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Multidisciplinary Research: Implications for Agricultural and Applied Economists

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We detail the rewards and barriers to participating in multidisciplinary research (MDR) using a 2011 survey of applied economists at U.S. universities. We compare these findings with an earlier 1993 survey to assess if rewards and barriers have changed over time. Different administrative levels of U.S. universities are sending contradictory signals regarding rewards from MDR. External funding agencies convey positive signals. Although the scope and breadth of questions addressed by applied economists are changing over time, institutional incentives and reward structures are not keeping pace with these changes. Progress toward adapting to new professional demands has been slow.

Key Words: agricultural and applied economics, faculty survey, multidisciplinary research, promotion and tenure

JEL Classifications: A1, Q00

Multidisciplinary research (MDR) has been a catchphrase in science for more than 20 years (Vastag, 2008). There has been an increasing cry to break down disciplinary "silos" to address the complex problems faced by today's world (Colwell, 1998; Kragt, Robson, and Macleod, 2013). The importance of using information from a range of science disciplines to solve real-world problems was elegantly articulated by Popper (1963) who wrote, "We are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline" (p. 88). A new debate on interdisciplinarity was triggered in the late 1960s and continued into the 1970s in the context of discussions about technology gaps, technology forecasting, and protection of the environment (Apostel et al., 1972). Recent publications emphasize how scientific innovation and economic growth are supported by MDR (National Academy of Science, Engineering, and Public Policy, 2007) and how greater integration across disciplines is required to address complex societal problems (National Academy of Sciences, Committee on Facilitating Interidisciplinary Research, 2004; National Academy of Sciences, Committee on a New Biology for the 21st Century, 2009). In response to this changing landscape, many academic

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institutions across the United States and internationally are investing in facilities and new talent to pursue MDR (Pfirman et al., 2005; Reis, 2000).[1]

U.S. federal agencies have significantly increased the funding available for multidisciplinary enquiry (Reis, 2000; Rhoten and Pfirman, 2007). Of interest to applied economists are recent requests for proposals (RFPs) from federal agencies that ask for submissions from multidisciplinary teams that include social scientists. Examples of these requests can be found in RFPs released by the USDA–Agriculture and Food Research (AFRI) Initiatives[2]; National Science Foundation–Science, Engineering and Education for Sustainability (SEES) initiatives[3]; and National Aeronautics and Space Administration–Research Opportunities in Space and Earth Sciences.[4] A greater focus on forming teams to solve what are now commonly referred to as "grand challenge" societal problems,[5] concomitant with increased funding support for these activities, are some factors that increase the incentives for economists to work with other disciplines and *vice versa*.

Batie (2008) notes that society is changing the information it demands from science and as a consequence, applied economists need to consider realigning their professional expectations to maintain their relevance. Specifically, there is an increased demand for science information that informs policy and management; reflects different value systems and cultural norms; and incorporates meaningful stakeholder engagement to move knowledge to action (Batie, 2008). These different demands challenge applied economists to respond to new developments and new paradigms for scientific enquiry.

Scientists at all stages of career progression are receiving signals that MDR is valued to tackle complex societal challenges. Early career scientists are increasingly exposed to multidisciplinary graduate programs (for example, the NSF Integrative Graduate Education and Research Traineeship), and fellowships opportunities (for example, the NSF SEES Fellows program) that encourage integration across disciplines and convey the message that multidisciplinary enquiry is valued.

Although MDR is being valued and encouraged from many quarters, including educational training, academic reward structures within the United States may not be keeping pace supporting these activities. The incentives and rewards for scientists engaging in research across or between disciplines differ, depending on the type of institution or even country in which they work. Institutions and sectors can have distinctly different goals and objectives for their scientists. In some sectors, for example, industry, government agencies, or national laboratories, multidisciplinary collaborations are encouraged and rewarded as a means of finding solutions to

[1] The Mellon Foundation has offered fellowships to faculty in the humanities and social sciences to "acquire systematic training outside their own disciplines" since 2002 (Mellon Foundation, 2008). Stanford University sets fundraising goals under the Stanford Challenge initiative to stimulate MDR. In May 2008, the University of Michigan announced plans to hire 100 interdisciplinary faculty members over 5 years in areas that advance interdisciplinary teaching and research.

[2] "These projects must be trans-disciplinary, involve multiple investigators, and address a significant regional issue with respect to greenhouse gas mitigation and adaptation through increased resiliency in agriculture production and sustainable natural resources management under variable climates." Downloaded on August 27, 2012, at www.nifa.usda.gov/funding/rfas/pdfs/12_climate.pdf.

[3] There are now 17 SEES programs (www.nsf.gov/funding/pgm_summ.jsp?pims_id=504707); many encourage the formation of mixed discipline teams to examine societal problems. Some solicitations specifically mandate a social science component. e.g., "Proposals that do not broadly integrate across the biological sciences, geosciences, engineering, and social sciences may be returned without review." Downloaded from NSF on August 27, 2012, at www.nsf.gov/pubs/2011/nsf11551/nsf11551.pdf.

