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

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1. Introduction

This article exploits rich and unique data to examine the involvement of agricultural and life science faculty at US land grant universities in academic engagement, commercialization, and scholarship. Building on Perkmann et al. (2013), specifically their call for representative and longitudinal evidence at the individual faculty level, we explore across two time-periods, 2005 and 2015, the prevalence, intensity, and importance of US land-grant faculty engagement with different types of university-industry relations (UIR). We also examine how faculty attitudes toward research choices shape their participation in UIR activities, and how they combine UIR with traditional scholarship activities (such as article publications and training of graduate students and post-docs). This article contributes to a growing body of literature that probes the connections between faculty UIR activities, attitudes, and research choice at public universities.

Perkmann et al (2013) focus their meta-analysis on two basic types of UIR. 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. This definition is used in other recent articles that examine UIR among university faculty in the UK (D'Este and Perkmann, 2011; Perkmann et al., 2011; Tartari et al., 2014; Tartari and Salter, 2015; Sengupta and Ray, 2017). It is important to note that at US land grant universities, involvement with AE dates back to the turn of the 20th century, stemming from an emphasis on agricultural and engineering sciences and working with farms and firms to improve performance. 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). This type of faculty involvement with industry is much more recent in the US and the UK. It took off at US universities following the passage of the Bayh-Dole Act in 1981 (Henderson and Jaffee, 1998; Thursby and Thursby, 2011). There is a vast body of research on academic commercialization and its impacts on faculty scholarship (Agarwal and Henderson, 2002; Azoulay et al. 2007.).

Perkmann et al (2013) reviews the state-of-knowledge about these somewhat contrasting but not mutually exclusive types of UIR. They probe the prevalence of AE and AC activities, mostly building on the recent flurry of research exploring how faculty engagement with UIR affects the productivity of traditional academic scholarship (AS). One of their main findings is that the vast majority of recent research on UIR examines only the less common activity of AC and mostly overlooks AE, the more pervasive and potentially important UIR in terms of faculty participation and actual resource flows, especially at public universities. The aforementioned studies in the UK confirm those conclusions, finding for example that faculty research funding from AE sources is upwards of 15 times greater than that from AC (Perkmann et al. 2011). Perkamann et al (2013) find surprisingly little examination of the two UIR activities side-by-side

and the factors shaping faculty engagement with them. This gap limits our broader understanding of how UIR fits into the activities of faculty, universities, and hence society. We fill those two major empirical gaps by exploiting random and representative, cross-sectional and panel survey data gathered in 2005 and 2015 from agricultural and life science faculty from all 52 of the original 1863 US land grant universities. This is exactly the type of data analysis promoted in their conclusion to advance research on UIR and AS.

This article addresses the following questions: What is the prevalence and intensity of AE and AC activities among agricultural and life science 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 AE, AC, both or neither type of UIR compare? To what degree are there synergies across AE, AC, and AS activities? And, last but certainly not least, how do the UIR activities and attitudes of land grant agricultural and life science faculty align with respect to issues related to research problem choice? As in all of the other recent studies, these questions are examined from the perspective that UIR activities "tend to be individually driven and pursued on a discretionary basis," (Perkmann et al. 2015, p. 424). Participation largely depends on the 'independent initiative of autonomous, highly skilled' faculty pursuing research and knowledge transfer activities that they value for intrinsic and/or extrinsic reasons.

The salience of these faculty UIR activities is large given the considerable financial stress that most US land grant universities (LGUs) faced over the past three decades due to significant declines in state and federal financial support (Just and Huffman, 2009). Both in public and private spheres, LGUs sought to increase the perceived and commercial value of their activities through UIR. In turn, most US LGUs intensively pursued academic commercialization as a potential mechanism to generate royalties and start-up revenue streams (Thursby and Thursby, 2011). At the same time, many LGUs faced tightening budget constraints in terms of extension budgets that put pressure on certain aspects of academic engagement (Hoag, 2005). This study seeks then to shed light on the ground-level performance of UIR activities at leading US LGUs – i.e., how faculty research activities, attitudes, and UIR unfolded - by examining detailed and representative survey data from agricultural and life science faculty at these institutions.

Much of the empirical analysis involves descriptive statistics examining types of UIR activity and academic scholarship in order to provide a nuanced portrayal of the prevalence, coincidence, intensity, and productivity of faculty engagement in AE, AC, and AS. Factor analysis highlights how attitudinal data align with AE, AC, and AS as well as with types of research funding pursued. Regressions involving these attitudinal factors provide further insight into UIR participation and intensity. These regressions also include classic demographic, institutional, and organizational factors in their specification as framed in Perkmann et al. (2013).

Combined, these empirical analyses identify key patterns of faculty activities and attitudes with respect to UIR and AS. They largely confirm the broad UK findings for US LGUs, showing that AE is much more pervasive and important than is AC among faculty in colleges of agriculture and life sciences in US LGUs, and that attitudes and activity choice align in ways that are consistent with faculty participating in UIR largely for reasons related to advancing scientific research rather than in pursuit of commercialization outcomes. This finding is buttressed by the

fact that almost 35 years after the passage of the Bayh-Dohl Act only around 1% of the funding for faculty research labs flows from AC UIR activities as compared to 15% or so from AE UIR activities, and the proportion of AC funds actually declined somewhat between 2005 and 2015. Consistent with that observation, so did faculty involvement with AC activities. The fuller portrayal of the pattern of UIR activities presented in section 5 provides further nuances.

The next section selectively reviews the literature on UIR activities, especially what UK research has revealed about factors shaping AE and AC activities. Section 3 develops some hypotheses based on the UK literature and the US land grant university context. Section 4 introduces the data and explains our methods, especially the use of factor and principal component analysis to construct, respectively, faculty 'attitude scores' and UIR intensity measures for faculty across AC and AE activities. Section 5 presents the results, and section 6 explores the implications of our findings for UIR.

2. Select Literature Review

Sengupta and Ray (2017) offer a broad and dynamic framing of the relationship between UIR (what they call Knowledge Transfer) and research outputs at UK research universities. They explore the potential for dynamic feedbacks between past research performance, and related UIR activities, to current research performance, in search of positive feedback loops or virtuous cycles between these two pillars of university research activity. Consistent with other recent studies, they distinguish between AE and AC in order to explore not only which might be more prevalent and important in terms of Knowledge Transfer activities associated with university research but also for their respective roles in promoting future university research advances. Using a longitudinal, university-level dataset spanning 2008-14, they find that both AE and AC are positively associated with past research performance. However, consistent with the much higher prevalence and intensity of AE relative to AC in UK universities, they also show that only AE has strong positive feedback effects on subsequent research performance, both via funding and research scholarship (using both quantity and quality measures). This sector-level finding in the UK sets the broad stage for our more ground-level consideration of UIR and research activities among agricultural and life science faculty at all of the major US Land Grant universities.

Previous studies of faculty involvement in AE and AC activities in UK research universities sets the specific backdrop for our study. Starting from the basic conceptual framework of Perkmann et al. (2013), three broad set of factors are hypothesized to shape faculty engagement in UIR: **individual** (training, age, gender, values or attitudes toward research as well as UIR, and productivity); **institutional** (e.g., field of study, department, peer engagement or attitudes), and **organizational** (university-wide factors including quality of institution, technology transfer office efficacy and emphasis, incentives for UIR or other scholarly activities and so forth). Recent UIR studies have tended to develop and explore hypotheses along one of these lines at a time, isolating attention on specific hypotheses with respect to one of these factors and then controlling for other factors in the main regression analysis.

Similar to D'Este and Perkmann (2011), our study highlights the role of faculty attitudes toward UIR, using survey questions on values shaping research choices to develop factor scores

that can then be used to examine participation decisions in different forms of UIR. In their study, they distinguish between two ways in which faculty attitudes toward UIR may shape participation. In the first, faculty are viewed as academic entrepreneurs who seek to engage in UIR for commercialization reasons, what we later refer to as 'extrinsic' goals. In the second, faculty are viewed as scientists operating in a 'strongly institutionalized environment' who mainly seek UIR collaborations to advance their research efforts, more consistent with what we later call 'intrinsic' goals (based also on questions related to why they do science). Their particular focus is on 'collaboration' drivers and associated UIR outcomes, and they attempt to identify which of the two sets of values, commercialization or research, are stronger drivers of faculty UIR activities. Their main regressions are ordered logits that exploit the count information they have on UIR participation in collaborative efforts of different types, which they use as a dependent variable along with attitudinal measures and a series of other individual and organizational control variables.

