding is very clearly not significantly related to academic rating (Tables 2a and 2b). While the number of observations reported in these regressions is low, these data were obtained by several aggregations over far larger amounts of observations. Furthermore, the insignificance results are all far from any conventional level of significance, while the significant results are strong.

Overall, then, the agricultural economics regressions are consistent with Proposition 3. Since the only regressions that yield significant results are those relating grant funding (albeit of one type, namely NRI grants) to academic rating, while those for contract funding are all clearly insignificant, it can be concluded that departments that are more highly rated tend to rely to a greater extent on grant funding relative to contract funding than do those that are less highly rated. However, there are nuances to this overall pattern: There are certain types of grants that do not conform to the theoretical analysis of section 1 because they are allocated through political processes or because they tend to be used for relatively applied research.

In light of Proposition 2, the insignificance results for the contract funding may be interpreted as follows. Higher ranked departments require more funding per unit of principal investigators' time to compensate them due to their greater opportunity cost. However, as evinced by the insignificance results, they are generally not outcompeted in the contract funding market. This may be due to their having an absolute advantage in the production of relevance in addition to their even greater advantage in the production of quality. Note that this interpretation would not imply that researchers at higher ranked departments are necessarily “better” at contractual research than the ones at lower ranked departments. The former may have a productivity advantage because of the more prestigious institutions’ more abundant resources, other than grant or contract funding.

To be sure, there are alternative or complementary explanations for the higher-ranked departments’ equal level of activity in contractual, applied research (Binenbaum 2002). For example, there may be synergies in the production of basic and applied research results. To a certain extent, fundamental contributions may be enhanced by keeping in touch with the real world. But if quality and relevance outputs are complements, they are imperfect ones, and a tradeoff between the two is the typical pattern.

V Concluding Comments

This paper develops and tests two main results. Proposition 1 predicts that sponsors with a stronger preference for high academic quality over immediate relevance are more likely to give funding in the form of grants. Sponsors’ preferences cannot be measured; however, Proposition 1 is testable if we allow ourselves to make some reasonable assumptions about differences in preferences between different sponsor types. The second result, Proposition 3, predicts that academic research units with a higher scholarly reputation are likely to receive a greater proportion of their funding in the form of grants. Auxiliary hypotheses being tested here concern the relationship between the use of grants (rather than contracts) and research being basic (rather than applied), and differences between broad areas of academic research in the propensity to use grants. In addition to the testable results, there is Proposition 2, which decomposes the effect of scholarly quality on contract funding into opposing effects.

Analysis of the Berkeley data yields significant results for Proposition 1 and the auxiliary hypotheses. The CRIS data permit tests of Proposition 3 which involve separate regressions for grant funding and contract funding. The only significant results here show a positive relationship between grant funding and academic quality (insofar as the latter is properly measured by reputational surveys among peers in the same discipline). Contract funding is uniformly not significantly related to academic reputation.

The theoretical and empirical results of this paper have two major implications. First, they confirm the existence of a division of labor in academia where elite departments tend to focus more on fundamental research than other departments. However, higher- and lower-ranked departments appear to be equally involved in more applied research. It may be attractive for researchers at more prestigious universities to remain involved in applied research because of possible synergies with more fundamental research. Second, they point towards the bivariate nature of research outputs. It makes more sense to view applied and basic research results as two different kinds of research outputs rather than opposite segments of a single dimension. If these two types of outputs are complements, they are imperfect ones, and important tradeoffs between them will often occur. Reputational surveys such as those of the NRC and of Perry tend to measure fundamental contributions rather than applied contributions. If one wanted to measure the "relevance" or directly utilitarian contribution of research, one would have to conduct surveys of the users of such research – government policymakers, managers in firms, farmers, etc. Thus, it can be argued that the rankings that are currently in vogue reflect a one-sided assessment involving only one type of research output, ignore the other major type of research output – possibly to the detriment of less prestigious departments.

Let me conclude with suggestions for future research. First, causal relationships between academic performance variables, such as rating, publications, or citations, and funding variables may well run both ways. Data sets such as those used here might be exploited more fully using time series analysis, perhaps enabling estimation of such bi-directional relationships.[18]

Second, repeated interactions may be a fertile ground for extending the model, which considers only a one-shot game. In the real world, sponsors and performers of academic research interact repeatedly over many years. This blurs to some extent the distinction between grants and contracts. Sponsors may use future withholding or renewal of funding as incentive mechanisms to induce production of deliverables by grant recipients. Furthermore, grant recipients' performance may affect their reputation and hence their competitive edge. However, the same considerations pertain to contracts. Enforcement in repeated games is typically imperfect; hence, the additional enforcement mechanism provided by contracts – sanctions for breach of contract – remains relevant.