[4] "Successful proposals will fully integrate social and economic sciences into the research questions, data used, and analytical approaches in order to couple remote sensing observations of land cover with research on the human dimensions of land-use change" Downloaded August 27, 2012, at http://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=304991/solicitationId=%7B7D8FA1EA-241A-344C-107A-660543B10CC0%7D/viewSolicitationDocument=1/A.2%20LCLUC%20Amend%208.pdf.

[5] Some of these fall into the category of "wicked problems" as discussed by Batie (2008).

specific questions (National Academy of Sciences, Committee on Facilitating Interdisciplinary Research, 2004). However, this is not universally the case.

In this article, we focus on the incidence and incentives for applied economists within U.S. academia to engage in MDR. We choose to focus on this group because many U.S. academic institutions do not have evaluative procedures that reward contributions to multidisciplinary scholarship in addition to disciplinary scholarship; or, if procedures are in place, institutions may have difficulty implementing and following them (Pfirman et al., 2005). Dual messages and incompatible evaluation metrics can create career challenges for academic scholars that engage in multidisciplinary work. Is the applied economics profession being successful at creating appropriate incentives to maintain its relevancy within a changing scientific landscape? Departments, institutions, and professional societies have an important role to play in influencing the acceptance (or otherwise) of multidisciplinary as well as disciplinary scholarship (National Academy of Sciences, Committee on Facilitating Interdisciplinary Research, 2004).

Applied economists have explored their role in solving problems with partners from other disciplines for decades (Ahearn, 1997; Antle and Wagenet, 1995; Dobbs, 1987; Johnson, 1971; Swanson, 1979; Young, 1995; Zilberman, 1994). The field of applied economics has an increasing percentage of positions that seek candidates with skills suitable for multidisciplinary collaboration or a demonstrated ability to work in multidisciplinary teams (Marks, Cobourn, and Mooney, 2011). The type of problems that applied economists address is increasing in scope and breadth, potentially changing our professional activities and the diversity of interests within the profession (Eidman, 1995; Zapata, 2009). However, we still know little about how our profession is engaged in multidisciplinary work or the impediments and rewards that might be faced by those working in a multidisciplinary context. Furthermore, we know little about the needs or opportunities for change at the department and institutional levels or potential roles for our national, regional, and other professional societies in shaping change. One exception may be the Southern Agricultural Economics Association that has examined some of these issues in past presidential addresses (Kilmer, 2004; Segarra, 1998; Zapata, 2009).

This article provides recent survey evidence on the current incidence, rewards, and impediments to multidisciplinary research as well as the attitudes and enthusiasm toward this work by applied economists. This is an important undertaking for many reasons, but not least for providing data that can be used to inform the adaptation of the U.S. applied economics profession to the changing societal demands for science information. One agricultural economist and dean summarizes these issues cogently: "...the days of hard-funded technicians and graduate research assistants are over, and we will have to behave more like Colleges of Sciences. This has long been recognized by the production agriculture disciplines, and Ag Econ units are beginning to come to the same realization...many of the opportunities for extramural grants for [agricultural] economists involve interdisciplinary research. This underscores the increasing importance of interdisciplinary research, not only to address issues, but also for the sheer survival of the Ag Econ profession" (D. Bernardo, Dean of College of Agricultural, Human, and Natural Resource Sciences, Washington State University, e-mail communication, August 3, 2011).

In addition, our agricultural and applied economics professional associations are eager to increase membership (Kilmer, 2004). This article contributes to a better understanding of the interests, concerns, and characteristics of U.S. academics that are one population targeted for membership. We also provide a comparison of current attitudes toward MDR with results from a similar 1993 survey (Young, 1993, 1995). This comparison yields insight into what changes have occurred within our profession over an 18-year period during which the research funding environment and science information landscape have continued to encourage MDR.

In the next section, we outline some of the challenges to MDR identified within the literature. After that, we discuss the sample frame for our 2011 survey, in which we gauge the

incidence of MDR in applied economics and assess the challenges and rewards associated with such endeavors. Then we compare the 2011 and 1993 survey results. We conclude by discussing the implications of our results for applied economists, universities, and professional societies.

Literature Review

The extent to which researchers from different disciplines cooperate or collaborate with each other varies widely. Rossini et al. (1978) define collaborations as multidisciplinary if experts from different fields work together within the boundaries of their own disciplines; cross-disciplinary if there is a coordinated effort to make use of two or more academic disciplines; interdisciplinary if boundaries between disciplines are transcended; and transdisciplinary when boundaries between disciplines cease to exist. Klein (1990) has a similar definition of multidisciplinary and adds that multidisciplinary analyses do not integrate concepts, epistemologies, or methodologies across the disciplines. Klein (1990) characterizes interdisciplinary work as "a synthesis of two or more disciplines, establishing a new level of discourse and integration of knowledge" whereas transdisciplinary work is accomplished using a common set of axioms that transcend disciplinary world views through an overarching synthesis (Klein, 2010). In contrast, Rawson (1994) states that work is interdisciplinary when it includes two disciplines and multidisciplinary when more than two disciplines are involved. Other definitions of these terms also exist (for example, Kragt, Robson, and Macleod, 2013). National Academy of Sciences, Committee on Facilitating Interdisciplinary Research (2004, p. 26) notes that a single definition is not likely to characterize the broad suite of activities that may be considered as interdisciplinary. Duffy (2011) and Young (1995) note that many of these terms are used interchangeably in practice. Young (1995) attributes this to "the inevitably vague boundaries between these concepts" (p. 119). It is difficult to provide a single label for a piece of work because the work may have elements that are interdisciplinary in some respects and other elements that are multidisciplinary, cross-disciplinary, or other. It is clear that competing definitions of the terms exist, further exacerbating the problem of definitive categorization.

