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6 How Would Universities Respond to Increased Federal Support for Graduate Students?

Ronald G. Ehrenberg, Daniel I. Rees, and
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6.1 Introduction

Projections of forthcoming shortages of Ph.D.'s, and thus new faculty for the academic sector, abound (e.g., see Bowen and Sosa 1989; National Science Foundation 1989; National Research Council 1990; and Atkinson 1990). The demand for new faculty is projected to grow due to increased retirements from an aging professoriate and projected rises in college enrollments. On the supply side, while the number of Ph.D.'s granted by U.S. universities has been roughly constant in recent years, nonacademic job opportunities are increasingly available to Ph.D.'s. Ph.D. recipients are also increasingly non–U.S. citizens whose observed probabilities of obtaining employment in the United States are low (see Ehrenberg 1991, chap. 7). Integration of supply and demand forces leads to the projections of forthcoming shortage; one major book projected at least a 43 percent underproduction of new doctorates in the arts and sciences as a whole during the 1997–2002 period (Bowen and Sosa 1989, table 8.5).

American college graduates are much less likely to receive doctorates today than they were 20 years ago. The ratio of doctorates granted by American

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universities to bachelor's degrees granted by American colleges and universities six years earlier, .064 in 1970–71, fell to .035 in 1978–79 and has remained roughly constant at the lower level since then (Ehrenberg 1991, table 6.4). Numerous factors probably contribute to this decline in the propensity of American college graduates to receive doctorates; however, one important factor may well be the increase in the length of time necessary for doctorate students to complete their programs.

The median registered time to degree for new Ph.D.'s granted in the United States in 1968 was 5.5 years. By 1988 this figure had risen to 6.9 years. The increase has been even more dramatic in some fields; for example, median registered time to degree in the social sciences rose from 5.1 to 7.4 years and in the humanities from 5.5 to 8.5 years during the same period (National Research Council 1989, table 1).[1]

Among the policies urged to prevent future Ph.D. shortages is increased federal support for graduate students. Such a policy would reduce the private costs of doctoral study and thus hopefully should increase the number of college graduates willing to undertake graduate study. To the extent that financial support reduces the time students need to complete degrees and increases their probability of completing doctoral programs, the future supply of Ph.D.'s should further increase. While conceptually these roles of financial support on the supply of doctorates are clear, empirical evidence on the effects of financial support on doctoral production actually is quite scanty (see Ehrenberg 1991, chap. 8).

Lost in the policy debate, however, has been any concern for the possibility that changes in federal, or other external to the institution, support for graduate education may simply induce an academic institution to redirect its own financial resources in a way that at least partially frustrates the intent of such a policy. For example, increased federal support for graduate students in the sciences may lead an institution to cut back somewhat on (or not increase as rapidly as it had planned) its own internal support for graduate students in the sciences and to use the funds saved either to support graduate students in other disciplines or for other purposes (e.g., non–graduate student expenditures or moderating planned tuition increase). Conversely, faced with cutbacks in federal or other external support, institutions may react by attempting to partially offset the cutbacks by increasing their own internal support for graduate education.

To the extent that changes in external financial support for graduate education lead institutions to alter their own support levels or allocations across fields, the resulting changes in the field composition and total number of doctorate students supported may be different than policymakers intended. The issue being raised here is very similar to one confronted by policymakers in

1. Bowen, Lord, and Sosa (1991) have shown that part of the reported increase in times to degree in the humanities is a statistical artifact caused by the grouping of individuals by year of degree rather than by year of program entrance, during a period in which the size of entering cohorts was decreasing.

the 1970s and early 1980s when concern was expressed that the net job creation effects of public-sector employment (PSE) programs, programs in which the federal government gave state and local governments funds to increase their employment levels, were considerably less than the number of positions funded. Empirical studies of what became known as the *displacement effect,* or *fiscal substitution effect,* of PSE programs did indeed find that on average an increase in PSE program positions typically led to a smaller increase in public-sector employment levels (see, e.g., Johnson and Tomola 1977; Borus and Hamermesh 1978; Adams et al. 1983).[2]

To fully evaluate the likely effects of an increase in federal support for graduate students, an analysis of the extent to which the federal funds would displace institutional funds is required. Such an analysis is undertaken in this paper, using institutionally based data for science (including social science) and engineering fields. Unfortunately, data do not exist that would permit similar analyses for the humanities and for professional fields other than engineering.

We begin in the next section with a discussion of the aggregate time-series evidence on how support for graduate students in science and engineering has changed. While this evidence suggests that federal policies may influence institutional support levels, causation cannot be inferred from these aggregate data.

In section 6.3, we present institutionally based econometric analyses of the determinants of the number of full-time graduate students in science and engineering fields that receive institutional support. The analyses are extended in section 6.4 to field-specific data, and attempts are made to ascertain if increased external support to one field may influence internal support allocations to other fields. Section 6.5 further extends the analyses and addresses how different types of external support (e.g., fellowships and traineeships, research assistantships, teaching assistantships) influence the distribution of types of internal support. The brief concluding section summarizes our findings and proposes an agenda for future research.

6.2 Aggregate Time-Series Evidence

Table 6.1 presents evidence for the 1966–88 period on the number of full-time science and engineering graduate (FTSEG) students in doctorate-granting institutions whose major source of support came from the federal government each year. Psychology and the social sciences are included among the sciences for the purposes of this table and those that follow.

The data in columns labeled A come from a National Science Foundation

2. More generally, economists have a long tradition of analyzing how various types of federal grants influence state and local government expenditure and taxation decisions (see Gramlich and Galper 1973); recently, economists have also analyzed the extent to which changes in state aid to local school districts influence teacher salaries, student-teacher ratios, and local property tax rates (see Ehrenberg and Chaykowski 1988).

Table 6.1 Full-Time Science and Engineering Graduate Students with Federal Support in Doctorate-Granting Institutions

	Number with Federal Support		Total Number		Share with Federal Support	
Year (fall)	A	B	A	B	A	B
1966	44,612		118,273		.377	
1969	51,620		141,199		.366	
1970	50,256		145,970		.344	
1971	45,101		142,169		.317	
1972	45,029		149,937		.300	
1974	43,089	47,989	169,145	195,455	.255	.246
1975	48,365	48,249	210,641	210,321	.230	.229
1976	48,508	48,594	215,355	214,094	.225	.227
1977	50,308	50,378	218,226	217,454	.231	.232
1978		51,273		216,613		.237
1979		52,874		223,414		.237
1980		52,939		230,535		.230
1981		50,897		234,194		.217
1982		47,206		236,939		.199
1983		47,333		243,661		.194
1984		47,476		245,530		.193
1985		48,716		248,782		.196
1986		51,060		258,055		.198
1987		53,093		263,003		.202
1988		54,852		268,385		.204

Sources for data used in authors' computations:

Column A—National Science Foundation, *Graduate Student Support and Manpower Resources in Graduate Science Education, Fall 1965 and Fall 1966*, fig. 9; *Fall 1969*, table C10a; *Fall 1970*, table C81; *Fall 1971*, table C9; National Science Foundation, *Graduate Science Education: Student Support and Postdoctorals, Fall 1972*, table C14; National Science Foundation, *Graduate Science Education: Student Support and Postdoctorals, Detailed Statistical Tables, Fall 1974*, table B13; *Fall 1975*, p. 11; *Fall 1976*, table B10; *Fall 1977*, table B10.

Column B—National Science Foundation, *Academic Science/Engineering: Graduate Enrollment and Support, Fall 1988*, table C14; *Fall 1991*, table C14.

(NSF) survey, the scope of which changed over time. For example, in 1972 the survey was expanded to include graduate students in doctorate-granting institutions in departments that granted only master's degrees, while in 1973 it was expanded to include graduate students in medical and clinical sciences. Response rates to this survey varied over time. The data in columns labeled B come from a separate but similar National Science Foundation survey. Response rates to this survey also varied over time. The two surveys overlapped during the 1974–77 period, yielding virtually identical aggregate numbers for those years.

During the 1966–88 period, the number of FTSEG students at doctorate-granting institutions whose major source of support came from the federal government fluctuated in the 43,000-to-almost-55,000 range. In recent years, however, there has been a clear upward trend. The number of students on federal support rose steadily between 1982 and 1988, and the 1988 level of 54,852 was over 16 percent higher than the 1982 level of 47,206.