Third, contracts may be preferred to grants for reasons other than to enforce production of deliverables. Parties may contribute other items such as materials, information, intellectual property, or human resources, and they may wish to commit each other to certain behaviors or policies like confidentiality. Contracts may thus be used for relationships that are more complex than simple research funding.

[18] Koshal et al. (1996) recognize the bidirectional nature of this relationship and address it through a simultaneous-equations empirical model, but clearly time series analysis would be a superior mode of analysis, as it enables inferences about (Granger) causility.

Fourth, allowing for multiple sponsors leads to complications of strategic interdependence, in particular to prisoner's dilemmas: Sponsors with similar objectives may free-ride on each other's funding of research units. One could perhaps avoid this sort of complications through a model where one type of sponsor cares only about relevance, and the other only about quality.

Fifth, one could extend the model by considering costly information, uncertainty, observability, or costs associated with breach of contract. One of the main rationales for competition for grants is its role of generating information for sponsors. As to uncertainty, one of the most brazenly cavalier assumptions made here is that of complete certainty. In reality, of course, research is, by its very nature, a highly uncertain process. As to observability of research output, there is no doubt that this is an important issue too. Research contracts specify deliverables and may also specify damages that apply if the deliverables are not produced in timely fashion. However, I do not know of a single example of this actually happening at any academic department. Contractual obligations are, or at least appear to be, invariably met. Why? is an interesting question. Perhaps reputation concerns play an important role here. Deliverables for contracts may be selected for having a high degree of certainty.

Sixth, a fuller understanding of the division of labor in academic research would require consideration of all the different outputs of universities and the allocation of resources between them.[19] Perhaps six main categories of university outputs can be identified here: fundamental and utilitarian research contributions, graduate and undergraduate education, extension activities, and community support.

Finally, a related set of issues pertains to departments' and researchers' motivations. Do researchers in less prestigious units aspire to making fundamental contributions without being to do so to the extent they would like? Or do researchers with more applied inclinations self-select to work at such units?

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[19] Cohn et al. (1989) is a pioneering contribution that attempts to empirically analyze universities' multiple outputs.

Table 1. Logit Regression of Berkeley Data

Table 1a: Excluding Sponsor Types

```
Logit estimates                                   Number of obs   =        846
                                                  LR chi2(8)      =     205.73
                                                  Prob > chi2     =     0.0000
Log likelihood = -439.51121                       Pseudo R2       =     0.1897
```

grant	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
biology	.3763413	.450977	-0.816	0.415	.0359394	3.940877
econ+bus	.1949227	.2559106	-1.245	0.213	.0148708	2.554994
engineer	.0486249	.0576404	-2.551	0.011	.0047625	.4964553
medical	.5191397	.6313408	-0.539	0.590	.0478755	5.629307
other	.1375704	.1735719	-1.572	0.116	.011603	1.631104
phy+math	.1481606	.1761028	-1.606	0.108	.0144212	1.522178
social	.3238656	.4000634	-0.913	0.361	.0287671	3.646143
basic	4.279016	.8824831	7.049	0.000	2.856251	6.410494

Table 1b: Including Sponsor Types

```
Logit estimates                                   Number of obs   =        846
                                                  LR chi2(12)     =     424.59
                                                  Prob > chi2     =     0.0000
Log likelihood = -330.08309                       Pseudo R2       =     0.3914
```

grant	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
biology	.3902568	.5284148	-0.695	0.487	.0274668	5.54489
econ+bus	.1442988	.2160299	-1.293	0.196	.0076723	2.713925
engineer	.0247057	.0328275	-2.785	0.005	.0018271	.3340616
medical	.2084179	.2843624	-1.149	0.250	.0143737	3.022052
other	.2307072	.3467671	-0.976	0.329	.0121242	4.39005
phy+math	.0538298	.0715563	-2.198	0.028	.0039766	.7286699
social	.2909015	.4045306	-0.888	0.375	.0190571	4.440537
federal	4.030238	1.076488	5.218	0.000	2.387659	6.802821
industry	.0082406	.0097484	-4.056	0.000	.000811	.0837356
nonfedgov	.0291361	.0226413	-4.550	0.000	.0063529	.1336253
UC	6.227311	3.806123	2.992	0.003	1.879523	20.63258
basic	1.657266	.4430105	1.890	0.059	.9814184	2.798533

Source: UC Berkeley Sponsored Projects Office

Table 2. Tobit Regressions of Agricultural Economics Funding

Dependent variable is funding of several types (Cooperative agreements, NRI grants, Special grants, and Other grants) from 1992 through 2001 in constant 1992 dollars. Explanatory variable is either a rated/non-rated dummy or rating.