In this article, we adopt a broad definition of MDR as research by teams or individuals that use information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge. Conversely, when we refer to disciplinary research, we mean research that takes place predominantly within the confines of an existing discipline, although we recognize that many disciplines such as agricultural and applied economics are inherently multidisciplinary to some degree.

There is a large amount of literature on the barriers and obstacles faced by participants in MDR (National Academy of Sciences, Committee on Facilitating Interdisciplinary Research, 2004). The National Academy of Sciences, Committee on Facilitating Interdisciplinary Research (2004) states that faculty are commonly expected to do "double duty" in meeting disciplinary obligations to their department and then finding additional time for MDR. Time and resources spent on MDR detract from time and resources available to produce disciplinary publications. Also, the contribution of an individual to an MDR publication may be difficult for colleagues and external reviewers to assess.[6] Disciplinary chauvinism, the inherently higher esteem for work within one's own discipline (Dobbs, 1987), may be another factor that deters participation. Previous research finds that institutional barriers can deter individual researchers from engaging in MDR. Barriers include institutionalized norms that do not support MDR such as 1) promotion and tenure guidelines that encourage sole-authored publications; and/or 2) publication in a narrow selection of disciplinary journals; 3) differential financial rewards for disciplinary vs. mixed discipline publications (Hilmer and Hilmer, 2005); and 4) a "top-down" priority setting that provides poor administrative support for activities that cut

[6] Kilmer (2004) proposes several ways to assess the impact of publications.

across departments or colleges. Duffy (2011) argues that changes in institutional culture that enhance administrative support, provide greater peer recognition, and professional rewards that are competitive with those of disciplinary work will enhance the success of faculty involved in MDR.

In addition to external incentives, success or failure within MDR is heavily dependent on the strength of interpersonal relations among team members, their ability to communicate, and their trust in each other (Harris, Lyon, and Clarke, 2008; Marzano, Carss, and Bell, 2006). Each discipline brings a different intellectual framework to the research, which builds in potential for conflict, especially at the early stages of team formation (Bracken and Oughton, 2006; Eggins and MacDonald, 2003; Somerville and Rapport, 2000). For example, stylized mathematical models of behavior favored by economists (and rewarded in disciplinary publications) may create barriers to communication with other fields that do not embrace these types of descriptions (Duffy, 2011). Social and natural scientists may also subscribe to different notions regarding proprietary data and reciprocity in coauthorship (Dobbs, 1987; Harris, Lyon, and Clarke, 2008). Strang (2009) notes that individuals might bring unequal levels of social, economic, and political capital to MDR teams; some individuals may be included as afterthoughts within the team, not as equal members, which may limit their potential to fully contribute to the team.

However, the extensive MDR experience of the first and second authors suggests that early joint planning and mutual trust founded on years of collaboration can often overcome these obstacles. There are many opinions regarding how best to foster MDR teams and activities so that they are successful. This article helps to fill a niche in the applied economics literature by contributing to the understanding of current impediments or concerns among practitioners of MDR in applied economics. The results might also provide benchmarks for reforming incentives structures for MDR at academic institutions and professional associations.

Survey Methods and Participants

In 2011, we conducted a web-based survey to elicit the perceptions toward, and degree of involvement in, MDR by members of agricultural and applied economics departments within the United States. A database of e-mail contacts was assembled during October and November of 2010 by visiting web sites for each U.S. department listed on the Agricultural and Applied Economics Association (AAEA) web site (AAEA, 2010). The e-mail database represents a significant proportion of the population of professionals working in those departments. However, we did not survey those whose e-mails were not available online during that time period nor individuals in any U.S. departments not listed on the AAEA site. We anticipate that the potential for selection bias from administering the survey through the Internet is minimal because the population of interest works at educational institutions where there is personal access to the Internet and e-mail. A link to the survey and a cover letter were e-mailed to 1,205 professionals with two follow-up e-mails within 3 weeks of initial contact. Respondents were able to submit the survey only once. When the survey was complete, respondents were not able to change their responses.

2011 Survey Results

Response Rate, General Characteristics, and Demographics

A total of 309 individuals completed or partially completed the survey for a response rate of 26%. Although modest, this rate compares favorably to other Internet surveys. For example, Dillman, Smyth, and Christian (2009) achieved only a 12.7% response. Responses show that survey respondents are primarily male (79% of respondents) and heavily dominated by senior faculty members: full professors comprise 53% of respondents, 21% are associate professors, and 21% are assistant professors. The remaining 5% are research faculty, emeritus faculty, department heads, retired, or have another faculty designation.