As the second panel indicates, however, the total number of FTSEG students enrolled in doctorate-granting institutions increased throughout the period, rising (using the consistent series B) from about 195,500 in 1974 to almost 268,400 in 1988. As a result, the share of FTSEG students in doctorate-granting institutions whose major source of financial support came from the federal government fell from almost 38 percent in 1966 to slightly over 19 percent in 1984. Between 1984 and 1988, as the number of FTSEG students with federal support increased, the share with federal support increased slightly to 20.4 percent. However, this is still well below the shares experienced in the late 1960s and early 1970s.

Table 6.2 repeats the percentage of FTSEG students with federal support data and adds information on the percentages whose major source of support was institutional funds, other outside funds, and self-support. In these NSF data, institutional funds include funds coming from state governments and administered by the institutions, other outside support includes funds derived from foundation and corporate as well as from foreign sources, while self-support includes loans, family support, and earnings from outside the university.

Quite strikingly, the fall from 1974 to 1988 in the percentage of FTSEG students whose major source of support was the federal government from 24.6 to 20.4 was substantially offset by the increase in the percentage of FTSEG students whose major source of support was institutional.[3] As noted above, while this suggests that changes in federal support for graduate students may induce institutions to alter their own support levels, causation should not be inferred from these aggregate time-series data.[4]

As the distribution of FTSEG students by major source of support has changed, so has the distribution of support recipients changed by type of support. Table 6.3 presents 1968, 1974, and 1988 information, in total and for

3. If the percentage of FTSEG students whose major source of support came from the federal government remained at its 1974 level of 24.6, about 11,000 more FTSEG students would have been supported by federal funds in 1988. About 113,000 FTSEG students' major source of support was institutional funds that year. If the percentage of FTSEG students whose major source of support came from institutional funds had remained at its 1974 level of 38.5, about 10,000 fewer students would have been supported by institutional funds in 1988.

4. We must also caution that these data refer to students' *major* sources of support. Suppose, for example, a student who was initially receiving a $15,000 tuition waiver from an institution subsequently received a supplementary $16,000 fellowship stipend from the federal government. The student's reported major source of support would shift from the institution to the federal government. However, no reduction in institutional support would have occurred. Thus, the use of these "major source of support" data may overstate the extent of substitution of external for institutional funds. The reader should keep this in mind when drawing conclusions from the econometric models presented below. Unfortunately, data are not collected on the variety of sources from which a student receives *any* support.

Table 6.2 **Percentage of Full-Time Science and Engineering Graduate Students by Major Source of Support in Doctorate-Granting Institutions**

	Federal Funds		Institutional Funds		Other Outside Support		Self-Support	
Year	A	B	A	B	A	B	A	B
1966	40.9%		35.0%		6.1%		18.0%	
1969	36.6		35.7		9.0		18.6	
1970	34.4		36.9		9.2		19.5	
1971	31.7		37.0		8.8		22.4	
1972	30.0		38.6		8.3		23.1	
1974	25.5	24.6%	39.9	38.5%	8.9	8.4%	25.8	28.6%
1975		22.9		36.7		8.0		32.4
1976	22.5	22.7	37.0	37.0	8.2	8.3	32.3	32.0
1977	23.1	23.2	36.9	37.0	8.5	8.4	31.6	31.5
1978		23.7		36.8		8.9		30.6
1979		23.7		37.1		9.0		30.3
1980		23.0		37.6		9.1		30.3
1981		21.7		38.5		9.6		30.2
1982		19.9		39.4		10.0		30.8
1983		19.4		39.5		10.0		31.0
1984		19.3		40.6		10.0		30.1
1985		19.6		41.0		10.6		28.9
1986		19.8		41.6		10.2		28.4
1987		20.2		41.9		9.5		28.4
1988		20.4		42.2		9.5		27.8

Sources: See table 6.1.

selected major fields, on the percentages of FTSEG students in doctorate-granting institutions by major type of support. The fellowship category includes fellowships and research traineeships, the RA category represents research assistantships, the TA category represents teaching assistantships, and the other category includes tuition waivers and self-support.[5]

In the aggregate, a steep decline between 1968 and 1988 in the percentage of students supported by fellowships has been offset by a small increase in the percentage supported by research assistantships and by a large increase in the percentage who are on other types of support. Focusing on the 1974–88 period, the almost 6-point decline in the percentage of students supported by fellowships was offset by a slightly larger increase in the percentage of students supported by research assistantships. However, patterns of change vary widely across fields. For example, during the 1974–88 period, the decline in the percentage of students in the social sciences supported by fellowships was offset primarily by an increase in the percentage supported by teaching assistantships.

5. In the NSF data, federal fellowships are offered to students who then decide which institution to attend, while traineeships are granted to institutions who then decide to which students to offer the awards.

Table 6.3 **Percentages of Full-Time Science and Engineering Graduate Students in Doctorate-Granting Institutions, by Field and Types of Major Support: 1968, 1974, 1988**

	A		B	
Field	1968	1974	1974	1988
Total				
Fellowship*	32.0%	20.1%	19.7%	14.0%
RA*	22.1	21.9	20.3	27.4
TA*	23.3	24.7	23.6	22.9
Other	22.6	33.3	36.4	35.7
Engineering				
Fellowship	29.4	15.2	14.3	8.7
RA	29.5	34.2	33.0	37.8
TA	13.2	15.2	15.4	17.7
Other	27.9	35.4	37.3	35.8
Physical science				
Fellowship			11.6	8.5
RA			30.1	42.6
TA			47.3	40.4
Other			10.9	8.5
Agriculture**				
Fellowship	21.6	10.1	10.1	5.8
RA	47.6	45.9	45.8	51.1
TA	8.3	9.0	7.8	9.6
Other	32.5	35.0	36.3	33.4
Biology				
Fellowship	38.0	24.7	25.7	23.4
RA	9.5	9.6	20.3	36.4
TA	30.2	35.8	26.5	21.6
Other	22.3	29.8	27.5	18.6
Health				
Fellowship			39.6	27.3
RA			5.5	12.1
TA			11.0	9.2
Other			43.9	51.4
Environmental Science				
Fellowship			10.7	9.1
RA			32.0	38.6
TA			24.2	24.6
Other			33.1	27.7
Math and CIS				
Fellowship	27.2	10.6	9.5	7.5
RA	8.6	11.3	10.3	15.6
TA	41.3	50.4	46.5	40.2
Other	22.8	27.7	33.7	36.9

(continued)

Table 6.3 (continued)

	A		B	
Field	1968	1974	1974	1988
Psychology				
Fellowship	41.1	24.7	24.2	11.0
RA	15.2	12.4	12.1	14.9
TA	21.2	21.6	20.8	22.0
Other	24.5	41.2	42.9	52.1
Social sciences				
Fellowship	36.2	22.4	21.0	17.4
RA	10.5	11.3	11.0	11.8
TA	18.5	19.4	17.5	20.2
Other	34.8	46.9	50.5	50.6

Sources: See table 6.1.

*Fellowship includes fellowships and research traineeships; RA = research assistantships; TA = teaching assistantships; Other includes tuition waivers and self-support.

**1969 figures are reported in the 1968 column.

Changes in external support of a particular type may well affect more than one type of institutional support. For example, an increase in the number of federally funded research assistantships received by an institution might prompt the institution to reduce the number of research assistantships it awards out of institutional funds but, in an effort to attract top students, to increase the number of fellowships it awards out of institutional funds. We provide estimates of such substitution across types of support in section 6.5.

Finally, it is worth noting that tables 6.1, 6.2, and 6.3 all refer to full-time students. In the aggregate, as the data presented in table 6.4 show, the percentage of science and engineering graduate students at doctorate-granting institutions who are enrolled part-time has risen over the 1974–88 period. No increase in the proportion of part-time students occurred in the field of engineering, where the sum of the proportions of students on fellowships, research assistantships, and teaching assistantships was higher in 1974 than it was in 1988 (table 6.3). In contrast, an increase in the proportion of part-time graduate students in the fields of psychology and the social sciences has occurred. Although we do not pursue the topic further here, analysis of how changes in federal and other external support levels influence the proportion of graduate students who are enrolled part-time is also of obvious interest.