Consistent with the findings of Perkmann et al. (2011), our study also explores the specific role of 'fields' and 'appointment type' as measures of institutional factors that can shape UIR participation. Their study makes a useful distinction between the likely UIR participation of faculty based on the type of science they do, basic or applied, as well as whether the faculty are 'star' scientists (citations). And, because UIR collaboration involves 'matching' between faculty and industry stakeholders and scientists, higher 'quality' faculty are also likely to find it easier to forge collaborative initiatives. Combining these factors, their hypotheses are then organized around the distinction between more basic and applied scientific fields and the matching probabilities to suggest why there might be substantial heterogeneity in UIR participation across fields. More applied or technologically oriented fields, such as engineering or food science in a college of agriculture and life sciences, would be ones where higher quality faculty would be more likely to participate in UIR, and star scientists perhaps even more so. In a more basic field, the same basic positive correlation between faculty quality and UIR might be present, but 'star scientists' could be less likely to be involved in UIR because the expected gains might be smaller and the constraints might not make it worthwhile. Put differently, the star scientists in basic sciences might put more emphasis on competitive federal grants and academic collaborations. Below, we build on this basic conceptual platform for the development of our LGU hypotheses about how fields of study within US agricultural and life science colleges may have distinctive patterns of UIR participation based on both their basic versus applied characteristics and what specific fields tend to value in terms of 'scientific' innovation.

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 transfers 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. In terms of incentives, linking tenure promotion or salary increases explicitly to external grants or commercialization could potentially shift behavior as well, though this administrative strategy may or may not align with values at the department level. Thus,

attention to peer-based values and connections with UIR may be just as important as explored in Tartari et al. (2014).

With respect to organizational – or university wide factors, in the next draft of this article, we will engage each of the aforementioned levels in specific ways. We incorporate information on the timing of the establishment of the technology transfer office and historical 'stock' measures of agricultural and life science patents as evidence of the university's experience, especially with commercialization activities. We also attempt to control for university quality using various research performance measures. We also exploit survey questions regarding faculty perceptions of the relative importance of academic engagement and commercialization activities in promotion and salary increases as compared to more traditional scholarship and service activities. Finally, similar to other studies, we also include control variables in our analysis of UIR participation choices, especially for individual demographic characteristics. We discuss these further in section 4.

3. US Land Grant University Context and Hypotheses

Three major legislative acts frame the longstanding tradition of academic engagement at US LGUs (Fitzgerald et al. 2016). The first is the Morrill Act of 1862 which granted states land to help finance the establishment of public universities dedicated to broadening access to education and training as well as advancing agricultural and mechanical arts in support of advancing the performance of those two major economic sectors. The second is the Hatch Act of 1887 which 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 that was 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 'academic engagement' at US LGUs that featured colleges of agriculture (and later 'life sciences') as the cutting-edge of UIR activities, with faculty appointments including explicit attention to 'extension' in combination with traditional research and instruction duties.

Faculty in US colleges of agriculture and life sciences generally span the breadth of basic and applied sciences reflected across the rest of public research universities as well described in both Perkmann et al. (2011) and Sengupta and Ray (2017). US LGU colleges of agricultural and life sciences generally consists of departments with mostly basic scientists, 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, they have social scientist departments of various names that include economists, sociologists, communications, and regional planning and development specialists. 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 as compared to answering applied questions. Thus, similar to Perkmann et

al. (2011), the fields in US LGUs tend to provide distinctive 'institutional' contexts in which to frame the likely connections between faculty and UIR activities.

Department homes are not 'clean' identifiers for the basic versus applied research orientation of faculty at LGUs. For example, the rapid expansion of genomic research over the past two decades has promoted a blending of biological science with more applied agricultural units. Path-breaking genomic and genetics research could readily be coming out of animal and plant science units as well as biological ones in a college of agriculture and life sciences. Likewise, efforts to improve eco-system outcomes of managed and natural systems could be emanating from both basic and applied units. One clean distinction between these types of fields though is the likelihood of faculty carrying extension appointments, which make 'academic engagement' with farmers, industry, or other non-university stakeholders a core (and basically required) activity area for some LGU faculty. Specifically, extension appointments are far more likely to occur in the applied agricultural/food sciences and social science departments than -they are in the biology units. Ecology units can fall on either side of that divide depending on what else they are linked with (e.g., forestry). Overall, though, between the likely divide between basic and applied research, and the lack of faculty with extension appointments, the biological departments (and to a lesser extent, ecology departments) are less likely to provide the institutional platform for 'academic engagement' than are the other two major types of applied and social science units in US colleges of agriculture and life sciences.

In the 1990s, academic commercialization efforts took off in US LGU colleges of agriculture and life sciences (Barham et al. 2002; Foltz et al. 2003). Biotechnology patents, in particular, 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 (add cites), with special attention paid to whether traditional scholarship activities and the pursuit of open science would be advanced or reduced by the attention to commercialization efforts (xyz). 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 longstanding 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 given that 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 highly unlikely as compared to other types of science faculty in colleges of agriculture 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. During that time period, most LGUs experienced an overall decline in revenues, and 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 their salaries. Indeed, many colleges of agriculture and life sciences pursued conversions of faculty salary contracts, moving from what had conventionally been 12-month to 9-month appointments in which 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 'extrinsic' or commercial 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 et al. (2014), US LGU agricultural and life science faculty reported declines in 'research time' and concomitant increases in time spent on administrative activities, as one way in which LGUs dealt with budget cuts and compliance demands was to reduce support staff and increase faculty reporting efforts. Likewise, faculty appeared to have taken on more 'administrative' responsibilities in terms of running programs and managing budgets and personnel. 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 also put downward pressure on the likelihood of US LGU faculty making the extra effort to pursue UIR activities.

- **Hypotheses**

The above literature review leads to a number of key testable hypotheses about the levels, extent of, and evolution over time of UIR activities in US Land Grant University Colleges of Agriculture and Life Sciences. Below we develop the general hypotheses for UIR activities, although in our analysis we will often break UIR into its constituent parts of AE and AC activities.

Hypothesis 1: Participation: US-LGU's have a high participation rate in UIR activities.
As outlined in the literature review, Land Grant universities have a long-standing tradition of working directly with industries, especially in the fields of agriculture and life sciences. We therefore expect this to lead to high UIR participation rates among faculty in agriculture and life sciences. Given that the tradition has been primarily about faculty engaging with industry on industry issues and problems, we expect this effect to be significantly stronger for AE than AC. What's not clear is whether AC is in ascendance given the push by LGU administrations and technology transfer offices to encourage higher levels of university commercialization of academic research.

Hypothesis 2: Rate of Change: UIR activities are increasing at US-LGU's based on the recent expansion of university AC promotion efforts. Because AC activities are potentially complementary to AE ones, and because they might appeal to faculty with more 'basic' science emphasis (Perkmann et al. 2011), UIR efforts could be expanding with AC. One potential counterpoint might be the overall decline in 'time for science' as reported in Barham et al. (2014).

Hypothesis 3: Funding: UIR activities provide significant funding for US-LGU research activities. Based on historical trends in AE and the recent expansion of AC activities, along with declines in state funding levels, UIR is expected to play a significant and perhaps growing role in funding faculty research activities.

Hypothesis 4: Synergies: UIR activities are broadly synergistic with other US-LGU outputs such as producing articles and training graduate students. A wide set of studies in the US and UK document the apparent synergies between UIR activities, especially patenting, and traditional academic scholarship in public and private research universities. We expect similar outcomes in this context.

Hypothesis 5: Scientific Motivations: The pursuit of scientific discoveries are the primary motivations shaping US-LGU faculty participation in UIR activities. Consistent with Sengupta and Ray (2017) and many other researches, we distinguish between scientific and commercial motivations in shaping research choices and engagement in UIR activities. We argue that researchers are most likely to participate in UIR when the potential for scientific advance aligns well with UIR. One reflection in this alignment is the match between stated preferences or values and UIR activity. This hypothesis is one of the main 'behavioral' ideas explored in this article.

Hypothesis 6: Monetary Incentives: Monetary or commercial incentives are a positive, significant but less common motivation for US-LGU faculty research problem choice and participation in UIR activities than are scientific motivations. As discussed above, faculty research activities are shaped by multiple factors. The potential for financial payoffs, at the individual or research lab level, are likely to be positively related to those choices, especially in fields where scientific interests and private sector interests closely align. Nonetheless, for many faculty, commercial incentives will play a much smaller role based on values, field orientation, success in securing public research funds, and so forth.