The majority of respondents, 97%, received their highest degree after 1970; the average time elapsed since degree completion is 21 years. Almost all respondents, 96%, have a PhD The most common terminal degree is agricultural economics (73% of respondents); 17% of respondents have a degree in economics and 10% in other disciplines. Land grant institutions account for 89% of respondents with 11% working at public, nonland grant institutions. Some 72% work in PhD granting departments, 27% in MS granting departments, and 1% in BS granting departments. Although this survey does not focus uniquely on AAEA members, a comparison with AAEA membership data can help determine the representativeness of the survey sample. The AAEA provided demographic information regarding the gender of its members. Approximately 20% of AAEA members are women, suggesting that the gender breakdown is likely to be a good representation of the profession. Other demographic information was not available for comparison.

Respondents were also asked to identify their primary field of specialization. These responses were then manually classified into several field areas (Column 2, Table 1). Approximately 22% of respondents identify themselves as production/farm management specialists,[7] 21% are marketing/trade, 18% are resource and environmental economists, and the remaining disciplinary areas are classified as "other."

Attitudes and Institutional Barriers

Table 2 presents results for questions that address individual attitudes and institutional barriers to MDR. Eighty-one percent of respondents agree that complex problems merit study by MDR teams (Question 1, Table 2) and 89% note that MDR collaborations are rewarding and can yield information that is useful for solving disciplinary problems (Questions 2 and 3, Table 2). There is less agreement about whether MDR is more valuable to society than disciplinary research; although 56% of respondents agree that MDR has greater value, 10% do not agree and 34% neither agree nor disagree (Question 4, Table 2). There is almost universal agreement (92%) that the economics discipline can provide contributions to MDR through its ability to link science with policy (Question 5, Table 2).

Seventy-six percent of respondents agree that their department supports collaborations with scientists from other disciplines (Question 6, Table 2), whereas 32% think that collaboration with scientists from other disciplines can jeopardize promotion and tenure for junior faculty (Question 7, Table 2). More than 50% of additional written comments submitted by assistant professors, 44% of comments from associate professors, and close to 79% of comments from full professors address the topic of MDR and its role in promotion and tenure. Without exception, comments from associate professors convey a pessimistic view of the pretenure academic recognition of MDR by departments and institutions. Full professors similarly express a less-than-positive view of the pretenure recognition of MDR but are slightly less pessimistic than associate professors. Responses from assistant professors indicate that their view is, on the whole, more positive than that of full or associate professors. Comments one and two capture the general tenor of many responses:

Comment 1

> "The biggest obstacle is the contradictory expectations, narrow disciplinary-based evaluation within departments, but multidisciplinary expectations at the college/university level."

Comment 2

> "I am close to the end of my career. During my career, MDR has been punished rather than rewarded. Maybe this is changing. It remains to be seen whether criteria for promotion and raises will adjust."

Common Roles in Multidisciplinary Research

Table 3 presents responses to questions addressing respondents' specific roles in MDR research, the collaborators they worked with as well as the

[7] To the extent that the production/farm management specialty is declining over time, our results could overrepresent the importance of the views of these specialists for the future.

Table 1. Comparison of Sample Characteristics (Young, 1993, 1995) and the 2011 Survey

	Statistic	Young 1993, 1995	2011 Survey	
			Full Sample	Subsample
Sample size		80	281	70
Work allocation	Percent			
>50% research		70	33	53
>50% extension		14	13	19
Other		16	54	29
Field specialty	Percent			
Production/farm management		62	22	50
Marketing/trade		11	21	27
Natural resource economics		19	18	17
Other		8	39	6
Years experience	Mean (SD)	17 (8)	20 (12)	18 (10)
MDR as percent of career research	Mean (SD)	47 (26)	36 (28)	48 (27)
MDR journal articles as a percent of total	Percent			
0–10%		12	46	21
11–40%		41	30	37
41–100%		47	24	41

SD, standard deviation; MDR, multidisciplinary research.

outcomes of their joint work. Ninety percent of respondents have applied for funding as part of a multidisciplinary team (Question 1, Table 3). Additional questions showed that 90% of these respondents strongly agree that their applications for external funding are more likely to be successful as a for member of a MDR team proposal and 89% reported that their own involvement in proposals submitted by MDR teams had positively affected their personal ability to secure external grant funding. Respondents have taken significant leadership roles in grant applications with 80% functioning as coprincipal investigator, 52% as investigator, and 46% taking the lead as principal investigator (Question 2, Table 3).

Applied economists most frequently collaborate with agricultural scientists, engineers, and physical scientists (Question 3, Table 3). The "other" category includes many related social science disciplines such as law, sociology, and political science. The most common joint activities are grant writing, manuscript preparation, and related activities such as data provision and sharing. These activities accounted for 71–74% of all interactions between applied economists and other scientists (Question 4, Table 3). Joint graduate student supervision or joint development of a theoretical framework was less common, involving fewer than 50% of respondents. These collaborative efforts are reported to have paid off with 91% of respondents publishing something with their MDR team and 74% of respondents having published a MDR journal article (Questions 5 and 6, Table 3). Question 7, Table 3 shows the disciplines with which applied economists have successfully published (as opposed to "worked with" as asked in Question 3, Table 3). The incidence of publication with disciplines is similar to the frequency of initial collaborations with a potentially slightly lower payoff for work conducted with engineers.