6.3 Institutionally Based Analyses

Consider the following simple equation that seeks to explain the number of FTSEG students in institution j in academic year t supported by institutional funds (I_{jt}).

$$I_{jt} = a_0 + a_1X_{jt} + a_2F_{jt} + a_3A_{jt} + v_{jt} + \varepsilon_{jt} \quad (1)$$

Table 6.4 **Percentage of Science and Engineering Graduate Students Enrolled Part-Time at Doctorate-Granting Institutions**

	Total		Engineering		Psychology		Social Sciences	
Year	A	B	A	B	A	B	A	B
1965	27.4%		43.9%		16.3%		23.2%	
1968	23.1		41.1		12.5		22.1	
1971	21.9		36.2		12.5		24.8	
1974	21.4	26.3%	37.5	40.5%	20.4	24.0%	25.7	28.0%
1977		29.1		43.6		24.2		31.1
1980		30.9		40.2		26.6		35.8
1983		32.0		38.8		28.4		33.5
1988		31.5		36.4		28.5		34.3

Sources: See table 6.1.

Here X_{jt} is the number of undergraduate students that the institution expects to enroll in science and engineering courses during the academic year; F_{jt} is the number of science and engineering faculty employed by the institution in the academic year; A_{jt} is the number of FTSEG students in the institution supported by federal government and other external funds in the academic year; v_{jt} is an institution-specific error term; and ε_{jt} is a random error term.

Presumably an increase in undergraduate student enrollments will increase the institution's demand for teaching assistants, so a_1 is expected to be positive. While an increase in science and engineering faculty size will similarly increase the institution's demand for graduate research assistants, holding undergraduate enrollments constant, it might decrease the institution's demand for teaching assistants. Thus, the sign of a_2 is a priori indeterminate.

The key variable in the model is the number of FTSEG students supported on external funds. At one extreme, if the number of students the institution supports is independent of the number that the federal government and other external sources support, no displacement takes place and a_3 will be zero. In contrast, if the institution reduces the number of students it supports by exactly the number that the federal government and other external sources support, displacement will be complete and a_3 will equal minus one. Values of a_3 between zero and minus one indicate partial substitution of external for institutional funds.

In theory, equation (1) can be estimated using a single year's data for a cross section of doctorate-producing universities. However, the institution-specific error term presents a problem. Surely there are many other variables besides an institution's undergraduate enrollments and its faculty size that should affect its willingness to finance graduate students out of its own internal funds. Omission of these variables, which are captured by the institution-specific error term, may lead to biased coefficient estimates.

For example, suppose institutions that place a high value on graduate education and research simultaneously support above-average (given their size) numbers of graduate students *and* hire first-rate faculty, who succeed in attracting above-average levels of support for graduate students from federal government and other external research grants. In the context of equation (1), this can be interpreted as high values for the institution-specific error term (v_{jt}) simultaneously causing the numbers of FTSEG students supported by external (A_{jt}) and institutional (I_{jt}) funds to be high. Thus, a spurious positive correlation will arise between the numbers of FTSEG students supported by institutional and external funds, and if we ignore the institution-specific error term, our estimate of a_3 will likely be biased.

One way around the problem is to try to make the institution-specific error term "observable" by including other variables with which it is likely to be correlated in the analyses (e.g., prestige measures of science and engineering fields in the institution and, in the case of private-sector institutions, measures of the institution's wealth). While we intend to pursue such strategies in later research, here we adopt a more parsimonious approach.

If one is willing to treat the institution-specific error term as fixed over time ($v_{it} = v_i$), one can obtain data for two time periods (t and s), write equation (1) down for both periods, and then take first differences to obtain

$$(2) \quad I_{jt} - I_{js} = a_1(X_{jt} - X_{js}) + a_2(F_{jt} - F_{js}) + a_3(A_{jt} - A_{js}) + (\varepsilon_{jt} - \varepsilon_{js})$$

Estimation of (2), in which all variables are expressed as changes, will yield unbiased estimates of the parameter of interest, a_3, because the unobserved fixed effect has been eliminated from the model. Alternatively, one can obtain unbiased estimates by using the two years of data and estimating an augmented version of the original model that includes institution-specific intercept terms.

Table 6.5 presents estimates that use the latter approach and data from 200 doctorate-producing universities on the number of FTSEG students supported on institutional funds during fall 1984 and fall 1983. In each of columns 1, 2, and 3, the number of FTSEG students supported on external funds in the fall of each year is divided into the number supported on federal government funds (GTOT), the number supported on foreign funds (FTOT), and the number supported on other U.S., primarily corporate and nonprofit organization, funds (OTOT). In columns 4, 5, and 6, these three sources are aggregated to get a total number of FTSEG students supported on external funds (ATOT). Support is defined here to include fellowships, traineeships, research assistantships, teaching assistantships, and other types (primarily tuition waivers). These data come from the annual National Science Foundation *Survey of Graduate Science and Engineering Students and Postdoctorates.*

Data on enrollments in undergraduate science and engineering courses by institution are not available. What is available from the annual National Center for Education Statistics' *Higher Educational General Information Survey* (HEGIS) is the total number of bachelor's degrees awarded in science and

Table 6.5 Determinants of Institutional Support for Full-Time Science and Engineering Graduate Students in Research and Doctorate Universities, Fall 1983 and Fall 1984: Fixed Effects Model (absolute value *t*-statistics)

	ITOT					
	1	2	3	4	5	6
GTOT	−.214 (1.9)	−.248 (2.3)	−.240 (2.0)			
OTOT	−.209 (2.0)	−.210 (2.0)	−.199 (1.9)			
FTOT	−.286 (1.9)	−.238 (1.6)	−.228 (1.5)			
ATOT				−.224 (3.3)	−.231 (3.5)	−.221 (3.4)
TD	−.001 (0.0)			−.001 (0.0)		
FTE	.113 (3.4)			.116 (3.5)		
TD2		.080 (1.0)			.082 (2.0)	
FTE2		.218 (4.0)			.217 (4.2)	
TDA			.074 (1.3)			.075 (1.4)
FTEA			.208 (4.5)			.207 (4.5)
R^2	.997	.997	.997	.997	.997	.997
FICE/DOF*	200/194	197/190	197/189	200/191	197/192	197/191

Sources for data used in authors' computations:

ITOT, FTOT, OTOT, GTOT: National Science Foundation, *Survey of Graduate Science and Engineering Students and Postdoctorates: Fall 19XX.*

FTE, FTE2, FTEA: National Science Foundation, *Survey of Scientific and Engineering Personnel Employed at Universities and Colleges: January 19XX.*

TD, TD2, TDA: National Center for Education Statistics, *Higher Educational General Information Survey (HEGIS): Academic Year 19XX.*

All of these are available as part of the National Science Foundation's *Computer Aided Science Policy Analysis and Research Database System* (CASPAR). However, ITOT is not reported in CASPAR and the underlying data tapes must be used to obtain this variable.

Note: All specifications in this table are estimated using the ABSORB command in Proc GLM in SAS.

Definitions:

ITOT = Number of full-time science and engineering graduate (FTSEG) students supported by instituitonal and state funds on fellowships, traineeships, research assistantships, teaching assistantships, or other types (primarily tuition waivers) of support in the fall of year *t*

GTOT = Number of FTSEG students supported by federal government funds in the fall of year *t*

FTOT = Number of FTSEG students supported by foreign funds in the fall of year *t*

OTOT = Number of FTSEG students supported by other U.S. (primarily corporate and nonprofit) funds in the fall of year *t*

ATOT = Sum of GTOT, FTOT, and OTOT

TD = Total bachelor's degrees in science and engineering awarded by the institution in the academic year

TD2 = Same as TD but for academic year $t+1$

TDA = Average of TD and TD2

FTE = Total full-time scientific and engineering personnel employed by the institution in January of year *t*

FTE2 = Same as FTE but for January of year $t+1$

FTEA = Average of FTE and FTE2

engineering fields by an institution in each academic year.[6] While there is not necessarily a one-to-one relationship between changes in course enrollments and changes in graduating majors, the latter is the best proxy available for the former. Changes in degrees granted may well also lag changes in undergraduate enrollments. Hence, it is not clear, for example, whether bachelor's degrees granted in science and engineering in 1983–84 (TD) or those granted in 1984–85 (TD2) should be the best predictor of the demand for graduate teaching assistants in fall 1984. Results are presented in table 6.5 for specifications that use both measures, as well as their average (TDA).

