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Academic Engagement, Commercialization, and Scholarship
Empirical Evidence from Agricultural and Life Scientists at US Land Grant Universities

Bradford Barham, Jeremy Foltz, and Ana Paula Melo

5.1 Introduction

Research on the factors shaping university-industry relations (UIR) has exploded in recent decades, as reflected by the hundreds of recent articles published on this topic.[1] At the heart of this take-off was the push by universities worldwide to pursue opportunities to commercialize intellectual property rights. Arguably, the 1981 passage of the Bayh-Dole Act put US public research universities at the forefront of this global expansion. It extended the intellectual property rights of American universities and their researchers to commercialize innovations and discoveries associated with federally sponsored research (Henderson, Jaffe, and Trajtenberg 1998; Grimaldi et al. 2011; Sampat 2006; Thursby and Thursby 2011). European and universities elsewhere followed suit to varying degrees. In the process, UIR around the globe expanded traditional scholarship models of publish-

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1. See, for example, Agrawal (2001); Djokovic and Souitaris (2008); Geuna and Muscio (2009); Perkmann et al. (2013); and Sengupta and Ray (2017).

ing and training students into directly engaging with industry and entering commercial domains via patents, start-ups, and other forms of corporate-university alliances.

Our study sheds light on the ground level of UIR at leading US land grant universities (LGUs) by examining the activities, attitudes, and research choices of individual agricultural and life science (ALS) faculty. At LGUs, faculty engagement with industry dates back to the end of the 19th century based on an explicit emphasis on practical agricultural and engineering sciences, formal extension appointments for faculty, and ongoing outreach with farms and firms to improve their performance. The recent salience of UIR activities to US LGUs stems from the financial stress they faced over the past three decades due to declines in state and federal support (Just and Huffman 2009; Ehrenberg 2012; Hoag 2005).[2] Hence most US LGUs pursued academic commercialization as a potential mechanism to generate royalties and start-up revenue streams (Thursby and Thursby 2011).

Our chapter exploits rich, unique, and representative individual-level cross-sectional and panel survey data gathered in 2005 and 2015 from ALS faculty from all 52 of the original 1863 US LGUs. We explore the prevalence, intensity, and importance of US land grant faculty's work with industry as compared to traditional scholarship activities. We also examine how faculty attitudes toward research choices shape their participation in UIR and how they combine UIR with traditional scholarship activities. We divide university industry relations into two types.[3] One is academic engagement (AE), defined as faculty participation in sponsored and collaborative research, contract research, consulting, and informal relationships with private firms and institutions. Academic commercialization (AC) is the other, defined as faculty participation in private intellectual property creation (via invention disclosures, patents, and licensing) and entrepreneurship (e.g., start-ups). These definitions are used in other recent articles that examine UIR among university faculty in Europe (D'Este and Perkmann 2011; Perkmann, King, and Pavelin 2011; Tartari, Perkmann, and Salter 2014; Tartari and Salter 2015; Sengupta and Ray 2017).

These apparently contrasting categories are not mutually exclusive types of UIR, with many faculty doing both AE and AC. In our analysis, we contrast faculty who engage in these three categories—engagement (AE), commercialization (AC), and both (AE/AC)—with faculty who are not engaged in any of the three, which we categorize as traditional scholarship (TS).[4]

2. For example, compared to the 2007–8 school year, state spending on higher education, which is a significant portion of LGU budgets nationwide, was down in 2015 by 23 percent, or $2,026 per student (Mitchell, Palacios, and Leachman 2015).

3. We follow the classification adopted in Perkmann et al. (2013).

4. We are cognizant of the long-standing tradition of faculty, especially at LGUs, engaging with industry. Our nomenclature is meant to distinguish between the traditional activities of teaching and research with UIR.

Together, these four categories (AE, AC, AE/AC, and TS) characterize how university faculty engage with industry.

We address four major questions: What is the prevalence and intensity of AE and AC activities among ALS faculty at flagship public research universities across the United States? What role does UIR play in funding faculty research? How do the research and teaching outputs of faculty active in UIR activities compare with those of traditional scholars? And last but certainly not least, how do the UIR activities and attitudes of land grant ALS faculty align with researcher motivations for their choice of research problem? Because UIR activities "tend to be individually driven and pursued on a discretionary basis" (Perkmann et al. 2015, 424), we examine them at the individual faculty level, where we can probe how they meet the values and motivations of faculty. Participation largely depends on the "independent initiative of autonomous, highly skilled" faculty pursuing research and knowledge transfer activities that they value for scientific and/or commercial reasons.

Our work builds on several recent research contributions and is especially motivated by the Perkmann et al. (2013) review on faculty activity in UIR. They identify three major information gaps, which we address directly in this chapter. One is the lack of comparative evidence from US universities regarding faculty engagement in distinct types of UIR activities, since the literature is mostly based on European university data. They also document surprisingly little examination of the two UIR activities (engagement and commercialization) side by side and the factors shaping faculty engagement with them. Although there is a vast body of research on AC and its impacts on faculty scholarship (Agrawal and Henderson 2002; Azoulay, Ding, and Stuart 2007), relatively little research compares and contrasts it with the full set of possible ways for faculty to engage with industry, as we do here. The third is the lack of temporal—including longitudinal—evidence that allows attention to trends over time of innovation in UIR. This is now a relatively mature episode, with the academic commercialization take-off in the United States having occurred by the 1990s and in Europe not long afterward, which warrants study.

Other recent papers help motivate this article. Sengupta and Ray (2017) probe the dynamic relationship between both types of UIR (what they call "knowledge transfer") and traditional research outputs at UK research universities. Using a longitudinal, university-level data set (spanning 2008–14), they find that both AE and AC are positively associated with past research performance. However, consistent with the higher prevalence and intensity of AE relative to AC in UK universities, they also show that only the former has strong positive feedback effects on subsequent research performance via both funding and research scholarship (using both quantity and quality measures). This major finding in the United Kingdom helps set the broad stage for our analysis of UIR and research activities among individual ALS faculty in the major US LGUs.

D'Este and Perkmann (2011) distinguish between two ways in which faculty attitudes toward UIR may shape their participation. In the first, faculty are viewed as academic entrepreneurs who seek to engage in UIR for commercialization reasons, what we refer to as commercial motivation. In the second, faculty are viewed as scientists operating in a strongly institutionalized environment who mainly seek UIR collaborations to advance their research efforts, what we later call intrinsic motivation. We recover these motivations from our data using factor analysis of attitudinal questions and then, in a similar fashion to D'Este and Perkmann, link them to faculty activity choices.

Finally, Perkmann et al. (2013), as well as Sengupta and Ray (2017), highlight the potential importance of university-level infrastructure, research quality, and incentives for promotion and salary increases in shaping faculty engagement with UIR activities. Specifically, the historical experience and current resource base associated with university technology transfer offices can positively shape UIR outcomes. Likewise, universities with higher-quality research performance may be more attractive to industry partners and thus attract UIR. Cutting the other way is the possibility that faculty at the very top universities, especially in some fields, may be less inclined toward applied research and UIR relative to pursuing large public or foundation grants and peer-based collaborations.

Our analysis of the data on LGU faculty answers the four research questions as follows. First, at US LGUs, AE, which includes sponsored research, industry collaborations, and presentations, is far more prevalent and intensively pursued than is AC, which includes patenting, licensing, and start-ups. Several decades into the LGU push toward commercialization, faculty participation appears to have plateaued at much lower levels than their academic engagement. And additional longitudinal evidence shows that AE is the more steadily pursued form of UIR, while AC appears to be more opportunistic, perhaps consistent with the notion that only occasional scientific breakthroughs are worthy of a patent.

Second, commercialization generates very low levels of revenue streams for the operation of LGU faculty research labs. By contrast, funding generated by sponsored research of various sorts (including continued support from commodity organizations) outpaces commercialization revenues by a ratio of about 10:1 and represents for many faculty a substantive portion of their research lab expenditures. Nonetheless, public funding, especially federal funds, continues to be the majority source of faculty lab funding. Thus while AE is far more important as a revenue stream for faculty research activities than is AC, it remains overall a distant second to public funds.