Sources: United States Department of Agriculture (USDA) CRIS data set; Perry (1993,1999)

a. ***Cooperative agreements funding*** on ***Rated/non-rated dummy***

Number of obs = 56
LR chi2(1) = 0.01
Prob > chi2 = 0.9252
Log likelihood = -342.58035

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
dummy	5155.743	54958.37	0.094	0.926	-104983.3	115294.8
_cons	-52708.16	41205.78	-1.279	0.206	-135286.4	29870.07

Obs. summary: 32 left-censored observations at Coop. agr. funding = 0
24 uncensored observations

b. ***Cooperative agreements funding*** on ***Rating***

Number of obs = 22
LR chi2(1) = 0.42
Prob > chi2 = 0.5193
Log likelihood = -148.65261

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rating	197.004	307.8771	0.640	0.529	-443.2614	837.2694
_cons	-36716.51	61265.45	-0.599	0.555	-164125	90691.98

Obs. summary: 11 left-censored observations at Coop. agr. funding = 0
11 uncensored observations

Table 2 (continued)

c. ***NRI grants funding*** on ***Rated/non-rated dummy***

```
                                                  Number of obs   =         56
                                                  LR chi2(1)      =      16.54
                                                        Prob > chi2     =     0.0000
Log likelihood = -675.00893

------------------------------------------------------------------------------
         |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
   dummy |   418920.3   96518.45      4.340   0.000        225493    612347.6
   _cons |   157906.8   64680.99      2.441   0.018      28283.15    287530.4
---------+--------------------------------------------------------------------

Obs. summary:         9 left-censored observations at NRI grants funding = 0
                     47 uncensored observations
```

d. ***NRI grants funding*** on ***Rating***

```
                                                       Number of obs   =         22
                                                        LR chi2(1)      =       5.71
                                                        Prob > chi2     =     0.0169
Log likelihood =  -299.9788

------------------------------------------------------------------------------
         |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  rating |   2814.657   1113.142      2.529   0.020      499.7505    5129.563
   _cons |   107217.5   211106.8      0.508   0.617       -331803    546238.1
---------+--------------------------------------------------------------------

Obs. summary:         1 left-censored observation at NRI grants funding = 0
                     21 uncensored observations
```

Table 2 (continued)

e. ***Special grants funding*** on ***Rated/non-rated dummy***

```
                                                  Number of obs   =         56
                                                   LR chi2(1)      =       0.08
                                                   Prob > chi2     =     0.7743
Log likelihood = -412.72595

------------------------------------------------------------------------------
         |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
   dummy |   80767.15   281245.6      0.287   0.775      -482861.6    644395.9
   _cons |  -195336.4     199496     -0.979   0.332      -595135.4    204462.6
---------+--------------------------------------------------------------------

Obs. summary:        30 left-censored observations at Special grants funding = 0
                     26 uncensored observations
```

f. ***Special grants funding*** on ***Rating***

```
                                             Number of obs   =         22
                                             LR chi2(1)      =       0.83
                                             Prob > chi2     =     0.3609
Log likelihood = -174.88284

------------------------------------------------------------------------------
         |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  rating |   3154.934   3424.735      0.921   0.367      -3967.194    10277.06
   _cons |  -644563.1   674106.1     -0.956   0.350       -2046444    757317.4
---------+--------------------------------------------------------------------

Obs. summary:        11 left-censored observations at Special grants funding = 0
                     11 uncensored observations
```

Table 2 (continued)

g. ***Other grants funding*** on ***Rated/non-rated dummy***

Number of obs = 56
LR chi2(1) = 0.38
Prob > chi2 = 0.5365
Log likelihood = -295.5208

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
dummy	-231514.7	371766.8	-0.623	0.536	-976551.9	513522.6
_cons	-443123.5	293417.5	-1.510	0.137	-1031145	144898.3

Obs. summary: 38 left-censored observations at Other grants funding = 0
18 uncensored observations

h. ***Other grants funding*** on ***Rating***

Number of obs = 22
LR chi2(1) = 0.40
Prob > chi2 = 0.5286
Log likelihood = -123.71015

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rating	1065.805	1733.346	0.615	0.545	-2538.886	4670.495
_cons	-342080.8	369137.4	-0.927	0.365	-1109744	425582.3

Obs. summary: 14 left-censored observations at Other grants funding = 0
8 uncensored observations

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