Finally, no data exist by institution on the number of faculty employed in science and engineering fields. However, from 1973 to 1985, the National Science Foundation's *Survey of Scientific and Engineering Personnel Employed at Universities and Colleges* collected information from doctorate-granting institutions in January of each year on the total number of full-time scientists and engineers employed.[7] These headcounts are not restricted to faculty nor even to doctorates, but they probably provide a reasonable approximation to the scale of research and teaching activity in science and engineering fields in the institution. Restricting the headcount to full-time employees assures that graduate assistants are not included in the total. Again, it is not a priori obvious whether the best predictor of the demand for research and teaching assistants in the fall of a year would be the number of full-time scientists and engineers employed in the institution in January of that year (FTE), which represents the previous academic year, or in January of the next year (FTE2), which represents the current academic year. Specifications are thus again estimated using both measures, as well as their average (FTEA).

The results displayed in table 6.5 suggest that changes in external support for FTSEG students *do* influence institutional support levels. The institutional responses to changes in the various sources of external support (GTOT, OTOT, and FTOT) reported in columns 1, 2, and 3 appear to be quite similar; indeed, formal F tests indicate one cannot reject the hypothesis that they are all equal. When the various sources are aggregated (ATOT), the specifications in columns 4, 5, and 6 suggest that for every 100 additional FTSEG students supported by external funds, institutions reduce the number of FTSEG students supported by institutional funds by 22 to 23. Whether the money saved was used to support graduate students in other fields or for other purposes cannot be determined from these data.

The above results assume instantaneous adjustment of the number of FTSEG students supported on institutional funds, the number of degrees granted, and faculty size. However, commitments to support graduate students are often made, at least implicitly, for more than one year at a time. As

6. In recent years, the scope of the HEGIS has been expanded, and it is now called the *Integrated Postsecondary Education Data System* (IPEDS).

7. The cessation of this survey in January 1985 precludes us from using more-recent data on institutional and external support for graduate students in our analyses.

such, considerable inertia may be built into the process, and the substitution of external for internal funds may be greater in the long run than in the short run.

One way to test for this is to build a lagged adjustment process directly into the model. Suppose that equation (1) is replaced by

$$(3) \qquad I^*_{jt} = b_0 + b_1X_{jt} + b_2F_{jt} + b_3A_{jt} + v_j + \varepsilon_{jt},$$

where I^*_{jt} is the number of FTSEG students that institution *j desires* to support out of its own funds in year *t*. Because of the inertia caused by multiyear commitments to graduate students and the institution's goal of maintaining relatively stable graduate enrollments and financial commitments to graduate students, I^*_{jt} is assumed to adjust to its desired number of institutionally supported FTSEG students only gradually.

Specifically, suppose that

$$(4) \qquad I_{jt} - I_{jt-1} = \lambda(I^*_{jt} - I_{jt-1}),$$

where λ ($0 \leq \lambda \leq 1$) is the fraction of the adjustment between this year's desired and last year's actual number of FTSEG students supported on institutional funds that the institution makes in the year. Substitution of (3) into (4) yields that

$$(5) \quad I_{jt} = \lambda b_0 + \lambda b_1X_{jt} + \lambda b_2F_{jt} + \lambda b_3A_{jt} + \lambda v_j + (1-\lambda)I_{jt-1} + \lambda\varepsilon_{jt}.$$

First, differencing to eliminate the unobservable fixed effects, one finds that

$$(6) \qquad I_{jt} - I_{jt-1} = \lambda b_1(X_{jt}-X_{jt-1}) + \lambda b_2(F_{jt}-F_{jt-1}) + \lambda b_3(A_{jt}-A_{jt-1}) + (1-\lambda)(I_{jt-1}-I_{jt-2}) + \lambda(\varepsilon_{jt}-\varepsilon_{jt-1})$$

Equation (6) differs from equation (2) in that the lagged change (from $t - 1$ to $t - 2$) in the number of FTSEG students supported by institutional funds appears on the right-hand side of (6). With three adjacent years' data on the number of students supported on institutional funds (here, data for fall 1984, 1983, and 1982), one can obtain consistent estimates both of the magnitude of the lagged adjustment term (λ) and of the extent to which external support substitutes for internal support (from b_3). To achieve this, an instrumental variable estimator must be used for $I_{jt-1} - I_{jt-2}$ to remove the spurious negative correlation between that variable and the error term $\lambda(\varepsilon_{jt} - \varepsilon_{jt-1})$ that the first differencing causes.[8]

Estimates of equation (6) appear in table 6.6 for the specifications that correspond to those found in columns 1, 2, and 3 of table 6.5. Column A for each specification uses the actual value of the lagged one-year change in the number of FTSEG students supported on institutional funds as an explanatory variable, while column B in each specification uses an instrumental variable

8. The variables used as instruments include I_{jt-1} and the values from periods $t - 1$ and $t - 2$ of all the other explanatory variables in the model.

Table 6.6 Determinants of Institutional Support for Full-Time Science and Engineering Students in Research and Doctorate Universities: Lagged Adjustment Model with Fixed Effects (absolute value *t*-statistics)

	CITOT					
	1a	1b	2a	2b	3a	3b
CGTOT	−.223 (2.1)	−.242 (2.3)	−.249 (2.4)	−.257 (2.4)	−.247 (2.4)	−.260 (2.5)
CFTOT	−.147 (1.0)	−.173 (1.2)	−.150 (1.0)	−.174 (1.1)	−.124 (0.8)	−.146 (1.0)
COTOT	−.298 (2.8)	−.254 (2.5)	−.254 (2.4)	−.241 (2.3)	−.260 (2.5)	−.233 (2.3)
CFTE	−096 (3.1)	.095 (3.0)				
CTD	−.031 (0.9)	−.015 (0.4)				
CFTE2		.149 (2.7)	.152 (2.7)			
CTD2		.041 (1.0)	.047 (1.1)			
CFTEA				.163 (3.5)	.164 (3.5)	
CTDA				.002 (0.0)	.024 (0.4)	
CITOTL*	.096 (1.6)	−.005 (0.0)	.055 (0.9)	−.017 (0.1)	.071 (1.1)	−.002 (0.0)
R^2	.090	.078	.083	.079	.010	.093
DOF	187	187	188	187	187	187

Sources: See table 6.5.

Notes:

CITOT	= ITOT(84) − ITOT(83)	CFTE	= FTE(84) − FTE(83)	CFTEA	= [FTE(85) − FTE(83)]2
CGTOT	= GTOT(84) − GTOT(83)	CTD	= TD(84) − TD(83)	CTDA	= [TD(85) − TD(83)]2
CFTOT	= FTOT(84) − FTOT(83)	CFTE2	= FTE(85) − FTE(84)	CITOTL	= ITOT(83) − ITOT(82)
COTOT	= OTOT(84) − OTOT(83)	CTD2	= TD(85) − FTE(84)		

See table 6.5 for variable definitions.

estimator. The "C" in front of each variable name indicates that each is in first-difference form.

Quite strikingly, in no case can one conclude that λ is statistically significantly different from zero. Put another way, institutions appear to fully adjust, to their desired levels the number of FTSEG students they support out of internal funds each year.

The first three columns of table 6.7 report similar estimates for the specifications that aggregate the various external support sources into a single variable (ATOT). Given the statistical insignificance of the lagged change in the number of students supported on internal funds in the previous table, only the specification that uses the actual lagged change is reported here. Again, adjustment appears to be complete ($\lambda = 0$), and displacement appears to be in the range of −.23.