Third, consistent with many previous studies, we find that UIR activities of both types are higher among faculty with higher levels of traditional academic scholarship outputs. Thus UIR and academic scholarship appear to be synergistic, reflecting at an individual level the dynamic feedbacks identified by Sengupta and Ray (2017) in UK data at a university level. This "synergy" finding also implies that concerns about major trade-offs between faculty UIR activity and traditional academic scholarship may be offtrack. Indeed, they appear to overlook a positive dynamic feedback loop that can nourish more of both types of activity over time.

Finally, the regression analysis reveals that individual-, institutional-, and university-level factors all help explain faculty UIR activity. As found elsewhere, attitudes and activity choice align in ways that are consistent with faculty participating in UIR for reasons related to advancing scientific research rather than pursuing commercialization outcomes. The university-level fixed effect results are also intriguing, as they suggest that higher levels of UIR activity are contingent on culture, history, location, and quality of science associated with the overall university (not just individual faculty).

The next section describes the context of colleges of agricultural and life sciences at US LGUs, while section 5.3 introduces the data and explains our methods. Section 5.4 presents the results, while section 5.5 discusses the implications of our findings for UIR in the United States. Section 5.6 concludes.

5.2 US Land Grant Universities

Three major legislative acts frame the long-standing tradition of academic engagement at US LGUs (Fitzgerald et al. 2012). The first is the Morrill Act of 1862, which granted states land to help finance the establishment of public universities. They emphasized agricultural and mechanical arts in support of those two major economic sectors while broadening access to education and training. The second is the Hatch Act of 1887, which provided funding to LGUs to invest in agricultural experimental stations. It recognized the value of increasing public commitment to research that advanced knowledge for both farmers and consumers with respect to production and nutrition/health outcomes. Finally, the Smith-Lever Act of 1914 created the infrastructure for delivering knowledge to society via an extension system. It aimed at both sharing research discoveries with farmers, firms, and consumers and identifying future research issues based on feedback from those and other "stakeholders." Combined, these three acts shaped a long and rich history of AE at US LGUs that featured colleges of agriculture (and later "life sciences") as the cutting edge of UIR activities. Some faculty appointments included explicit attention to "extension" in combination with traditional scholarship: research and instruction duties.

Faculty in US colleges of agricultural and life sciences generally span the breadth of basic and applied sciences reflected across the rest of public research universities. Some departments are filled primarily with basic scientists. This holds especially in "biology" departments, such as genetics, molecular biology, and biochemistry, as well as in "ecology" departments (of various names). There are mostly applied (but some basic) scientists in animal science departments (including specialties in dairy or poultry science), food and nutrition science departments, plant science departments (including agronomy, entomology, horticulture, plant pathology, and soil science), and agricultural or biosystems engineering. Finally, colleges of agricultural and life sciences have social science departments of various names that include economists, sociologists, journalism and communications scholars, and regional planning and community development faculty. While most of these social scientists tend to work on more "applied" questions, there are also some who could be viewed as closer to "basic" in their orientation to pursuing advances on "theory" and "measurement" issues rather than emphasizing applied questions. Thus the fields in US LGUs tend to provide distinctive "institutional" contexts in which to frame the likely connections between faculty and UIR activities.

In the 1990s, as with other universities, AC efforts took off in US LGUs colleges of agricultural and life sciences (Barham, Foltz, and Kim 2002; Foltz, Kim, and Barham 2003; Sampat 2006). Biotechnology patents especially were viewed as a potential source of growth and expansion in both UIR and revenue streams for universities and faculty inventors. A plethora of literature explores this period (Phan and Siegel 2006; Grimaldi et al. 2011), with a primary focus on whether academic activities and the pursuit of open science would be advanced or reduced by the attention to commercialization efforts (Thursby and Thursby 2011). At the "field level," this AC push arguably expanded the potential for higher levels of faculty participation in UIR among more basic scientists who might be able to pursue patents on discoveries more readily than they might seek out sponsored research or active collaboration with industry scientists. Thus it is arguable that AC engagement may be higher among biologists, but the long-standing engagement with AE activities by the more applied scientists could also readily give rise to patenting and commercialization efforts depending on the research topics and discoveries being pursued. These cross-cutting trends make it difficult to envision a clear distinction in terms of AC participation across the natural science fields. On the other hand, social scientists are far less likely to be engaged with patenting and licensing efforts. Most of their "idea" discoveries are likely to be algorithms and statistical or system modeling innovations rather than material ones. As a result, AC participation among social scientists is likely to be lower than other types of science faculty in colleges of agricultural and life sciences.

The rise in US LGU efforts to promote AC coincided with a secular decline in federal and state support for higher education (Ehrenberg 2012). While LGUs were initially able to largely compensate for that decline by raising tuition fees, significant pressures on the research and salary expenditures were experienced especially between 2005 and 2015 (Mitchell, Palacios, and Leachman 2015). During that time period, most LGUs experienced an overall decline in state revenues. Faculty increasingly experienced real declines in salary levels as well as increased pressure to pursue extramural funding of various types—including UIR—to support their labs and salaries (American Academy of Arts and Sciences 2016). Indeed, many colleges of agricultural and life sciences pursued conversions of faculty salary contracts from 12-month to 9-month appointments. Faculty were "incentivized" to pursue the additional 3 months of salary through external sources or "administrative" postings. All of these changes could potentially be viewed as commercial or financial motivations to increase both AE and AC efforts, if in fact they held potential for filling holes in research budgets and faculty summer salary needs.

Two other contextual trends in US LGUs warrant attention here. One is the pressure on research time associated with "changes" in university budgets. As documented in Barham, Foltz, and Prager (2014), US LGU ALS faculty reported declines in "research time" and concomitant increases in time spent on administrative activities. Reducing support staff and increasing faculty reporting efforts is one way in which LGUs dealt with budget cuts and compliance demands. This could have put pressure on faculty to limit UIR as part of the overall pressure on their time, especially research time. The other one, which is "more speculative," is the potential for morale issues associated with this long period of budget pressures and time constraints. It seems likely that these could have either dampened enthusiasm for UIR activities (exhaustion) or increased incentives for faculty to pursue especially commercial links for more personal gain.

5.3 Data, Methods, and Descriptive Statistics

This chapter is based on data collected in surveys of ALS faculty conducted in 2005 and 2015. In each data collection effort, we administered a survey to nearly 3,000 ALS faculty at all of the US LGUs established in 1863.[5] Both surveys had a sample frame that included all tenure-track faculty scientists in ALS departments at these LGUs. We culled faculty names from university web directories to create the cross-sectional sample frame and then randomly selected a sample of scientists who were sent a web-based survey with follow-up paper-mail reminders as in Dillman (2011). In addition to the random samples in both years, we also resampled respondents from the 2005 survey in 2015 in order to have longitudinal data on faculty. The response rate in 2015 was 32 percent based on respondents who answered at least one survey question, with a higher response rate in 2005 of 68 percent.[6]

5. The institutional review board at UW-Madison approved both of these surveys, with the latest approval being #2015–0924.

6. For more about the surveys, see Goldberger et al. (2005) and Barham et al. (2017).

Table 5.1 Types of UIR and survey items included

			Survey item description
University-industry relations	Academic engagement	Faculty participation in sponsored and collaborative research, contract research, and information relationships with private firms and institutions.	Research support from private industry Research support from commodity organizations Collaborated with scientists in private industry Coauthored with scientists in private industry Presented to farmers or farm organizations Presented to commodity groups Presented to the private industry Farmers or farm org. helped you identify a research problem Collaborated on a research project with farmers or farm org. Coauthorship on paper or patent with farmers or farm org.
	Academic commercialization	Faculty participation in private intellectual property creation—via invention disclosure, patents, and licensing—and entrepreneurship (e.g., start-ups).	Licensing or patenting revenue # disclosures generated # patent applications generated # patents issued # patents licensed out # products under regulatory review generated # products on the market generated # start-up companies founded

Response rates in 2015 did vary somewhat by discipline, from a high of 42 percent among plant scientists (the largest discipline represented) to only 28 percent among agricultural engineering scientists (the smallest discipline). We accept the null hypothesis of no response rate bias (see Barham et al. 2017) with respect to the following observed characteristics: field, gender, faculty size of the agricultural college, total university research funding, or total full-time university student enrollment. In appendix A, we report further sample restrictions. Our final sample for analysis, from the random sample data collection, covers 925 scientists in 2005 and 615 in 2015 across all 52 LGUs. We also report results from the longitudinal sample of 244 scientists surveyed in both years.