Challenges to Team Formation and Professional Rewards over Time

Table 4 presents the responses to questions related to team formation and communication and perceptions of professional rewards over time. Over half of the survey respondents agree that reconciling different research methodologies and vocabularies is an obstacle to MDR (Questions 1 and 2, Table 4). Forty-one percent of respondents agree that obtaining data from other scientists on a timely basis is an obstacle to MDR (Question 3, Table 4). We did not ask whether it is more difficult to get data from colleagues working in other disciplines or those

Table 2. Individual Attitudes and Institutional Barriers to Multidisciplinary Research (MDR): 2011 Survey

	Disagree/Strongly Disagree	Neither Agree nor Disagree	Agree/Strongly Agree
		Individual Attitudes	
1. Complex societal problems are best studied by MDR teams[a]	5%	14%	81%
2. Collaboration with scientists from other disciplines is personally rewarding[b]	1%	10%	89%
3. MDR has exposed me to tools from other sciences that I have used to examine economic problems[c]	15%	22%	63%
4. MDR has a greater value to society than single-discipline research[d]	10%	34%	56%
5. Economics provides an integrative framework that can link other sciences with policy[d]	3%	5%	92%
		Institutional Barriers	
6. My department culture supports collaborations with scientists from other disciplines[e]	10%	14%	76%
7. Collaborating with scientists from other disciplines can jeopardize promotion and tenure for junior faculty[e]	40%	28%	32%

[a] N = 279.
[b] N = 243.
[c] N = 246.
[d] N = 280.
[e] N = 247.

working within their own discipline, so the response may reflect some of the general challenges faced by professionals working in any team environment rather than multidisciplinary teams specifically. Shared authorship was not considered an obstacle to professional advancement by 50% of respondents (Question 4, Table 4).

The majority of respondents report that they are optimistic about the future role of MDR in providing opportunities for the profession. Fifty-four percent agree that there have been rewards to MDR in the past, whereas 67% report that rewards are likely to increase in the future. Eighty-five percent agree (most of them strongly) that the ability to successfully engage in MDR could positively affect employment prospects over time (Questions 5–7, Table 4). The profession overall seems to be enthusiastic about MDR, suggesting that the benefits from engagement outweigh the career and personal costs (Question 8, Table 4).

Discussion of 2011 Survey Results

The results of the 2011 survey of applied economists suggest that there is broad support for, and engagement in, MDR as well as disciplinary research and there is little evidence of disciplinary chauvinism. Although respondents noted there was provision for engaging in MDR within the current institutional structure of many U.S. universities, they also expressed reservations about whether this activity was appropriate for untenured faculty. These responses are, in some part, contradictory, suggesting a tension or lack of clarity concerning institutional support for faculty participating in MDR. This tension is reflected in the qualitative responses that were received. Institutional acceptance and rewards seem to be inconsistent at different levels of administration. Specifically, departmental rewards and incentives are less positive than those offered by administrators such as deans and vice presidents of research.

Table 3. Role of 2011 Survey Respondents

		All Respondents (%)
1. Have you applied for funding with a multidisciplinary team member?	Yes	90
	No	10
2. What was your role in the funding applications? (Select ALL that apply)	PI/Director	46
	Co-PI/Director	80
	Investigator	52
	Other	3
3. What other disciplines were included in the research team? (Select ALL that apply)	Physical sciences	37
	Pure sciences	21
	Agricultural sciences	77
	Engineering	42
	Health Sciences	12
	Other	27
4. Characterize your interaction with the other scientists (Select ALL that apply)	Swap data and/or results	74
	Write journal article	71
	Write report/other manuscript	73
	Develop theoretical framework	45
	Share graduate student	44
	Write a grant	89
	Other	15
5. Was any of your multidisciplinary work published in any form?	Yes	91
	No	9
6. Have you ever published a journal article with a coauthor that meets the definition of multidisciplinary?	Yes	74
	No	26
7. Select those disciplines you have published with (Select ALL that apply)	Physical sciences[a]	38
	Pure sciences[b]	16
	Agricultural sciences[c]	77
	Engineering	32
	Health sciences[d]	14
	Other	33

[a] For example, geology, hydrology, or ecology.
[b] For example, chemistry or physics.
[c] For example, agronomy or animal science.
[d] For example, medicine or exercise and sports physiology.
PI, Principal Investigator.

Assistant professors submitted qualitative comments regarding MDR that were more optimistic than their senior colleagues. Survey results do not provide evidence that can be used to address why this might be the case. However, some possible explanations could be that their senior colleagues have become more cautious as a result of their own (negative) experiences, or that rewards for MDR are changing, or that mixed signals are being provided to junior faculty. Despite mixed opinions regarding professional rewards at the departmental level, it is clear that funding agencies have provided a strong incentive for applied economists to engage in MDR with 90% of respondents agreeing that their success in achieving funding is higher as a member of a multidisciplinary team.