The last three columns of table 6.7 report estimates of specifications in which the extent to which the number of FTSEG students supported by institutional funds varies with the number supported on external funds is allowed to vary across public and private institutions and across research I universities and other doctorate-granting institutions. Research I universities are those that award at least 50 Ph.D. degrees annually and receive at least \$33.5 million

Table 6.7 **Determinants of Institutional Support for Full-Time Science and Engineering Students in Research and Doctorate Universities: Lagged Adjustment Model with Fixed Effects and All External Support Sources Aggregated Together (absolute value *t*-statistics)**

	CITOT					
	1	2	3	4	5	6
CATOT	−.239 (3.7)	−.234 (3.7)	−.231 (3.7)	.121 (0.7)	.143 (0.8)	.128 (0.7)
CATOT*R1			−.406 (3.0)	−.405 (3.1)	−.382 (2.9)	
CATOT*P			−.127 (0.8)	−.145 (0.9)	−.143 (0.9)	
CFTE	.093 (3.0)			.083 (2.7)		
CTD	−.026 (0.7)			−.039 (1.1)		
CFTE2	.146 (2.7)			.140 (2.6)		
CTD2	.041 (1.0)			.045 (1.1)		
CFTEA		.158 (3.4)			.145 (3.1)	
CTDA		.006 (0.1)			−.007 (0.1)	
CITOTL	.078 (1.4)	.047 (0.8)	.060 (1.0)	.046 (0.8)	.009 (0.1)	.028 (0.4)
$\bar{R}^2$	.095	.090	.106	.131	.128	.138
DOF	189	190	189	187	188	187

Definitions: All variables are defined in tables 6.5, and 6.6 save for:
CATOT = [GTOT(84) + FTOT(84) + OTOT(84)] − [GTOT(83) + FTOT(83) + ITOT(83)]
R1 = 1 for research I institutions, 0 for other
P = 1 for public institutions, 0 for other

annually in federal research support. Most award considerably more than 50 science and engineering Ph.D.'s each year.[9]

These specifications suggest that substitution of external for institutional funds supporting graduate students occurs only at the relatively large (in terms of doctorates produced and external research support generated) research I institutions. No such substitution tends to occur in those institutions with smaller-scale doctorate and research programs. Furthermore, the extent of substitution of external for institutional funds at research I institutions does not appear to differ between public and private institutions.

6.4 Disaggregation by Field

To conclude that, in the aggregate, when the number of FTSEG students supported by external funds increases by 100, institutions reduce the number of FTSEG students they support out of institutional funds by about 22 to 23 is not to say that the response will be the same across all fields. To address the latter issue requires that separate analyses be undertaken by field.

A first approach is to estimate variants of equation (1), using field-specific data. Data on institutional and external FTSEG student support levels, the

9. For example, in 1988, 70 institutions awarded at least 100 science and engineering Ph.D.'s, with Berkeley alone awarding 576 (see National Science Foundation 1989, table 10).

number of full-time scientific and engineering personnel employed, and the number of bachelor's degrees granted were collected by institution for seven broad science and engineering subfields. Field-specific equations were estimated, and the coefficients of the external support variables that were obtained are displayed in panels A and B of table 6.8.

The coefficients of the external support variables for each field in panel A come from field-specific specifications similar to the specification found in column 1 of table 6.5. The effects on internal support levels of changes in federal government, other U.S., and foreign support levels often appear to differ from each other at this level of disaggregation. Formal F tests indicate that this is indeed the case.[10] Only for the engineering and mathematical sciences fields can one *not* reject the hypothesis that the marginal effects of changes in the number of FTSEG students supported by the various external funding sources are equal.

Nonetheless, it is interesting to aggregate the external support variables and estimate what the "average" substitutability of internal for external support is for each field. The results obtained when one does this are found in panel B of table 6.8; the coefficient estimates presented there come from field-specific variants of the model estimated in column 4 of table 6.5.

External support appears to partially substitute for internal support in six of the seven fields. This substitution is statistically significant in five of these six fields. The magnitude of the substitution ranges from almost 50 percent in the physical sciences, where an additional 100 FTSEG students supported on external funds are estimated to reduce the number of internally supported students by about 48, down to about 10 percent in the mathematical sciences. Only for the relatively small environmental sciences fields do increases in external support appear to be associated with increases in internal support.[11] There is weak evidence that fields which, on average, have a greater share of their students supported on institutional funds tend to reduce their own internal support for FTSEG students the most when the number of externally supported students is increased.[12]

The model that underlies the estimates presented above treats each field separately and does not allow for the possible interdependency of internal

10. The computed F-statistics are:

Engineering	$F(2,137) = 1.22$	Environmental sciences	$F(2,147) = 5.47$
Physical sciences	$F(2,180) = 3.48$	Psychology	$F(2,176) = 3.73$
Life sciences	$F(2,183) = 4.61$	Mathematics	$F(2,181) = 1.04$
Social sciences	$F(2,179) = 3.59$		

In each case, the critical value to reject the null hypothesis at the .05 level is 3.09.

11. In October 1984, only 4.6 percent of all FTSEG students in doctorate-granting institutions were enrolled in environmental science fields (National Science Foundation 1990, table C1).

12. Across the seven fields, the correlation of the average proportion of supported students in a field supported by institutional funds and the estimate of the substitution of external for internal funds in the field (the coefficients in panel B) is −.32. However, if one drops environmental sciences from the sample, the correlation across the six remaining fields falls to under −.2.

Table 6.8 **Determinants of Institutional Support for Full-Time Science and Engineering Graduate Students in Research and Doctorate Universities, Fall 1983 and Fall 1984: Fixed Effects Model, by Field**

	Engineering	Physical Sciences	Life Sciences	Social Sciences	Environmental Sciences	Psychology	Mathematical Sciences
A							
GTOT	−.148 (1.1)	−.522 (6.5)	−.486 (7.3)	.094 (0.7)	.316 (2.6)	−.659 (4.6)	−.044 (0.2)
FTOT	−.059 (0.3)	−.425 (1.2)	−.464 (2.1)	−.346 (3.0)	.434 (2.1)	1.479 (1.6)	.193 (0.8)
OTOT	−.270 (2.9)	−.480 (3.4)	.036 (0.2)	−.450 (3.3)	−.108 (0.8)	−.163 (1.0)	−.221 (1.6)
FICE	142	187	190	186	151	185	188
B							
ATOT	−.204 (2.7)	−.479 (7.1)	−.380 (7.4)	−.219 (3.2)	.251 (2.8)	−.412 (3.7)	−.104 (1.2)
C							
ATOT	−.199 (1.9)	−.653 (6.7)	−.328 (3.7)	−.318 (3.3)	.232 (2.0)	−.499 (4.5)	−.162 (1.6)
TOT	−.028 (0.6)	−.021 (1.0)	−.019 (0.4)	.042 (1.0)	−.001 (0.1)	.018 (1.4)	.038 (2.0)
D							
ATOT	−.149 (1.5)	−.633 (6.8)	−.310 (3.7)	−.318 (3.4)	.233 (2.1)	−.517 (4.8)	−.171 (1.8)
TOT	−.040 (1.0)	−.024 (1.2)	−.026 (0.5)	.043 (1.0)	−.001 (0.0)	.019 (1.5)	.038 (2.0)
FICE	113	113	113	113	113	113	113

Notes: Panel A, same specification as table 6.5, column 1, but all data field-specific; Panel B, same specification as table 6.5, column 4, but all data field-specific; Panel C, same as B, but TOT added; Panel D, same as C, but seemingly unrelated regression method used, where TOT = sum of ATOT across all seven fields and FICE = number of institutions included in the analyses.

support levels across fields. So, for example, an increase in the number of students supported on external funds in one field might induce an institution to reduce the number of students it supports out of institutional funds in that field and then use all or part of the savings to fund more graduate students out of internal funds in other fields.

One way to test whether such interdependencies exist is to estimate a system of equations of the form

$$(7)\qquad I_{jkt} = a_{0k} + a_{1k}X_{jkt} + a_{2k}F_{jkt} + a_{3k}A_{jkt} + a_{4k}A_{jt} + v_{jk} + \varepsilon_{jkt}$$
$$k = 1, 2, \ldots, 7.$$

In the above equations, the subscript k indexes the field of study. The number of students in the field supported out of institutional funds (I_{jkt}) is assumed to depend on both the number of students in the field supported by external funds (A_{jkt}) *and* the number of students supported by external funds in the institutions as a whole (A_{jt}). Other factors staying the same, an increase of 100 in the number of students in field k supported by external funds would lead to a change of $100(a_{3k} + a_{4k})$ in the number of students in field k supported by internal funds. Similarly, an increase of 100 in the number of FTSEG students supported in the institution as a whole by external funds, with no increase in the number of students in field k supported by external funds, would lead to a change of $100a_{4k}$ in the number of students in field k supported by internal funds. A positive estimate a_{4k} thus indicates that part of any increase in external support for graduate students elsewhere in a university is implicitly used to support graduate students in field k.