Table 5.1 details the set of questions with respect to faculty UIR activities in our data. AE activities span a similar range described in the aforementioned studies in the United Kingdom. They cover collaborations, sponsored research by industry (and commodity organizations), presentations to industry or farmers, and research problem identification. Likewise, AC activities span invention disclosures, patenting, licensing, product development, and start-ups.

We use these UIR-related items in the data to construct categorical variables of AE and AC participation measures as well as ones that identify when individuals do both. We classify individuals not fitting in any UIR category as traditional scholars. The participation measure is "liberal" in the sense that participating in any of the AE or AC activities identifies an individual with that category. We use these categorical variables to describe trends in UIR participation on the "extensive" margin.

In addition to individual participation in UIR, the subsequent analysis also focuses on other faculty research activities. We mostly focus on publishing articles, training graduate students, and receiving research funding. Those research activities are incorporated into the comparisons of faculty across UIR categories in order to help identify the potential for synergies or trade-offs between UIR and traditional scholarship outcomes. Similarly, we use data on total research grant revenues and different sources of revenue, such as federal, state, industry, commodity groups, foundations, and licensing revenues.

Two other important sets of measures from the survey warrant description here. First, in both 2005 and 2015 surveys, respondents were asked about what motivated them to pursue a certain research topic in the last five years. They are generally oriented toward "intrinsic" motivations, such as "scientific curiosity" or "potential contribution to scientific theory," or extrinsic ones, such as "potential marketability" or "potential to patent and license the discovery." The full set of 14 questions are shared in table 5.8. The items are arranged in a five-point Likert scale, with a score of 1 being "Not at all" and a score of 5 being "Extremely." Responses to these questions are examined using factor analysis in order to uncover latent factors that might shape faculty research choice. We interpret the estimated factor loadings to identify the subset of items with internal consistency, which we classified as two factors: intrinsic and extrinsic motivations to pursue research. We calculate indexes for each measure of intrinsic and extrinsic motivations. Indexes are calculated as the response average for the block of items within each factor as reported in table 5.9.

We begin with three broad observations that start to frame US LGUs' participation in UIR activities. They can be gleaned from tables 5.2, 5.3, and 5.4. Table 5.2 provides a comparison for 2005 and 2015 of the prevalence of each of the UIR activities. Table 5.3 provides a comparison over time of faculty participation in the four UIR categories. In table 5.4, we describe participation rates in AE and AC UIR activities by gender, rank, appointment type, and field.

We find that US LGU faculty participation rates in UIR activities are high (table 5.2), averaging 78 percent of faculty participating in any type of UIR (table 5.3). Consistent with other evidence in the literature, AE is far more prevalent than AC, with about 76 percent of LGU faculty pursuing AE as compared to 19 percent in some type of AC in 2015. Moreover, if we isolate on the exclusive AC category in table 5.3, we find that around 2–3 percent of faculty are just doing AC in the two time periods. In other

Table 5.2 AE and AC activity participation rates and counts, 2005 and 2015

	2005		2015		
	Rate	Count	Rate	Count	Δ p.p.
Academic engagement					
Had research support from private industry	0.47	437	0.45	275	−0.03
Had research support from commodity organizations	0.32	294	0.29	177	−0.03
Collaborated with scientists in private industry	0.29	265	0.36	219	0.07**
Coauthored with scientists in private industry	0.13	118	0.15	93	0.02
Presented to farmers or farm organizations	0.42	385	0.38	233	−0.04
Presented to commodity groups	0.32	299	0.31	188	−0.02
Presented to the private industry	0.32	299	0.29	181	−0.03
Had help from farmers or farm organizations to you identify a research problem	0.37	341	0.38	233	0.01
Collaborated on a research project with farmers or farm organizations	0.27	253	0.31	192	0.04
Coauthorship on paper or patent with farmers or farm organizations	0.03	30	0.03	18	−0.00
Academic commercialization					
Received any royalties income from patent (past five years)	0.04	39	0.05	31	0.01
Had licensing or patenting revenue returned to your research lab (last year)	0.02	23	0.04	23	0.01
Number of disclosures generated	0.16	144	0.13	81	−0.02
Number of patent applications generated	0.16	146	0.11	68	−0.05**
Number of patents issued	0.10	88	0.06	39	−0.03*
Number of patents licensed out	0.04	40	0.04	22	−0.01
Number of products under regulatory review generated	0.02	20	0.01	9	−0.01
Number of products on the market generated	0.07	67	0.05	29	−0.03*
Number of start-up companies founded	0.04	35	0.03	17	−0.01

Table 5.3 Faculty participation rates in UIR, 2005 and 2015

	2005	2015	Diff.
Academic engagement (AE)	0.75	0.76	0.01
Academic commercialization (AC)	0.26	0.19	–0.07**
Mutually exclusive measures			
Academic engagement (AE)—exclusively	0.53	0.60	0.07*
AE and AC	0.22	0.17	–0.05**
Academic commercialization (AC)—exclusively	0.03	0.02	–0.01
Traditional scholarship	0.22	0.22	0.00

words, the vast majority of faculty engaged in AC activities are also active in AE. The proportion of faculty that are not engaged in UIR, the TS category, is greater than the total proportion active in AC. Thus academic commercialization is the least prevalent in the mix of faculty engagement types examined here.

UIR participation declined somewhat between 2005 and 2015. Declines

Table 5.4 Individual characteristics of UIR categories, 2005 and 2015

	2005				2015			
	AE	AE/AC	AC	TS	AE	AE/AC	AC	TS
Male	0.54	0.23	0.03	0.20	0.58	0.19	0.02	0.21
Female	0.50	0.17	0.04	0.29	0.63	0.11	0.02	0.24
Rank								
Professor	0.50	0.25	0.03	0.22	0.57	0.21	0.02	0.20
Associate professor	0.59	0.20	0.03	0.18	0.64	0.09	0.01	0.25
Assistant professor	0.54	0.17	0.04	0.24	0.61	0.14	0.03	0.21
Fields								
Ag engineering	0.54	0.33	0.04	0.09	0.58	0.29	0.03	0.10
Animal science	0.59	0.33	0.03	0.05	0.61	0.24	0.02	0.13
Biology	0.19	0.24	0.12	0.45	0.34	0.18	0.11	0.38
Plant science	0.59	0.28	0.03	0.10	0.69	0.22	0.01	0.08
Ecology	0.65	0.09	0.01	0.25	0.63	0.06	0.01	0.29
Food/nutrition	0.49	0.36	0.03	0.12	0.44	0.35	0.00	0.21
Social sciences	0.53	0.04	0.01	0.41	0.57	0.03	0.02	0.39

Note: This table displays summary statistics by type of UIR and traditional scholarship. Proportions sum to 100 across columns. AE = academic engagement; AC = academic commercialization. We define traditional scholarship (TS) as those that do not engage in either AC or AE.

in commercialization activities led the way, with a 7 percentage point decline from 26 percent of respondents in 2005 to 19 percent in 2015. When we look at the four exclusive measures, this change concentrates on faculty moving from practicing both engagement and commercialization to engagement only. AE participation was essentially unchanged. The decline in AC between 2005 and 2015 contradicts the expected increase based on university-level commercialization promotion in previous decades. We conclude that the popular perception following university rhetoric on the expansion of UIR activities is not borne out by the behavior of LGU faculty in terms of engaging with industry in commercialization activities.

Across fields, participation varies between 60 and 95 percent of faculty engaging in any of the three types of UIR, as detailed in table 5.4. Although participation rates shown in the table are within each faculty characteristic, we also performed statistical tests to identify the differences in UIR participation across categories. There is statistically significant variation at a 95 percent level across gender, with men being on average 8 percentage points more likely to engage in any UIR than women. We find no statistically significant differences in participation by appointment type and/or level. In terms of field-of-study differences, the highest rates are in applied/production agricultural disciplines, while the lowest UIR participation rates are in the 60–70 percent range for the biological and social sciences. This outcome is also consistent with findings from the United Kingdom mentioned above, where more basic research is associated with relatively lower UIR activity.