Hypothesis 7: Fields of Study: US-LGU faculty in different fields of study have distinct participation rates in and patterns of UIR. As discussed above and detailed in Perkmann et al. (2011), the match between 'institutional factors' and UIR activities is likely to be shaped by how well different fields of study and their research emphases align with the needs of private economic agents, such as firms and farmers. In the US LGU case, we would expect applied science types, such as animal and plant scientists, to be more engaged in UIR activities, especially AE activities, than are more basic-research oriented biological, ecological and social scientists.

Hypothesis 8: Extension orientations: Faculty with extension appointments have a higher propensity to engage in AE activities. The job description of faculty with extension appointments 'bakes in' academic engagement with the emphasis placed on linking research to outreach efforts in an integrated fashion. This would be especially true for faculty in the applied sciences, where they might also be expected by those with only research and instruction appointments to provide a bridge to 'industry' stakeholders.

4. Data and Methods

In the spring of 2016 we administered a survey to nearly 3000 agricultural and life science faculty at all of the US 1863 LGUs (The Institutional Review Board at UW-Madison approved this survey, #2015-0924). Similar to the 2005 survey, the 2015 sample frame included all tenure-track faculty scientists in agricultural and life science departments at these land-grant universities. We culled faculty names from university web directories to create the sample frame and then randomly selected a sample of 2,972 scientists who were sent a web-based survey with follow-up paper-mail reminders as in Dillman (2011). The response rate was 39.7% based on respondents who answered at least one survey question.

Response rates did vary somewhat by discipline, from a high of 42% among plant scientists (the largest discipline represented) to only 28% 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.

As shown in Table 1, the survey includes a rich set of questions with respect to faculty UIR activities. AE activities span a similar range described in the aforementioned studies in the UK including 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. Table 2 provides a comparison for 2005 and 2015 of the prevalence of each of the UIR activities. We use these data to construct categorical variables of AE and AC participation measures, as well as ones that identify when individuals do neither UIR or both (we call that AE/AC). 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 as the main way describe trends in UIR participation on the 'extensive' margin.

We also use the same questions from Table 2 to construct intensive measures of AE and AC participation using principal component analysis (PCA). Construction of those measures are described more fully in the appendix, but these intensity measures are used mostly in the regression analysis when we explore correlations of different individual, institutional, and organizational factors with UIR activity. The measures themselves also provide a richer portrayal of the 'depth' of AE and AC activities.

In addition to these key outcome variables, the subsequent analysis also focuses on other faculty research activities, which we label as AS (academic scholarship). We mostly focus on published articles and training of graduate students and post-docs, though the survey data include some other measures like books and conference abstracts. Those research activities are incorporated into the comparisons of faculty across UIR categories in order to help identify the potential for synergies or tradeoffs between UIR and AS outcomes. Similarly, we use data on total research grant revenues and different sources, such as federal, state, industry, commodity groups, foundations, and licensing revenues, to examine the relative importance of funding streams and levels to relate them to UIR categories.

One other important set of measures from the survey warrant description here. In both 2005 and 2015 surveys, respondents were asked about the reasons motivating them to pursue a certain research topic in the last five years. They are generally oriented toward 'scientific' motivations, such as 'scientific curiosity' or 'potential contribution to scientific theory', or commercial ones, such as 'potential marketability' or 'potential to patent and license the discovery'. The full set of 14 questions are shared below. They are all asked using a 1-5 Likkert 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 identify latent factors that might shape faculty research choice. That approach is also more fully described in the Appendix, with the actual measures being shared in the next section.

Many of the hypotheses are examined with basic descriptive statistics, either cross-tabulations of UIR participation and intensity measures against a variety of individual, institutional, and organizational characteristics or by looking at trends over time. We also run regressions on participation and intensity of UIR outcomes to identify multivariate correlations in a manner consistent with most of the aforementioned UK papers. This paper does not pursue causal identification of UIR choices in order to allow for a broader focus on UIR activities among US-LGU faculty.

5. Results

Three basic observations help to frame US-LGU participation in UIR activities. They can be gleaned from Tables 3 and 4, which provide, respectively, a description of participation rates in AE and AC UIR activities by gender, rank, appointment type, and field and a comparison over time of faculty participation in the four UIR categories.

- Consistent with hypothesis 1, US-LGU faculty participation rates in UIR activities are very high. Between 80-90% of faculty in most fields participate in UIR, with minimal variation across rank, gender, or appointment type. The lowest UIR participation rates are in the 60-70% range for the ecological and social sciences. This outcome is also consistent with findings from the UK mentioned above.

- Also consistent with the explanation of hypothesis 1, AE participation is far more prevalent than AC, with about 75% of faculty pursuing AE as compared to less than 1/5 in AC. Moreover, if we isolate on the AC only category in Table 4, we find that around 2-3% of faculty are just doing AC in the two time periods. The vast majority of faculty engaged in AC activities are also active in AE. And, the proportion of faculty that are engaged in neither AE nor AC is greater than the total proportion active in AC. Thus, academic commercialization is the least prevalent of the three broad categories of UIR activity in our data.

- UIR participation, overall, fell somewhat between 2005 and 2015; declines in AC activities led the way, with a decline of 30% from 26% of respondents in 2005 to 18% in 2015. Declines in AE participation, across the ten years, were minor from 77% to 75%. Thus, the decline in AC participation between 2005 and 2015 is in contradiction to hypothesis 2 that envisioned an increase based on university-level support in previous

decades. We conclude that the popular perception following university rhetoric on expansion of UIR activities is not borne out by the behavior of faculty in terms of engaging with industry.

Since the test of hypothesis 2 presented above might be due changes in the composition of types of faculty rather than individual faculty themselves changing their behavior, it is worth tracking the persistence of UIR activities. We use a smaller panel dataset gathered as part of the study to probe the persistence of individual participation in each of the categories. Table 5 provides a transition matrix between 2005 and 2015 of UIR participation counts across the categories. We offer three observations based on the transition patterns. First, there is a high exit rate out of AC reflected in the AC row, where only 14% stay in that category and over 50% drop out of AC activities. Aside from AC, all of the other UIR categories show a relatively high rate of persistence over time. Second, the AC-only category is by far the least likely to gain faculty across the time periods, reflecting the low likelihood of faculty activity in just AC. Third, a transition to AE/AC from any of the other categories is far more likely, suggesting the potential joint nature of AC with AE rather than AC as an independent activity. Thus, the decline in AC evident in the cross-sectional data also shows up as a lack of persistence of faculty activity in this arena. We return to this observation below after considering more of the evidence from our data.

Research funding outcomes for different UIR participation categories are reported in Table 6 which includes amounts of funding from different sources as well as shares. The most important observations with respect to UIR activities and funding outcomes emerge from comparing industry and commodity funding outcomes with those from patent revenues in both 2005 and 2015. Notice first that in neither of the two time periods did any individuals in the AC-only category report receiving licensing revenues from their inventions, while in the AE/AC category the mean funding amounts from licensing were under $10,000 per year and less than 2% of the research budget for those faculty in both 2005 and 2015. By contrast, the mean funding amounts for both industry and commodity organizations for the AE/AC categories were 15-20 times the amounts of licensing revenues and accounted for more than 25% of the faculty's total research budgets. Across the board then, AE funding is far more important in its support for US-LGU faculty research than is AC, more than 3 decades after the passage of Bayh-Dole and more than 25 years after most of these universities began pursuing commercialization opportunities with earnest. Another way to look at the data in Table 6 is that across all of the UIR categories federal funding remains the primary source of research funds, with industry and commodity organizations playing a substantial but subordinate role. Licensing revenues are a trivial source overall. Thus, hypothesis 3 on funding is confirmed only for AE not AC activities and overall UIR activities do not appear to

With respect to AS or traditional research activities, faculty participating in UIR activities look solid among US-LGU faculty. Table 7 reports for each category of UIR on articles published in the last 5 years, main advisor for PhD and Masters' students, as well as on industry collaborations and patents. Consistent with previous studies, the most active faculty in UIR, the AE/AC group have the highest article productivity and number of Ph.D. students trained. Their outputs are consistent with 'synergy' between UIR and AS activities, as is found in more careful econometric studies elsewhere (e.g., Foltz, Kim, & Barham, 2003). Secondary comparisons of AE and AC faculty with the Neither category also show similar or higher productivity levels for

AS activities, so there is no prima facie evidence to contradict hypothesis 4 and substantial evidence from the AE/AC category of the potential for synergies between UIR and AS. Table 7 is also noteworthy for providing continued evidence of rising productivity over time of US-LGU faculty based on article counts (Prager et al. 2014), although no effort is undertaken here to control for 'quality' or increases in 'co-authorship' either of which could lead to an 'adjustment' in the raw measure provided here.