Team communication was noted as a challenge, particularly vocabulary and methodology. One respondent submitted a comment that academic training for agricultural and applied economists has become less broad over time, leading to greater communication difficulties: "It is very odd how many [applied economics] PhDs in the last 10 years know very little about

Table 4. Internal Challenges and Professional Rewards Over Time for Multidisciplinary Research (MDR): 2011 Survey

	Disagree/Strongly Disagree	Neither Agree nor Disagree	Agree/Strongly Agree
		Internal Challenges	
1. Reconciling differing research methodologies is an obstacle to MDR[a]	23%	24%	53%
2. Reconciling different vocabularies is an obstacle to MDR[b]	20%	21%	60%
3. Obtaining data from other scientists on a timely basis is an obstacle to MDR[a]	29%	30%	41%
4. Shared authorship in MDR can be an obstacle to professional advancement[c]	50%	25%	25%
		Professional Rewards Over Time	
5. The professional rewards for economists from involvement in MDR HAVE increased over time[d]	20%	25%	54%
6. The professional rewards for economists from involvement in MDR are LIKELY TO increase in the future[d]	6%	27%	67%
7. Increased involvement by economists in MDR could positively affect the employment prospects for economists in the future[d]	2%	13%	85%
8. The overall benefits of MDR outweigh the costs[e]	4%	16%	80%

[a] N = 247.
[b] N = 246.
[c] N = 245.
[d] N = 280.
[e] N = 244.

agriculture and related disciplines." Graduate training in applied economics within the United States has, in recent years, focused more narrowly on economic theory and econometrics with less emphasis on courses in agricultural or applied economics applications. Another respondent noted that team-building and formation are time-consuming, but once the investments had been made, the collaborations work well. Overcoming differences in methodology and vocabulary are not insurmountable; however, the additional investment in time and resources to generate the collaborations can be problematic (reinforcing Harris, Lyon, and Clarke, 2008). This could prove to be a disincentive for junior faculty to engage in MDR because of the pressure to publish a number of articles within the limited timeframe available before their promotion and tenure decision. Shared authorship was not identified as a strong disincentive to MDR. This could reflect the trend over time toward multiple authored papers in economics and applied economics (Sutter and Kocher, 2004) and the low monetary disincentive for adding additional authors (Hilmer and Hilmer, 2005).

Comparison of 2011 Survey with 1993 Survey

We have an opportunity to explore, to some degree, whether practitioners' attitudes, perceptions, and barriers to MDR have changed over time by comparing the 2011 survey results with responses obtained by a smaller, similar survey conducted in 1993 (Young, 1993, 1995). During the 18 years that elapsed between the surveys, there has been a considerable increased emphasis on MDR as a means of addressing complex societal problems, concomitant with a significant increase in available funding for these activities.

Young (1993, 1995) conducted a mail survey of 112 agricultural economists to assess their perceptions of the benefits and challenges of participating in MDR. Young (1995) received a 73% response rate to his mail survey. His sample was drawn from agricultural economists who had successfully published at least one MDR research article. A direct comparison of the results from both surveys is difficult because the 2011 sample is drawn from the general population of agricultural/applied economists working at U.S. academic departments listed on the AAEA web site (AAEA, 2010). We address the difference in sample composition by selecting a subsample of respondents from the 2011 survey for comparison with Young's 1993 respondents using propensity score-matching (Rosenbaum and Rubin, 1983; Smith and Todd, 2001) based on respondent characteristics from 2011 and 1993. The characteristics used are listed in Table 1 and include work allocation, field specialty, years of professional experience, MDR as a percent of total career research, and MDR journal articles as a percent of total publications.[8] The 2011 subsample based on propensity score matching contains 70 respondents.

Descriptive statistics for the 1993 survey respondents, the complete set of respondents to the 2011 survey, and the 2011 subsample are presented in Table 1. As compared with the full group of 2011 respondents, the 2011 subsample is weighted more heavily toward individuals with a majority research appointment, those specializing in production/farm management fields, and those individuals with a greater focus on, and experience with, MDR (as a percent of career research and total publications).

Although the 2011 subsample compares favorably with characteristics of the 1993 respondents, some differences remain. For example, there are fewer individuals in the 2011 subsample with a majority research appointment in comparison with the 1993 respondents. Furthermore, our ability to control for covariates between the 1993 and 2011 samples is limited by the number of respondent characteristics collected in 1993. Because the 2011 subsample is not a perfect match with Young (1993, 1995), we interpret our comparisons between the two surveys with caution.