While suggestive of different norms, the decline in commercialization

Table 5.5 **Persistence in faculty participation in UIR**

	2015				
	AE	AE/AC	AC	TS	Total
2005					
Academic engagement (AE)	99	27	2	18	146
AE and AC	16	30	2	4	52
Academic commercialization (AC)	1	2	1	2	6
Traditional scholarship (TS)	11	1	2	26	40
Total	127	60	7	50	244

This table reports results from the panel data linking individuals between 2005 and 2015 waves.

captured in the cross-section analyses might be a result of changes in the demographic composition of types of faculty. To control for potential demographic composition changes, we next investigate the individuals for which we have panel data among which demographic composition is constant. This smaller panel data set was gathered as part of the ongoing study to examine the persistence of individual participation in each of the categories. Table 5.5 provides a transition matrix between 2005 and 2015 of UIR participation rates across the categories.

We offer four observations based on the transition patterns in table 5.5. First, AE or mixed UIR categories show a higher rate of persistence over time than does commercialization only. There is a high exit rate out of AC reflected in the AE/AC and AC rows, where only a little over half of faculty that were doing commercialization in 2000–2005 stay engaged in AC activities in the 2010–15 time period. By contrast, about 85–90 percent of faculty who were engaged in AE or both activities in 2000–2005 remain engaged with AE activities in 2010–15. Second, the AC category is by far the least likely to gain faculty across the two time periods, reflecting the low likelihood of faculty activity in just commercialization. In fact, the decline in AC evident in the cross-sectional data also shows up as a lack of persistence and a lack of new faculty entrants into this activity. Third, a transition to AE/AC from any of the other categories is far more likely, suggesting the potential joint nature of AE with AC rather than the move to commercialization as an independent activity. Fourth, 25 percent of traditional scholars transitioned to AE activities over time, but at the same time, a larger number of scholars transitioned from UIR categories into the TS category. Thus the TS category increases from 16 percent to 20 percent of the sample, showing its robustness to the purported increase in UIR emphasis at LGUs.

Table 5.6 shows research funding for different UIR participation categories. It compares amounts of funding from different sources as well as the shares associated with each funding source.[7] Across all the UIR categories,

7. Note that "private industry" and "commodity organization" funding are used to define AE, and "patent royalties" is used to define AC. Therefore, by definition, these amounts are zero for some UIR categories.

Table 5.6 **Research lab financial sources across UIR types, 2005 and 2015**

		2005				2015			
		AE	AE/AC	AC	TS	AE	AE/AC	AC	TS
Research lab revs mean	$	155,491	213,848	197,625	107,411	293,202	403,127	346,602	271,649
Research lab revs median	$	75,000	150,000	101,500	60,000	100,000	200,000	250,000	60,000
Fed grants	$	89,900	112,497	157,860	77,634	180,415	238,995	274,314	223,796
	%	51.86	50.97	63.14	60.71	49.03	52.30	73.00	64.58
State grants	$	15,335	18,127	7,432	6,370	20,216	18,422	14,286	18,168
	%	9.16	6.25	7.32	8.06	8.14	5.18	2.86	5.22
Private industry	$	16,618	39,090	—	—	36,547	69,626	—	—
	%	11.96	17.63	—	—	12.67	17.15	—	—
Commodity orgs	$	7,385	10,623	—	—	19,348	24,674	—	—
	%	8.37	8.78	—	—	8.84	7.92	—	—
Foundations	$	6,016	9,339	6,398	7,087	12,326	17,228	35,232	15,828
	%	4.04	3.61	3.59	6.99	6.08	5.06	10.21	6.14
University funds	$	10,717	14,521	21,747	9,487	16,513	28,892	16,341	11,190
	%	10.90	7.74	17.50	15.19	11.05	9.44	13.21	13.49
Patent royalties	$	—	3,699	—	—	—	4,110	—	—
	%	—	1.06	—	—	—	1.42	—	—
Others	$	3,440	1,418	3,250	1,003	5,454	1,181	6,429	471
	%	2.08	1.02	5.31	2.51	1.18	0.55	0.71	1.56

federal funding remains the primary source of research funds, with industry and commodity organizations playing a substantial but subordinate role. At less than 2 percent overall, licensing revenues from AC activities are a trivial source, and they are one-tenth the value of the funds earned from private industry and one-third the value of funds from commodity organization sources. Interestingly, faculty who earned patent royalties are only found within the AC faculty who also engage in AE. It is also worth noting that for the median research lab revenue, those associated with faculty engaged in AC and AE/AC have the highest research funding levels across both years of data. Both AE-only and TS labs have lower levels of funding.

For each category of UIR, table 5.7 reports on scholarly outputs—namely, articles published in the last five years and being the main advisor for PhD and master's students. Consistent with many other previous studies in the literature, academic outcomes are robust to faculty participation in UIR activities. The most active faculty in UIR, the AE/AC group, have the highest article productivity (mean of 23 articles in 2010–15) and a similar number of PhD students trained (mean of 2.5 in 2010–15) to the AC group (2.6). These compare with about 14 articles over 2010–15 for AE and TS categories and 1.6 PhD students for those two categories. The high outputs of the AE/AC group are consistent with synergies between UIR and scholarly outputs that are found in econometric studies elsewhere (e.g., Foltz, Kim,

Table 5.7 Scholarly outputs across UIR types, 2005 and 2015

	2005							
	AE		AE/AC		AC		TS	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Scholarly articles (5 yrs)	11.55	9	16.79	14	14.81	13	10.61	9
Master students (5 yrs)	3.08	2	2.61	2	1.94	1	2.95	1
PhD students (5 yrs)	1.22	1	1.75	1	1.88	2	1.72	1
	2015							
	AE		AE/AC		AC		TS	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Scholarly articles (5 yrs)	14.41	12	23.45	19	21.36	16	14.37	11
Master students (5 yrs)	2.79	2	2.41	2	1.86	1	1.77	1
PhD students (5 yrs)	1.61	1	2.48	2	2.64	2	1.67	1

and Barham 2003). Table 5.7 is also noteworthy for providing continued evidence of rising productivity over time of US LGU faculty based on article counts (Prager, Foltz, and Barham 2014).[8]

We turn next to table 5.8, showing the values or stated preferences of US LGU faculty with respect to their motivations for "research problem choice." We first report for both 2005 and 2015 the average scores (1 low to 5 high) and compare them across UIR categories. In both years, "enjoy the research" and "scientific curiosity" scores average well above 4 for all categories of faculty. By contrast, the scores for "potential marketability" or "private firms commercialization interest" are lower for all the UIR categories relative to intrinsic motivations by at least a full point and oftentimes two or three points.

We next use factor analysis to recover underlying factors explaining the variance in the motivations for research choices data. Two factors explain most of the variance in the data, which we identify as intrinsic and extrinsic motivation factors (table 5.9). We constructed indexes (simple average) within the items identified as a factor. Some have consistent "high loadings" within each identified factor, such as scientific curiosity or potential contribution to scientific theory, which we interpret as intrinsic motivation. Meanwhile, likely interest by private firms in commercializing the discovery

8. We make no effort to control for quality or potential increases in coauthorship, either of which could lead to an adjustment in the raw measure provided here. The evidence from Foltz, Kim, and Barham (2003) suggests that quantity and quality (as measured by citations) are highly correlated, which means the bias from unmeasured quality could be small. We have no evidence on which way the bias from coauthorship patterns might go.

Table 5.8 **Research choice criteria across UIR types, 2005 and 2015**

Research choice criteria	2005 AE	2005 AE/AC	2005 AC	2005 TS	2015 AE	2015 AE/AC	2015 AC	2015 TS
Enjoy doing this kind of research	4.50	4.53	4.69	4.69	4.27	4.33	4.50	4.50
Potential contribution to scientific theory	3.49	3.78	4.38	4.13	3.37	3.73	4.50	3.83
Scientific curiosity	4.15	4.26	4.44	4.36	4.02	4.17	4.36	4.40
Probability of publication in professional journal	3.88	3.86	4.09	4.09	3.81	3.90	4.50	4.02
Potential marketability	2.42	3.35	2.69	1.64	1.77	3.06	2.21	1.36
Availability of private and corporate funds	2.88	3.35	2.03	1.71	2.84	3.48	2.00	1.89
Request made by clientele	3.28	3.32	2.06	2.09	3.09	2.97	1.64	1.76
Feedback from extension personnel	2.79	2.61	1.78	1.70	2.62	2.42	1.71	1.62
Potential to patent and license the findings	1.48	2.47	2.25	1.18	1.20	2.46	1.86	1.11
Interest by private firms in commercializing the discovery	1.79	2.76	2.09	1.25	1.44	2.66	1.71	1.15
Importance to society	4.31	4.27	4.28	4.21	4.06	4.27	4.29	3.95
Approval of colleagues	2.50	2.43	2.03	2.50	2.29	2.48	2.29	2.25
Availability of public funds	3.92	4.04	3.91	3.63	3.76	4.14	4.00	3.49
Availability of research facilities	3.46	3.83	3.25	3.11	3.28	3.89	4.14	2.86

Note: These questions are reported using a five-point Likert scale, with a score of 1 being "Not at all" and a score of 5 being "Extremely."