Given two years of data, one can first difference the data to eliminate the assumed institution/field fixed effects (v_{jk}) and obtain consistent estimates of the parameters from the system of equations in (7). The coefficients that result for the number of FTSEG students with external support in the field (ATOT) and in the institution as a whole (TOT) are displayed in panels C and D of table 6.8. The data used here come from a sample of 113 institutions that reported data in both years for all seven fields. The estimates reported in panel D use the seemingly unrelated regression method to improve efficiency by taking account of the correlation of the error terms across fields within an institution. In most cases, these estimates vary only marginally from the estimates reported in panel C.

Of key interest are the estimated coefficients for TOT. These estimates suggest that increases in the overall number of students supported by external funds in the science and engineering fields are used partially to subsidize graduate education in the social sciences, psychology, and mathematical sciences. However, only the latter effect is statistically significantly different from zero. Other factors being equal, an increase of 100 in the number of FTSEG students supported by external funds outside of these fields leads to an increase in the number of students supported on institutional funds of roughly 4 in the social sciences, 2 in psychology, and 4 in the mathematical sciences. As noted in earlier sections, whether a similar subsidization of graduate education in the humanities occurs cannot be ascertained from these NSF data because they lack information on graduate student support in humanities fields.

6.5 Disaggregation by Type of Support

FTSEG students who are supported from external funds often have different types of support than those who are supported from institutional funds. For example, the former are more likely to receive research assistantships, while the latter are more likely to receive teaching assistantships.[13]

13. More generally, in fall 1984 the proportions of FTSEG students supported from institutional and external funds, by type of support, in our sample were:

	Fellowship/ Traineeship	Research Assistantship	Teaching Assistantship	Other
Institutional	.140	.176	.574	.110
External	.279	.515	.018	.188

It is possible that an institution that receives an increase in one type of external support for FTSEG students may reduce the number of students that it supports out of institutional funds on that type of support and use some or all of the savings to increase the number of FTSEG students it supports internally on other types of support. So, for example, an increase in external support for research assistants may lead an institution to reduce the number of research assistantships it offers out of institutional funds but to increase its allocation of internal funds to teaching assistantships and fellowships.

To allow for this possibility, equation (1) can be generalized to the four-equation system

$$\text{(8)} \qquad IT_{jt} = a_{0T} + a_{1T}X_{jt} + a_{2T}F_{jt} + \Sigma_z a_{3TZ}AZ_{jt} + vT_{jt} + \varepsilon_{jTt}$$

T, Z = SUM, TA, RA, OTH. The numbers of FTSEG students supported from institutional and external funds are decomposed in each case into the numbers supported on fellowships and traineeships (SUM), on teaching assistantships (TA), on research assistantships (RA), and on other types—primarily tuition waivers—of support (OTH). Assuming that the institution-specific error terms are fixed over time ($vT_{jt} = vT_j$), with two years of data one can again estimate the equations in first-difference form to obtain unbiased estimates.

Estimates of this system appear in table 6.9. While an increase in the number of FTSEG students supported by externally funded research assistantships is associated with a decrease in the number of FTSEG students supported by institutional research assistantships, a large share of these "saved" institutional funds are redirected toward increasing the number of students supported by institutional teaching assistantships and fellowships. An increase in external funding for teaching assistantships leads to a substantial reduction in institutional teaching assistantships. In contrast to the research assistantship results, however, none of these "saved" institutional funds appears to be diverted to other types of support for graduate students. Finally, changes in external fellowships and traineeships and in other types of support each seem to affect primarily other, rather than the same, internal types of support.

Similar estimates of the coefficients of the various external types of support variables appear in table 6.10 for analyses done separately by field. Increases in external support for fellowships and traineeships lead to statistically significant reductions in institutional support for fellowships in five of the seven fields. Similar statistically significant "own substitution" effects occur in four of the seven fields for research assistantships and five of the seven fields for teaching assistantships. Many statistically significant "cross-substitution" effects are present, although the pattern is not always consistent across fields. For example, an increase in external fellowship support is associated with an increase in institutional teaching assistant support in the life sciences but with a decrease in such support in the social sciences. Findings of this type confirm the need to undertake separate analyses by field.

Table 6.9 Determinants of Institutional Support for Full-Time Science and Engineering Graduate Students in Research and Doctorate Universities, Fall 1983 and Fall 1984: Fixed Effects Model, by Type of Support (absolute value *t* statistics)

	ISUM	IRA	ITA	IOTH
ASUM	−.066 (1.2)	−.039 (0.4)	−.086(1.2)	.122 (2.1)
ARA	.091 (2.1)	−.205 (2.5)	.106 (1.8)	−.082 (1.8)
ATA	−.172 (0.8)	−.602 (1.5)	−.796 (2.7)	−.267 (1.1)
AOTH	−.148 (3.3)	−.189 (2.3)	−.067 (1.1)	.013 (0.3)
FTE	.109 (1.3)	.058 (2.3)	.015 (0.8)	.027 (0.1)
TD	.001 (0.0)	−.008 (0.3)	−.013 (0.7)	.001 (0.1)
R^2	.990	.990	.998	.961
FICE/DOF	200/188	200/188	200/188	200/188

Definitions:
ISUM = Number of FTSEG students supported by institutional and state funds on fellowships and traineeships
ITA = Number of FTSEG students supported by institutional and state funds on teaching assistantships
IRA = Number of FTSEG students supported by institutional and state funds on research assistantships
IOTH = Number of FTSEG students supported by institutional and state funds on other (primarily tuition waivers) types of support
ASUM = Same as ISUM but supported by federal government, foreign, or other US (FFO) funds
ARA = Same as IRA but supported by FFO funds
ATA = Same as ITA but supported by FFO funds
AOTH = Same as IOTH but supported by FFO funds
Other variables are defined in table 6.5.

6.6 Concluding Remarks

This paper has demonstrated that doctorate-producing universities respond to changes in the number of FTSEG students supported on external funds by altering the number of FTSEG students that they support on institutional funds. While institutional adjustment to changes in external support levels appears to be quite rapid, in the aggregate the magnitude of these responses is quite small. A increase of 100 in the number of FTSEG students supported by external funds is estimated to reduce the number supported on institutional funds by 22 to 23. Since some of the institutional funds that are "saved" may be redirected to support graduate students in the humanities and other fields not represented in the data, the total effect of such a policy change on institutional support for graduate students is probably somewhat smaller.

Two qualifications are in order here. First, institutions are likely to react quite differently to changes in external support levels that they perceive as being transitory as opposed to changes that they perceive as being permanent.[14] Transitory increases, which are not expected to recur in future years,

14. We owe this point to Michael McPherson.

Table 6.10 Determinants of Institutional Support for Full-Time Science and Engineering Graduate Students in Research and Doctorate Universities, Fall 1983 and Fall 1984: Fixed Effects Model, by Field and Type of Support (absolute value *t* statistics)