We turn next in Table 8 to 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) for a select set of questions related to 'scientific motivations' versus 'commercial motivations' and compare them across UIR categories. Note first that in both years, 'enjoy the research' and 'scientific curiosity' scores are generally well above 4 for all categories of faculty doing UIR activities and are significantly higher for AC and Neither than for AE and AE/AC. By contrast, the scores for 'potential marketability' or 'private firms commercialization interest' are lower within all of the UIR categories relative to scientific motivations, by at least a full point and often times two or three points. By the same token, there is considerable variation across the UIR categories with respect to the commercial motivation scores with the AE/AC category having the highest scores and the neither and AE categories having the lowest. While we explore these values further in the regressions below, this descriptive evidence is consistent with hypotheses 5 and 6 that identify scientific motivation as more important to US-LGU faculty research motivations than are commercial ones.

The next set of results integrate the principal components analysis (PCA) done to create UIR activity 'intensity' measures with the factor analysis scores from the 'research choice' attitudes just discussed. The purpose is to provide a 'visual' heat map of the correlations across UIR activities and attitudes. While the previous measures of AE and AC have been binary categories, the PCA methods allow us to examine the intensity of UIR activities. Prior to presenting those figures, we briefly discuss each of the measures.

The 'intensity' measures, as described further in the appendix, were generated by pooling the UIR activity measures and using PCA methods to generate 'weights' that map into the intensity of AE and AC activity. Those weights, reported in the appendix, are used to construct deciles of AE and AC intensity. Figure 1 reports for those deciles the distribution of UIR types for the pooled 2005 and 2015 data. Figure 1a shows the high level of concentration of AE and AE/AC types in the top 7 deciles of the academic engagement index, while Figure 1b shows similar high levels of concentration for the AC and AE/AC types in the upper three deciles of commercial engagement.

The factor scores for scientific and commercial latent factors were constructed from the factor loadings identified in Table 9. Each have some consistent 'high weights', such as scientific curiosity or potential contribution to scientific theory for the scientific latent factor and likely interest by private firms in commercializing the discovery and potential marketability of the final product for the commercial latent factor.

Correlations between the PCA and latent factor measures are explored in Figures 2 and 3. The first one explores the intensity of AE engagement with respect to the two latent factors and

shows a strong negative correlation between AE and the scientific latent factor and a strong positive correlation between AE and the commercial factor. They appear to be almost mirror images of each other. By contrast, in Figure 3, there is a weakly positive correlation between AC index and the academic factor and a somewhat stronger positive correlation between AC and the commercial factor. Broadly speaking these figures support hypotheses 5 and 6 related to the factors shaping faculty engagement with UIR activities.

We explore one more set of 'correlations' with our 'intensity' of UIR measures before we turn to the multivariate regressions. In Figure 4, we examine the changing share of funding from federal and private sources for both AE and AC intensity measures (again expressed in terms of 'deciles'). In the case of AE intensity, the share of private funding rises steadily from a neglible share in the first decile of AE intensity to around 20% in the middle deciles to more than 50% in the top decile with a big jump occurring in the top 3 deciles of the AE index. Meanwhile, federal funding falls from just over 60% in the bottom deciles of AE intensity to under 40% in the top deciles. With respect to AC intensity, there is basically no shift in funding sources, with federal funding continuing to at around 50% across the deciles. This contrast, in combination with the evidence from the Table 5, is suggestive of there being positive payoffs in private funding associated with AE intensity relative to the low payoffs associated with AC intensity.

The last set of empirical results focus on a multivariate regression analysis of UIR activities. We ran both a participation regression, a binomial analysis of AE and AC participation, and an intensity regression. We report only on the latter one here to show the intensity measures of AE and AC involvement provide more variation and reveal more from the explanatory factors than does the regression based on binary measures. In Table 10 we report on how individual and institutional factors shape UIR participation with regressions that use university-fixed effects. The next iteration of the article will expand on university level measures to incorporate all three levels of potential explanations.

The main results from the multivariate regression are as follows. First and foremost, as suggested by hypothesis 7, significant differences emerge across fields in terms of UIR intensity. The reference field in our regressions is plant scientists, and relative to that field there are significantly lower levels of intensity for AE for all other fields but animal science. Consistent with Perkmann et al. (2011), biology and social sciences have the most negative difference in intensity of AE relative to plant sciences. The only significant difference on the AC intensity side relative to AE is the significant and negative coefficient on the social sciences field measure. Second, and not surprisingly, the percentage share of a faculty member's extension appointment is positively and significantly related to the intensity of AE involvement and negatively and significantly related to the intensity of AC involvement, both of which seem consistent with the expected roles of those faculty. This result confirms hypothesis 8, and provides additional confidence in the regression results. Third, faculty attitudes are a significant explanatory factor with respect to the intensity of UIR activity ways that are consistent with the 'heat maps' offered in Figures 1 and 2 above. Specifically, higher scientific factor scores are negatively related to AE intensity and positively related to AC intensity, while higher commercialization factor scores are positively related to the intensity of AE and AC. Thus, the value alignment of attitudes and activities is somewhat distinct across UIR activities, with a more complementary view of AC for both factors. This might be consistent with faculty who do both AE and AC seeing them as

complements rather than substitutes, while many of the faculty who do just AE seeing them potentially as substitutes. Finally, as suggested by the descriptive statistics above, we see no significant differences across gender in AE and AC intensity and only small significant effects of rank in the AC intensity measure, with more senior professors being somewhat more likely to be more intensive in their AC activities but no more intensive in their AE activities. We also see no significant differences in AE or AC intensity based on whether the faculty member got their Ph.D. originally at a LGU.

6. Discussion

This article examines the UIR activities of agricultural and life science faculty at the premier US LGUs, using survey data gathered from large, random samples in 2005 and 2015. In so doing, it provides a complement to a series of recent studies of UIR outcomes in the UK, and it focuses on the links between fields, faculty attitudes toward research, and UIR activities. It fills a gap identified in Perkmann et al. (2013) by carefully exploring the relative importance of two distinct lines of UIR activities, what are called in the literature academic engagement and academic commercialization. Because US LGUs are 'ground-zero' of US public research university UIR activities, the empirical context is of significance to the broader US university research context.

Our findings are broadly consistent with the UK studies on a number of important fronts. First, faculty participation rates in UIR activity are quite high; generally, around 80-90% of 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% of faculty in either survey participated in just AC activities. About 20% did both AE and AC and another 50-60% or so were active in AE only. Moreover, UIR activity trended a bit downward between 2005 and 2015, driven by a decline in faculty participation in AC activities.

Third, as a source of research funding for agricultural and life science faculty at US LGUs, AE completely dominates AC. Overall, patent license revenues provide about 1% of lab revenues, as compared to close to a 20% share for industry and commodity group funds. This outcome appears to be in 'steady-state' thirty-five years after the passage of the Bayh-Dole Act and more than twenty-five 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 is not the first paper to suggest that university patents appear to be like lottery tickets in terms of their potential to fund research in the scientific fields captured in this study. A big winner now and then may be great for the university and the lucky inventor, but consistent funding for faculty research continues to come from public funds and sponsored research arrangements, not from academic commercialization efforts.

This study also finds descriptive evidence for both 2005 and 2015 that UIR activities appear to be synergistic with traditional academic scholarship activities. Specifically, the number of peer-reviewed publications and graduate students trained are higher for the AE/AC faculty

than they are for any of the other UIR categories. This outcome is consistent with many studies that find the more productive researchers are also often the ones most highly 'in demand' or active in UIR activities. Across the other categories, there are no significant differences between faculty engaged, say, in AE and those that are not involved in either type of UIR. While this study does not undertake the type of longitudinal dynamic statistical analysis of Sengupta and Ray (2017) who find positive feedbacks between AE and research outcomes, prima facie evidence here is consistent with that outcome. Note that the AE/AC faculty persist across time periods and they tend to have more research revenues and higher publication and student counts.