Table 5.9 **Factor loadings estimation, after rotation**

Item	Extrinsic	Intrinsic
Potential contribution to scientific theory		0.62
Probability of publication in professional journal		0.48
Enjoy doing this kind of research		0.51
Scientific curiosity		0.63
Request made by clientele	0.52	
Feedback from extension personnel	0.47	
Potential to patent and license the research findings	0.67	
Interest by private firms in commercializing the discovery	0.75	
Potential marketability	0.67	
Availability of private and corporate funds	0.52	
Availability of research facilities		
Approval of colleagues		
Availability of public, state, and federal funds		
Importance to society		

Note: Factors are calculated jointly for both waves. Comparing eigenvalues and their variances, we confirm the existence of two factors. Together, they explain 93 percent of the variance. We used principal factor with orthogonal quartimax rotation to estimate the factor loadings. Measures on intrinsic and extrinsic motivations are calculated as the average of the items within each identified factor.

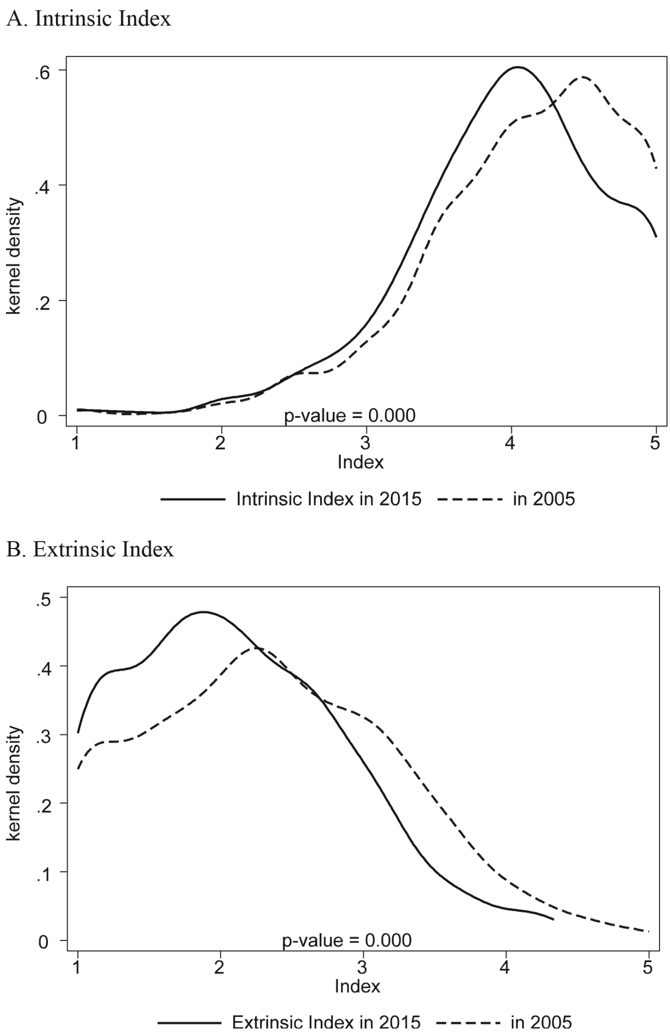


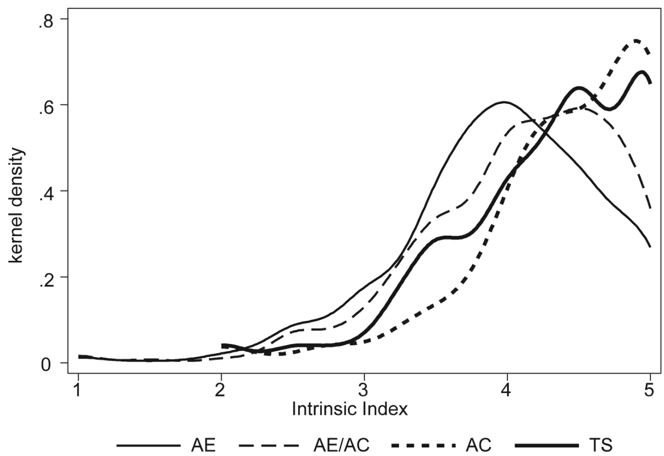
Fig. 5.1 Distribution of extrinsic and intrinsic incentives indexes, pooled cross-section data

Note: This figure displays the distribution of the calculated intrinsic and extrinsic indexes from the cross-section data for individual surveys in both 2005 and 2015.

and potential marketability of the final product "load high" in what we interpret as extrinsic motivation.

We show the distribution of the indexes by UIR category in figure 5.1. In 2005 and 2015, faculty report higher mean intrinsic than extrinsic motivations when it comes to research problem choice. The distribution of intrinsic motivations is skewed to the right, averaging 4 points. Meanwhile, extrinsic

A. Intrinsic Motivation



B. Extrinsic Motivation

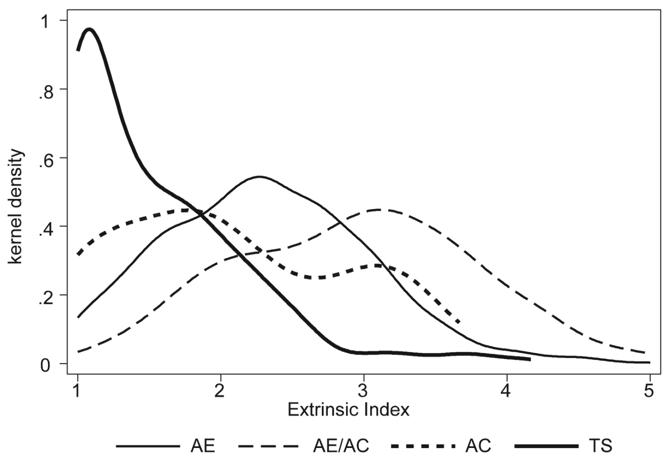


Fig. 5.2 Distribution of intrinsic and extrinsic motivation by UIR category, 2005 and 2015 pooled—index

Note: This figure displays the distribution of the calculated intrinsic and extrinsic indexes from the cross-section data for individual surveys in both 2005 and 2015 by UIR category.

motivation appears to be less important to faculty, averaging 2 points. Both measures decreased between 2005 and 2015, with the larger decrease in extrinsic motivation moving the distribution of that measure to be almost entirely distributed below "neutral." Meanwhile, the intrinsic index, while decreasing, remained strongly distributed in the very to extremely important zone.

In figure 5.2, we report the distributions of the motivation indexes by

UIR category. As would be expected by their actions, traditional scholars are skewed far to the right on intrinsic motivations and far to the left on commercial ones. Yet we see that both categories of commercialization (AC and AE/AC) also have high levels of scientific motivation, with only AE as distinctly below the others. AE/AC appears to show both the highest average levels of commercial motivation and the greatest diversity of motivations within the category, as exemplified by a flatter distribution. The AC-only group shows high levels of intrinsic motivation as well as a bimodal distribution of commercial motivation, with some at both high and low levels.[9]

5.4 Empirical Strategy and Results

Descriptive statistics show remarkable differences in academic outputs across UIR categories and in factors shaping research topic choice. In order to isolate these relationships, we use regression techniques to estimate correlations between UIR categories and various university outputs. The models, which should be interpreted as correlational rather than causal, use TS as our comparison category.