Field	ISUM	IRA	ITA	IOTH
Engineering				
ASUM	−.116 (2.4)	.080 (0.6)	−.167 (1.4)	−.011 (0.2)
ARA	−.022 (1.1)	−.089 (1.6)	.042 (0.9)	−.144 (5.2)
ATA	−.063 (0.5)	−.657 (1.7)	−.870 (2.7)	−.437 (2.3)
AOTH	−.048 (1.9)	−.045 (0.6)	.072 (1.2)	−.042 (1.2)
Physical Sciences				
ASUM	−.189 (3.5)	−.139 (1.7)	.089 (0.8)	−.003 (0.1)
ARA	−.090 (2.8)	−.243 (4.9)	−.310 (4.5)	.030 (1.8)
ATA	−.028 (0.1)	.181 (0.4)	−1.609 (2.6)	−.120 (0.8)
AOTH	−.014 (0.2)	.041 (0.4)	−.447 (3.0)	.016 (0.5)
Life Sciences				
ASUM	−.126 (2.5)	−.311 (3.1)	.222 (3.2)	.055 (1.3)
ARA	.112 (3.5)	−.452 (7.0)	−.087 (2.0)	−.053 (2.0)
ATA	−.190 (1.1)	−.480 (1.4)	−.200 (0.8)	−.067 (0.5)
AOTH	.075 (1.3)	−.336 (2.9)	.050 (0.6)	.043 (0.9)
Social Sciences				
ASUM	−.174 (3.2)	.064 (1.3)	−.094 (2.0)	−.069 (1.2)
ARA	.125 (0.9)	−.104 (0.8)	−.016 (0.1)	.143 (1.0)
ATA	.402 (0.7)	−.299 (0.6)	−.517 (1.1)	1.220 (2.1)
AOTH	−.302 (3.9)	−.052 (0.8)	.003 (0.1)	.092 (1.2)
Environmental Sciences				
ASUM	.057 (0.8)	−.018 (0.2)	.264 (2.7)	.051 (0.7)
ARA	.029 (0.5)	−.079 (1.4)	.074 (1.0)	−.017 (0.3)
ATA	.080 (0.3)	−.222 (0.8)	−.231 (0.6)	−1.379 (5.2)
AOTH	.073 (0.8)	−.030 (0.3)	.188 (1.5)	.079 (0.9)
Psychology				
ASUM	−.126 (1.1)	.069 (0.6)	−.215 (1.7)	−.609 (3.3)
ARA	−.241 (2.1)	−.126 (1.1)	−.096 (0.8)	.025 (0.1)
ATA	.099 (0.3)	−.088 (0.3)	−1.072 (3.3)	−.214 (0.5)
AOTH	−.120 (1.9)	.037 (0.6)	−.090 (1.3)	−.050 (0.5)
Mathematical Sciences				
ASUM	−.548 (4.5)	.106 (1.1)	.310 (1.7)	.284 (4.1)
ARA	.127 (1.5)	−.444 (6.7)	.182 (1.5)	−.181 (3.7)
ATA	−.178 (0.6)	−.326 (1.5)	−1.317 (3.2)	.162 (1.0)
AOTH	.114 (1.4)	.061 (1.0)	.024 (0.2)	−.015 (0.3)

Note: The underlying model is the same as that estimated in table 6.9, save that all variables are field-specific. See table 6.9 for variable definitions.

are unlikely to lead to large reallocations of institutional funds. Institutions may treat such increases as windfalls and compensatingly reduce their own expenditures for graduate support temporarily.

In contrast, permanent increases, which institutions may view as fundamentally altering their wealth levels, are likely to lead to larger institutional commitments to graduate education and thus to less substitution of external for institutional funds. To the extent that the variation in changes in external support levels across institutions during a two-year period reflect primarily transitory fluctuations, our estimates may thus well overstate the extent to which institutions would reduce their own internal support for FTSEG students in response to an increase in external support that was perceived to be more permanent.

Second, changes in external support levels in one year may affect the intertemporal allocation of institutional funds to support FTSEG students.[15] For example, the provision of external fellowships to support first-year entering graduate students in a field in year t might induce an institution to reduce its internal support for entering students in the field in year t. However, to the extent that substitution was not one for one, the size of its entering class will have increased and thus the number of advanced FTSEG students who "need" support will increase in subsequent years. To the extent that an institution uses some, or all, of the "saved" internal funds in year t to support an increased number of FTSEG students in subsequent years, focusing on contemporaneous responses (as we have done) will overstate the extent of substitution of external for institutional funds. A similar result would occur if institutions that previously provided support to students for four years used some of the saved internal funds in year t to provide fifth-year support in year $t + 4$ for some of the new students who entered in year t.

Policymakers also need be concerned that the magnitudes of the responses appear to differ significantly across fields. There is also evidence that even within science and engineering there is some fungibility of external support across fields. In particular, institutional support for the social sciences, psychology, and the mathematical sciences appears to increase somewhat in response to increases in external support to other science and engineering fields which permit institutions to reduce their own support to these other fields.

Finally, policymakers need be concerned that changes in external support levels influence the distribution of institutional support by type of support. For example, in the aggregate an increase in the number of FTSEG students supported by externally funded research assistantships is associated with a decrease in the number of FTSEG students supported by institutional research assistantships. However, a share of these "saved" funds is redirected to increasing the number of students receiving teaching assistantships out of institutional funds. It is often conjectured, although it has not been proven, that

15. We owe this point to Robert Hauser.

teaching assistantships slow down degree progress relative to research assistantships (see Ehrenberg 1991, chap. 8). As such, the latter shift may partially frustrate the goal of policymakers when they increase external support for research assistantships for FTSEG students.

The analyses reported in this paper are only a start at addressing the issues we pose. To a large extent, they focus on changes in external and institutional support levels between fall 1983 and fall 1984. While this was a period in which approximately half of the institutions in the sample faced increases in external support and half faced decreases, one wonders whether institutional responses would differ in periods when external support changes all tended to move in one direction and, more generally, whether institutional responses are stable over time. As discussed above, our focus on this one-year period also precluded us from distinguishing between institutional responses to transitory and permanent changes in external support for graduate students and from analyzing how such changes influence institutions' intertemporal decisions on allocating internal funds. Subsequent research by us will attempt to use a panel of 11 years' data (1974–84 period) from these institutions to address these issues.

Throughout the paper, differences in institutional characteristics that might influence universities' desire and willingness to support graduate students are, for the most part, "buried" in the unobservable fixed effects. Generalizations of the empirical models could productively be explicitly tied to models of university utility maximization subject to budget constraints (see, e.g., Garvin 1980; James 1990). One implication that likely flows from such an approach is that institutional support for graduate students should depend on the "wealth" levels of institutions. This suggests that measures of state budgetary tightness (in the public sector) or endowment strength (in the private sector) are candidates to be added to the empirical models. Similarly, an institution's willingness to support graduate students in a field may well depend upon the "quality," or the recent change in the "quality," of the field and of other fields in the institution. As such, estimation of whether the extent that external funds substitute for internal funds varies with field quality measures is also clearly warranted.

References

Adams, Charles, et al. 1983. A pooled time series analysis of the job creation impact of public service employment grants to large cities. *Journal of Human Resources* 18(Spring):283–94.

Atkinson, Richard C. 1990. Supply and demand for scientists and engineers: A national crisis in the making. Presidential address delivered to the American Association for the Advancement of Science. New Orleans, La.

Borus, Michael, and Daniel Hamermesh. 1978. Estimating fiscal substitution by public service employment programs. *Journal of Human Resources* 12(Fall):561–65.
Bowen, William G., Graham Lord, and Julie Ann Sosa. 1991. Measuring time to the doctorate. *Proceedings of the National Academy of Sciences* 88(February):713–17.
Bowen, William G., and Julie Ann Sosa. 1989. *Prospects for faculty in the arts and sciences*. Princeton, N.J.: Princeton University Press.
Ehrenberg, Ronald G. 1991. Academic labor supply. Part 2 of *Economic challenges in higher education,* ed. Charles Clotfelter, Ronald Ehrenberg, Malcolm Getz, and John Siegfried. Chicago: University of Chicago Press.
Ehrenberg, Ronald G., and Richard P. Chaykowski. 1988. On estimating the effects of increased aid to education. In *When public sector workers unionize,* ed. Richard B. Freeman and Casey Ichniowski. Chicago: University of Chicago Press.
Garvin, Donald. 1980. *The economics of university behavior.* New York: Academic Press.
Gramlich, Edward M., and Harvey Galper. 1973. State and local fiscal behavior and federal grant policy. *Brookings Paper on Economic Activity* 4(1):15–58.
James, Estelle. 1990. Decision processes and priorities in higher education. In *The Economics of American universities,* ed. Stephen Hoenack and Eileen Collins. Albany: State University of New York Press.
Johnson, George, and James Tomola. 1977. The fiscal substitution effects of alternative approaches to public service employment. *Journal of Human Resources* 12(Winter):3–26.
National Research Council. 1989. *Summary report 1988: Doctorate recipients from United States universities.* Washington, D.C.: National Academy Press.
———. 1990. *Biomedical and behavioral research scientists: Their training and supply.* Vol. 1, *Findings.* Washington, D.C.: National Academy Press.
———. 1989. Future scarcities of scientists and engineers: Problems and solutions. Washington, D.C.: National Science Foundation, Division of Policy Research and Analysis, Directorate for Scientific, Technological andd International Affairs. Mimeograph.
———. 1990. *Academic science engineering: Graduate enrollment and support, fall 1988.* Washington, D.C.: National Science Foundation.