This study examines factors shaping both the participation and intensity of engagement of US-LGU faculty with UIR activities. Institutional factors, specifically 'fields' or 'disciplines' are a significant conditioning factor as shown in Perkmann et al. (2011), with more applied science fields like plant and animal sciences having higher UIR rates than more basic ones like biological and ecological ones. Most of the differences in UIR activity by fields are driven by variations in AE rather than AC as shown in the 'intensity' of UIR activity regressions. This finding is consistent both with 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 appears to occur regularly as shown in the transition matrix in Table 5 above.

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 to identify a causal relationship between attitudes and UIR activity involvement, agricultural and life science faculty at US-LGUs report that their research problem choices are strongly driven by scientific factors, such as curiosity or the potential to contribute to scientific theory relative to commercialization motives. 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.

When we develop factor scores for faculty attitudes and relate them to the intensity of AE and AC activity, we find somewhat distinctive relationships between those and UIR outcomes. Specifically, higher factor scores for both science and commercial motives are positively associated with more intensive AC activity, while there is a negative correlation between the science motives and AE intensity and a positive one between commercial motives and AE activity. This distinction may reflect an applied versus basic science divide that may separate some lines of AE research from AC areas, especially in the applied fields of plant sciences, animal sciences, and food and nutritional sciences.

One shortcoming of this draft of the article is that university-level effects, which are the third major pillar of factors identified in the Perkmann et al. (2013) article are not explicitly examined. Instead, the regressions are run with university-fixed effects. These specifications should help to reduce the risk that the field and individual factor estimates are biased by serious omitted variable considerations. However, a fuller understanding of the factors shaping UIR

participation will also be advanced once a set of more continuous and potentially variable measures for university-level factors are incorporated.

7. Conclusion

Attention to UIR promotion at US universities took off in the 1990s and 2000s, with much of the emphasis placed on promoting academic commercialization of intellectual property rights in the form of patents and in some cases through support for faculty-assisted 'start-ups'. A huge amount of what one might call 'research on research' has examined that push, exploring the potential effects of this new type of UIR on the pursuit of science and innovation by faculty. This type of research on research has been pursued around the world, focusing on the balance between the three missions of learning, creation of knowledge, and technology transfer. Many articles in this journal and others, dedicated even more narrowly to the topic of technology transfer, have probed these issues, searching for synergies, tradeoffs, and factors shaping UIR activity. Most studies find that traditional academic scholarship has not 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.

This study essentially confirms those findings but using comprehensive UIR data from US Land Grant Universities, which are often viewed as the core of US public research universities. Some names of these LGUs are illustrative: University of California-Berkeley, Cornell University, University of Florida, University of Illinois, Iowa State University, Kansas State University, Ohio State University, Texas A&M, University of Wisconsin, and Washington State University. At these and other US LGUs, the longstanding tradition of academic engagement, involving sponsored research and direct collaboration with scientists and managers in industry and agriculture dominate the new academic commercialization relationships in prevalence, importance for funding, and intensity of involvement. Moreover, these two types of UIR may be complements, with AC being an occasional outgrowth of AE in some fields, which might depend on the continuity of AE relationships to emerge.

Future research with these data will attempt to pursue a more causal identification of some of the UIR participation and intensity outcomes shown above using historical information as instruments as well as more of the panel data. In addition, given the significant growth in the proportion of women faculty in the US LGUs over time, and the lack of significant effects found so far with respect to gender and UIR, we intend to see whether the US-LGU context is distinct from some recent European studies that find a persistent gender gap in UIR activities.

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Table 1: Types of university-industry relations 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.	Had research support from private industry Had research support from commodity organizations Collaborated with scientists in private industry Co-authored 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 to you identify a research problem Collaborated on a research project with farmers or farm org. Co-authorship 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).	Had licensing or patenting revenue returned to your research lab Number of disclosures generated Number of patent applications generated Number of patents issued Number of patents licensed out Number of products under regulatory review generated Number of products on the market generated Number of start-up companies founded

Table 2: AE and AC Activity Participation Rates and Counts, 2005 and 2015

Academic Engagement	**2005**		**2015**		Δ p.p.
	Rate	Count	Rate	Count	
Had research support from private industry	0.46	458	0.40	282	5.91
Had research support from commodity organizations	0.32	318	0.26	185	5.62
Collaborated with scientists in private industry	0.31	309	0.33	233	-2.02
Co-authored with scientists in private industry	0.13	126	0.14	100	-1.53
Presented to farmers or farm organizations	0.44	439	0.36	253	8.10
Presented to commodity groups	0.35	348	0.28	201	6.36
Presented to the private industry	0.34	337	0.28	196	5.97
Farmers or farm org. helped to you identify a research problem	0.38	383	0.36	256	2.10
Collaborated on a research project with farmers or farm org.	0.29	291	0.30	211	-0.72
Co-authorship on paper or patent with farmers or farm org.	0.03	30	0.03	20	0.17

Commercial Engagement	**2005**		**2015**		Δ p.p.
	Rate	Count	Rate	Count	
Had licensing or patenting revenue returned to research lab	0.02	23	0.03	19	0.38
Had invention disclosures have you generated from research program	0.15	153	0.12	86	-20.55
Had patent applications generated from research program	0.16	159	0.11	76	-32.44
Had patents issued from research program	0.09	93	0.06	41	-37.68
Had patents licensed out from research program	0.04	41	0.04	25	-13.81
Had products under regulatory review generated from research program	0.02	21	0.01	10	-32.69
Had products on the market generated from research program	0.08	77	0.05	32	-41.26
Had start-up companies founded from research program	0.04	42	0.03	18	-39.42

Table 3: Individual characteristics of UIR categories, 2005 and 2015

	2005				2015			
	AE	AC	AE/AC	Neither	AE	AC	AE/AC	Neither
Gender								
Female	0.54	0.04	0.18	0.23	0.62	0.03	0.10	0.26
Male	0.55	0.03	0.23	0.19	0.58	0.02	0.18	0.22
Rank								
Professor	0.53	0.03	0.25	0.19	0.57	0.02	0.20	0.21
Associate Professor	0.58	0.03	0.21	0.17	0.65	0.01	0.08	0.26
Assistant Professor	0.55	0.04	0.18	0.23	0.60	0.05	0.14	0.22
Other	0.00	0.00	0.33	0.67	0.46	0.04	0.19	0.31
Fields								
Ag Engineering	0.58	0.03	0.32	0.06	0.62	0.03	0.21	0.14
Animal Science	0.58	0.04	0.32	0.06	0.61	0.03	0.21	0.15
Biology	0.24	0.10	0.26	0.40	0.35	0.11	0.20	0.34
Plant Science	0.61	0.03	0.26	0.09	0.69	0.02	0.23	0.07
Ecology	0.57	0.01	0.16	0.26	0.64	0.01	0.08	0.27
Food/Nutrition	0.53	0.02	0.33	0.12	0.46	0.00	0.34	0.20
Social Sciences	0.62	0.02	0.04	0.33	0.60	0.00	0.03	0.37
Other	0.46	0.00	0.08	0.43	0.14	0.00	0.14	0.71

Table 4: Faculty participation rates in UIR, 2005 and 2015

	2005	**2015**	Δ p.p.
AE only	54.7%	59.0%	4.3
AE/AC	22.3%	15.8%	-6.5
AC only	3.4%	2.4%	-1.0
Neither	19.6%	22.9%	3.3
AE	77.2%	74.8%	-2.4
AC	25.7%	18.1%	-7.6