In the first set of estimates, we explore individual and institutional determinants of UIR engagement, including the relative role of faculty motivations, and field- and university-specific effects while controlling for faculty characteristics. We estimate equation (1) using a linear probability model with standard errors clustered at the university level to account for university-level heteroskedasticity. Our dependent variable UIR_{ifu} is a binary indicator variable for any UIR engagement, relative to TS. We adopt a flexible functional form to capture the potential correlation between motivation and UIR participation, $\Sigma_{k=1}^{k=4} Q_{k_i^m}$, with $m \in \{\text{Int, Ext}\}$. The regressors $Q_k F^m$ are indicators for each quartile k of each motivation F^m distribution. We omit the first quartile: $Q_1 F^m$. The vector X measures individual characteristics and includes gender, university appointment (professor, assistant professor, or full professor), and an indicator for whether the scientist was awarded a PhD from a land grant institution. The variables μ_f and ν_u are field and university fixed effects, respectively.

$$(1)\quad UIR_{ifu} = \alpha + \sum_{k=1}^{k=4} \beta_k^S Q_k F_i^{\text{Sci}} + \sum_{k=1}^{k=4} \beta_k^C Q_k F_i^{\text{Com}} + \gamma X_i + \mu_f + \nu_u + \varepsilon_{ifu}.$$

To demonstrate the correlations between UIR participation and our variables of interest, which are all categorical, we plot the effects in a series of figures. Figures 5.3 and 5.4 plot the set of estimated parameters for categorical variables β_k^m, μ_f, and ν_u, which are, respectively, motivation categories, university effects, and field effects.

9. Results for the exclusive AC category need to be interpreted with caution due to the small number of cases in our sample.

Figure 5.3 shows the parameter estimates for quartiles of the intrinsic and extrinsic motivation indexes on the probability that a faculty member engages in UIR activities. The figure shows estimated parameters for both unconditional (no other controls) and conditional (all controls in equation [1]) along with 95 percent confidence bands. The figure shows that as the intrinsic index increases, the probability of doing UIR activities marginally decreases, with intrinsic motivation playing a small role in differentiating UIR engagement. As for extrinsic motivation, there is a higher probability of UIR engagement as this indexes increases. These correlations corroborate the descriptive statistics that intrinsic motivation is high across the board, whereas extrinsic motivation plays an important role in differentiating UIR engagement. Overall, these determinants are robust to the inclusion of a variety of controls.

In figure 5.4, we show how the estimated parameters on university fixed effects, estimated from equation (1), vary across universities, with the University of Wisconsin-Madison (UW-Madison), which has the oldest technology transfer office among US universities, used as the baseline. There are relatively high university-specific effects, which indicate more UIR activity at that university compared to UW-Madison, at some of the large LGUs such as Illinois; the University of Massachusetts Amherst; the University of California, Davis; and Purdue. But we also see some smaller LGUs such as Alaska and Vermont in the top 15. There are some surprising effects with Cornell in the bottom tier along with a number of smaller LGUs that have fewer resources and newer traditions of UIR. Since we have controlled in these regressions for both individual- and university-observable characteristics, the best interpretation for these results is a measure of the UIR "culture" at these universities. Institutions such as Cornell may have stronger basic science cultures with less focus on UIR, while the large LGUs that are high on the list may have stronger outreach and extension cultures that promote more UIR.

The second half of the figure shows the estimated parameters on the field of specialty-level fixed effects, with plant sciences, which is the largest category, as the baseline. The other production agriculture sciences—namely, animal sciences, agricultural engineering, and food and nutrition studies—are not statistically distinguishable from plant sciences. This result, likely driven by academic engagement in production agriculture fields, is expected. Ecology and basic biological sciences, however, show lower levels of UIR engagement than do plant sciences, despite those fields possibly having higher potential in commercialization. This may be due to the stronger basic science orientation of these fields relative to applied production sciences. And as one would expect, the social sciences are at the lowest levels of all of the agriculture and life science college disciplines in terms of UIR activities.

In a second set of regression estimates, we isolate how each type of UIR activity correlates with academic productivity. The uniqueness of our data

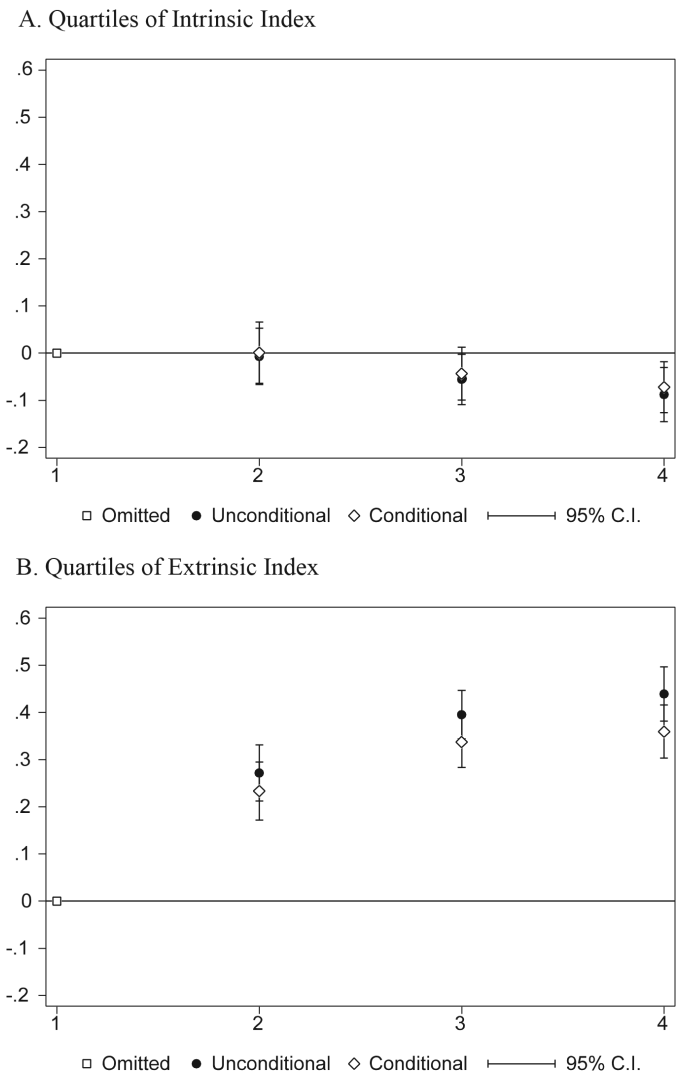


Fig. 5.3 Linear probability model: (Any) UIR engagement by quartile of attitudes

Note: Coefficients are for quartiles of motivation, with the first quartile as omitted variable. Dependent variable is an indicator for whether individual engages in any UIR type (1) as opposed to being a traditional scholar (0). Unconditional estimates include a survey year dummy. Controls for the conditional estimates include gender, position as professor, a dummy for whether PhD was in a land grant institution, field (plant science, ag/engineering, animal science, biology, ecology, food/nutrition, and sociology), and university fixed effects, which correspond to the 52 land grant universities. Standard errors are clustered at the university level.

A. University Estimated FE

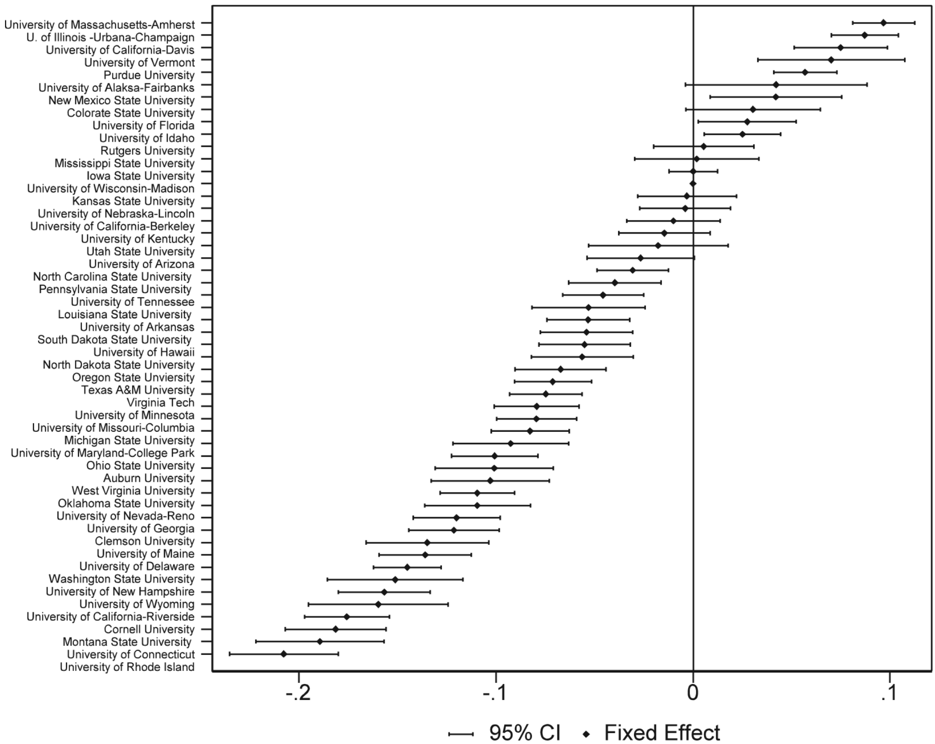


Fig. 5.4 Linear probability model of UIR engagement—field and university fixed effects