Changes between 1993 and 2011

Both surveys asked similar questions pertaining to the value of, and future trends for, MDR. Table 5 reports these results for the 1993 and 2011 surveys as well as the 2011 subsample. Results are expressed as the percentage of respondents who agree or disagree with the statements or questions posed.[9] Table 5 also reports the mean response and the p-statistic from a Mann-Whitney-Wilcox (MWW) U test comparing both 2011 response distributions against the 1993 response distribution.[10]

A comparison between the 1993 survey respondents and the 2011 subsample shows there are two statements for which responses differed significantly. The first is "MDR has a greater value to society than single discipline research." The responses in the 2011 subsample are similar to those in the full sample and indicate less support for this statement than in 1993 (Question 1, Table 5). Based on the increased emphasis on MDR from scientific and funding agencies over the timeframe between these surveys, we expected the opposite. Alternatively, the result may be explained by greater participation in, and general acceptance

[8] We report those from a nearest neighbor match. The results are robust across several matching techniques.

[9] For the 1993 and 2011 surveys, we combine the responses strongly disagree and disagree into a single category, neutral into a second, and strongly agree and agree into a third. Young (1993. 1995) did not use this exact phrasing in his Likert scales. Responses to Young (1993) were recategorized to provide an approximation of the degree of agreement or disagreement with the phrases or questions presented in 2011. Although not a perfect comparison, this strategy allows us to compare attitudes toward very similar questions across the timespan.

[10] MWW is a nonparametric test used to compare Likert responses across samples (Clason and Dormody, 1994; de Winter and Dodou, 2010). Rejection of the null hypothesis indicates that the response distributions across the two samples are not identical.

Table 5. Percentage of Responses by Comparison Question, 1993 and 2011 Full Sample and 2011 Subsample

		2011 Survey	
2011 Survey Statement	Young (1993)	Full Sample	Subsample
1. MDR has a greater value to society than single discipline research			
Strongly disagree/disagree	3.95	10.36	10.00
Neutral	14.47	33.93	37.14
Strongly agree/agree	81.58	55.71	52.86
Mean (MWW *p* value)	2.78 (N/A)	2.45 (0.0001)	2.43 (0.0003)
2. MDR has been more helpful in advancing my career than single-discipline research			
Strongly disagree/disagree	29.87	32.39	22.86
Neutral	25.97	30.36	28.57
Strongly agree/agree	44.16	37.25	48.57
Mean (MWW *p* value)	2.14 (N/A)	2.05 (0.3783)	2.26 (0.4299)
3. Increased involvement by economists in MDR could positively affect the employment prospects for economists in the future			
Strongly disagree/disagree	1.28	2.49	2.86
Neutral	6.41	12.46	11.43
Strongly agree/agree	92.31	85.05	85.71
Mean (MWW *p* value)	2.91 (N/A)	2.83 (0.0968)	2.83 (0.1966)
4. The professional rewards for economists from involvement in MDR HAVE increased over time[a]			
Strongly disagree/disagree	16.44	20.36	30.00
Neutral	28.77	25.36	27.14
Strongly agree/agree	54.97	54.29	42.86
Mean (MWW *p* value)	2.39 (N/A)	2.34 (0.7486)	2.13 (0.0712)
5. The professional rewards for economists from involvement in MDR are LIKELY TO increase in the future[a]			
Strongly disagree/disagree	16.44	6.45	8.57
Neutral	28.77	26.88	32.86
Strongly agree/agree	54.97	66.67	58.57
Mean (MWW *p* value)	2.39 (N/A)	2.60 (0.0246)	2.50 (0.4350)

Notes: The *p* value reported is for the Mann-Whitney-Wilcoxon (MWW) test of the 2011 distribution of responses (in the full or either subsample) vs. the 1993 distribution of responses.

[a] In 1993, the question posed was, "How do you perceive the trend in professional rewards for agricultural economists from involvement in MDR over time?" In the 2011 survey, we split this question into two parts. We asked respondents to indicate whether they "have" seen and whether they are "likely to" see an increase in professional rewards from MDR. We compare the responses of the "have" and "likely" questions with the single question from 1993.

MDR, multidisciplinary research; N/A, not applicable.

of, MDR within applied economics departments in the earlier era. It is also possible that the difference in results between 1993 and 2011 may be the result of some residual unexplained selection bias in the 1993 sample. Given that caveat, responses from the 2011 survey suggest that practitioners tended to see less societal value from MDR than did respondents in 1993.

The second question for which we find a statistically significant difference in responses is "The professional rewards for economists from involvement in MDR HAVE increased over time." In the 2011 subsample, there is less agreement with this statement than in either the full 2011 set of responses or the 1993 responses (Question 4, Table 5).

There is little difference in the mean response, or in the distribution of responses, between the 2011 subsample and the 1993 response distribution for the remaining questions. There are, however, several statistically significant differences between the full 2011 response set and the 2011 subsample. There is significantly greater agreement among the 2011 subsample with the question "MDR has been more helpful in advancing my career than single discipline research" than found in the full sample (with an MWW p value of 0.013). However, although 43% of the 2011 subsample agree with the statement "The professional rewards for economists from involvement in MDR HAVE increased over time" and 59% of the 2011 subsample agree that "The professional rewards for economists from involvement in MDR are LIKELY TO increase in the future," there is more agreement exhibited by the full 2011 response set (54% and 67%, respectively).