Comment Michael S. McPherson

It is useful, I think, to locate this valuable paper in relation in two literatures. One is the stream of research in public finance that concerns itself with the "flypaper effect"—the proposition that grant money provided by an external agency to an institution or a lower level of government, even when it is fungible in principle, tends to "stick where it hits."[1] The other stream of literature is the small but recently growing set of empirical studies of the behavior of colleges and universities. A classic in this literature is David Breneman's

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1. In addition to the studies mentioned by the authors concerning the employment effects of federal support for public-sector employment, there are numerous studies on topics ranging from welfare and health care to education. For a brief survey, see McPherson and Schapiro (1991), chapter 4.

dissertation on the impact of institutional incentives on time to degree for graduate students at the University of California at Berkeley—a study later reported in an NBER volume (Breneman 1976). Recent work includes a fine study by Steve Hoenack and Dan Pierro (1990) of the interaction between the University of Minnesota and the state legislature, which includes empirical estimates of the legislature's reaction functions, and some work Morton Schapiro and I (McPherson and Schapiro 1991, chap. 4) have done studying the impact of changes in external funding on universities' allocation of resources across a set of activities.

An examination of either or both of these literatures points to the real difficulties in doing this kind of thing well. One is trying to extract a single set of behavioral relationships from among a set of mutually dependent decisions made by an institutional actor. Many relevant variables are hard to measure, and theory gives us only limited guidance about suitable empirical specifications. When the actor whose behavior is being modeled is a governmental or not-for-profit institution, we are in even worse shape for theory, since we don't have behavioral models of this kind of "firm" that we have much confidence in.

However, the only way to make progress is to try to push ahead on both empirical and theoretical fronts, and Ehrenberg, Rees, and Brewer's study provides an interesting first attempt to examine universities' behavioral responses to fluctuations in external support for graduate students. The authors find evidence of moderate "substitution" of federal for institutional graduate student support and evidence that the degree of substitutability differs across fields.

Modeling and Empirical Implementation

There are a couple of issues worth noting concerning the connection between the authors' theoretical discussion and their empirical implementation.

Dollars versus Bodies

Both the general public finance problem of fungibility from which this paper takes off and indeed its own theoretical discussion run in terms of dollars: How does external funding for one activity influence the institution's own funding for that activity and its funding for other activities? The data, however, apparently compel the authors to do their empirical work in terms of "bodies"—numbers of students—rather than dollars. The fact that some sorts of support are probably more costly than others makes for some difficulties in translating the authors' findings into conclusions about dollar substitutability.

Suppose, to illustrate, that a student who would have gotten a $15,000 university fellowship gets a federal fellowship of equal value instead. The university might take $10,000 of the $15,000 it would have spent on aiding this student and use it for some other purpose and then use the other $5,000 in support to another student who would otherwise have gotten nothing. In terms of body counts, the federal money shows no substitutability—the same number of students get institutional support whether or not the federal support is provided. But in dollar terms, two-thirds of the federal money is substituted out of student aid into support of other activities. It is interesting in this context that when the authors examine the impact of different types of external support on different types of internal support (section 6.5), some interesting patterns emerge. In particular, more federal research assistantships lead to fewer institutionally funded research assistantships and more institutionally financed teaching assistantships. Although we lack data on the cost to the institution of these different types of support, the results seem likely to be consistent with the story I have told here. Given the available data, there is not much the authors can do to translate their bodies results into dollars results, but there is need for caution in interpreting the results.

Dynamics of University Behavior

A second, very interesting, problem concerns the authors' use of a partial adjustment model to examine the dynamics of university behavior. Reflection on this modeling strategy—which seems a natural one to try—is worthwhile, since it may shed light on some of the underlying mechanisms at work within the university. The partial adjustment model seems to make sense with regard to adjustments of institutional support for students to factors such as number of undergraduate degrees granted. If your undergraduate population rises, you will increase the number of graduate students on university-supported teaching assistantships, with a lag.

But does it make as much sense for variation in external funding? The university gets a new stream of federal funding for students. The partial adjustment model says that the university continues to support students out of institutional funds for awhile, presumably using the new stream of federal funding to support added students, and then gradually reduces the number of added students, instead switching students over to federal funding. This gives more substitution in the long run than in the short run, as the partial adjustment model supposes.

This could happen, but a different kind of story seems more likely. The university gets a new stream of federal funding and instantly reshuffles its budget to finance more existing students from federal resources, either saving the institutional money or devoting it to other purposes. Then, if the federal support continues, the university uses that new funding base to expand its total graduate student operation, expanding the number of students and increasing the number on institutional funds. Here there is more substitution in the short run than in the long run. I've never been a dean (and never hope to be one), but it seems to me this is what I would try to do if more federal student support funds became available to my budget.

As the authors note in their conclusion, following up on discussion at the conference, the nature of the university's response here will depend on whether changes in federal support are viewed by the institution as permanent or transitory. The story as I have told it fits the case of a permanent increase. A transitory increase would presumably lead to a lot of short-run substitution as the university tries to "save" its windfall gain by using federal money to substitute for institutional money.[2]

The larger point, though, is that if the dynamics of university funding decisions follow the pattern described here, the partial adjustment model used in this paper may not be a very good way to capture what is going on. What seems to be true is that the university is making (roughly) two kinds of decisions: one about how "big" to be, in terms of the total number of graduate students the institution wants to have around, and another about how to finance them. The first decision, one suspects, could be handled well by some kind of partial adjustment model into which changes in federal support would enter. The second decision, about how to finance existing students, seems more likely to depend on contemporaneous variables. Both aspects of the model would need to be sensitive to the issue of distinguishing responses to permanent and transitory changes. Elaborating models that can capture more of these complexities is an important agenda for future work. Notice that it is inducing schools to expand the total size of their programs—or, more precisely, to expand their "output" in terms of completed degrees—that is the policy goal of federal support. Thus, looking at the relation between (permanent) variations in federal student support and total enrollments or (lagged) degree production might be an interesting approach in future work.

Directions for Future Research

As these remarks perhaps suggest, I would strongly endorse the authors' proposal that future work attempt to connect these kinds of empirical investigations with more explicit and complete models of university behavior. These don't necessarily have to be optimizing models, in which the university maximizes some objective function subject to constraints. There is, I think, a great deal of room for models that view university decisions as the outcome of contending political forces or as the result of behavioral rules that need not necessarily be derived from a single objective function.

There are at least two good reasons for striving to embed these kinds of empirical investigations in a more comprehensive picture of university functioning. One is the familiar problem of getting the equations specified correctly. For example, it is likely that increases in federal research assistant support are correlated with changes in the institution's success in winning grants.

2. I'm therefore puzzled by the authors' statement in section 6.6 that "transitory increases . . . are unlikely to lead to large reallocations of institutional funds." This seems to be contradicted by their next sentence.

That sort of success will influence a number of other financial flows that may wind up affecting the institution's allocation of resources to graduate student aid. It is easy to think of more potential interdependencies than one can plausibly incorporate in an empirical analysis; but better modeling of the university's behavior may help us keep track of the more important possibilities.

The second point is that it really is important to try to keep track of what universities do with resources that are freed up by increases in external support. In work that I have done with Morton Schapiro, we have attempted to trace impacts of changes in research funding on the growth in tuitions, institutional support for student aid, and spending on instruction. If external money is fungible, where it gets "funged" to is an important question for empirical investigation and for public policy consideration. To do the empirical work, one needs a more comprehensive picture of the choices the institution faces about where to devote its resources.

References

Breneman, David. 1976. The Ph.D. production process. In *Higher education as an industry,* ed. Joseph Froomkin, Dean Jamison, and Roy Radner. Cambridge, Mass.: Ballinger.

Hoenack, Stephen A., and Daniel J. Pierro. 1990. An econometric model of a public university's income and enrollments. *Journal of Economic Behavior and Organization* 14:403–23.

McPherson, Michael, and Morton Owen Schapiro. 1991. *Keeping college affordable: Government and educational opportunity* (Washington, D.C.: Brookings Institution).