Table 5: Persistence in faculty participation in UIR

Count

		2015			
		AE	AE/AC	AC	Neither
2005	AE	101	17	1	11
	AE/AC	25	27	2	1
	AC	2	2	1	2
	Neither	19	4	2	26

Percentage

		2015			
		AE	AE/AC	AC	Neither
2005	AE	78%	13%	1%	8%
	AE/AC	45%	49%	4%	2%
	AC	29%	29%	14%	29%
	Neither	37%	8%	4%	51%

Table 6: Research lab financial sources across UIR types, 2005 and 2015

		2005				2015			
		AE	AE/AC	AC	Neither	AE	AE/AC	AC	Neither
Research Lab Revs (Median)	$	75,000	150,000	103,000	60,000	100,000	200,000	183,500	53,000
Research Lab Revs (Mean)	$	153,362	219,839	141,030	100,630	287,147	423,324	286,402	255,975
Fed Grants	$	73,963	103,219	96,836	64,931	158,765	217,316	218,993	199,701
	%	35.54	39.05	58.54	46.75	38.03	42.09	67.81	50.88
State Grants	$	18,585	19,606	10,932	5,392	20,306	20,284	18,250	18,231
	%	9.84	6.71	9.22	7.58	8.09	5.33	5.50	5.13
Private Industry	$	16,779	39,093	-	-	36,628	74,522	-	-
	%	12.11	17.96	0.00	0.00	12.92	16.99	0.00	0.00
Commodity Orgs	$	8,815	11,240	-	-	19,915	30,238	-	-
	%	9.29	9.20	0.00	0.00	9.10	8.45	0.00	0.00
Foundations	$	6,070	9,510	2,648	5,613	12,898	27,257	23,062	17,366
	%	4.03	4.15	1.67	6.32	6.30	5.66	8.99	6.67
University Funds	$	10,757	14,420	21,653	10,122	16,889	29,856	15,035	12,421
	%	10.60	7.42	17.73	16.14	11.32	9.89	12.88	15.13
Patent Royalties	$	-	3,861	-	-	-	8,076	-	-
	%	0.00	1.21	0.00	0.00	0.00	1.53	0.00	0.00
Others	$	16,919	16,433	9,119	9,821	22,510	17,587	11,063	10,824
	%	16.80	12.13	10.74	17.11651	12.65	9.57	4.81	15.07

Table 7: Scholarly outputs across UIR types, 2005 and 2015

2005

	AE		**AE/AC**		**AC**		**Neither**	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
% sample in each category	54.72		22.29		3.41		19.58	
Scholarly articles (5 yrs)	11.34	9	16.42	14	12.91	14	10.39	9
PhD students (5 yrs)	3.16	2	2.79	2	1.94	1	3.04	2
Masters students (5 yrs)	1.41	1	1.74	1	1.69	2	1.61	1
Collab. Industry (past year)	1.05	0	1.63	1	0	0	0	0
Invention disclosures (5 yrs)	0	0	1.73	1	1.21	1	0	0
Patents (5 yrs)	0	0	1.69	1	1.17	1	0	0
Patent royalties*	-	-	44.12	0	0	0	-	-

2015

	AE		**AE/AC**		**AC**		**Neither**	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
% sample in each category	58.99		15.75		2.38		22.88	
Scholarly articles (5 yrs)	14.12	11.50	23.48	19	19.81	16	14.38	11
PhD students (5 yrs)	2.79	2	2.43	2	1.43	1	1.89	1
Masters students (5 yrs)	1.67	1	2.71	2	1.87	1	1.62	1
Collab. Industry (past year)	1.15	0	1.93	1	0	0	0	0
Invention disclosures (5 yrs)	0	0	2.32	1	1	1	0	0
Patents (5 yrs)	0	0	1.79	1	0.80	1	0	0
Patent royalties*	-	-	716.67	0	0	0	-	-

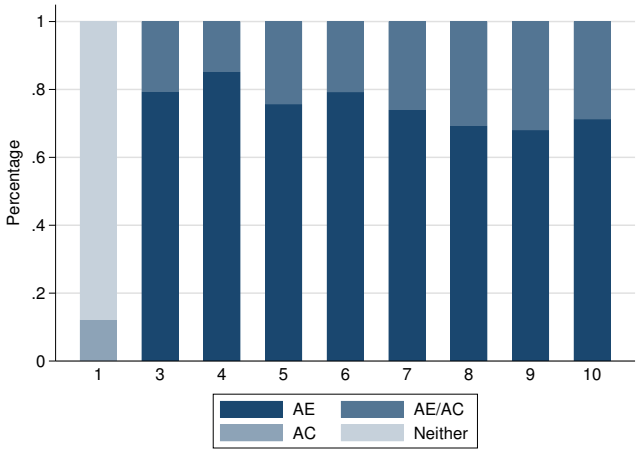
*Conditional on receiving any patent.

Table 8: Research choice criteria across UIR types, 2005 and 2015

	2005				**2015**			
Research Choice Criteria	AE	AC	AE/AC	Neither	AE	AC	AE/AC	Neither
Enjoy research	4.52	4.76	4.5	4.65	4.28	4.63	4.34	4.5
Scientific curiosity	4.15	4.55	4.27	4.38	4.01	4.56	4.19	4.39
Importance to society	4.32	4.39	4.25	4.13	4.08	4.31	4.26	3.99
Potential Marketability	2.49	2.82	3.38	1.67	1.76	2.50	3.10	1.38
Private Firms Commerc.	1.82	2.18	2.76	1.32	1.45	2.25	2.71	1.15

Figure 1: Distribution of UIR types (dummy) by deciles of UIR indexes (PCA), 2005 and 2015 pooled

(a) Deciles of Academic Engagement



(b) Deciles of Academic Commercialization

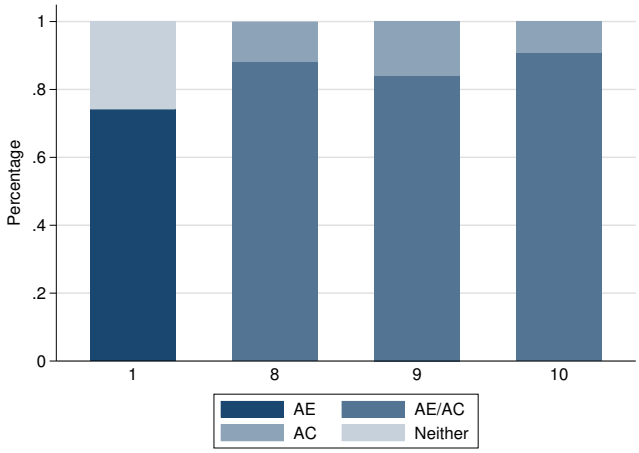


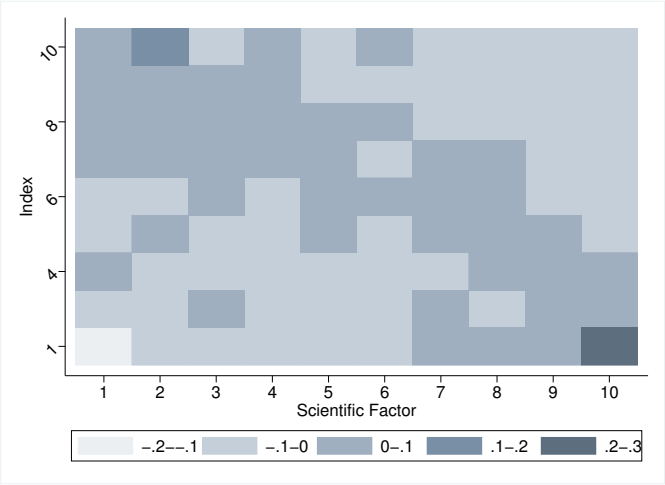
Table 9: Factor Loadings Estimation, after rotation

Item	**Extrinsic**	**Intrinsic**
Potential contribution to scientific theory		0.608
Publication probability in professional journals		0.4954
Enjoy doing this kind of research		0.4878
Scientific curiosity		0.6146
Availability of research facilities	0.3841	0.3077
Requests made by clientele	0.5329	-0.3396
Feedback from extension personnel	0.4887	
Potential to patent and license the research findings	0.6562	
Likely interest by private firms in commercializing the discovery	0.7355	
Potential marketability of the final product	0.6739	
Availability of public (state and federal) funding	0.3264	
Availability of private (corporate) funding	0.5346	
Colleagues approval		
Importance to society		

Note: Factors are calculated jointly for both waves. Comparing eigenvalues and its variances we confirm the existence of two factors. Together, they explain 92% of the variance. We used Principal Factor with orthogonal quartimax rotation to estimate the factor loadings.