Young (1993, 1995) also explores questions designed to shed light on some obstacles to MDR team formation such as differing research methodologies and vocabularies between disciplines and logistics such as data collection and sharing and shared authorship. The Likert response choices in 1993 were "no problem," "moderate problem," and serious problem." Because the response choices differ between the two surveys, a comparison between responses presented in Table 2 and those obtained in 1993 is approximate rather than exact.

In 1993, reconciling differing methodologies and vocabularies was considered to be a moderate or serious problem to successful MDR by almost 80% of respondents. Approximately 63% of respondents replied that obtaining needed data from scientists on a multidisciplinary team on a timely basis was a moderate or serious problem. Thirty percent responded that achieving a fair share of authorship was a moderate or serious problem. Responses to Questions 1–4 in Table 4 suggest that in the 18 years between 1993 and 2011, applied economists have not experienced statistically significant changes in their perceptions of these factors.

Discussion of 2011 and 1993 Survey Results

The results presented previously suggest that despite greater engagement in MDR, there is a smaller percentage of current practitioners who perceive that professional rewards have increased over time in comparison with the optimism expressed by their counterparts in 1993. The time periods for comparison are different so this could be interpreted in several ways. One possible explanation is that rewards did increase during the later 1980s but the rate of increase has declined in recent years; we do not have data to test this hypothesis. Alternatively, the early optimism exhibited by respondents in 1993 could now be tempered by the reality of the persistence of conflicting incentives that academics face with respect to engaging in MDR as well as many other possible reasons. The 2011 subsample of individuals (on average, having more experience with MDR than the full sample), although enthusiastic concerning the rewards from MDR, is slightly less optimistic about the past and future professional rewards for MDR than are respondents with less experience practicing MDR (reflected in the full 2011 set of responses). It is possible that individuals with more MDR experience have faced more of the tensions between disciplinary and interdisciplinary work than those for whom it represents a smaller part of their research portfolio.

Summary and Recommendations for the Profession

Overall, our results demonstrate that there is considerable interest and participation in MDR among applied economists and a view that the professional rewards from engaging in MDR have been increasing and are likely to increase more in the future. However, optimism about the future rewards from MDR differs by degree of experience with MDR. All respondent categories express positive views regarding the likely future rewards from participating in MDR, but practitioners most involved in MDR are slightly more conservative regarding the prospect for future rewards than are those respondents less invested in MDR. Part of the

universal optimism about the future of MDR is likely the result of the fact that the majority of the survey respondents have been involved in pursuing external funding opportunities as part of an MDR team. There is overwhelming agreement among respondents that MDR is more likely to be funded than disciplinary research, a perspective that coincides with the marked push in funding programs for MDR. Over time, an increase in MDR driven by these funding opportunities/incentives may help combat the pessimism expressed by department promotion and tenure committees: Our results indicate that economists have become more successful in publishing their multidisciplinary work as journal articles (37% in 1993 vs. 56% in 2011). However, despite this increase in publishing, some obstacles to MDR such as vocabulary and methodological differences as well as data-sharing difficulties remain, but respondents suggest that patience and time can overcome these impediments to MDR collaboration.

This considerable enthusiasm for participating in MDR from survey respondents is, however, tempered by some "institutional" realities regarding conflicting incentives as well as issues related to appropriate evaluation of MDR work. Granting agencies and academic administrators strongly support MDR, but promotion and tenure criteria at the departmental level still rely heavily on disciplinary publications. Respondents caution that MDR is a risky promotion and tenure strategy for junior faculty. This view is more prevalent among senior faculty than junior faculty. In a time of rapidly evolving budget demands and a push toward teams that address "grand challenge" questions, there is tension between incentives and rewards from outside and within the profession. External funding demands MDR in many cases, but internal promotion and tenure incentives continue to promote disciplinary research. At the department level, part of the problem may be attributed to the difficulty of assessing the quality of multidisciplinary research outputs. Greater attention to developing criteria and evaluation mechanisms that accommodate both disciplinary and multidisciplinary work would be helpful. Thus, college and university administrators should consider disseminating information to departments about the changing demands for science information and institutional demands. Similarly, senior faculty and department chairs should consider creating an environment that supports a broader scope of enquiry that includes applied economics and MDR.

Although the critical compromise for increasing incentives for MDR will occur at the department level, applied economics professional societies also have a role to play (National Academy of Sciences, Committee on Facilitating Interdisciplinary Research, 2004). Based on our survey results, we suggest that professional societies consider awards that target both disciplinary and MDR publications. Extension awards might be offered for both disciplinary and multidisciplinary teams. Journals could improve the review process for some MDR articles by ensuring that cross-disciplinary experts are included on reviews of MDR articles and promoting change through policy statements (National Academy of Sciences, Committee on Facilitating Interdisciplinary Research, 2004). These and other issues related to professional relevance have been considered in several presidential addresses (for example, Batie, 2008; Eidman, 1995; Kilmer, 2004; Zapata, 2009), but evidence of changes in incentives remains low. Whether or not a more positive environment for applied economists is realized in the future will depend on resolving the conflict between external and internal incentives. We believe resolving these conflicts will reinforce trust by society in the relevance of applied economics.

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