Note: For both panels, dependent variable is an indicator for whether individual engages in any UIR type (1) as opposed to being a traditional scholar (0). (a) Coefficients are for 52 university indicators, with University of Wisconsin-Madison as omitted variable. (b) Coefficients are for field indicators, with plant science as the omitted variable. We choose plant science as the omitted variables for being the most popular field in our sample. Additional controls include gender, position as professor, and a dummy for whether PhD was in a land grant institution. Standard errors are clustered at the university level.

set allows us to control for an often unobserved dimension of individual heterogeneity: faculty motivations, both intrinsic and extrinsic. This allows us to measure the direct effects of these characteristics beyond their effects that run through UIR engagement. We also control for individual, field, and institutional characteristics.

We estimate different versions of equation (2), in which Y_{ifu} varies in each regression covering the number of journal articles, PhD graduates, and total funding for scientist i in field f at university u. AC, AE/AC, and AE are our mutually exclusive measures of UIR, and TS is the omitted baseline category. The values F_i^I and F_i^E are the index scores for intrinsic and extrinsic

B. Field Estimated

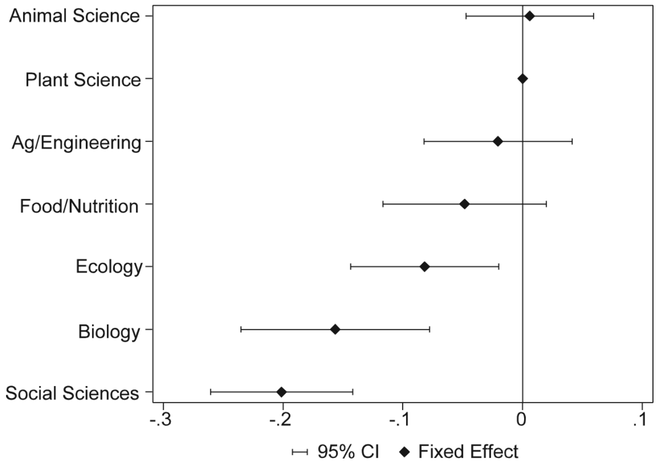


Fig. 5.4 (cont.)

motivation, respectively. The vector X measures individual characteristics and includes gender, university appointment (professor, assistant professor, or full professor), and an indicator for whether the scientist was awarded a PhD from a land grant institution. The variables μ_f and ν_u are field and university fixed effects, respectively. The standard errors are clustered at the university level to control for university-level heteroskedasticity.

$$(2)\ Y_{ifu} = \alpha + \beta_1 AC + \frac{\beta_2 AE}{AC} + \beta_3 AE + \psi_S F_i^S + \psi_C F_i^C + \gamma X_i + \mu_f + \nu_u + \varepsilon_{ifu}.$$

Table 5.10 shows the results of estimating equation (2) with journal articles and PhD students produced over the last five years as the dependent variable. The columns provide increasing levels of control variables: the first is the baseline, the second adds in our motivational measures, the third adds individual controls, and the fourth adds field and university fixed effects. One sees two dominant statistically significant and large effects: (1) compared to traditional scholars, AE/AC and AC-only faculty produce more journal articles and more PhD students, and (2) levels of intrinsic motivations are directly correlated with both journal articles and PhD students, whereas extrinsic (commercial) motivations do not play a direct role besides those embedded in how they determine UIR participation. Overall, the picture that emerges from table 5.10 is that UIR faculty, especially those with commercial ties, are more productive than traditional scholars. In addition, those in the AE-only category appear to produce scholarship and students at about the level of traditional scholars.

Table 5.11 shows the results of estimating equation (2) using the amount

Table 5.10 OLS estimates—journal articles publications and PhD graduates under supervision, 2005 and 2015 pooled

	Journal articles				PhD graduates			
AE only	0.556	1.635*	1.588*	0.543	−0.321**	−0.070	−0.072	0.070
	(0.82)	(0.84)	(0.75)	(0.15)	(0.15)	(0.14)	(0.14)	(0.14)
AE/AC	7.155***	7.625***	6.902***	4.881***	0.316*	0.611***	0.449**	0.545***
	(1.13)	(1.05)	(1.03)	(1.11)	(0.18)	(0.20)	(0.19)	(0.17)
AC only	5.061***	4.403**	4.440**	3.857**	0.445	0.466	0.510	0.693*
	(1.8)	(1.81)	(1.80)	(1.63)	(0.37)	(0.38)	(0.36)	(0.36)
Intrinsic motivation		3.921***	4.241***	3.868***		0.405***	0.470***	0.447***
		(0.47)	(0.49)	(0.50)		(0.08)	(0.08)	(0.08)
Extrinsic motivation		0.201	0.337	0.282		−0.160**	−0.105	−0.041
		(0.42)	(0.41)	(0.42)		(0.07)	(0.07)	(0.06)
Survey year; individual controls; field/university FE	x	x	x x	x x x	x	x	x x	x x x
Observations	1,479	1,479	1,479	1,479	1,479	1,479	1,479	1,479
R-squared	0.070	0.110	0.153	0.223	0.024	0.049	0.174	0.271
p-value F-test (UIR = 0)	0.00	0.00	0.00	0.00	0.187	0.011	0.055	0.007

Note: Coefficients on UIR categories are relative to traditional scholars (omitted). AE = academic engagement; AC = academic commercialization. Dependent variables are total of articles published in the last five years and number of PhD graduates under supervision in the last five years. Individual controls include gender, position as professor, and a dummy for whether PhD was in a land grant institution. Field includes plant science, ag/engineering, animal science, biology, ecology, food/nutrition, and sociology. University fixed effects correspond to the 52 land grant universities. Standard errors are clustered at the university level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5.11 OLS estimates, total and public funding, 2005 and 2015 pooled

	Total funding (IHS)				Public funding (IHS)			
AE only	1.174***	1.369***	1.383***	1.337***	1.039***	1.555***	1.558***	1.573***
	(0.27)	(0.28)	(0.28)	(0.27)	(0.34)	(0.37)	(0.37)	(0.35)
AE/AC	2.080***	2.111***	2.109***	1.964***	1.822***	2.368***	2.316***	2.288***
	(0.27)	(0.30)	(0.31)	(0.30)	(0.36)	(0.40)	(0.40)	(0.39)
AC only	1.724***	1.554***	1.536***	1.362***	1.320*	1.306**	1.309**	1.288*
	(0.41)	(0.38)	(0.38)	(0.39)	(0.68)	(0.63)	(0.64)	(0.71)
Intrinsic motivation		0.858***	0.846***	0.715***		0.996***	1.013***	0.916***
		(0.11)	(0.12)	(0.11)		(0.18)	(0.18)	(0.19)
Extrinsic motivation		0.096	0.081	0.197*		−0.261*	−0.252*	−0.151
		(0.09)	(0.09)	(0.10)		(0.14)	(0.14)	(0.16)
Survey year; individual controls; field/university FE	x	x	x x	x x x	x	x	x x	x x x
Observations	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540
R-squared	0.059	0.102	0.107	0.161	0.023	0.056	0.059	0.100
p-value F-test (UIR = 0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Coefficients on UIR categories are relative to traditional scholars (omitted). AE = academic engagement; AC = academic commercialization. Dependent variables are current annual budget and its subcategory of total public funding. Total public funding categories are USDA, NSF, NIH, other federal agencies, and state agencies. Individual controls include gender, position as professor, and a dummy for whether PhD was in a land grant institution. Field includes plant science, ag/engineering, animal science, biology, ecology, food/nutrition, and sociology. University fixed effects correspond to the 52 land grant universities. Standard errors are clustered at the university level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

of total funding and public funding as two dependent variables. It is worth noting that our categories of UIR are partially created with funding data, so we should expect a positive relationship with total funding, though not with public funding. Here we see very strong and statistically significant correlations of any UIR activity with both total funding and federal funding. While the former is somewhat expected, the latter suggests that rather than being a distraction from TS directions, faculty engagement in UIR activities is synergistic in terms of bringing in federal funding, which is generally associated with TS. Again, we see strong correlations of intrinsic motivations with both total and federal funding, suggesting a direct effect, whereas extrinsic motivation does not have such a direct effect.