Figure 2: Correlation between attitudes and AE Index for pooled cross-section data

(a) Academic Engagement vs. Academic Factor



(b) Academic Engagement vs. Commercial Factor

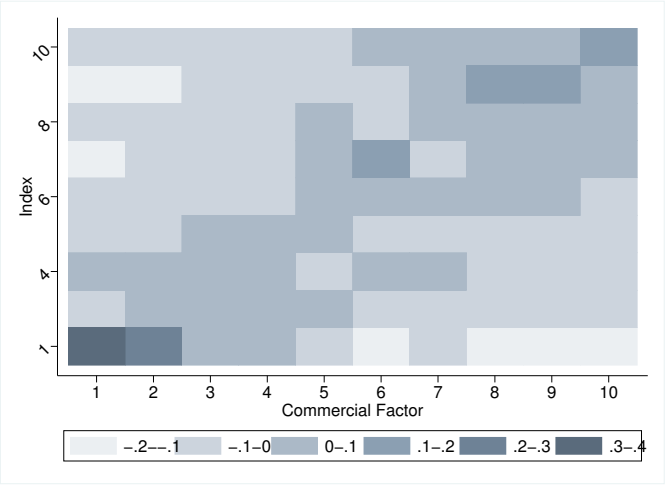
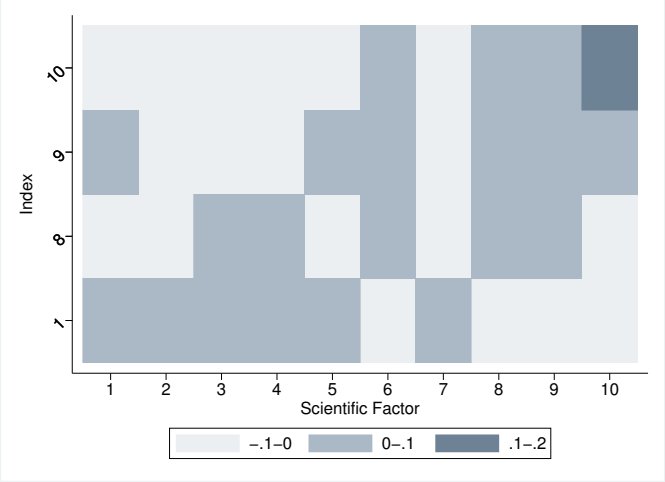


Figure 3: Correlation between attitudes and AC Index for pooled cross-section data

(a) Academic Commercialization vs. Academic Factor



(b) Academic Commercialization vs. Commercial Factor

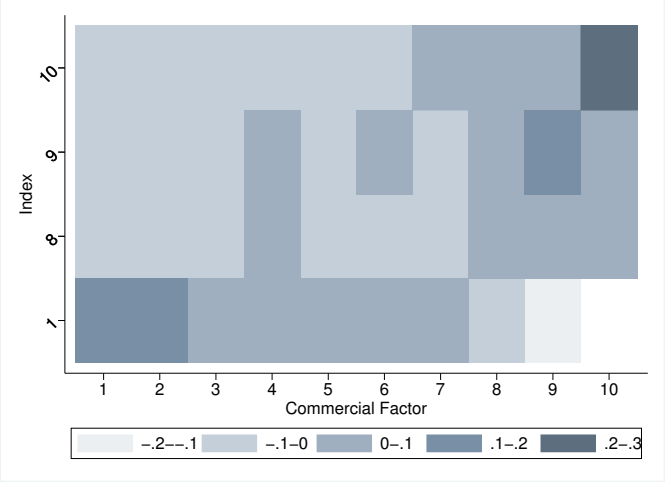
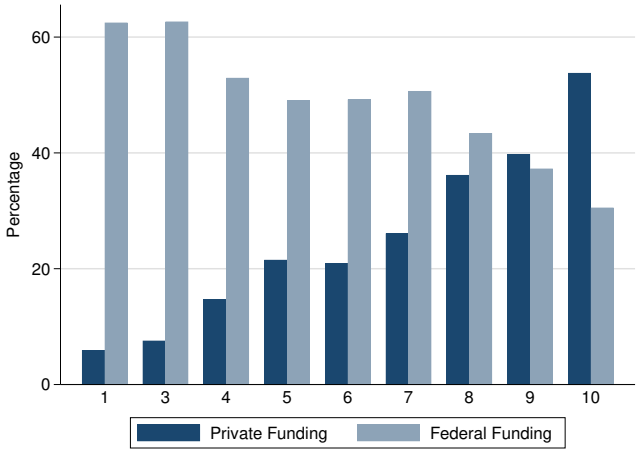


Figure 4: Percentage of funding source by deciles of UIR indexes (PCA), 2005 and 2015 pooled

(a) Deciles of Academic Engagement



(b) Deciles of Academic Commercialization

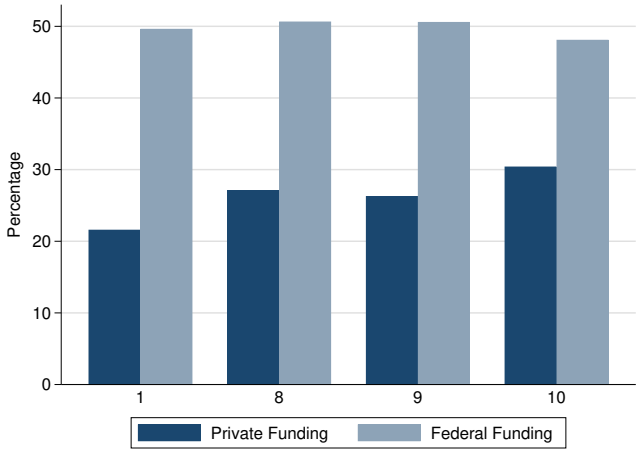


Table 10: AE and AC intensity index regressions

	(1) **AE Index (sd)**	(2) **AC Index (sd)**
Scientific Factor Score (sd)	-0.15853***	0.03806**
	(0.04434)	(0.01774)
Commercial Factor Score (sd)	0.38630***	0.16327***
	(0.05092)	(0.05111)
Field		
Plant Science (Ommited)	-	-
Ag./Engineering	-0.73482***	-0.05966
	(0.23003)	(0.05569)
Animal Science	-0.16133	-0.06407
	(0.12554)	(0.05235)
Biology	-0.66008***	0.04561
	(0.12471)	(0.08036)
Ecology	-0.49452***	-0.05600
	(0.11857)	(0.03674)
Food/Nutrition	-0.42103**	-0.03050
	(0.16028)	(0.08293)
Social Sciences	-0.74381***	-0.04146*
	(0.12675)	(0.02361)
Rank		
Professor	-0.11607	0.11577***
	(0.10240)	(0.04286)
Associate Professor	-0.10039	0.04771*
	(0.10251)	(0.02453)
Assistant Professor (Ommited)	-	-
Male	0.06240	0.01045
	(0.07589)	(0.02280)
Extension and Outreach; Formal (pct)	0.01105***	-0.00156**
	(0.00165)	(0.00068)
PhD from a Land Grant Univ.	0.04405	-0.02698
	(0.04499)	(0.03750)
Wave = 2015	0.14209*	0.02232
	(0.08162)	(0.02842)
University Fixed Effects	Yes	Yes
Constant	0.16965	-0.04989
	(0.12599)	(0.04742)
Observations	716	719
R-squared	0.50345	0.22270

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Appendix:
Measuring university-industry relations (UIR) and research incentives.

1 University-industry relation indexes: principal components analysis

Principal component analysis (PCA) is a widely used application of basic linear algebra. It reduces the dimensionality of a set of variables while preserving the larger set's main features. PCA reduces the dimension of the data by projecting its points onto lower dimensions (or principal components). It seeks to minimize the distance between the data and the components while maximizing their variance and keeping the components uncorrelated. From the resulting set of all components, we keep the ones explaining the larger share of the variance, dropping less important ones. The continuous scores C_j are linear combinations of the original variables X:

$$C_j = a_{11}X_1 + a_{12}X_2 + ... + a_{mn}X_n \tag{1}$$

Applying this to our context allows us to assign to each individual a continuous measure for the degree of engagement in each of our university-industry relations measures. Empirically, we use pre-programed packages in Stata[1] to estimate the weights and the scores (or indexes) for our sample. Our method consists of two main steps. First, we estimate the principal components using all set of variables as an exploratory exercise. The eigenvectors suggest us to keep two components. Each of them have factor loadings consistent with our priors on how to split the variables into commercial and academic engagement ones.[2] Second, we run the principal component analysis on each set of dedicated measures separately. We chose this way to not force them to be uncorrelated. We pooled both years of data for this exercise.

In Figure 1, we plot the density distribution of the scores - standardized to have mean zero and standard deviation 1 - for both years. The AE distribution is more dispersed than AC, which is expected given the larger number of people engaged in AE type of activities than in AC.

[1] *pca* and *predict*

[2] Detailed results upon request.

Table 1: Coefficients for the prediction of Principal Component Index for UIR types.