5.5 Discussion

Our empirical results present a number of new findings for the study of UIR activities at US universities on several important fronts. First, faculty participation rates in UIR activities are quite high; generally, around 70–80 percent of US LGU agricultural and life scientists engage in AE, AC, or both. Second, faculty participation in UIR is predominantly in the area of AE, the more traditional type of research collaboration involving sponsored research, industry collaboration (including farmers and their commodity organizations), and other types of research exchanges (presentations and shared problem identification). In fact, only about 2–3 percent of faculty in either the 2005 or 2015 survey participated in just AC activities. Third, as a source of research funding for ALS faculty at US LGUs, AE industry revenues completely dominate AC license revenues, but the largest individual faculty funding levels come from those who do both AE and AC. Overall, patent license revenues provide about 1 percent of lab revenues as compared to approximately 25 percent share of lab revenues coming from industry and commodity group funds. This funding outcome appears to be in "steady state" now 35 years after the passage of the Bayh-Dole Act and more than 25 years after the takeoff of US public university patenting activity, as the ratio of AE to AC funding was the same in 2015 as it was in 2005.

This study also finds descriptive evidence that UIR activities are highly correlated and likely synergistic with traditional academic scholarship activities. This outcome is consistent with previous studies that find the more productive researchers are also often the ones most highly "in demand" or active in UIR activities. While this study does not undertake the type of longitudinal dynamic statistical analysis as do Sengupta and Ray (2017), who find positive feedbacks between AE and research outcomes at the university level, prima facie evidence presented in our work at the individual faculty level is consistent with that outcome. In particular, our finding that the AE/AC faculty persist across time periods and that this group has more research revenues and higher publication and student counts demonstrates this individual positive feedback loop.

In examining factors shaping the participation of US LGU faculty with UIR activities, we find that institutional factors, specifically "fields" or "disciplines," are a significant conditioning factor, with more applied science fields such as plant and animal sciences having higher UIR rates than more basic ones such as biological and ecological ones. Additional analyses show that most of the differences in UIR activity by field are driven by variations in AE rather than AC. This finding is consistent with both the lower overall participation in AC and the fact that most of the faculty active in AC are also active in AE. The reverse is not true. Most faculty engaged in AE are not active in AC. In this regard, it appears that AC may be somewhat opportunistic and may depend on the types of inventions or discoveries being made by scientists. Put simply, ongoing collaboration with industry or sponsored research arrangements may, from time to time, give rise to the pursuit of invention disclosures and patents, and so entry and exit into AC activities appear to occur regularly, as shown in the transition matrix in table 5.5.

The most substantive individual factors shaping the intensity of participation in UIR appear to be faculty "attitudes" with respect to research problem choice. While we do not attempt here to identify a causal relationship between attitudes and UIR activity involvement, ALS faculty at US LGUs report that their research problem choices are strongly driven by intrinsic factors, such as curiosity or the potential to contribute to scientific theory relative to intrinsic motives. This is true across all the UIR categories used here, though what distinguishes AE, AC, and AE/AC from TS is a somewhat stronger level of extrinsic motive. This basic preference for science has been a consistent outcome across decades of surveys of US LGU faculty and is consistent also with the continued importance of federal competitive grants as a primary source of research funding.

Finally, university fixed effect measures in our UIR regressions reveal statistically significant differences in university "cultures" with respect to UIR. These differences appear to relate to the timing of initial commercialization activity and potentially to other historical and locational factors that could be important for how they shape faculty behavior over time. This is an area of ongoing interest and potentially productive future inquiry.

5.6 Conclusion

This chapter has examined UIR activities of ALS faculty at the premier US LGUs, using survey data gathered from large, random, and longitudinal samples in 2005 and 2015. The analysis of this unique set of data fills an empirical gap identified in the literature by carefully exploring the relative importance of AE and AC. Because US LGUs are the "ground zero" of US public research university UIR activities, the empirical context is of broader significance to the United States and beyond. We have found descriptive and correlational evidence that traditional academic scholarship has not systematically been distorted or constrained in the ways that some originally feared and that UIR—while important to faculty, universities, and society—is not a fundamental threat to the advancement of science.

At US LGUs, the long-standing tradition of AE, involving sponsored research and direct collaboration with scientists and managers in industry and agriculture, dominates the new AC relationships in prevalence and importance for faculty research funding. Moreover, these two types of UIR appear to be complements, with AC being an occasional outgrowth of AE in some fields and for some faculty, which likely depends on the continuity of AE relationships to emerge. Seen in this way, the UIR activities of agricultural and life scientists at LGUs are more of a natural outgrowth of the land grant system's traditional model of working with industry to foster improved outcomes in their own states and the nation. Fears of UIR subverting the LGU mission appear to be misplaced. Rather, we find that UIR complements the traditional work of top scholars in ALS fields in part by helping them access more funding and connections with industries in their field.

The data described and analyzed in this article represent a valuable resource for investigators who seek to understand the workings of ALS research in the United States. Future exploration with these data will seek to pursue causal identification of UIR participation and intensity outcomes using historical information as instruments as well as more exploitation of the panel data. Expanding the focus on university-level factors seems worth special attention in this effort. Adding to the current data set with measures of journal quality would also be a useful contribution. In addition, given the significant growth in the proportion of women and foreign faculty in the US LGUs over time, there are open important questions as to whether this has changed the dynamics of UIR participation. Using the data described in this chapter to analyze how the ALS research establishment has or has not diversified over the last quarter century, and the effects thereof on research output and topics, is an important avenue for understanding the conduct of science.

Appendix

Sample Selection and Imputation of Missing Values

Within the subsample of individuals who completed the survey, there was a large number of missing responses. We assumed a set of hypotheses in order to impute the missing values. (1) Research attitudes: Likert scale ranging

Table 5.A1 **Summary of response rates for the random and panel samples and subsample selection criteria**

	2005	2015
Full sample	2,330	2,972
Valid responses	1,590	977
Response rate (%)	68	32
Random sample	1,328	711
Panel sample	262	266
Panel matched	**244**	
Random sample 2005–15	2,039	
drop field=other,missing	19	
drop not professorship, missing	83	
drop cross-missing	397	
Final subsample (random sample)	**1,540**	

from 1 to 5. We assigned a neutral value, 3, if the individual answered the block at least partially. When all responses are missing, variables remain coded as missing. (2) UIR-related measures: individual responses with missing values are replaced with 0 when the person answered part of the block. When all individual responses for the questions within the block are missing, we do not input values. (3) Extension and outreach: missing responses are coded as 0 if the block was partially answered. If all questions within block were not answered, variables remain coded as missing. (4) PhD students: missing responses are coded as 0 if the block was partially answered. If all questions within the block were not answered, variables remain coded as missing. For each block, we created variables indicating the total number of imputed values, and results are robust to adding these variables in the regression as a control. These results are available upon request.

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Comment Nicola Bianchi

This chapter explores the characteristics of university-industry relations (UIR) among agricultural and life science (ALS) faculty at US land grant universities (LGUs). This research question is interesting because there is a common belief that US universities are relying more and more on UIR to replace dwindling funding from the state and federal government. Despite the plausible growing importance of UIR activities, little is known about their features, their links with professors' academic output, and their consequences for academic research.

This chapter contributes to our understanding of UIR in several ways. It uses extensive survey data collected in 2005 and 2015 to explore UIR at LGUs. The sample is large, covering 946 professors in 2005 and 626 professors in 2015. Among these faculty members, 234 are surveyed in both years, allowing the analysis to have a panel component. Moreover, the survey asks detailed questions about UIR, permitting the authors to distinguish between different forms of UIR. Specifically, the chapter is able to differentiate between academic engagement (AE) and academic commercialization (AC). AE describes any form of faculty participation in shared research.

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