Academic Engagement

Item	**Weights**
Funding Sources: Private Industry	0.34
Funding Sources: Commodity Organization	0.36
Research: Collaborated with scientists in private	0.29
Research: Co-authored with scientists in private industry	0.17
Research Presentation: farmers or farm organizations	0.35
Research Presentation: commodity groups	0.36
Research Presentation: private industry	0.27
Help Identifying Research Question: Farmers or Farm Org.	0.38
Research Collaboration: Farmers or Farm Org.	0.38
Paper/Patent Co-authorship: Farmers or Farm Org.	0.17

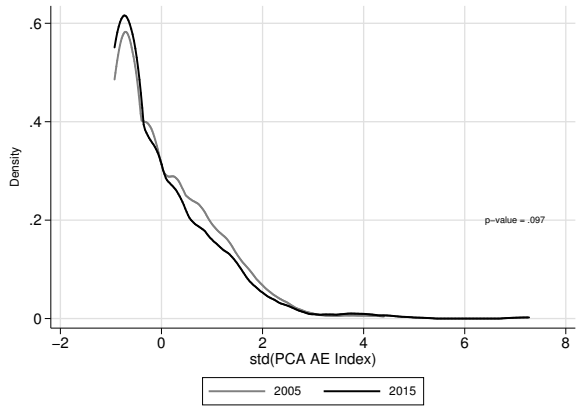
Commercial Engagement

Item	**Weights**
Funding Sources: Licensing or patenting revenues returned	0.21
Outputs from research: Invention disclosures	0.18
Outputs from research: Patent Applications	0.49
Outputs from research: Issued Patents	0.50
Outputs from research: Patentes Licenced Out	0.48
Outputs from research: Products under regulatory review	0.03
Outputs from research: products on the market	0.44
Outputs from research: start-up companies founded	0.05

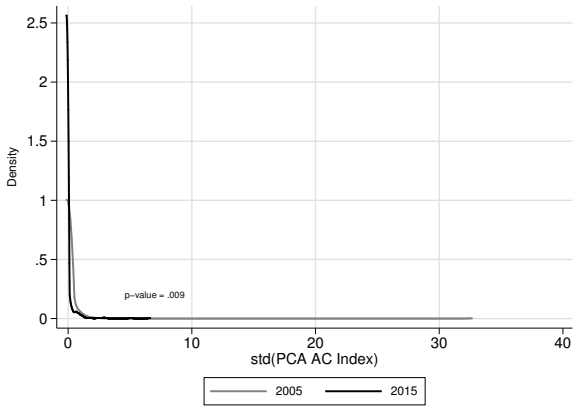
Note: this table displays the resulting weights used to predict the PCA scores for the Academic and Commercial Engagement indexes. The calculated eigenvalues suggest we should keep one component in both cases. The first component for the AE variables explains 32% of the variation in the data. For the AC variables, the first component explains 47% of the variation in the data.

Figure 1: Kdensity Distribution of PCA indexes by UIR types, the cross-section samples in 2005 and 2015

(a) Academic Engagement



(b) Commercial Engagement



2 Research Incentives and Attitudes: factor analysis method

Factor analysis, as PCA, is another useful tool to reduce the dimensionality of a vector of variables and to control for measurement error. The method assumes each measure to be imperfect proxies for latent factors. In our context, we apply factor analysis to a set of 14 items related to attitudes towards research. It identifies blocks of correlation across the questions and to estimate the distribution of underlying factors that commonly explain the variance in the data.

Formally, these models estimate (unobserved) latent traits based on observed measures. Consider $F_i = (F_{i1}, ...F_{iK})$ as the set of K latent factors, $K = \{1, ..., K\}$. Each vector of factors F_i will be estimated from the set of N measures $M_{i,n}$, $n = \{1, ..., N\}$. Individuals are indexed by $i = \{1, ..., I\}$. Each measurement ($M_{i,n}$) for each individual i is such that:

$$M_{i,n} = \beta_n' F_i + \epsilon_{i,n} \tag{2}$$

where $\beta_n = (\beta_{n1}, ..., \beta_{nK})$ are the factor loadings. The recovered factors are the ones that explain the maximum variance from the dataset. This procedure reduces the number of measures from N to K, while also controlling for measurement error, $\epsilon_{i,n}$.

For this exercise, we used the pre-programed Stata packages *factor, rotate* and *predict*. The factor estimation strategy employed here is a simple three step exercise of: (i) determining the number of factors; (ii) rotation and estimation of the factor loadings; (iii) prediction of the factors scores. For this analysis, we used all the sample pooled for both years. The method is intuitively comparable to PCA, but the main and crucial difference can be seen by comparing Equations 1 and 2. PCA is a linear combination of the items, with the PCA as a result of this operation. On the other hand, by applying factor analysis, we are assuming the items are a proxy for one or more unknown underlying factors. In fact, each item is a linear combination of the latent factors.

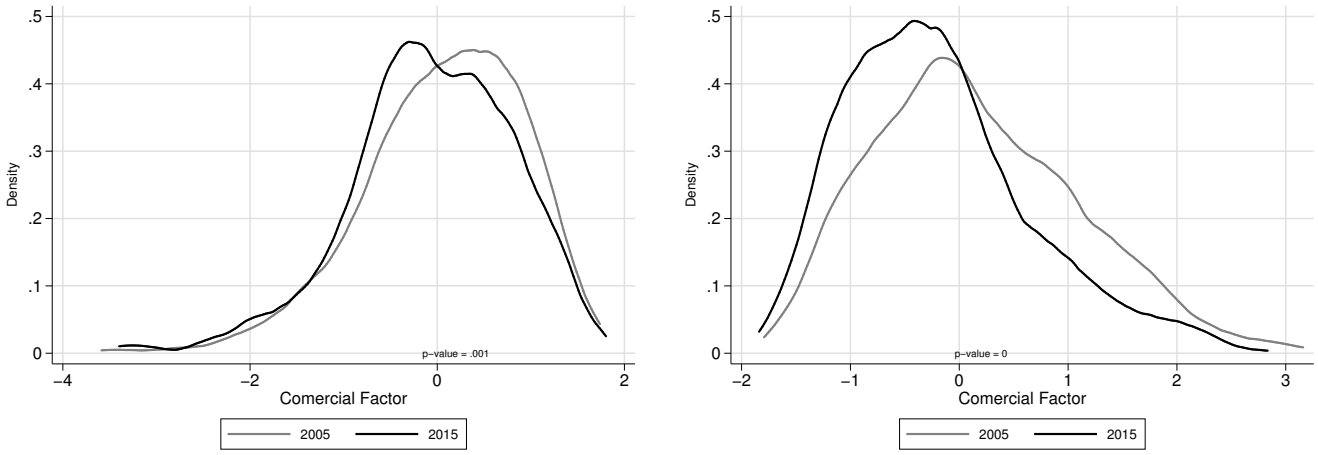
Table 2 shows the results. We display the factor loadings that are higher than 0.3, which reveals a clear pattern. The first set of items composing the first factor block could be interpreted as intrinsic incentives for research while the second block is more related to extrinsic incentives. The resulting distributions for each factor, by year, is displayed in Figure 2.

Table 2: Factor Loadings Estimation, after rotation

Item	**Extrinsic**	**Intrinsic**
Potential contribution to scientific theory		0.608
Publication probability in professional journals		0.4954
Enjoy doing this kind of research		0.4878
Scientific curiosity		0.6146
Availability of research facilities	0.3841	0.3077
Requests made by clientele	0.5329	-0.3396
Feedback from extension personnel	0.4887	
Potential to patent and license the research findings	0.6562	
Likely interest by private firms in commercializing the discovery	0.7355	
Potential marketability of the final product	0.6739	
Availability of public (state and federal) funding	0.3264	
Availability of private (corporate) funding	0.5346	
Colleagues approval		
Importance to society		

Note: Factors are calculated jointly for both waves. Comparing eigenvalues and its variances we confirm the existence of two factors. Together, they explain 92% of the variance. We used Principal Factor with orthogonal quartimax rotation to estimate the factor loadings.

Figure 2: Distribution of Extrinsic and Intrinsic Incentives Factors, pooled cross-section data.



Note: This figure displays the distribution of the estimated latent factors from the cross-section data for individuals surveys both in 2005 and 2015. Sample size is 1,005 for 2005 and 711 for 2015. P-values are for the test with equality fo the distributions as the null hypothesis.

References

Vyas, S; Kumaranayake, L. (2006). Constructing socio-economic status indexes: how to use principal components analysis. Health Policy Plan. Nov; 21(6):459-68.

Gorsuch, R. L. (2003). Factor Analysis, Volume 2 of Handbook of Psychology, pp. 143âĂŞ64.